UNIVERSITY OF ZAMBIA

TABLE OF CONTENTS

SCHOOL OF NATURAL SCIENCES 2020/21

35. CHE 3222: Analytical Chemistry
36. CHE 3411: Main Group Elements and Transition Metal Chemistry
37. CHE 3422: Organometallics and Inorganic Reaction Mechanism
38. CHE 3511; Organic Specroscopic and Aromatic Chemistry (Deferred)
39. CHE 3522: Polyfunctional Compounds, Molecular Rearrangements and Organic Synthesis
40. CHE 3611: Colloids and Electrochemistry
41. CHE 4111: Information Storage and Biochemical Genetics
42. CHE 4522: Physical Organic and Natural Products Chemistry
43. CHE 4411: Inorganic Spectral Techniques and Its Application in Group Theory
44. CHE 4715: Essentials of Medicinal Chemistry
45. CSC 2000: Computer Programming
46. CSC 2101; Computer Systems
47. CSC 2111: Computer Architecture
48. CSC 2202: Operating Systems
49. CSC 2702; Databases and Information Management Systems
50. CSC 2901: Discrete Structures
51. CSC 2912: Numerical Analysis
52. CSC 3011: Algorithms and Complexity
53. CSC 3070: Programming Concepts (Deferred)
54. CSC 3080; Information Management Systems (Deferred)
55. CSC 3120; Digital Electronics
56. CSC 3150: Application Packages (Deferred)
57. CSC 3301: Programming Languages Paradigms
58. CSC 3600; Software Engineering
59. CSC 3612: IT Project Management
60. CSC 4035; Web Programming and Technologies
61. CSC 4130: Advanced Hardware Design and Implementation
62. CSC 4505;Graphics and Video Computing
63. CSC 4630: Advanced Software Engineering
64. CSC 4631: Software Testing and Maintenance
65. CSC 4642: Software Quality Assurance
66. CSC 4745: Multimedia and Human Computer Interaction
67. CSC 4792: Data Mining and Warehousing
68. CSC 4812: Cloud and High-Performance Computing
69. CSC 4822: Routing and Switching Technologies
70. CSC 4845: Fundamental of Cluster and High-Performance Computing
71. GES 2130; The Geography of Africa With Special Reference to Zambia
72. GES 2210: Fundamentals of Physical Geography
73. GES 2322: Fundamentals of Natural Resources Economics
74. GES 2411: Mapping and Field Techniques in Geography
75. GES 2420: Research and Statistical Methods in Geography
76. GES 3151: Regional Planning and Development
77. GES 3321; Environment and Natural Resources Economics
78. GES 3330: Environment and Development

79. GES 3342: Environmental Planning and Management
80. GES 3361: Population, Culture and Environment
81. GES 4165; Migration, Refugees and The Environment
82. GES 4172; Rural Land Use and Landscapes
83. GES 4181: Urban Geography and Planning
84. GES 4285; Geographical Hydrology
85. GES 4372: Tourism, Environment and Development
86. GES 4385: Environmental Hazards and Disasters
87. GES 4472; Fundamentals of Geographic Information System
88. M 1100: Foundation Mathematics
89. MAT 1110; Foundation Mathematics and Statistics for Social Sciences
90. MAT 1120: Introductory Mathematics, Statistics and Probability
91. MAT 2001: Principles of Financial Mathematics
92. MAT 2100; Analytic Geometry and Calculus
93. MAT 2300: Introduction to Real Analysis
94. MAT 2602: Introduction to Statistics
95. MAT 2901: Introduction to Probability
96. MAT 3001: Insurance and Alternative Risk Transfer
97. MAT 3001: Principles of Finance and Financial Reporting
98. MAT 3100; Advanced Calculus
99. MAT 3110; Engineering Mathematics II
100. MAT 3200: Abstract Algebra
101. MAT 3300: Real Analysis
102. MAT 3401; Topology
103. MAT 3601: Mathematical Statistics
104. MAT 3622; Linear Regression
105. MAT 3632: Fundamental of Survival Analysis
106. MAT 3902: Probability Theory
107. MAT 4011: Operational Risk Management
108. MAT 4022: Pension Design and Valuation
109. MAT 4032: Financial Engineering
110. MAT 4100: Complex Variables
111. MAT 4119; Engineering Mathematics II
112. MAT 4300: Elements of Functional Analysis
113. MAT 4600; Multivariate Statistical Analysis
114. MAT 4615; Nonparametric Methods
115. MAT 4645; Time Series Analysis
116. MAT 4671: Statistical Methods in Risk
117. PHY 1010; Introductory Physics
118. PHY 1015; Introductory Medical Physics
119. PHY 2231; Thermodynamics and Properties of Matter
120. PHY 2511: Introduction to Classical Mechanics
121. PHY 2522: Analytical Mechanics and Special Theory of Relativity
122. PHY 2611; Electricity and Magnetism

123. PHY 2712; Optics
124. PHY 3242: Statistical and Thermal Physics
125. PHY 3411: Analogue Electronics 1
126. PHY 3422; Digital Electronics1
127. PHY 3621: Electromagnetic Theory
128. PHY 4031: Computational Physics II
129. PHY 4121; Nuclear Experimental Techniques
130. PHY 4132: Theoretical Nuclear Physics
131. PHY 4222: Solid State Physics II
132. PHY 4242: Fundamentals of Medical Physics
133. PHY 4535: Quantum Mechanics II
134. PHY 4815; Physics of Renewable Resources and Environment

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

2020 FINAL EXAMINATIONS

BIO 1401: BIOMOLECULES AND CELLS

THEORY PAPER

TIME: ONE AND HALF HOURS

INSTRUCTIONS:

1. Use the answer sheet provided to answer the questions.
2. Answer all questions.
3. Choose the best answer.
4. Each correct answer carries 4 marks.
5. Each wrong answer carries (-1) mark.
6. A blank space carries (-1) mark.
7. I don't know carries 0 mark.
8. You are not allowed to communicate with other candidates during the examination.
9. Hand over the question paper and answer sheet at the end of the examination.

---

1. Determine the electronic configuration of the sodium ion Na^+.

   1. $1s^2\ 2s^2\ 3p^6$.
   2. $1s^2\ 2s^4\ 2p^6$.
   3. $1s^2\ \ 2s^4\ 2p^4$.
   4. $1s^2\ 2s^6\ 2p^2$.
   5. $1s^2\ 2s^2\ 2p^6$.
   6. I do not know.

2. Determine the number electrons in the outermost shell of an element with atomic number of 16.

   1. 0
   2. 6
   3. 2
   4. 8
   5. 10
   6. I do not know.

3. Choose the **correct** statement.

   1. An atomic orbital can have a maximum of two shells.
   2. An atomic shell can have a maximum of two atomic orbitals.
   3. The second atomic shell can have a maximum of eight electrons.
   4. The first atomic shell can be occupied by a maximum of three orbitals.
   5. The "s "orbital has higher energy than the "p "orbital of the same shell.
   6. I do not know.

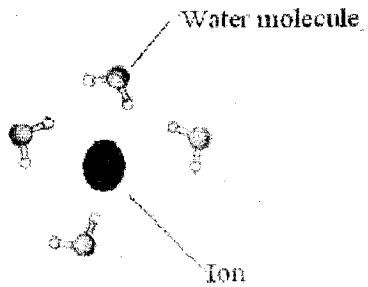
4. Insects can walk on the surface of water body because of ...

   1. The presence of covalent bonds in water.
   2. Adhesion between the insect legs and water molecules.
   3. Cohesion between the insect legs and water molecules.
   4. Capillarity between the water molecules.
   5. The presence of hydrogen bonds between water molecules.
   6. I do not know.

5. Water bodies have a relatively constant surface temperature, because...

   1. water freezes at four degrees Celsius.
   2. the temperature does not rise when water changes from one state to another.
   3. water density does not change with change in temperature.
   4. of the high amount of energy required to raise water temperature.
   5. of the low specific heat capacity of water.
   6. I do not know.

6. Choose the ion surrounded by water molecules in the figure below.



1. Cl^-
2. Na^+
3. SO_4
4. K
5. Fe
6. I do not know.

7. Water is said to be a universal solvent because it can dissolve different ...

1. hydrophilic and hydrophobic substances.
2. polar substances.
3. lipids
4. fatty acids.
5. biological molecules.
6. I do not know.

8. Choose the **correct** statement about the properties of water.

1. Its specific heat makes its temperature unstable.
2. Its latent heat of vaporisation helps in the cooling of living organism.
3. Its density properties make it a universal solvent.
4. Its polarity makes its evaporation easy.
5. Its density increases as its temperature drops below 4°C.
6. I do not know.

9. Which of the following statements is **correct**?

1. Glucose and fructose are optical isomers of each other.
2. Glucose exists as L- and D optical isomers.
3. There is no difference between optical and structural isomers.
4. Isomerism reduces the number of types of organic compounds.
5. Glucose and galactose are stereoisomers of each other.
6. I do not know.

10. In β-glucose the OH group of carbon … is ... the ring.

1. one; below
2. two; above
3. three; above
4. two, below
5. one; above
6. I do not know.

11. A β-glycosidic bond is present in …

1. amylose
2. amylopectin
3. maltose
4. glycogen
5. lactose
6. I do not know.

12. The difference between glucose and galactose is …

1. the OH group on carbon 1 is below the ring in glucose and above in galactose.
2. the OH group on carbon 2 is below the ring in glucose and above in galactose.
3. the OH group on carbon 3 is below the ring in glucose and above in galactose.
4. the OH group on carbon 4 is below the ring in glucose and above in galactose.
5. the OH group on carbon 5 is below the ring in glucose and above in galactose.
6. I do not know.

13. Identify the class of carbohydrates that are used in the synthesis of nucleic acids.

1. Trioses
2. Tetroses
3. Pentoses
4. Hexoses
5. Ketoses
6. I do not know.

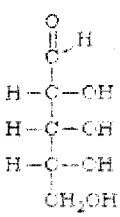
14 Carbohydrates are less efficient energy sources than fats because they…

1. have a higher hydrogen to oxygen ratio.
2. have a lower hydrogen to oxygen ratio.
3. are hydrophobic substances.
4. are hydrophilic molecules.
5. have a higher number of double bonds.
6. I do not know.

15. Cellulose is made up of repeating units of...

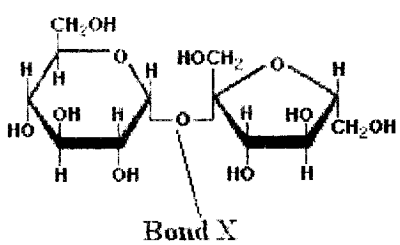
1. β-1-4 linkage between D-glucose units
2. β-1-2 linkage between D-glucose units
3. α-1-4 linkage between D-glucose units
4. α-1-2 linkage between D-glucose units
5. α-1-6 linkage between D-glucose units
6. I do not know.

16. The structure in the figure below is...



1. a furanose open chain.
2. a ketose open chain
3. a pyranose open chain.
4. an aldose open chain.
5. a deoxyribose open chain.
6. I do not know.

17. The structure in the figure below is... and bond X is...



1. sucrose / β1,4 glycosidic bond.
2. lactose / α 1,2 glycosidic bond.
3. maltose/ α1,2 glycosidic bond.
4. sucrose / α1,2 glycosidic bond.
5. maltose/ α1,4 glycosidic bond.
6. 6. I do not know.

18. Which of the following is not a function of lipids?

1. Insulation of nerve tissues.
2. Buoyancy in aquatic animals.
3. Energy storage.
4. Hormonal action.
5. Enzymatic action.
6. I do not know.

19. Identify the saturated fatty acid.

1. $C_{16}H_{30}O_2$
2. $C_{17}H_{32}O_2$
3. $C_{18}H_{36}O_2$
4. $C_{20}H_{38}O_2$
5. $C_{22}H_{40}O_2$
6. I do not know.

20. Natural lipids are ....

1. readily soluble in water.
2. amphoteric substances.
3. polymers of fatty acids
4. amphipathic.
5. effective buffers in solution.
6. I do not know.

21. Lipids are insoluble in water because lipid molecules are ...

1. hydrophilic.
2. Neutral.
3. zwitterions.
4. hydrophobic.
5. double stranded.
6. I do not know.

22. Fatty acids which are liquids at ordinary room temperature are called ...

1. lipids
2. fats
3. water
4. oils
5. glycerol
6. I do not know.

23. Which of the following is **not** a lipid?

1. Fats.
2. Oils.
3. Wax.
4. Collagen.
5. Oleic acid.
6. I do not know.

24. $C_3H_8O_3$ is ...

1. a lipid.
2. a fatty acid.
3. an alcohol.
4. a steroid.
5. a triose.
6. I do not know.

25. An ester bond is a characteristic of ....

1. glycerides.
2. fatty acids
3. glycerol.
4. proteins.
5. disaccharides.
6. I do not know.

26. Which one of the following may contain sulphur?

1. DNA.
2. Protein.
3. Starch.
4. Oleic acid.
5. Glycogen.
6. I do not know.

27. Natural amino acids are ....

1. insoluble in water.
2. amphoteric substances.
3. polymers of proteins.
4. amphipathic.
5. polymers of fatty acids.
6. I do not know.

28. When an amino acid is introduced into a basic solution, ..

1. it will be negatively charged.
2. it will be neutralised.
3. it will be positively charged.
4. its polarity will not be affected.
5. the solution will become acidic.
6. I do not know.

29 The optical activity of some amino acids results from the fact that it's alpha carbon ...

1. has no net charge.
2. is a carboxylic acid.
3. is bonded to four different chemical groups
4. is bonded to two or more amino groups.
5. is symmetrical.
6. I do not know.

30. Choose a form which represents the primary structure of proteins.

1. Helical structure.
2. Beta pleated sheet.
3. Amino acid sequence
4. Globular structure.
5. Quaternary structure.
6. I do not know.

31. Hydrogen bonds in a secondary structure of protein molecules are found between ...

1. carboxylic group of one amino acid and sulphide (SH) group of another amino acid.
2. carboxylic group of one amino acid and amino group of another amino acid.
3. one alkyl group of one amino acid and another alkyl group of a second amino acid.
4. phosphate of one amino acid and an alkyl group of the second amino acid.
5. amino group of one amino acid and a hydroxyl group of another amino acid.
6. I do not know.

32. When two cysteine side chains are involved in chemical bonding in proteins they form ...

1. ionic bond.
2. a polar bond.
3. phosphodiester bond.
4. disulphide bridges.
5. glycosidic bond.
6. I do not know.

33. Which of the following is an example of a fibrous protein?

1. Haemoglobin.
2. Collagen.
3. Enzymes.
4. The alpha helix.
5. A quaternary structure.
6. I do not know.

34. One similarity between myoglobin and haemoglobin is that they...

1. both have four subunits.
2. are energy storage molecules.
3. are structural proteins.
4. are oxygen binding proteins.
5. are oxygen transporting proteins.
6. I do not know.

35. Name types of non-covalent bonds that are involved in tertiary structure of proteins.

1. Hydrogen bonds
2. Van der Waals forces and hydrogen bonds.
3. Ionic, hydrogen and hydrophobic bonds
4. Van der Waals forces, Ionic, hydrogen and hydrophobic bonds.
5. Ionic, hydrogen and hydrophobic bonds
6. I do not know.

36. Choose the statement which is **true** about enzymes.

1. Many enzymes do not require non-protein groups to function efficiently.
2. Enzymes do not change the amount of activation energy.
3. Enzymes increase the amount of activation energy required.
4. Enzymes decrease the amount of activation energy required.
5. Enzymes are lipoprotein in nature.
6. I do not know.

37. Which of the following statements is **wrong** about enzyme activity?

1. Enzyme activity is directly dependent on substrate concentration.
2. Enzyme activity is reduced by lowering temperature.
3. One enzyme can catalyse more than one type of chemical reaction.
4. The substrate binds the active site of the enzyme.
5. If there were no enzymes in cells biochemical reactions would be very slow.
6. I do not know.

38. The change in the shape of an enzyme to the point where it loses its function is called...

1. deactivation.
2. neutralization.
3. denaturation.
4. condensation.
5. activation.
6. I do not know.

39. Which of the following statements is **correct**?

1. The products of a catalysed chemical reaction have the same energy as the substrates.
2. An enzyme gets modified after a chemical reaction.
3. The reactants in an enzyme catalysed reaction do not required any external energy.
4. All the energy given out during a biochemical reaction is absorbed by the products.
5. Coenzymes are always necessary in a chemical reaction.
6. I do not know.

40. The majority of enzymes work best at pH of ....

1. 1.
2. 3.
3. 7.
4. 10.
5. 14.
6. I do not know.

41. Which type of bonding is present between the N-1 of pyrimidine and deoxyribose of DNA?

1. Double bond
2. Hydrogen bond.
3. Ionic bond.
4. Phosphodiester bond.
5. N– glycosidic bond.
6. I do not know.

42. Which carbon atom of deoxyribose is bonded to N – 9 of a purine?

1. C1.
2. C2.
3. C3.
4. C4.
5. C5.
6. I do not know.

43. Which one of the following statements is **not true**?

1. Two strands of DNA are antiparallel.
2. DNA double helix is held together by weak bonds.
3. RNA is wider and longer than DNA.
4. Sequence of bases carries the genetic information.
5. The double stranded structure of DNA is twisted into a right-handed helix.
6. I do not know.

44. Phosphodiester bonds in the formation of DNA are between ....

1. nitrogenous bases.
2. opposite strands of DNA.
3. carbon 5 of the incoming nucleotide and carbon 3 of the growing strand.
4. carbon 2 of the incoming nucleotide and carbon 4 of the growing strand.
5. carbon 1 of the incoming nucleotide and a nitrogenous base of the growing strand.
6. I do not know.

45. Given the following mRNA base sequence, determine the anticodon for tRNA for the highlighted codon: 5- **AGC**UGACUA – 3

1. TCT- 5
2. TCT- 3
3. UCG- 5
4. UCG- 3
5. UGC- 3.
6. I do not know.

46. Which of the following biomolecules requires a template for its synthesis?

1. Polysaccharides
2. Phospholipids
3. Proteins
4. Nitrogenous bases
5. DNA
6. I do not know.

47. The sedimentation coefficient of a prokaryotic ribosome is 70S; Its two subunits are...

1. 50S and 20S
2. 50S and 30S
3. 60S and 10S
4. 35S and 35S
5. 65S and 5S
6. I do not know

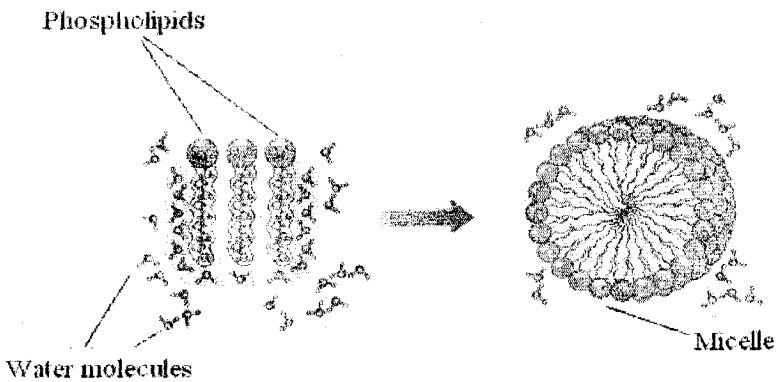
48. Pili in some bacterial cells can best be described as...

1. the outer covering.
2. genetic material.
3. thread- like projections on the surface.
4. vesicles in the cytoplasm.
5. organelles.
6. I do not know.

49. Choose a structure that is present in prokaryotic cells.

1. Nucleolus
2. Nucleus
3. Nucleoid
4. Nuclear membrane
5. Nucleosome
6. I do not know

50. Phospholipids are able to form a micelle in water as shown in the diagram below.



The micelle is formed because…

1. of hydrophilic interactions between water and phospholipid tails.
2. of hydrophobic interactions between water and phospholipids head.
3. of hydrophilic interactions between different water molecules.
4. of hydrophobic interactions between phospholipid tails.
5. of hydrophobic interactions between phospholipid heads.
6. I do not know.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

2020 FINAL EXAMINATIONS

BIO 1400: MOLECULAR CELL BIOLOGY AND GENETICS

THEORY PAPER

TIME: THREE HOURS

INSTRUCTIONS:

1. Use the answer sheet provided to answer the questions.
2. Answer all questions.
3. Choose the best answer.
4. Each correct answer carries 4 marks.
5. Each wrong answer carries (-1) mark.
6. A blank space carries (-1) mark.
7. I don't know carries 0 mark.
8. Table 1 of critical chi-squared values in provided at the end of the examination paper.
9. You are not allowed to communicate with other candidates during the examination.
10. Hand over the question paper and answer sheet at the end of the examination.

---

1. Determine the electronic configuration of the sodium ion Na^+.

   1. $1s^2\ 2s^2\ 3p^6$.
   2. $1s^2\ 2s^4\ 2p^6$.
   3. $1s^2\ \ 2s^4\ 2p^4$.
   4. $1s^2\ 2s^6\ 2p^2$.
   5. $1s^2\ 2s^2\ 2p^6$.
   6. I do not know.

2. Determine the number electrons in the outermost shell of an element with atomic number of 16.

   1. 0
   2. 6
   3. 2
   4. 8
   5. 10
   6. I do not know.

3. Choose the **correct** statement.

   1. An atomic orbital can have a maximum of two shells.
   2. An atomic shell can have a maximum of two atomic orbitals.
   3. The second atomic shell can have a maximum of eight electrons.
   4. The first atomic shell can be occupied by a maximum of three orbitals.
   5. The "s "orbital has higher energy than the "p "orbital of the same shell.
   6. I do not know.

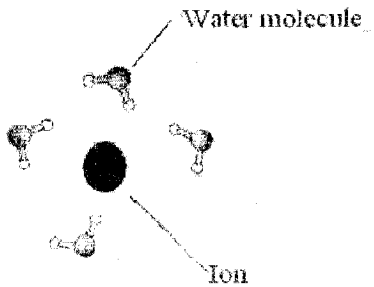
4. Insects can walk on the surface of water body because of ...

   1. The presence of covalent bonds in water.
   2. Adhesion between the insect legs and water molecules.
   3. Cohesion between the insect legs and water molecules.
   4. Capillarity between the water molecules.
   5. The presence of hydrogen bonds between water molecules
   6. I do not know.

5. Water bodies have a relatively constant surface temperature, because...

   1. water freezes at four degrees Celsius.
   2. the temperature does not rise when water changes from one state to another.
   3. water density does not change with change in temperature.
   4. of the high amount of energy required to raise water temperature.
   5. of the low specific heat capacity of water.
   6. I do not know.

6. Choose the ion surrounded by water molecules in the figure below.



1. Cl^-
2. Na^+
3. SO_4
4. K
5. Fe
6. I do not know.

7. Water is said to be a universal solvent because it can dissolve different ...

1. hydrophilic and hydrophobic substances.
2. polar substances.
3. lipids
4. fatty acids.
5. biological molecules.
6. I do not know.

8. Choose the **correct** statement about the properties of water.

1. Its specific heat makes its temperature unstable.
2. Its latent heat of vaporisation helps in the cooling of living organism.
3. Its density properties make it a universal solvent.
4. Its polarity makes its evaporation easy.
5. Its density increases as its temperature drops below 4°C.
6. I do not know.

9. Which of the following statements is **correct**?

1. Glucose and fructose are optical isomers of each other.
2. Glucose exists as L- and D optical isomers.
3. There is no difference between optical and structural isomers.
4. Isomerism reduces the number of types of organic compounds.
5. Glucose and galactose are stereoisomers of each other.
6. I do not know.

10. In β-glucose the OH group of carbon ... is ... the ring.

1. one; below
2. two; above
3. three; above
4. two; below
5. one; above
6. I do not know.

11. A β-glycosidic bond is present in ...

1. amylose
2. amylopectin
3. maltose
4. glycogen
5. lactose
6. I do not know.

12. The difference between glucose and galactose is ...

1. the OH group on carbon 1 is below the ring in glucose and above in galactose.
2. the OH group on carbon 2 is below the ring in glucose and above in galactose.
3. the OH group on carbon 3 is below the ring in glucose and above in galactose.
4. the OH group on carbon 4 is below the ring in glucose and above in galactose.
5. the OH group on carbon 5 is below the ring in glucose and above in galactose.
6. I do not know.

13. Identify the class of carbohydrates that are used in the synthesis of nucleic acids.

1. Trioses
2. Tetroses
3. Pentoses
4. Hexoses
5. Ketoses
6. I do not know.

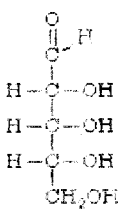
14. Carbohydrates are less efficient energy sources than fats because they.

1. have a higher hydrogen to oxygen ratio.
2. have a lower hydrogen to oxygen ratio.
3. are hydrophobic substances.
4. are hydrophilic molecules.
5. have a higher number of double bonds.
6. I do not know.

15. Cellulose is made up of repeating units of...

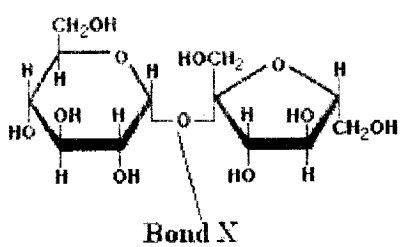
1. β-1-4 linkage between D-glucose units
2. β-1-2 linkage between D-glucose units
3. α-1-4 linkage between D-glucose units
4. α-1-2 linkage between D-glucose units
5. α-1-6 linkage between D-glucose units
6. I do not know.

16. The structure in the figure below is...



1. a furanose open chain.
2. a ketose open chain
3. a pyranose open chain.
4. an aldose open chain.
5. a deoxyribose open chain.
6. I do not know.

17. The structure in the figure below is... and bond X is...



1. sucrose / β1,4 glycosidic bond.
2. lactose / α 1,2 glycosidic bond
3. maltose/ α1,2 glycosidic bond.
4. sucrose / α1,2 glycosidic bond.
5. maltose/ α1,4 glycosidic bond.
6. 6. I do not know.

18. Which of the following is not a function of lipids?

1. Insulation of nerve tissues.
2. Buoyancy in aquatic animals.
3. Energy storage.
4. Hormonal action.
5. Enzymatic action.
6. I do not know.

19. Identify the saturated fatty acid.

1. $C_{16}H_{30}O_2$
2. $C_{17}H_{32}O_2$
3. $C_{18}H_{36}O_2$
4. $C_{20}H_{38}O_2$
5. $C_{22}H_{40}O_2$
6. I do not know.

20. Natural lipids are ....

1. readily soluble in water.
2. amphoteric substances.
3. polymers of fatty acids
4. amphipathic.
5. effective buffers in solution.
6. I do not know.

21. Lipids are insoluble in water because lipid molecules are ...

1. hydrophilic.
2. Neutral.
3. zwitterions.
4. hydrophobic.
5. double stranded.
6. I do not know.

22. Fatty acids which are liquids at ordinary room temperature are called ...

1. lipids
2. fats
3. water
4. oils
5. glycerol
6. I do not know.

23. Which of the following is **not** a lipid?

1. Fats.
2. Oils.
3. Wax.
4. Collagen.
5. Oleic acid.
6. I do not know.

24. $C_3H_8O_3$ is ...

1. a lipid.
2. a fatty acid.
3. an alcohol.
4. a steroid.
5. a triose.
6. I do not know.

25. An ester bond is a characteristic of ....

1. glycerides.
2. fatty acids
3. glycerol.
4. proteins.
5. disaccharides.
6. I do not know.

26. Which one of the following may contain sulphur?

1. DNA.
2. Protein.
3. Starch.
4. Oleic acid.
5. Glycogen.
6. I do not know.

27. Natural amino acids are ....

1. insoluble in water.
2. amphoteric substances.
3. polymers of proteins.
4. amphipathic.
5. polymers of fatty acids.
6. I do not know.

28. When an amino acid is introduced into a basic solution, ...

1. it will be negatively charged.
2. it will be neutralised.
3. it will be positively charged.
4. its polarity will not be affected.
5. the solution will become acidic.
6. I do not know.

29. The optical activity of some amino acids results from the fact that it's alpha carbon ...

1. has no net charge.
2. is a carboxylic acid.
3. is bonded to four different chemical groups
4. is bonded to two or more amino groups.
5. is symmetrical.
6. I do not know.

30. Choose a form which represents the primary structure of proteins.

1. Helical structure.
2. Beta pleated sheet.
3. Amino acid sequence
4. Globular structure.
5. Quaternary structure.
6. I do not know.

31. Hydrogen bonds in a secondary structure of protein molecules are found between ...

1. carboxylic group of one amino acid and sulphide (SH) group of another amino acid.
2. carboxylic group of one amino acid and amino group of another amino acid.
3. one alkyl group of one amino acid and another alkyl group of a second amino acid.
4. phosphate of one amino acid and an alkyl group of the second amino acid.
5. amino group of one amino acid and a hydroxyl group of another amino acid.
6. I do not know.

32. When two cysteine side chains are involved in chemical bonding in proteins they form ...

1. ionic bond.
2. a polar bond.
3. phosphodiester bond.
4. disulphide bridges.
5. glycosidic bond.
6. I do not know.

33. Which of the following is an example of a fibrous protein?

1. Haemoglobin.
2. Collagen.
3. Enzymes.
4. The alpha helix.
5. A quaternary structure.
6. I do not know.

34. One similarity between myoglobin and haemoglobin is that they...

1. both have four subunits.
2. are energy storage molecules.
3. are structural proteins.
4. are oxygen binding proteins.
5. are oxygen transporting proteins.
6. I do not know.

35. Name types of non-covalent bonds that are involved in tertiary structure of proteins.

1. Hydrogen bonds
2. Van der Waals forces and hydrogen bonds.
3. Ionic, hydrogen and hydrophobic bonds
4. Van der Waals forces, Ionic, hydrogen and hydrophobic bonds.
5. Ionic, hydrogen and hydrophobic bonds
6. I do not know.

36. Choose the statement which is **true** about enzymes.

1. Many enzymes do not require non-protein groups to function efficiently.
2. Enzymes do not change the amount of activation energy.
3. Enzymes increase the amount of activation energy required.
4. Enzymes decrease the amount of activation energy required.
5. Enzymes are lipoprotein in nature.
6. I do not know.

37. Which of the following statements is **wrong** about enzyme activity?

1. Enzyme activity is directly dependent on substrate concentration.
2. Enzyme activity is reduced by lowering temperature.
3. One enzyme can catalyse more than one type of chemical reaction.
4. The substrate binds the active site of the enzyme.
5. If there were no enzymes in cells biochemical reactions would be very slow.
6. I do not know.

38. The change in the shape of an enzyme to the point where it loses its function is called...

1. deactivation.
2. neutralization.
3. denaturation.
4. condensation.
5. activation.
6. I do not know.

39. Which of the following statements is **correct**?

1. The products of a catalysed chemical reaction have the same energy as the substrates.
2. An enzyme gets modified after a chemical reaction.
3. The reactants in an enzyme catalysed reaction do not required any external energy.
4. All the energy given out during a biochemical reaction is absorbed by the products.
5. Coenzymes are always necessary in a chemical reaction.
6. I do not know.

40. The majority of enzymes work best at pH of ....

1. 1.
2. 3.
3. 7.
4. 10.
5. 14.
6. I do not know.

41. Which type of bonding is present between the N-1 of pyrimidine and deoxyribose of DNA?

1. Double bond.
2. Hydrogen bond.
3. Ionic bond.
4. Phosphodiester bond.
5. N– glycosidic bond.
6. I do not know.

42. Which carbon atom of deoxyribose is bonded to N – 9 of a purine?

1. C1.
2. C2.
3. C3.
4. C4.
5. C5.
6. I do not know.

43. Which one of the following statements is **not true**?

1. Two strands of DNA are antiparallel.
2. DNA double helix is held together by weak bonds.
3. RNA is wider and longer than DNA.
4. Sequence of bases carries the genetic information.
5. The double stranded structure of DNA is twisted into a right-handed helix.
6. I do not know.

44. Phosphodiester bonds in the formation of DNA are between ....

1. nitrogenous bases.
2. opposite strands of DNA.
3. carbon 5 of the incoming nucleotide and carbon 3 of the growing strand.
4. carbon 2 of the incoming nucleotide and carbon 4 of the growing strand.
5. carbon 1 of the incoming nucleotide and a nitrogenous base of the growing strand.
6. I do not know.

45. Given the following mRNA base sequence, determine the anticodon for tRNA for the highlighted codon: 5- **AGC**UGACUA – 3

1. TCT- 5
2. TCT- 3
3. UCG- 5
4. UCG- 3
5. UGC- 3,
6. I do not know

46. Which of the following biomolecules requires a template for its synthesis?

1. Polysaccharides
2. Phospholipids
3. Proteins
4. Nitrogenous bases
5. DNA
6. I do not know.

47. The sedimentation coefficient of a prokaryotic ribosome is 70S; Its two subunits are...

1. 50S and 20S
2. 50S and 30S
3. 60S and 10S
4. 35S and 35S
5. 65S and 5S
6. I do not know

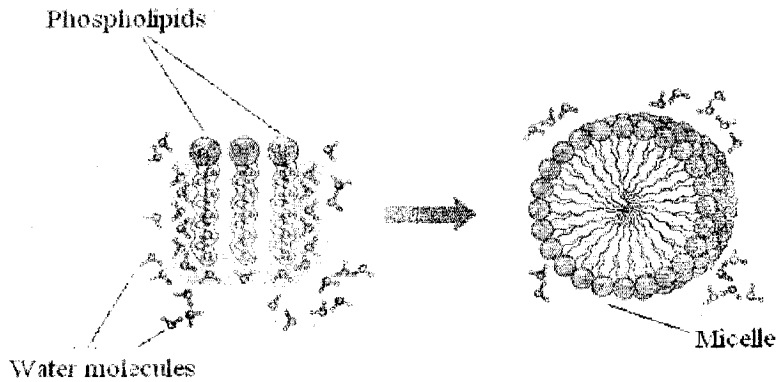
48. Pili in some bacterial cells can best be described as...

1. the outer covering.
2. genetic material.
3. thread- like projections on the surface.
4. vesicles in the cytoplasm.
5. organelles.
6. I do not know.

49. Choose a structure that is present in prokaryotic cells.

1. Nucleolus
2. Nucleus
3. Nucleoid
4. Nuclear membrane
5. Nucleosome
6. I do not know

50. Phospholipids are able to form a micelle in water as shown in the diagram below.



The micelle is formed because…

1. of hydrophilic interactions between water and phospholipid tails.
2. of hydrophobic interactions between water and phospholipids head.
3. of hydrophilic interactions between different water molecules.
4. of hydrophobic interactions between phospholipid tails.
5. of hydrophobic interactions between phospholipid heads.
6. I do not know.

51. Bacterial cells grown for several generations in a heavy nitrogen isotope and allowed to replicate once in a culture of a light nitrogen isotope. Which of the following results is correct?

1. 50% heavy and 50% light DNA
2. 100% light DNA.
3. 100% hybrid DNA.
4. 50% hybrid and 50% light DNA.
5. 50% hybrid and 50% heavy DNA.
6. I do not know.

52. Which of the following statements is **false** about DNA replication?

1. The Okazaki fragments are oriented 5' to 3' away from the replication fork.
2. The lagging strand is oriented 5' to 3' towards the replication fork.
3. There are no Okazaki fragments on the leading strand template.
4. The leading strand is oriented 5' to 3' towards the replication fork.
5. The leading and lagging strands are antiparallel.
6. I do not know.

53. Which of the following enzymes is used to seal the gaps between adjacent DNA fragments?

1. DNA polymerase I
2. DNA Polymerase III
3. RNA polymerase
4. Primase
5. DNA ligase
6. I do not know.

54. DNA replication starts when the ...

1. bonds between hydrogen base and deoxyribose sugar breaks.
2. bonds between the nitrogen base and ribose sugar breaks.
3. leading strand produces Okazaki fragments.
4. hydrogen bonds between the nucleotides of two strands break.
5. phosphodiester bonds between the adjacent nucleotides break.
6. I do not know.

55. The elongation of the leading strand during DNA synthesis...

1. depends on the action of the enzyme topoisomerase.
2. occurs in 3' to 5' direction.
3. progresses away from the replication fork.
4. produces Okazaki fragments.
5. depends on the action of the enzyme helicase.
6. I do not know.

56. Which of the following statements is **incorrect** about transcription?

1. It involves a specific segment of DNA.
2. It involves the whole DNA.
3. It uses DNA as a template for the synthesis of an RNA molecule.
4. It produces a complementary copy of the specific segment of the DNA template.
5. It progresses in the 5' to 3' direction
6. I do not know.

57. What is the function of the sigma factor in transcription?

1. Separates the DNA double helix into two strands.
2. It guides the RNA polymerase to the correct site of the DNA template.
3. It transcribes two strands of DNA
4. It is responsible for transcription elongation.
5. It is involved in the termination of transcription.
6. I do not know.

58. During post-transcriptional processing of RNA in eukaryotes, ...

1. all of the exons are removed and discarded.
2. the RNA is modified by DNA.
3. introns are cut from the RNA and the exons are joined together.
4. the RNA molecule is translated into a protein molecule.
5. the DNA molecule is synthesised from an RNA template.
6. I do not know.

59. How many tRNA molecules are required to translate the 61 codons of the genetic code?

1. 3
2. 4
3. 20
4. 61
5. 64
6. I do not know.

60. The genetic code translates the language of...

1. anticodons into that of amino acids.
2. amino acids into that of ribonucleotides
3. ribonucleotides into that of amino acids.
4. ribonucleotides into that of deoxyribonucleotides.
5. deoxyribonucleotides into that of ribonucleotides.
6. I do not know.

61. During the process of translation...

1. termination is achieved by the binding of formyl methionine to the stop codon.
2. all incoming tRNA s must first bind to the P-site.
3. initiation begins with the binding of the ribosome to the start anticodon.
4. all incoming tRNAs must first bind to the A-site.
5. termination is achieved by the binding of methionine to the stop codon.
6. I do not know.

62. During amino acid activation in prokaryotic translation …

1. an incoming amino acid binds to the A-site of the ribosome.
2. an amino acid binds to its tRNA.
3. tRNA binds to the 30s ribosomal subunit.
4. tRNA binds to the 50s ribosomal subunit.
5. an amino acid reacts with ATP and a specific aminoacyl synthetase.
6. I do not know.

63. Which one of the DNA base sequences below would be for a tripeptide of arginine? (CGU), leucine (UUA), and valine (GUG)?

1. CGUUUAGUC
2. GCAAAUCAG
3. GCAAATCAG
4. CGTTTUGAC
5. GCAAATCAC
6. I do not know.

64. How many tRNA synthetase enzyme are required to translate 61 codons?

1. 3
2. 4
3. 20
4. 60
5. 64
6. I do not know.

65. The first step of the formation of initiation complex during translation takes place when …

1. an incoming amino acid binds to the A-site of the ribosome.
2. an amino acid binds to its tRNA.
3. tRNA binds to the 30s ribosomal subunit.
4. tRNA binds to the 50s ribosomal subunit.
5. an amino acid reacts with ATP and a specific aminoacyl synthetase.
6. I do not know.

66. Termination of protein synthesis is achieved by the binding of …

1. methinonine to the stop codon.
2. ribosome to the stop codon.
3. tRNA to the stop codon.
4. release factor to the stop codon
5. elongation factor to the stop codon.
6. I do not know

67. An operon is ...

1. a group of proteins that work together.
2. a group of amino acids that build proteins that work together.
3. a double stranded DNA sequence of ribonucleotides.
4. a DNA sequence made up of genes that work together.
5. an RNA sequence made up of unrelated genes.
6. I do not know.

68. In the *Lac*-operon, the gene product of *Lac A* gene is ...

1. β-galactosidase.
2. β-galactoside isomerase.
3. β-galactoside permease.
4. β- galactoside transacetylase.
5. β-galactoside.
6. I do not know.

69. Identify the condition in the *Lac* operon, which facilitates a high level of gene expression.

1. Low glucose, low lactose.
2. Low glucose, high lactose.
3. High glucose, absence of lactose.
4. High glucose, high lactose
5. Absence of glucose, high lactose.
6. I do not know.

70. The operator gene of the *Lac* operon is turned on when a lactose molecule binds to the ..

1. promotor site.
2. repressor molecule.
3. operator.
4. structural genes.
5. primer.
6. I do not know.

71. Autosomal chromosomes in humans are in ...

1. 22 pairs.
2. 23 pairs.
3. 44 pairs.
4. 46 pairs.
5. 48 pairs.
6. I do not know.

72. A chromosome in which the centromere is situated in the middle is known as....

1. telocentric.
2. metacentric.
3. sub-metacentric.
4. acrocentric.
5. sub-acrocentric.
6. I do not know.

73. The nucleosome...

1. is located in the nuclear membrane.
2. has DNA and non-histone proteins.
3. is responsible for packing RNA into chromosomes.
4. Contains a nitrogenous base, a pentose sugar and a phosphate group.
5. contains a core of histones with DNA wrapped around it.
6. I do not know.

74. Choose the statement which is **true** about alleles.

1. Alleles are the alternative forms of a gene.
2. Genes are the alternative forms of an allele.
3. The different alleles of a gene are randomly located on different chromosomes.
4. The different alleles of a gene are located on the same chromosome.
5. Alleles of a gene are always in heterozygous state.
6. I do not know.

75. Which one of the following processes describes the activities that include both cell division and cellular growth?

1. Mitosis.
2. Meiosis I.
3. Cytokinesis.
4. Meiosis II.
5. Interphase.
6. I do not know.

76. DNA is synthesised during ...

1. prophase.
2. metaphase.
3. the G_1 phase.
4. the G_2 phase.
5. the S phase.
6. I do not know.

77. Choose the event which corresponds to prophase.

1. Formation of a wall plate.
2. Formation of four (4) haploid chromosomes.
3. Formation of spindle fibres.
4. Alignment of chromosomes along the equatorial plate.
5. Separation of sister chromatids.
6. I do not know.

78. Separation of homologous chromosomes during meiosis takes place during ....

1. Cytokinesis.
2. Anaphase I.
3. Prophase I.
4. Metaphase II.
5. Anaphase II.
6. I do not know.

79. Crossing-over occurs during ....

1. prophase of meiosis I.
2. prophase of meiosis II.
3. metaphase of meiosis I.
4. metaphase of meiosis II.
5. anaphase of meiosis I.
6. I do not know.

80. Someone who is homozygous for a gene has.... for that gene.

1. only one dominant allele
2. only one recessive allele
3. two different alleles
4. neither dominant nor recessive alleles
5. two copies of the same allele
6. I do not know.

A cross was made between plants with red flowers (C^R) and plants with white flowers (C^W). The offspring had pink flowers. (Use this information to answer questions 81 and 82).

81. Identify the parental cross which gave rise to the results above.

1. $C^R C^R \times C^R C^R$
2. $C^W C^R \times C^W C^R$
3. $C^R C^R \times C^W C^W$
4. $C^W C^W \times C^W C^W$
5. $C^R C^R \times C^W C^R$
6. I do not know.

82. Identify the kind of inheritance shown in question 81 (above).

1. Complete dominance
2. Incomplete dominance
3. Codominance
4. Inheritance involving lethal genes
5. Multiple allele inheritance
6. I do not know.

83. Choose the **correct** statement.

1. The genotype of an organism is the same as the phenotype.
2. The genotype is influenced by the environment.
3. The physical appearance of an organism is called the phenotype.
4. The genetic constitution of an organism is called the phenotype.
5. The genotype and phenotype are both influenced by the environment.
6. I do not know.

84. Choose the statement which is **false**.

1. A dominant allele can be expressed in the presence of a recessive allele.
2. Co-dominant alleles are expressed equally.
3. Incompletely dominant alleles express an intermediate phenotype.
4. A recessive allele can be expressed in the presence of a dominant allele.
5. Recessive alleles are only expressed in the homozygous state.
6. I do not know.

85. In a cross between cattle with red coat colour and that of white coat colour, offspring produced had red coat colour with white spots. Determine the type of alleles controlling this types of coat colour.

1. Dominant alleles
2. Recessive alleles.
3. Codominant alleles.
4. Incompletely dominant alleles.
5. Both dominant and recessive alleles.
6. I do not know.

86. The Law of Segregation is illustrated by...

1. the dihybrid cross.
2. gene linkage.
3. the test - cross.
4. Independent assortment.
5. the monohybrid cross.
6. I do not know.

87. The expected Mendelian phenotypic ratio of a dihybrid inheritance test cross is ...

1. 3:1.
2. 3:1:1.
3. 9:3:3:1.
4. 1:1.
5. 1:1:1:1.
6. I do not know.

88. When Mendel crossed tall plants with short plants, half of the offspring were tall and the other half were short. This is because...

1. the tall parental plants were homozygous.
2. the short parental plants were heterozygous.
3. the tall parental plants were heterozygous.
4. both parental plants were homozygous.
5. both parental plants were heterozygous
6. I do not know.

89. A tall green male pea plant with genotype **TtGg** is crossed with a short white female pea plant whose genotype is **ttgg**. Determine the type of cross.

1. monohybrid cross.
2. monohybrid test cross.
3. dihybrid cross.
4. dihybrid test cross.
5. multiple allelic cross.
6. I do not know.

90. What percentage of white offspring will be produced from a cross between a heterozygous purple and a recessive white pea plant?

1. 0%
2. 25%.
3. 50%.
4. 75%.
5. 100%
6. I do not know.

91. In a Mendelian dihybrid cross the F_2 offspring have ...phenotypes and .. genotypes.

1. 9, 3
2. 9, 4
3. 3, 9
4. 4, 9
5. 16,1
6. I do not know.

92. In peas, round seed shape (**R**) is dominant to wrinkled seed shape (**r**), and yellow seed colour (**Y**) is dominant to green seed colour (**y**). A pea plant which is homozygous round and has green seed colour is crossed with a pea plant that has heterozygous round seed shape and heterozygous yellow seed colour. Determine the genotypes of the parental plants in this cross.

1. RyRy X RrYy.
2. RRYY X RrYy.
3. RRyy X rryy.
4. RRyy X RrYy.
5. rryy X RrYy.
6. I do not know.

93. Which of the following represents linked genes?

1. Genes which assort independently.
2. Genes located on different chromosomes.
3. Genes located only on autosomal chromosomes.
4. Genes located on the same chromosome.
5. Genes located only on sex chromosomes.
6. I do not know.

94. A cross was carried out between two plants; **YyRr** (Yellow/Round) and **yyrr** Green/Wrinkled) in which allele **Y** is responsible for yellow colour and allele y is responsible for green colour while allele **R** is responsible for round shape and allele **r** is responsible for wrinkled shape. Out of 100 progeny, the following results were obtained:

Yellow round	40
Yellow wrinkled	10
Green round	10
Green wrinkled	40

A chi-squared test was then carried out to test the results of the progeny using Table 1.

The calculated chi-squared value is...

1. 9
2. 18
3. 27
4. 36
5. 45
6. I do not know

95. The tabulated (critical) chi-squared value at 5% in Questions 94 (above) is...

1. 2.4
2. 3.8
3. 6.0
4. 7.8
5. 9.5
6. I do not know

96. Base on the results in Questions 94 and 95 the **correct** conclusion is as follows:

1. The alleles are segregating in the expected ratio.
2. The gene for seed shape is linked to the gene for seed colour.
3. The gene for seed shape and the gene for seed colour are on different chromosomes.
4. The difference between the observed results and expected results is not significant.
5. The expected ratio of the progeny phenotypes is 9:3:3:1
6. I do not know.

97. Height in humans is influenced by the ...

1. phenotype and environment.
2. environment and genotype.
3. diet and environment.
4. phenotype and environment.
5. diet and exercise.
6. I do not know.

98. What is (are) the possible blood group(s) for a child whose parents are both heterozygous for blood group A?

1. Blood group A only.
2. Blood group B only.
3. Blood groups A or O.
4. Blood groups B or O.
5. Blood group AB only.
6. I do not know.

99. What is the sex chromosome content of a human sperm?

1. X
2. Y
3. XX
4. XY
5. YY
6. I do not know

100. A family has 3 boys and 1 girl. What is the chance that the next child will be a girl?

1. 25%
2. 33%
3. 50%
4. 75%
5. 100%
6. I do not know.

Table 1. Chi-square table

The probabilities associated with values of χ^2

DEGREES OF FREEDOM	PROBABILITY										
	0.01	0.05	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
1	6.6	3.8	2.7	1.6	1.1	0.71	0.45	0.27	0.15	0.064	0.016
2	9.2	6.0	4.6	3.2	2.4	1.83	1.39	1.02	0.71	0.446	0.211
3	11.3	7.8	6.3	4.6	3.7	2.95	2.37	1.87	1.42	1.005	0.584
4	13.3	9.5	7.8	6.0	4.9	4.04	3.36	2.75	2.19	1.649	1.064
5	15.1	11.1	9.2	7.3	6.1	5.13	4.35	3.66	3.00	2.343	1.610
6	16.8	12.6	10.6	8.6	7.2	6.21	5.35	4.57	3.83	3.070	2.204
7	18.5	14.1	12.0	9.8	8.4	7.28	6.35	5.49	4.67	3.822	2.833
8	20.1	15.5	13.4	11.0	9.5	8.35	7.34	6.42	5.53	4.594	3.490
9	21.7	16.9	14.7	12.2	10.7	9.41	8.34	7.36	6.39	5.380	4.168

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2020 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 2002: STATISTICAL ANALYSIS OF BIOLOGICAL DATA
THEORY PAPER

TIME: THREE HOURS

INSTRUCTIONS: ANSWER **FIVE** QUESTIONS, **TWO** FROM EACH SECTION AND THE **FIFTH** FROM EITHER SECTION. ILLUSTRATE YOUR ANSWER WHERE NECESSARY. THREE STATISTICAL TABLES, THE NORMAL DISTRIBUTION, THE *t* DISTRIBUTION AND PEARSON PRODUCT MOMENT CORRELATION COEFFIENT CRITICAL VALUES ARE PROVIDED.

SECTION A

1. 10 students were randomly selected and asked to report the number of books they each read in the last month. Table 1 shows what they reported.

   Table 1. Number of books read by each student in one month.

Student	1	2	3	4	5	6	7	8	9	10
Number of books	5	3	4	3	0	1	4	4	8	0

   (a) Calculate the mean, mode and median.
   (b) Calculate the range, variance, and standard deviation.
   (c) Construct a box plot and comment on the skewness of the data.

2. (a) Consider Figure 1 below and answer the following questions:

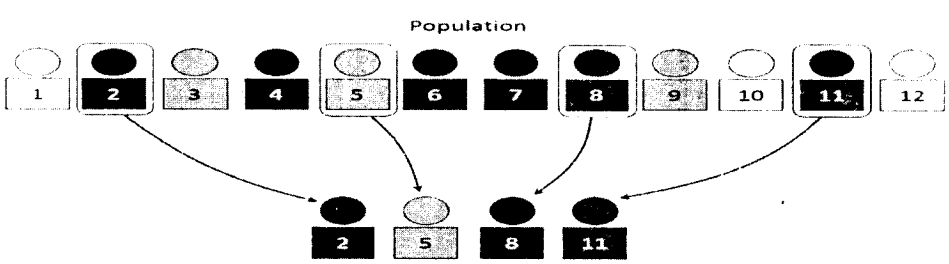


Figure 1: Sample drawn from a population.
Source: https://www.netquest.com/blog

TURN OVER

i. Identify and describe the sampling method shown in Figure 1.
ii. Calculate the K^{th} term.
iii. Suppose we randomly selected a sample with our starting point as person 3, state which members of the population will be part of the sample.
iv. State the advantages and disadvantages of this sampling method.

(b) A school has 800 male students and 200 female students, and a researcher wants to have a sample size of 100.

i. State the sampling method that should be used to ensure that the sample reflects the gender balance of the school and give reasons for your answer.
ii. Describe the method identified in 2(b) i.
iii. Calculate how many male students and how many female students will be part of the sample.

3. In a study, individuals with drug addiction were asked about co-occurring drug and alcohol addictions. Let the discrete random variable X represent the number of co-occurring addictive substances used by the subjects. Table 2 summarises the frequency distribution for this random variable.

Table 2: Summary of the frequency distribution for variable X.

Number of substances used	Frequency
0	144
1	342
2	142
3	72
4	39
5	20
6	6
7	9
8	2
9	1

PROCEED TO NEXT PAGE

(a) Construct a table of the relative frequency and cumulative frequency for this discrete distribution.
(b) Construct a bar graph of probability distribution and a line graph representing the cumulative probability distribution.
(c) Find the probability that an individual selected at random used five addictive substances.
(d) Find the probability that the individual selected at random used fewer than three addictive substances.
(e) Find the probability that the individual selected at random used more than six addictive substances.
(f) Find the probability that the individual selected at random used between 2 and 5 addictive substances.

4. Based on the data collected from the UNZA Health Services, an estimation of the percentage of adults who have at some point been told that they have hypertension is 23.53%. If we selected a random sample of 20 adults in the UNZA community and assumed the probability that each has been told that he or she had hypertension was 0.24. Find the probability that the number of people in the sample who had been told that they had hypertension would be:
(a) Exactly three.
(b) Three or more.
(c) Fewer than three.
(d) Between three and seven.

SECTION B

5. (a) A researcher wishes to estimate the proportion of adult males who are under 1.5 metres tall. She wants to be 90% confident that her estimate is within 5% of the true proportion.
i. Determine how large a sample should be taken if in a sample of 300 males, 30 were under 1.5 metres tall.
ii. Determine how large a sample size would be required if no estimate of the sample proportion is available.
(b) For a sample of 24 operating rooms taken in a hospital study, the mean noise level was 41.6 decibels, and the standard deviation was 7.5. Find the 95% confidence interval of the true mean of the noise level in the operating rooms.

TURN OVER

6. The average production of groundnuts in Chongwe District is 3000 kilograms (kg) per acre. A new groundnut variety has been developed and is tested on 60 individual plots of land. The mean yield with the new variety is 3120kg of groundnuts per acre, and the population standard deviation is 578 Kg. Determine whether there is an increase in the average production at $\alpha = 0.05$.

7. A researcher wanted to compare the pulse rates, in beats per minute, of identical twins to see whether there was any difference. Eight pairs of twins were selected. The rates are given in Table 3 as number of beats per minute.

Table 3. Pulse rates of identical twins in beats per minute.

Twin A	87	92	78	83	88	90	84	93
Twin B	83	95	79	83	86	93	80	86

Use the data in Table 3 to determine whether there is a significant difference in the average pulse rates of the twins at $\alpha = 0.01$.

8. A lecturer of Biostatistics wants to see how the number of absences for a student in her class affects the student's final grade. The data obtained from a sample are shown in Table 4.

Table 4. Number of absences and final grades of Biostatistics students.

No. of absences (x)	10	12	2	0	8	5
Final grade (y)	70	65	96	94	75	82

Use the data in the Table 4 to answer the following questions:

(a) Compute the correlation coefficient, r.
(b) State the hypotheses.
(c) Determine whether there is a significant linear relationship between the number of absences and the student's final grade at $\alpha = 0.05$. **Use Table I.**
(d) Find the equation of the regression line.

END OF EXAMINATION

BIO 2002 STATISTICAL FORMULAE

Formulae for the mean

Population mean

$$\mu = \frac{\Sigma X}{N}$$

Sample mean

$$\bar{X} = \frac{\Sigma X}{n}$$

Formula for variance

Population variance $\sigma^2 = \frac{\Sigma(X-\mu)^2}{n}$

Sample variance $S^2 = \frac{\Sigma X^2 - [(\Sigma X)^2/n]}{n-1}$

Formula for coefficient of variation (CV)

For populations

$$CV = \frac{\sigma}{\mu} X\ 100\%$$

For samples

$$CV = \frac{s}{\bar{X}} X\ 100\%$$

Formula for confidence interval of the mean when σ is known (when $n \geq 30$, s can be used if σ is unknown).

$$\bar{X} - z_{\alpha/2}\left(\frac{\sigma}{\sqrt{n}}\right) < \mu < \bar{X} + z_{\alpha/2}\left(\frac{\sigma}{\sqrt{n}}\right)$$

Formula for the confidence interval of the mean when σ is unknown and $n < 30$.

$$\bar{X} - t_{\alpha/2}\left(\frac{s}{\sqrt{n}}\right) < \mu < \bar{X} + t_{\alpha/2}\left(\frac{s}{\sqrt{n}}\right)$$

Formula for the confidence interval for a proportion

$$\hat{p} - z_{\alpha/2}\sqrt{\frac{\hat{p}\hat{q}}{n}} < p < \hat{p} + z_{\alpha/2}\sqrt{\frac{\hat{p}\hat{q}}{n}}$$

Where $\hat{p}$ = X/n and $\hat{q} = 1 - \hat{p}$

Formula for sample size for means

$$n = \left(\frac{z_{\alpha/2} \cdot \sigma}{E}\right)^2$$

Where E is the maximum error

Formula for sample size for proportions.

$$n = \hat{p}\hat{q}\left(\frac{z_{\alpha/2}}{E}\right)^2$$

Formulae for the z test for means

$z = \frac{\bar{X}-\mu}{\sigma/\sqrt{n}}$ for any value n

$z = \frac{\bar{X}-\mu}{s/\sqrt{n}}$ for $n \geq 30$

Formula for t tests for means

$t = \frac{\bar{X}-\mu}{s/\sqrt{n}}$ for $n < 30$

Formula for z tests for proportions

$z = \frac{\hat{p}-p}{\sqrt{pq/n}}$

Formulae for the z test for comparing two means from independent populations

$$z = \frac{(\bar{X}_1-\bar{X}_2)-(\mu_1-\mu_2)}{\sqrt{\frac{\sigma_1^2}{n_1}+\frac{\sigma_2^2}{n_2}}}$$

$z = \frac{(\bar{X}_1-\bar{X}_2)-(\mu_1-\mu_2)}{\sqrt{\frac{s_1^2}{n_1}+\frac{s_2^2}{n_2}}}$ when σ_1^2 and σ_1^2 are unknown and provided $n_1 \geq 30$ and $n_2 \geq 30$

Formula for testing the difference between two means from small independent samples (one or both sample sizes are less than 30)

Variances assumed to be unequal

$$t = \frac{(\bar{X}_1-\bar{X}_2)-(\mu_1-\mu_2)}{\sqrt{\frac{s_1^2}{n_1}+\frac{s_2^2}{n_2}}}$$

Where the degrees of freedom are equal to the smaller of the n_1-1 or n_2 -1.

Formula for testing the difference between two means from small independent samples.

Variances are assumed to be equal

$$t = \frac{(\bar{X}_1-\bar{X}_2)-(\mu_1-\mu_2)}{\sqrt{\frac{(n_1-1)s_1^2+(n_2-1)s_2^2}{n_1+n_2-2}}\sqrt{\frac{1}{n_1}+\frac{1}{n_2}}}$$

Where degrees of freedom are equal to $n_1 + n_2 - 2$.

Formula for the t test for comparing two means from dependent samples

$t = \frac{\bar{D}-\mu_D}{s_{D/\sqrt{n}}}$

With d.f. = n -1 and where

$$\bar{D} = \frac{\Sigma D}{n} \quad and \quad s_D = \sqrt{\frac{n\Sigma D^2 - (\Sigma D)^2}{n(n-1)}}$$

Formula for the z test for comparing two proportions

$$z = \frac{(\hat{p}_1 - \hat{p}_2) - (p_1 - p_2)}{\sqrt{\bar{p}\bar{q}(\frac{1}{n_1} + \frac{1}{n_2})}}$$

Where

$$\bar{p} = \frac{X_1 + X_2}{n_1 + n_2} \qquad \hat{p}_1 = \frac{X_1}{n_1}$$

$$\bar{q} = 1 - \bar{p} \qquad \hat{p}_2 = \frac{X_2}{n_2}$$

Formula for correlation coefficient

$$r = \frac{n(\Sigma xy) - (\Sigma x)(\Sigma y)}{\sqrt{[n(\Sigma x^2) - (\Sigma x)^2]\,[n(\Sigma y^2) - (\Sigma y)^2]}}$$

Where n is the number of data pairs

t test for significance of the correlation coefficient, r

$$t = r\sqrt{\frac{n-2}{1-r^2}}$$

With degrees d.f. equal to n-2

Formula for the regression line y' = a + bx where

$$a = \frac{(\Sigma y)(\Sigma x^2) - (\Sigma x)(\Sigma xy)}{n(\Sigma x^2) - (\Sigma x)^2} \text{ and } b = \frac{n(\Sigma xy) - (\Sigma x)(\Sigma y)}{n(\Sigma x^2) - (\Sigma x)^2}$$

Formular for Binomial distribution

$$P(X) = \frac{n!}{(n-X)!X!} \cdot p^X \cdot q^{n-X}$$

Formular for Poisson distribution

$$P(X; \lambda) = \frac{e^{-\lambda}\lambda^X}{X!}$$

Table E The Standard Normal Distribution

Cumulative Standard Normal Distribution

z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
−3.4	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0002
−3.3	.0005	.0005	.0005	.0004	.0004	.0004	.0004	.0004	.0004	.0003
−3.2	.0007	.0007	.0006	.0006	.0006	.0006	.0006	.0005	.0005	.0005
−3.1	.0010	.0009	.0009	.0009	.0008	.0008	.0008	.0008	.0007	.0007
−3.0	.0013	.0013	.0013	.0012	.0012	.0011	.0011	.0011	.0010	.0010
−2.9	.0019	.0018	.0018	.0017	.0016	.0016	.0015	.0015	.0014	.0014
−2.8	.0026	.0025	.0024	.0023	.0023	.0022	.0021	.0021	.0020	.0019
−2.7	.0035	.0034	.0033	.0032	.0031	.0030	.0029	.0028	.0027	.0026
−2.6	.0047	.0045	.0044	.0043	.0041	.0040	.0039	.0038	.0037	.0036
−2.5	.0062	.0060	.0059	.0057	.0055	.0054	.0052	.0051	.0049	.0048
−2.4	.0082	.0080	.0078	.0075	.0073	.0071	.0069	.0068	.0066	.0064
−2.3	.0107	.0104	.0102	.0099	.0096	.0094	.0091	.0089	.0087	.0084
−2.2	.0139	.0136	.0132	.0129	.0125	.0122	.0119	.0116	.0113	.0110
−2.1	.0179	.0174	.0170	.0166	.0162	.0158	.0154	.0150	.0146	.0143
−2.0	.0228	.0222	.0217	.0212	.0207	.0202	.0197	.0192	.0188	.0183
−1.9	.0287	.0281	.0274	.0268	.0262	.0256	.0250	.0244	.0239	.0233
−1.8	.0359	.0351	.0344	.0336	.0329	.0322	.0314	.0307	.0301	.0294
−1.7	.0446	.0436	.0427	.0418	.0409	.0401	.0392	.0384	.0375	.0367
−1.6	.0548	.0537	.0526	.0516	.0505	.0495	.0485	.0475	.0465	.0455
−1.5	.0668	.0655	.0643	.0630	.0618	.0606	.0594	.0582	.0571	.0559
−1.4	.0808	.0793	.0778	.0764	.0749	.0735	.0721	.0708	.0694	.0681
−1.3	.0968	.0951	.0934	.0918	.0901	.0885	.0869	.0853	.0838	.0823
−1.2	.1151	.1131	.1112	.1093	.1075	.1056	.1038	.1020	.1003	.0985
−1.1	.1357	.1335	.1314	.1292	.1271	.1251	.1230	.1210	.1190	.1170
−1.0	.1587	.1562	.1539	.1515	.1492	.1469	.1446	.1423	.1401	.1379
−0.9	.1841	.1814	.1788	.1762	.1736	.1711	.1685	.1660	.1635	.1611
−0.8	.2119	.2090	.2061	.2033	.2005	.1977	.1949	.1922	.1894	.1867
−0.7	.2420	.2389	.2358	.2327	.2296	.2266	.2236	.2206	.2177	.2148
−0.6	.2743	.2709	.2676	.2643	.2611	.2578	.2546	.2514	.2483	.2451
−0.5	.3085	.3050	.3015	.2981	.2946	.2912	.2877	.2843	.2810	.2776
−0.4	.3446	.3409	.3372	.3336	.3300	.3264	.3228	.3192	.3156	.3121
−0.3	.3821	.3783	.3745	.3707	.3669	.3632	.3594	.3557	.3520	.3483
−0.2	.4207	.4168	.4129	.4090	.4052	.4013	.3974	.3936	.3897	.3859
−0.1	.4602	.4562	.4522	.4483	.4443	.4404	.4364	.4325	.4286	.4247
−0.0	.5000	.4960	.4920	.4880	.4840	.4801	.4761	.4721	.4681	.4641

For z values less than −3.49, use 0.0001

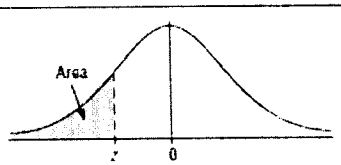


Table E *(continued)*

Cumulative Standard Normal Distribution

z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0.0	.5000	.5040	.5080	.5120	.5160	.5199	.5239	.5279	.5319	.5359
0.1	.5398	.5438	.5478	.5517	.5557	.5596	.5636	.5675	.5714	.5753
0.2	.5793	.5832	.5871	.5910	.5948	.5987	.6026	.6064	.6103	.6141
0.3	.6179	.6217	.6255	.6293	.6331	.6368	.6406	.6443	.6480	.6517
0.4	.6554	.6591	.6628	.6664	.6700	.6736	.6772	.6808	.6844	.6879
0.5	.6915	.6950	.6985	.7019	.7054	.7088	.7123	.7157	.7190	.7224
0.6	.7257	.7291	.7324	.7357	.7389	.7422	.7454	.7486	.7517	.7549
0.7	.7580	.7611	.7642	.7673	.7704	.7734	.7764	.7794	.7823	.7852
0.8	.7881	.7910	.7939	.7967	.7995	.8023	.8051	.8078	.8106	.8133
0.9	.8159	.8186	.8212	.8238	.8264	.8289	.8315	.8340	.8365	.8389
1.0	.8413	.8438	.8461	.8485	.8508	.8531	.8554	.8577	.8599	.8621
1.1	.8643	.8665	.8686	.8708	.8729	.8749	.8770	.8790	.8810	.8830
1.2	.8849	.8869	.8888	.8907	.8925	.8944	.8962	.8980	.8997	.9015
1.3	.9032	.9049	.9066	.9082	.9099	.9115	.9131	.9147	.9162	.9177
1.4	.9192	.9207	.9222	.9236	.9251	.9265	.9279	.9292	.9306	.9319
1.5	.9332	.9345	.9357	.9370	.9382	.9394	.9406	.9418	.9429	.9441
1.6	.9452	.9463	.9474	.9484	.9495	.9505	.9515	.9525	.9535	.9545
1.7	.9554	.9564	.9573	.9582	.9591	.9599	.9608	.9616	.9625	.9633
1.8	.9641	.9649	.9656	.9664	.9671	.9678	.9686	.9693	.9699	.9706
1.9	.9713	.9719	.9726	.9732	.9738	.9744	.9750	.9756	.9761	.9767
2.0	.9772	.9778	.9783	.9788	.9793	.9798	.9803	.9808	.9812	.9817
2.1	.9821	.9826	.9830	.9834	.9838	.9842	.9846	.9850	.9854	.9857
2.2	.9861	.9864	.9868	.9871	.9875	.9878	.9881	.9884	.9887	.9890
2.3	.9893	.9896	.9898	.9901	.9904	.9906	.9909	.9911	.9913	.9916
2.4	.9918	.9920	.9922	.9925	.9927	.9929	.9931	.9932	.9934	.9936
2.5	.9938	.9940	.9941	.9943	.9945	.9946	.9948	.9949	.9951	.9952
2.6	.9953	.9955	.9956	.9957	.9959	.9960	.9961	.9962	.9963	.9964
2.7	.9965	.9966	.9967	.9968	.9969	.9970	.9971	.9972	.9973	.9974
2.8	.9974	.9975	.9976	.9977	.9977	.9978	.9979	.9979	.9980	.9981
2.9	.9981	.9982	.9982	.9983	.9984	.9984	.9985	.9985	.9986	.9986
3.0	.9987	.9987	.9987	.9988	.9988	.9989	.9989	.9989	.9990	.9990
3.1	.9990	.9991	.9991	.9991	.9992	.9992	.9992	.9992	.9993	.9993
3.2	.9993	.9993	.9994	.9994	.9994	.9994	.9994	.9995	.9995	.9995
3.3	.9995	.9995	.9995	.9996	.9996	.9996	.9996	.9996	.9996	.9997
3.4	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9998

For z values greater than 3.49, use 0.9999.

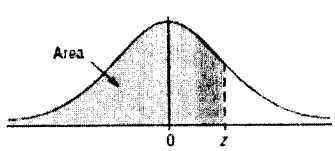


Table F (The *t* Distribution)

	Confidence intervals	80%	90%	95%	98%	99%
	One tail, α	0.10	0.05	0.025	0.01	0.005
d.f.	Two tails, α	0.20	0.10	0.05	0.02	0.01
1		3.078	6.314	12.706	31.821	63.657
2		1.886	2.920	4.303	6.965	9.925
3		1.638	2.353	3.182	4.541	5.841
4		1.533	2.132	2.776	3.747	4.604
5		1.476	2.015	2.571	3.365	4.032
6		1.440	1.943	2.447	3.143	3.707
7		1.415	1.895	2.365	2.998	3.499
8		1.397	1.860	2.306	2.896	3.355
9		1.383	1.833	2.262	2.821	3.250
10		1.372	1.812	2.228	2.764	3.169
11		1.363	1.796	2.201	2.718	3.106
12		1.356	1.782	2.179	2.681	3.055
13		1.350	1.771	2.160	2.650	3.012
14		1.345	1.761	2.145	2.624	2.977
15		1.341	1.753	2.131	2.602	2.947
16		1.337	1.746	2.120	2.583	2.921
17		1.333	1.740	2.110	2.567	2.898
18		1.330	1.734	2.101	2.552	2.878
19		1.328	1.729	2.093	2.539	2.861
20		1.325	1.725	2.086	2.528	2.845
21		1.323	1.721	2.080	2.518	2.831
22		1.321	1.717	2.074	2.508	2.819
23		1.319	1.714	2.069	2.500	2.807
24		1.318	1.711	2.064	2.492	2.797
25		1.316	1.708	2.060	2.485	2.787
26		1.315	1.706	2.056	2.479	2.779
27		1.314	1.703	2.052	2.473	2.771
28		1.313	1.701	2.048	2.467	2.763
29		1.311	1.699	2.045	2.462	2.756
30		1.310	1.697	2.042	2.457	2.750
32		1.309	1.694	2.037	2.449	2.738
34		1.307	1.691	2.032	2.441	2.728
36		1.306	1.688	2.028	2.434	2.719
38		1.304	1.686	2.024	2.429	2.712
40		1.303	1.684	2.021	2.423	2.704
45		1.301	1.679	2.014	2.412	2.690
50		1.299	1.676	2.009	2.403	2.678
55		1.297	1.673	2.004	2.396	2.668
60		1.296	1.671	2.000	2.390	2.660
65		1.295	1.669	1.997	2.385	2.654
70		1.294	1.667	1.994	2.381	2.648
75		1.293	1.665	1.992	2.377	2.643
80		1.292	1.664	1.990	2.374	2.639
90		1.291	1.662	1.987	2.368	2.632
100		1.290	1.660	1.984	2.364	2.626
500		1.283	1.648	1.965	2.334	2.586
1000		1.282	1.646	1.962	2.330	2.581
(z) ∞		1.282[a]	1.645[b]	1.960	2.326[c]	2.576[d]

[a] This value has been rounded to 1.28 in the textbook.
[b] This value has been rounded to 1.65 in the textbook.
[c] This value has been rounded to 2.33 in the textbook.
[d] This value has been rounded to 2.58 in the textbook.

Source: Adapted from W. H. Beyer, *Handbook of Tables for Probability and Statistics*, 2nd ed., CRC Press, Boca Raton, Fla., 1986. Reprinted with permission.

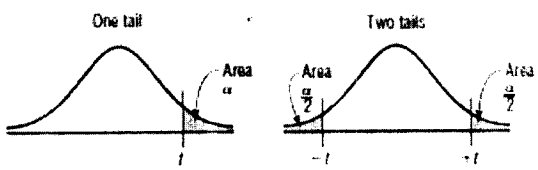


Table I Critical Values for the PPMC

Reject H_0: $\rho = 0$ if the absolute value of r is greater than the value given in the table. The values are for a two-tailed test; d.f. $= n - 2$.

d.f.	$\alpha = 0.05$	$\alpha = 0.01$
1	0.999	0.999
2	0.950	0.999
3	0.878	0.959
4	0.811	0.917
5	0.754	0.875
6	0.707	0.834
7	0.666	0.798
8	0.632	0.765
9	0.602	0.735
10	0.576	0.708
11	0.553	0.684
12	0.532	0.661
13	0.514	0.641
14	0.497	0.623
15	0.482	0.606
16	0.468	0.590
17	0.456	0.575
18	0.444	0.561
19	0.433	0.549
20	0.423	0.537
25	0.381	0.487
30	0.349	0.449
35	0.325	0.418
40	0.304	0.393
45	0.288	0.372
50	0.273	0.354
60	0.250	0.325
70	0.232	0.302
80	0.217	0.283
90	0.205	0.267
100	0.195	0.254

Source: From *Biometrika Tables for Statisticians*, vol. 1 (1962), p. 138. Reprinted with permission.

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2020 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 2101: ECOSYSTEMS AND BIODIVERSITY
THEORY PAPER

TIME: THREE HOURS

INSTRUCTIONS: ANSWER **FIVE** QUESTIONS; **TWO** FROM EACH SECTION AND THE **FIFTH** FROM EITHER SECTION. ILLUSTRATE YOUR ANSWER WHERE NECESSARY. USE **SEPARATE ANSWER BOOKS** FOR EACH SECTION.

SECTION A

1. Summarise each of the following:
   (a) Energy flow in an ecosystem.
   (b) Ecosystem structure.
   (c) Consumers.
   (d) Inverted pyramid of biomass.

2. Summarise each of the following:
   (a) Factors that affect the distribution of organisms in aquatic ecosystems.
   (b) Primary productivity.
   (c) Nitrogen fixation.
   (d) Characteristics of tropical rain forests.

3. Discuss the process of decomposition and factors that affect it.

4. Discuss the levels of integration in an ecosystem, with an organism being the lowest level of organization.

SECTION B

5. Contrast between each of the following:
   (a) Seral and climax communities.
   (b) Exponential and logistic population growth.

TURN OVER

6. Summarise each of the following.
   (a) Sex ratio in populations.
   (b) Population density.
   (c) Fecundity.
   (d) Population distribution.

7. Describe any three aquatic biomes.

8. (a) Explain how the De-Lury method could be used to estimate animal population size in an ecosystem.
   (b) Summarise weaknesses of the method explained in 8(a) above.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2020 ACADEMIC YEAR

FINAL EXAMINATIONS

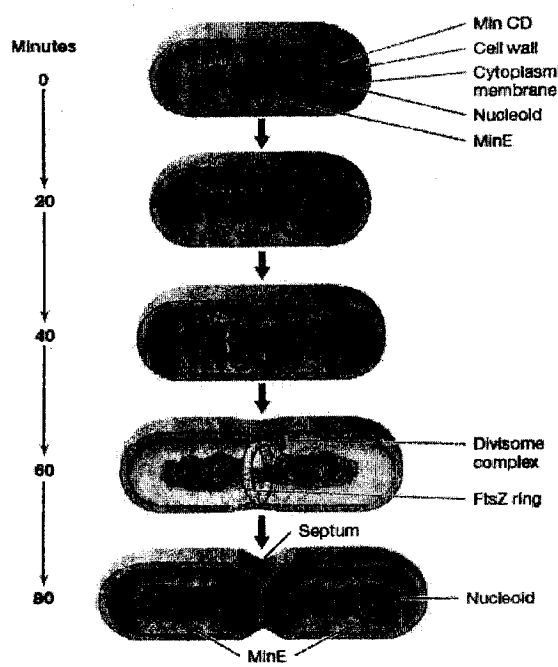
BIO 2302: BASIC MICROBIOLOGY
THEORY PAPER

TIME: THREE HOURS

INSTRUCTIONS: ANSWER **ALL** QUESTIONS FROM SECTION A. ANSWER **TWO** QUESTIONS FROM SECTION B AND **ONE** FROM SECTION C. CIRCLE THE CORRECT ANSWER FOR SECTION A AND USE SEPARATE ANSWER BOOKS FOR SECTION B AND C.

SECTION A

1. Shown below is a growth scheme for cells of *Escherichia coli.*



What is the doubling time of the bacterium shown in this figure?
(a) 20 minutes.
(b) 80 minutes.
(c) 2 hours forty minutes.
(d) 60 minutes.

TURN OVER

2. The function of the FtsZ ring is to ...
   (a) direct the partition between the nucleoids.
   (b) block the formation of a septum between the nucleoids.
   (c) prevent the separation of the daughter cells.
   (d) determine the generation time.

3. Microbial generation time depends on ...
   (a) size of microbial cell.
   (b) the organelles of microbial cell.
   (c) nutritional and genetic factors, and temperature.
   (d) the volume of the cell cytoplasm.

4. Min proteins ensure that the ... forms only at the cell center and not at the cell poles
   (a) nucleosome
   (b) chromatid
   (c) centriole
   (d) divisome

5. ... is when male and female reproductive structures are present in the same fungal mycelium.
   (a) Gametangium
   (b) Sporangium
   (c) Homothallic
   (d) Karyogamy

6. Fungi reproduce asexually by ...
   (a) budding.
   (b) producing spores.
   (c) fragmentation.
   (d) All of the above are correct.

7. Use of garden tools first on infected plants then healthy plants facilitates transmission of plant viruses by ...
   (a) nematode transmission.
   (b) pollen transmission.
   (c) mechanical transmission.
   (d) seed transmission.

8. In fungi, sexual reproduction often occurs in response to...
   (a) adverse environmental conditions.
   (b) optimum temperature.
   (c) sufficient moisture.
   (d) spore dispersal methods.

CONTINUE ON NEXT PAGE.

9. Fungi are classified primarily by their ...
   (a) method of fragmentation.
   (b) method of spore dispersal.
   (c) method of reproduction.
   (d) growth rate.

10. Sterilization is a process that destroys ...
   (a) all viable microbes.
   (b) viruses.
   (c) spores.
   (d) All of the above are correct.

11. Which one of the following statements is not true?
   (a) A complete virus particle consists of a nucleic acid surrounded by a protective coat of protein called capsid, formed from identical protein called capsomeres.
   (b) Complex viruses have a helical symmetry head and an icosahedral symmetry tail.
   (c) In enveloped viruses the nucleocapsid is surrounded by a lipid bilayer derived from the modified host cell and studded with an outer layer of virus envelope glycoproteins.
   (d) The filamentous rod of helical viruses can be short or highly rigid, or long and flexible.

12. In quantitative virology, efficiency with which virions infect host cells is rarely 100% and may often be considered less because;
   (a) Some virions are inactive and fail to cause infection.
   (b) Some viruses produce many incomplete particles during infection.
   (c) In other cases, especially RNA viruses, the viral mutation rate is so high that many virions contain defective genomes.
   (d) All of the above are correct.

13. Which one of the following is false about retroviruses?
   (a) They are animal viruses.
   (b) They are responsible for causing certain kinds of cancers and acquired immunodeficiency syndrome, AIDS.
   (c) They use reverse transcriptase to copy information found in the RNA into DNA.
   (d) They have double stranded DNA in their virions.

14. ... refers to the process in which the virions lose their outer coat and the viral genome is exposed.
   (a) Attachment
   (b) Assembly
   (c) Penetration
   (d) Uncoating

TURN OVER

15. Viral proteins which are synthesized ... are called ...proteins. These include proteins of the virus ...
    (a) early, early, capsid.
    (b) early, structural, enzymes.
    (c) late, replication, capsid.
    (d) late, late, capsid.

16. Algae and protozoa are ...
    (a) prokarytotes.
    (b) eukaryotes.
    (c) protists.
    (d) Both b and c are correct.

17. Which one of the following is not a characteristic of algae?
    (a) Algae are photosynthetic organisms.
    (b) Algae can either be unicellular or multicellular organisms.
    (c) Algae lack a well-defined body, so, structures like roots, stems or leaves are absent.
    (d) Reproduction in algae only occurs in asexual forms.

18. A diatom is a single-celled alga which has a cell wall of ...
    (a) chitin.
    (b) peptidoglycan.
    (c) cellulose.
    (d) silica.

19. ... are resting forms of protozoa.
    (a) Endospores
    (b) Seeds
    (c) Cysts
    (d) Rhizomes

20. Which one of the following is not used by protozoa for mobility?
    (a) Cilia.
    (b) Flagella.
    (c) Pseudopodia.
    (d) Fimbrae.

21. Lipopolysaccharide in cell walls is characteristic of ...
    (a) Gram-positive bacteria.
    (b) Gram-negative bacteria.
    (c) fungi.
    (d) algae.

22. Growth of microbes in a solid media is identified by the formation of ...
    (a) pellicle at the top of media.
    (b) colonies.
    (c) sediment at the bottom.
    (d) turbidity.

CONTINUE ON NEXT PAGE.

23. The correct order of taxonomic groups from higher to lower rank is ...
    (a) Kingdom—Order—Class—Family.
    (b) Order—Class—Division—Family—Genus—Species.
    (c) Kingdom—Order—Division—Family—Class—Genus—Species.
    (d) Kingdom—Division—Class—Order—Family—Genus—Species.

24. Which of the following are characteristics of archaebacteria different from eubacteria.
    (a) methane-producers.
    (b) extreme halophiles.
    (c) thermoacidophiles.
    (d) methane-producers, extreme halophiles, and thermoacidophiles.

25. According to Bergey's Manual of Systematic Bacteriology, prokaryotes that lack a cell wall belong to the group ...
    (a) Gracilicutes.
    (b) Firmicutes.
    (c) Tenericutes.
    (d) Mendosicutes.

26. What is the approximate size of the bacterial cell?
    (a) 2mm in diameter.
    (b) 1mm in diameter.
    (c) 2 micrometers in diameter.
    (d) 0.5 to 1.0 micrometer in diameter.

27. When rod shaped bacteria appears in pairs, it is known as ...
    (a) Diplobacilli.
    (b) Streptobacilli.
    (c) Diplococci.
    (d) Staphylococci.

28. Bacteria with less than a complete twist or comma shaped is known as ...
    (a) spirilla.
    (b) helical.
    (c) vibrioid.
    (d) spirochetes.

29. Bacteria having clusters of flagella at both poles of cells are known as ...
    (a) Lophotrichous.
    (b) Peritrichous.
    (c) Amphitrichous.
    (d) Monotrichous.

30. Peptidoglycan layer is present in large quantity in ...
    (a) Gram-positive bacteria.
    (b) Gram-negative bacteria.
    (c) fungi.
    (d) algae.

TURN OVER

31. Teichoic acid present in Gram-positive bacteria can bind to which ion ...
    (a) Fe^{2+} ions.
    (b) phosphorus ions.
    (c) Mg^{2+} ions.
    (d) sulphur ions.

32. The organisms which can use reduced inorganic compounds as electron donors are known as ...
    (a) chemotrophs.
    (b) organotrophs.
    (c) lithotrophs.
    (d) phototrophs.

33. The isolation of gonorrhea-causing organism, Neisseria gonorrhoeae by the use of certain antibiotics in media is an example of which of the following?
    (a) Selective media.
    (b) Differential media.
    (c) Enriched media.
    (d) Assay media.

34. The optimum pH for the growth of most bacteria lies between ...
    (a) 4.5-5.0.
    (b) 6.5-7.5.
    (c) 2-3.5.
    (d) 9-9.5.

35. Which of the following methods is used for determining the decrease in the amount of growth?
    (a) test done on agar medium plate.
    (b) test done into an agar medium or broth.
    (c) test done by transfering water-soluble substances to sterile media.
    (d) by phenol-coefficient method.

36. Which of the following is not the characteristic of a growth curve?
    (a) Shows development of microbial population under relatively stable environmental conditions.
    (b) Plotted with logarithmic numbers.
    (c) Graphs numbers of microbes versus time.
    (d) Each growth curve consists of four distinct phases.

37. The organism which grows best above 45°C are called ...
    (a) psychrophilic.
    (b) mesosphilic.
    (c) thermophilic.
    (d) Halophilic.

CONTINUE ON NEXT PAGE

38. Which of the following is used for the proper maintenance and preservation of pure cultures?
    (a) Periodic transfer to fresh media.
    (b) Preservation by overlaying cultures with mineral oil.
    (c) Preservation by lyophilization.
    (d) All of the above.

39. A cluster of polar flagella is called ...
    (a) lophotrichous.
    (b) amphitrichous.
    (c) monotrichous.
    (d) petritrichous.

40. Which of the following is the most important structure related to microbial attachment to cells?
    (a) Flagellum.
    (b) Plasmid.
    (c) Peptidoglycan.
    (d) Glycocalix.

SECTION B

1. Discuss the significance of the microbial growth curve in production of large quantities of cellular organisms.

2. (a) State five methods of sterilization.
   (b) Discuss the sterilization of Paracetamol tablets at the point of manufacturing.

3. (a) Summarise the classification of bacteria based on morphology and nutrition.
   (b) Describe the preparation of 105 culture plates of nutrient. It is estimated that each culture plate holds 11.4 ml of the agar. Calculate the mass of nutrient powder required to make the agar (47.01g/1litre).

SECTION C

4. Describe the subcellular organization of fungal:
   (a) Cell wall.
   (b) Septa.

5. Summarise two of the following:
   (a) Endospore formation in bacteria.
   (b) Control of microorganisms by chemical agents.
   (c) Lytic cycle of viruses.
   (d) Bacteriophage structure.
   (e) Economic importance of algae.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2020 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 2701: BASIC PHYSIOLOGY
THEORY PAPER

TIME: TWO HOURS

INSTRUCTIONS: ANSWER **ALL** QUESTIONS IN SECTION **A, ONE** QUESTION FROM SECTION **B** AND ONE QUESTION FROM SECTION **C**. USE THE **PROVIDED ANSWER SHEET** FOR SECTION **A**, AND SEPARATE ANSWER BOOKS FOR SECTIONS **B** AND **C**. ILLUSTRATE YOUR ANSWER WHERE NECESSARY.

SECTION A: Multiple Choice Questions

1. Which of the following is a natural auxin?
   (a) NAA
   (b) 2,4-D
   (c) 2,4,5,-T
   (d) IAA

2. Auxin transport is.....
   (a) always basipetal both in roots and shoots.
   (b) always acropetal both in roots and shoots.
   (c) acropetal in roots and basipetal in shoots.
   (d) basipetal in roots and acropetal in shoots.

3. Which one of the following hormones is not found in plants?
   (a) IAA.
   (b) 2,4-D.
   (c) Brassinosteroids.
   (d) Gibberellins.

4. Decapitation of apical bud results in overcoming apical dominance due to.....
   (a) reversion of auxin-induced cytokinin biosynthesis inhibition and initiation of meristematic activity of axillary buds.
   (b) the efflux of cytokinins from the axillary buds that promotes their growth.
   (c) the rapid accumulation of auxin in axillary buds that facilitates their growth.
   (d) increased meristematic activity of axillary bud resulting from efflux of growth inhibiting substances from them.

5. Which of the following elements is a constituent of biotin and coenzyme A?
   (a) Copper.
   (b) Molybdenum.
   (c) Sulfur.
   (d) Iron.

6. Which of the following cannot be considered as a criterion for essentiality of an element for plants?
   (a) Element must be essential for normal growth and reproduction.
   (b) Element must be easily absorbed by plant roots.
   (c) Element must have a specific role in plant growth and development.
   (d) Element must have a direct involvement in plant metabolism.

7. The primary electron acceptor from excited P_{680} in PSII is.....
   (a) Phylloquinone.
   (b) Q_A.
   (c) Tyr_Z.
   (d) Pheophytin.

8. Which of the following reactions in Calvin cycle is reversible?
   (a) Conversion of sedoheptulose 1, 7-bisphosphate to sedoheptulose 7-phosphate.
   (b) Synthesis of ribulose 1, 5-bisphosphate from ribose 5-phosphate.
   (c) Synthesis of 3-phosphoglyceraldehyde from 3PGA.
   (d) Conversion of xylulose 5-phosphate to ribulose 5-phosphate.

9. The excited state of chlorophyll molecule responsible for the photochemical reaction of photosynthesis is.....
   (a) first singlet state.
   (b) second singlet state.
   (c) triplet state.
   (d) normal state.

10. A potato tuber weighing 0.5 gm and water potential of 1 MPa is immersed in coconut for 1 h. The tuber is removed and again weighed. What do you conclude about the water potential of coconut water if potato tuber weight after the treatment is reduced to 0.35 gm?
    (a) Less than 1 MPa.
    (b) More than 1 MPa.
    (c) 0 MPa.
    (d) It is not possible to find water potential of coconut water.

11. Which of the following is true for the Calcium (Ca) deficiency symptom in young leaves?
    (a) Stunted growth, dark green leaves with dead spots.
    (b) Young leaves at bud hooked, then die back at edges, stalk dies at bud.
    (c) Rosette growth, leaves small, puckered.
    (d) Chlorosis, young leaves light green.

12. Which of the following mineral nutrient is not involved in redox reactions in plant cells?
    (a) Sodium.
    (b) Iron.
    (c) Zinc.
    (d) Copper.

13. Which of the following mineral nutrients are important in energy storage and structural integrity?
    (a) Fe, P, and Ni.
    (b) B, P, and Ni.
    (c) B, Si, and Fe.
    (d) B, P, and Si.

14. The photosynthetic and mitochondrial transports are affected by which of the following three elements?
    (a) Cu, Mn, and Fe.
    (b) Zn, Cu, and Fe.
    (c) Co, Mn, and Fe.
    (d) Cu, Mg, and Cl.

15. Which of the following is a list of macronutrient elements?
    (a) Potassium, copper and sulphur.
    (b) Zinc, copper and iron.
    (c) Phosphorus, silicon and magnesium.
    (d) Sodium, calcium and iron.

16. An element is considered essential if it.....
    (a) induces budding and flowering.
    (b) is found in plant ash.
    (c) is present in the soil where the plant is growing.
    (d) is not replaceable and is indispensable for the growth of the plant.

17. In which of the following photosynthesizing organisms is chlorophyll-a absent in?
    (a) Bacteria.
    (b) Flowering plants.
    (c) Herbs.
    (d) Algae.

18. In the Calvin cycle, 1 molecule of glucose is formed from.....
    (a) $6CO_2 + 30ATP + 12NADPH$.
    (b) $6CO_2 + 12ATP$.
    (c) $6CO_2 + 18ATP + 12NADPH$.
    (d) $6CO_2 + 18ATP + 30NADPH$.

19. What is the main role of the antenna pigment molecules in the thylakoid membranes?
    (a) Split water and release oxygen to the reaction-center chlorophyll.
    (b) Harvest photons and transfer light energy to the reaction-center chlorophyll.
    (c) Synthesize ATP from ADP and Pi.
    (d) Concentrate photons within the stroma.

Figure 1 shows the absorption spectrum for chlorophyll a and the action spectrum for photosynthesis. Answer questions 20 to 22 based on the figure.

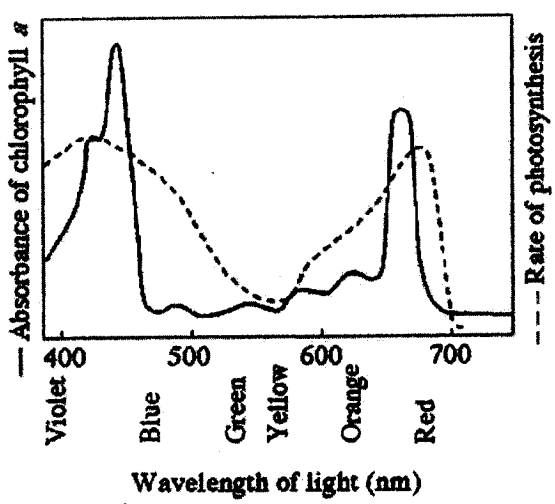


Figure 1. Chlorophyll-a absorption spectrum

20. Why is the absorption spectrum for chlorophyll-a and the action spectrum for photosynthesis different?
    (a) Green and yellow wavelengths inhibit the absorption of red and blue wavelengths.
    (b) Bright sunlight destroys photosynthetic pigments.
    (c) Oxygen given off during photosynthesis interferes with the absorption of light.
    (d) Other pigments absorb light in addition to chlorophyll-a.

21. What wavelength of light in Figure 1 is most effective in driving photosynthesis?
    (a) 420 mm.
    (b) 475 mm.
    (c) 575 mm.
    (d) 730 mm.

22. Compared with the lines for chlorophyll-a in Figure 1, where would you expect to find the lines to differ for chlorophyll-b?
    (a) The absorption spectrum line would be lowest for chlorophyll-b somewhat to the right of that for chlorophyll a (500—600).
    (b) The rate of photosynthesis line for chlorophyll-b would be lowest from 600—700 nm.
    (c) The lines for the two types of chlorophyll would be almost completely opposite.
    (d) The lines for the two types of chlorophyll would be almost completely identical.

23. In a protein complex for the light reaction (a reaction center), energy is transferred from pigment molecule to pigment molecule, to a special chlorophyll-a molecule, and eventually to the primary electron acceptor. Why does this occur?
    (a) These chlorophyll-a molecules are associated with higher concentrations of ATP.
    (b) The potential energy of the electron has to go back to the ground state.
    (c) Each pigment molecule has to be able to act independently to excite electrons.
    (d) The molecular environment lets it boost an electron to a higher energy level and also to transfer the electron to another molecule.

24. Carotenoids are often found in foods that are considered to have antioxidant properties in human nutrition. What related function do they have in plants?
    (a) They take up toxins from the water.
    (b) They dissipate excessive light energy.
    (c) They cover the sensitive chromosomes of the plant.
    (d) They reflect orange light.

25. The reaction-center chlorophyll of photosystem I is known as P700 because.....
    (a) there are 700 chlorophyll molecules in the center.
    (b) this pigment is best at absorbing light with a wavelength of 700 nm.
    (c) there are 700 photosystem I components to each chloroplast.
    (d) the plastoquinone reflects light with a wavelength of 700 nm.

26. Aspartame is a very sweet artificial sweetener used in some fizzy drinks, giving such drinks very high water potential. If one consumes a large bottle of such a drink, the body would respond in a certain way. Which of these statements best describes the way the body would respond?
    (a) More antidiuretic hormone (ADH) is produced, increasing the volume of urine.
    (b) Less antidiuretic hormone (ADH) is produced, decreasing the volume of urine.
    (c) Less antidiuretic hormone (ADH) is produced, increasing the volume of urine.
    (d) More antidiuretic hormone (ADH) is produced, decreasing the volume of urine.

27. Which of these neurons will transmit an impulse fastest?
    (a) Myelinated axon, 30 μm diameter.
    (b) Myelinated axon, 2 μm diameter.
    (c) Unmyelinated axon, 30 μm diameter.
    (d) Unmyelinated axon, 20 μm diameter.

28. Read the following statements about the concentration of hormones in the human menstrual cycle.
    1. Shortly before ovulation, the concentration of estrogen is high and the concentration of progesterone is low.
    2. During the last quarter of the cycle, the concentration of estrogen and progesterone fall.
    3. At the end of menstruation, the concentration of estrogen is low but rising, and the concentration of progesterone is low.
    4. Just before ovulation, the concentration of LH and FSH suddenly rise.

    Which ones of the above statements are correct?
    (a) 1, 2, 3 and 4.
    (b) 1, 2 and 4 only.
    (c) 2 and 3 only.
    (d) 3 and 4 only.

29. Which of the following statements is incorrect about the endocrine system?
    (a) Endocrine glands are ductless.
    (b) Endocrine glands secrete hormones into the blood.
    (c) All hormones bind to receptors on the cell surface of their target cells.
    (d) Hormones are transported in the blood plasma.

30. Estrogen exerts both positive and negative feedback effects on the secretion of gonadotropins, acting through estrogen receptors on neurons in the hypothalamus. Which neuronal population mediates the negative feedback?
    (a) Gonadotropin releasing hormones (*GnRH*) neurons in the preoptic area.
    (b) Kisspeptin (*KISS1*) neurons in the preoptic area.
    (c) Kisspeptin (*KISS1*) neurons in the infundibular nucleus.
    (d) Vasopressin neurons in the paraventricular nucleus.

31. At what stage of oogenesis is the female gamete when released from the ovary?
    (a) Oogonium.
    (b) Primary oocyte.
    (c) Secondary oocyte.
    (d) Ovum.

32. Which of the following conditions could shift the oxygen dissociation curve to the right?
    (a) Increase in temperature.
    (b) Decrease in DPG.
    (c) Increase in pH.
    (d) Decrease in partial pressure of carbon dioxide.

33. In what way is most of carbon dioxide transported in blood?
    (a) As CO_2 dissolved in plasma.
    (b) As HCO_3^- in plasma.
    (c) As HCO_3^- in erythrocytes.
    (d) As carbamino-haemoglobin in erythrocytes.

34. Which of the following is true about chemical synaptic transmission?
    (a) The flow of neurotransmitters from the presynaptic cell into the postsynaptic cell is driven by simple diffusion.
    (b) Binding of neurotransmitters to receptors on postsynaptic cell membrane could elicit an excitatory postsynaptic potential.
    (c) The flow of ions from the presynaptic cell into the postsynaptic cell is driven by simple diffusion.
    (d) The arrival of an action potential hyperpolarises the plasma membrane of the presynaptic cell, causing some of the synaptic vesicles to fuse with the terminal axonal membrane, and releasing the neurotransmitters into the synaptic cleft.

35. Which of the following is triggered by the hormone cortisol?
    (a) Glycogenolysis.
    (b) Gluconeogenesis.
    (c) Glycogenesis.
    (d) None of the above.

36. Which one of the following hormones is secreted by the neurohypophysis?
    (a) Prolactin.
    (b) Vasopressin.
    (c) Aldosterone.
    (d) Growth hormone.

37. Which of the following occurs in the body in response to secretion of glucagon?
    (a) Conversion of glucose to glycogen in liver cells.
    (b) Decrease in the blood glucose concentration.
    (c) Increased uptake of glucose by muscle cells.
    (d) Production of cyclic AMP in the target cells.

38. Which of the following does not describe the counter current multiplier in mammalian kidneys?
    (a) The repetitive reabsorption of sodium chloride by the thick ascending loop of Henle and continued inflow of new sodium chloride from the proximal tubule into the loop of Henle.
    (b) The current that is generated and multiplied when the sodium and chloride ions are repeatedly exchanged between the loop of Henle and blood vessels.
    (c) Having two limbs of the loop of Henle, side by side, with fluid flowing in opposite directions enabling a buildup of high concentration of solutes at the bottom of the loop of Henle.
    (d) All of the above.

39. Which of the following is not a brain center involved in the regulation of breathing?
    (a) Medullary respiratory center.
    (b) Homeostatic center.
    (c) Apneustic center.
    (d) Pneumotaxic center.

40. In humans, the peripheral ..... in the ..... respond to carbon dioxide and pH levels in the blood, and send impulses to the cardiovascular control center in the medulla oblongata.
    (a) Chemoreceptors, aortic bodies.
    (b) Chemoreceptors, carotid bodies.
    (c) Baroreceptors, carotid bodies.
    (d) Baroreceptors, aortic bodies.

Figure 2 shows various lung volumes represented by letters V to Z. Answer questions 41 and 42 based on the figure.

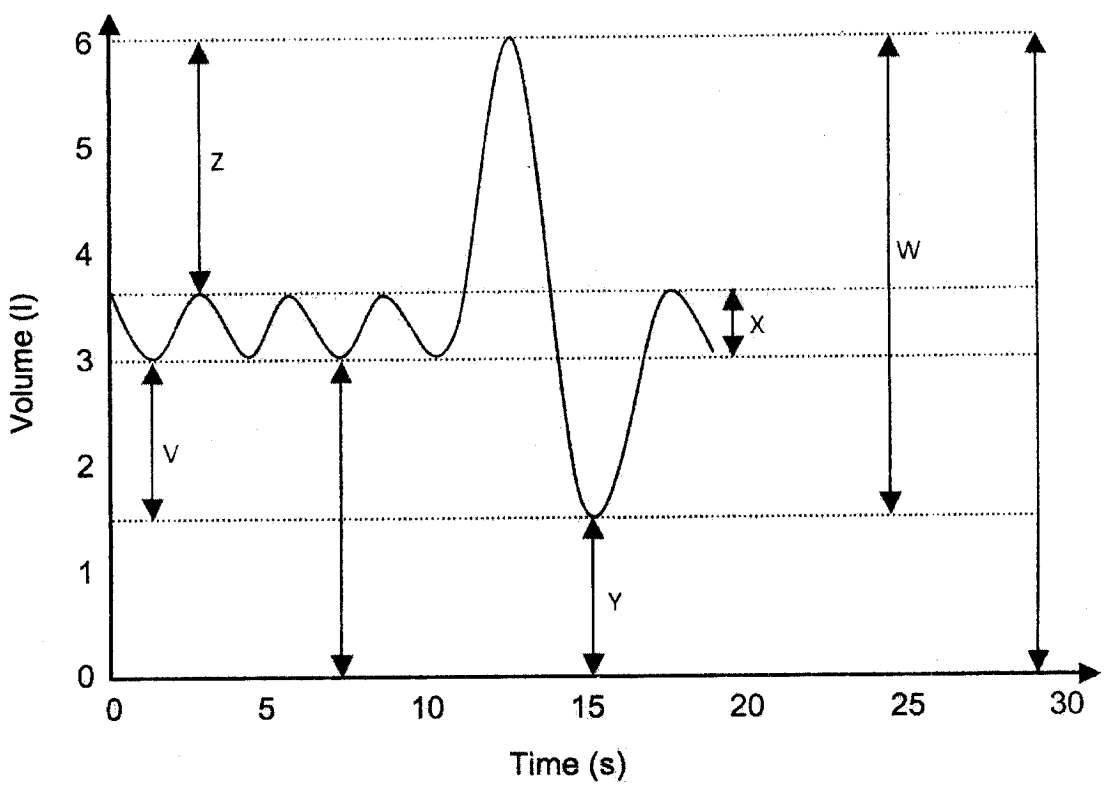


Figure 2. Lung volumes based on spirometer traces.

41. What is the term used to describe the volume represented by letter W?
    (a) Tidal volume.
    (b) Total lung capacity.
    (c) Expiratory reserve volume.
    (d) Vital capacity.

42. Which letter represents the volume of air left in the lungs after the strongest possible expiration?
    (a) W
    (b) X
    (c) Y
    (d) Z

43. Which of the following is not used by freshwater animals to overcome the osmoregulatory challenges in their environment?
    (a) Producing dilute urine.
    (b) Having salt glands located above the orbit of the eye.
    (c) Refraining from drinking fresh water.
    (d) Actively transporting salt from the external medium across the epithelium.

44. Which of the following is a correct list of glands that secrete saliva?
    (a) Parotid glands, pyloric glands and submandibular glands.
    (b) Sublingual glands, lacrimal glands and submandibular glands.
    (c) Sublingual glands, submandibular glands and parotid glands.
    (d) Pyloric glands, areolar glands and submandibular glands.

45. What is the function of the enzyme ptyalin?
    (a) To hydrolyze bonds between aromatic amino acids a second amino acid.
    (b) To split lactose into glucose and galactose.
    (c) To cleaves the internal α-1, 4 glycosidic linkages.
    (d) To bind vitamin B12 and allows it to be absorbed by the ileal epithelium.

46. Which of the following is not accurate about the physiological role of bile?
    (a) Contains bile salts which emulsify the large fat particles of the food.
    (b) Contains enzymes that cause fat digestion.
    (c) Serves as a means for excretion of bilirubin and excesses of cholesterol.
    (d) Aids in absorption of the digested fat end-products through the intestinal mucosal membrane.

47. When centrifuged without adding an anticoagulant, a unit volume of normal human blood separates into distinct bands consisting approximately...
    (a) 45% of packed erythrocytes, 1% leucocytes and platelets, and 54% plasma.
    (b) 45% of packed erythrocytes and platelets, 1% leucocytes, and 54% plasma.
    (c) 45% of packed erythrocytes, 1% leucocytes and platelets, and 54% serum.
    (d) 45% of packed erythrocytes and platelets, 1% leucocytes, and 54% serum.

48. The feeling of hunger and satiety are physiologically controlled in the hypothalamus. In which hypothalamic nucleus is the satiety center located?
    (a) Ventromedial nucleus.
    (b) Arcuate nucleus.
    (c) Paraventricular nucleus.
    (d) Lateral nucleus.

49. Which of the following is a function of the hormone secreted by the thymus gland?
    (a) Increases the sensitivity of the cardiovascular system to sympathetic nervous activity.
    (b) Increases blood calcium by stimulating bone calcium release into the bloodstream.
    (c) Stimulates the development of T cells.
    (d) Promote sodium (salt) reabsorption.

50. Which of the following hormones is secreted by gonads?
    (a) Activin.
    (b) Luteinising hormone.
    (c) Follicle stimulating hormone.
    (d) Both (b) and (c) above are correct.

SECTION B: Plant Physiology

1. (a) Discuss the pathways for water movement into the root xylem following osmotic uptake in the root hairs from the soil.
    (b) Discuss water transport in trees through the xylem tracheary elements.

2. (a) With the help of examples where possible, explain the six physiological effects of gibberellins on plant growth and development.
    (b) Summarise three commercial applications of gibberellins.

SECTION C: Animal Physiology

3. Discuss oxygen transport in human blood.

4. (a) Discuss the generation and maintenance of a resting membrane potential in neurons.
    (b) Explain why impulses travel in one direction through an axon and at synapses.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2020 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 2801: DIVERSITY OF PLANTS
THEORY PAPER

TIME: TWO HOURS

INSTRUCTIONS: ANSWER **ALL** QUESTIONS FROM SECTION **A**, **ONE** QUESTION FROM SECTION **B**, AND **ONE** QUESTION FROM SECTION **C**. USE THE PROVIDED ANSWER SHEET FOR SECTION **A** AND **SEPARATE ANSWER BOOKS** FOR SECTIONS **B** AND **C**. ILLUSTRATE YOUR ANSWER WHERE NECESSARY.

SECTION A: MULTIPLE CHOICE QUESTIONS

1. Which of the following divisions of algae is characterized by the possession of chlorophyll a and chlorophyll b?
   (a) Xanthophyta
   (b) Phaeophyta
   (c) Chlorophyta
   (d) Rhodophyta

2. All algae contain.....
   (a) nuclei
   (b) chloroplasts
   (c) both (a) and (b)
   (d) none of the above

3. Characteristics used to classify algae into divisions include.....
   (a) form of storage material
   (b) location and number of flagella
   (c) accessory pigments used in photosynthesis
   (d) all of the above

4. Which algal division lacks motile cells?
   (a) Chlorophyta
   (b) Charophyta
   (c) Rhodophyta
   (d) Phaeophyta

5. The vegetative body of algae is known as.....
   (a) mycelium
   (b) synngium
   (c) plasmodium
   (d) thallus

TURN OVER

6. The kelps are members of the division.....
   (a) Chlorophyta
   (b) Rhodophyta
   (c) Phaeophyta
   (d) Xanthophyta

7. Algae can be found growing in .....
   (a) the sea
   (b) temporary water pools
   (c) lakes
   (d) all of the above

8. Desmids are algae which are characterized by.....
   (a) filamentous thallus
   (b) branched thallus
   (c) unicellular with semi cells
   (d) jointed thallus

9. The vegetative plant body of *Vaucheria* is.....
   (a) uniseriate filament
   (b) biseriate filament
   (c) tubular and branched
   (d) none of the above

10. An akinete is a reproductive cell of algae formed by.....
   (a) failing to develop flagella
   (b) being heavily thick walled
   (c) being able to grow during the growing season
   (d) the modification of a vegetative cell containing extra food and thick cell wall

11. The number of flagella in motile cells of green algae is.....
   (a) two
   (b) four
   (c) 60 or 120
   (d) all of the above

12. Laminarin and mannitol are the reserve food of .....
   (a) Charophyta
   (b) Rhodophyta
   (c) Phaeophyta
   (d) Chlorophyta

13. Which among the following is also known as bog moss?
   (a) *Riccia*
   (b) *Sphagnum*
   (c) *Marchantia*
   (d) *Funaria*

PROCEED TO NEXT PAGE

14. Dispersal of spores in some liverworts is aided by .....
    (a) elaters
    (b) peristome teeth
    (c) indusium
    (d) calyptra

15. Meiosis occurs in mosses during .....
    (a) gamete formation
    (b) antheridia and archegonia formation
    (c) spore formation
    (d) spore germination

16. The antherozoids of *Funaria* are .....
    (a) monociliated
    (b) multiciliated
    (c) biciliated
    (d) nonflagellated

17. Bryophytes are characterized by .....
    (a) having chloroplasts
    (b) having archegonia
    (c) having thalloid plant
    (d) all of the above

18. Which of the following is diploid in moss plants?
    (a) spore
    (b) gamete
    (c) spore mother cell
    (d) none of the above

19. The protonema is a stage in the life of .....
    (a) *Riccia*
    (b) *Anthoceros*
    (c) *Funaria*
    (d) *Marchantia*

20. The sporophyte in bryophytes is attached to the gametophyte by means of .....
    (a) stalk
    (b) root
    (c) foot
    (d) apophysis

21. Which of the following divisions of algae is characterized by the possession of chlorophyll a and chlorophyll b?
    (a) Xanthophyta
    (b) Phaeophyta
    (c) Chlorophyta
    (d) Rhodophyta

TURN OVE

22. An androspore is a .....
    (a) male reproductive cell
    (b) female reproductive cell
    (c) progenitor of nannandrium
    (d) zygote

23. The pseudoelaters are found in the sporophytes of.....
    (a) *Marchantia*
    (b) *Funaria*
    (c) *Anthoceros*
    (d) *Riccia*

24. The common photosynthetic pigments of green algae are.....
    (a) A unique chlorophyll *c*
    (b) Chlorophyll *a* and *b*
    (c) Chlorophyll *a* and *c*
    (d) Chlorophyll *a* and *d*

25. Quadriflagellate zoospores are produce by.....
    (a) *Spirogyra*
    (b) *Oedogonium*
    (c) *Cladophora*
    (d) *Vaucheria*

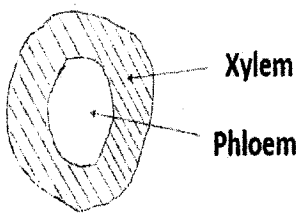
26. The following is true about leaves in species of *Selaginella*:
    (a) They are spirally and alternately arranged.
    (b) They are either dimorphic or isomorphic.
    (c) They occur in three ranks.
    (d) They are macrophylls.

27. Species of *Selaginella* with dimorphic leaves have.....
    (a) two smaller upper or ventral leaves and three larger lower or dorsal leaves
    (b) two smaller upper or dorsal leaves and three larger lower or ventral leaves
    (c) two smaller upper or dorsal leaves and two larger lower or lateral leaves
    (d) two larger upper or dorsal leaves and two smaller lower or lateral leaves

28. The type of stele where the central core is occupied by pith, surrounded by continuous phloem surrounded by a layer of xylem, which is in turn surrounded by a continuous layer of phloem is called.....
    (a) ectophloic siphonostele.
    (b) dictyostele.
    (c) amphiphloic siphonostele.
    (d) protostele.

PROCEED TO NEXT PAGE

29. The vascular bundle shown in the figure below is known as.....



(a) bicollateral vascular bundle.
(b) amphivasal vascular bundle.
(c) amphicribral vascular bundle.
(d) collateral vascular bundle.

30. Gametic meiosis is characteristic of which type of life cycle?
(a) Haplontic life cycle
(b) Diplontic life cycle.
(c) Diplohaplontic life cycle.
(d) Isomorphic alternation of generations.

31. The Lycophytes are made up of the orders.....
(a) Ophioglossales, Selaginellales and Psilotales
(b) Isoetales, Lycopodiales and Selaginellales
(c) Isoetales, Lycopodiales and Equisetales
(d) Equisetales Selaginellales and Lycopodiales

32. In Quillworts megasporangia are located .....
(a) at the basal part of the innermost fertile leaves.
(b) on the strobilus, at the basal part of sporophylls.
(c) at the basal part of the outermost fertile leaves.
(d) at the basal part of the sterile leaves.

33. Identify the structures labelled 'A'in the species of *Selaginella* shown below.

(a) dorsal (lateral) leaves.
(b) sporophylls of a strobilus.
(c) ventral (lateral) leaves.
(d) sporangia.

TURN OVER

34. Genera *Psilotum* and *Tmesipteris* belong to the order
    (a) Jungermanniales.
    (b) Psilotales.
    (c) Isoetales.
    (d) Selaginellales.

35. The carpels of the flower are referred to collectively as the.....
    (a) androecium.
    (b) gynoecium.
    (c) sporophylls.
    (d) tepals.

36. Which of the following statements is not true about Monilophytes?
    (a) They belong to the subclasses Marattiidae and Polypodiidae.
    (b) They consist of over 12000 Species, most of which are in the Polypodiidae.
    (c) They have pollen grains that directly come in contact with the ovule after pollination.
    (d) They have complex vascular systems of the siphonostele type.

37. The developmental morphology where immature leaves of ferns are coiled is known as.....
    (a) circinate vernation.
    (b) palmate venation
    (c) ternate morphology.
    (d) imparipinate vernation.

38. One distinctive feature of Marattiod ferns (Marattiidae) is.....
    (a) the presence of a polycyclic siphonostele.
    (b) the frond
    (c) discrete sporangia
    (d) the annulus

39. In Leptosporangiate ferns, an extension of a pinnule margin that overlaps a sorus is called a.....
    (a) costa
    (b) false indusium
    (c) true indusium
    (d) rachis

40. The following genus has an exosporic gametophyte
    (a) *Azolla*
    (b) *Isoetes*
    (c) *Selaginella*
    (d) *Lycopodium*

41. An aquatic fern that has a symbiotic, nitrogen-fixing cyanobacteria living inside its leaf clefts is.....
    (a) *Salvinia*
    (b) *Marsilea*
    (c) *Azolla*
    (d) *Pilularia*

PROCEED TO NEXT PAGE

42. The sporangia of Equisetum species are found on umbrella-like structures known as sporagiophores in groups of .
    (a) Five to ten.
    (b) Eight.
    (c) Less than 45.
    (d) More than 45

43. Which of the following is a heterosporous genus?
    (a) *Psilotum.*
    (b) *Salvinia.*
    (c) *Pinus.*
    (d) *Lycopodium.*

44. *Psilotum* species lack true roots and instead have rhizoids that arise from the rhizome. How then do they obtain nutrients and water from the soil?
    (a) They absorb water and nutrients via the dichotomously branched aerial stems
    (b) They absorb water and nutrients via rhizomes, with the help of fungi (mycorrhizal associations).
    (c) They absorp nutrients through all the parts of the plant.
    (d) They use rhizoids to absorb nutrients and water.

45. Sporangia of Salvinia species are borne on .....
    (a) Strobili
    (b) Floating leaves.
    (c) Submerged leaves.
    (d) Sporophylls and cataphylls.

46. The reproductive structures of the Welwitschiales are
    (a) Flowers.
    (b) Strobili.
    (c) Ovaries.
    (d) Gemmae .

47. The following plant has recently been used to remove arsenic from toxic landfills.
    (a) *Pteris vittata*
    (b) *Matteuccia struthiopteris*
    (c) *Pteridium aquilinum*
    (d) *Omunda regalis*

48. The largest major group of green plants are the
    (a) Pteridophytes.
    (b) Bryophytes.
    (c) Angiosperms.
    (d) Algae.

TURN OVER

49. A plant that has male and female reproductive structures on separate flowers of the same individual is .....
    (a) Monoecious
    (b) Dioecious
    (c) Monophyllous
    (d) Epiphytic.

50. Which of the following statements is not true?
    (a) The gametophytic generation is the dominant generation in bryophytes, but in the so called higher plants, the sporophytic generation is dominant.
    (b) The Bryophytes lack true roots but have rhizoids.
    (c) Bryophytes like other land plants possess multicellular sporangia that also have a sterile layer of jacket cells, which protects the spores from desiccation.
    (d) Monilophytes have secondary growth similar to that found in vascular plants.

SECTION B

1. (a) Describe the structure of the plant body and a single cell of *Ulothrix*.
   (b) Describe sexual reproduction in *Ulothrix* and explain why it is considered as an example of the origin of sex.

2. Summarise any FOUR of the following:
   (a) Structure of swarmer and its types in green algae.
   (b) Alternation of generations.
   (c) Heterotrichous thallus.
   (d) Difference between an aplanospore and an akinete.
   (e) Sexual reproduction in *Vaucheria*.

SECTION C

3. Describe the diversity, distribution and significant features of the Rosaceae.

4. Summarise any two of the following:
   (a) Sporangiophores in *Equisetum*.
   (b) Haplontic life cycle.
   (c) Polar nuclei of the angiosperm female gametophyte.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2020 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 2812: DIVERSITY OF ANIMALS
THEORY PAPER

TIME: TWO HOURS

INSTRUCTIONS: ANSWER **ALL** QUESTIONS IN **SECTION A** ON THE PROVIDED ANSWER SHEET; **ONE** FROM SECTION B; AND **ONE** FROM SECTION C. ILLUSTRATE YOUR ANSWER WHERE NECESSARY. USE **SEPARATE ANSWER BOOKS** FOR SECTION B AND SECTION C.

SECTION A

1. Choose the correct order that shows the most inclusive taxon to the most exclusive taxon.
   (a) species → class → kingdom
   (b) class → species → genus
   (c) kingdom → genus → species
   (d) class → kingdom → species

2. ..... is the final phase in pseudopodial action.
   (a) Formation of a semi-rigid tube
   (b) Flow of endoplasm
   (c) The ectoplasm changing from liquid to gel
   (d) The gel changing to liquid in the ectoplasm

3. Choose the statement that is true about ciliates.
   (a) They lack locomotory structures.
   (b) Possession of apical complex.
   (c) These organisms are parasitic.
   (d) They possess two kinds of nuclei.

4. Binary fission can be described as .....
   (a) division of a protozoan cell into two similar daughter cells.
   (b) formation of multiple daughter cells after many nuclear divisions.
   (c) formation of two cells that have different sizes from one protozoan.
   (d) any type of cell division.

TURN OVER

5. Members of the subphylum ..... use flagella for locomotion.
   (a) Apicomplexa
   (b) Sarcodina
   (c) Mastigophora
   (d) Ciliophora

6. Choose the statement that is **false** about metazoans.
   (a) They have epithelial and connective tissue.
   (b) These are unicellular organisms.
   (c) Their bodies are arranged along an anterior and posterior axis.
   (d) They have either endoskeleton or exoskeleton.

7. The ..... theory proposes that metazoans evolved premetazoan that consisted of a small spherical colony.
   (a) Syncytial
   (b) Colonial
   (c) Ciliate
   (d) Unicellular

8. The monolayer of flagellated cells that is found in the phylum Porifera is referred to as .....
   (a) pinacoderm.
   (b) mesohyl.
   (c) asconoid.
   (d) choanoderm.

9. Glass sponges belong to the class .....
   (a) Calcarea.
   (b) Demospongiae.
   (c) Homoscleromorpha.
   (d) Hexactinellida.

10. Cnidocytes play a major role in ..... among Cnidarians.
    (a) movement
    (b) detecting stimuli
    (c) removal of waste products
    (d) growth

11. The major body layers in cnidarians are .....
    (a) gastrodermis and mesoglea.
    (b) gastrodermis and epidermis.
    (c) epidermis and mesoglea.
    (d) gastrodermis, epidermis and mesoglea.

PROCEED TO THE NEXT PAGE

12. Choose the **false** statement about the bilaterians.
    (a) They are asymmetrical.
    (b) There is a concentration of nervous tissue in the anterior region.
    (c) They have a distinct ventral and anterior axis.
    (d) Most of these organisms have circular and longitudinal muscles.

13. Blood has a higher protein concentration than coelomic fluid mainly due to .....
    (a) absence of cells in the coelomic fluid.
    (b) presence of respiratory pigments in blood.
    (c) presence of more water in coleomic fluid.
    (d) absence of ions in blood.

14. The pharynx in bilaterians is found in the ..... region of the gut.
    (a) hindgut.
    (b) foregut.
    (c) midgut
    (d) posterior

15. Parasitic platyhelminthes belonging to the classes ..... have intermediate hosts.
    (a) Cestoda and Monogenea
    (b) Trematoda and Monogenea
    (c) Cestoda and Trematoda
    (d) Turbelleria and Monogenea

16. The first intermediate host of digeneans is a .....
    (a) mollusc.
    (b) arthropod.
    (c) vertebrate.
    (d) protozoan.

17. The major difference between the life cycle of ascaroid nematodes and filaroid nematodes is that .....
    (a) filaroids have three hosts.
    (b) ascaroids have one host.
    (c) filaroids have one host.
    (d) ascaroids have two hosts.

18. Choose the **false** statement about nematode morphology.
    (a) Cylindrical body that is tapered at the posterior and anterior ends.
    (b) Bilaterally symmetrical body.
    (c) Anterior end is radially symmetrical.
    (d) Absence of cuticle.

TURN OVER

19. Annelids belonging to subclass Oligochaeta do not possess .....
    (a) chaete.
    (b) metameres.
    (c) septa.
    (d) parapodia.

20. Presence of a spirally coiled shell is characteristic of molluscs that belong to the class .....
    (a) Gastropoda.
    (b) Aplacophora.
    (c) Bivalvia.
    (d) Cephalopoda.

21. Members of the Class ..... do not possess a radula.
    (a) Bivalvia
    (b) Monoplacophora
    (c) Polyplacophora
    (d) Gastropoda

22. All organisms in the subphylum ..... possess pedipalps.
    (a) Crustacea
    (b) Chelicerata
    (c) Hexapoda
    (d) Myriapoda

23. One major difference between subphylum Crustacea and the subphylum Myriapoda is the .....
    (a) presence of three tagmata in crustaceans.
    (b) possession of numerous leg bearing segments in myriapods.
    (c) presence of three tagmata in myriapods.
    (d) absence of exoskeleton in crustaceans.

24. Choose the **false** statement about members of the Class Hexapoda.
    (a) The abdomen bears the legs and wings.
    (b) They have three tagmata.
    (c) Abdominal segments do not have appendages.
    (d) They have a pair of antenna on the head.

25. These two classes of Echinodermata do not possess arms.
    (a) Ophiuroidea and Asteroidea
    (b) Holothuroidea and Crinoidea
    (c) Echinoidea and Holothuroidea
    (d) Crinoidea and Asteroidea

PROCEED TO THE NEXT PAGE

26. Which of the following is one of the main characteristics of the phylum Chordata?
    (a) Possession of wings in the adult stage.
    (b) Presence of legs for locomotion in the adult stage.
    (c) Possession of a tail at some stage in the life cycle.
    (d) Possession of pelvic and pectoral girdle.

27. In the past tunicates were grouped together with molluscs and at times with Radiates. Name the group where tunicates are currently placed.
    (a) Urochordata.
    (b) Hermichordata.
    (c) Cephalochordata.
    (d) Invertebrata.

28. The group Agnatha is different from the Gnathostomata because of .....
    (a) absence of jaws.
    (b) possession of a two chambered heart.
    (c) having members of the species that are marine.
    (d) rounded caudal fin.

29. Name the sub groups the Cyclostomata.
    (a) Ostracordermi, Petromyzoniformes Myxiniformes.
    (b) Selachii, Batoidae Pleuracanthodii.
    (c) Clandoselachii, Elasmobranchii. Teleostei
    (d) Acanthodii, Dipnoi, Urodela.

30. Choose the Phrase that best identifies group Chondrichthyes.
    (a) Fishes with mucous skin.
    (b) Fishes with forked caudal fins
    (c) Fishes with cartilaginous skeleton.
    (d) Fishes with ventral large mouth.

31. Which of the following that is subdivision or subclass of the group Osteichthyes?
    (a) Anura
    (b) Nothobranchus
    (c) Acraniata
    (d) Actinopterygii

32. State a morphological difference between Cyclostomata and Chondrichthyes.
    (a) Cyclostomata have mucous skin and Chondrichthyes do not.
    (b) Cyclostomata do not lay eggs and Chondrichthyes lay external eggs.
    (c) Cyclostomata are graizers and Chondrichthyes pradators.
    (d) Cyclostomata do not have paired appendages and Chondrichthyes have paired appendages.

33. State the feeding type in Cephalochordates
    (a) Phagocytosis.
    (b) Saprophytic feeding.
    (c) Filter Feeding.
    (d) Scavenging.

34. Identify the vertebrate group with the highest diversity.
    (a) Mammalian.
    (b) Aves.
    (c) Osteichthyes.
    (d) Chorichthyes.

35. Identify a phrase that best describes Amphibians.
    (a) Possession lung for respiration.
    (b) Mouth cavity with protractible tongue.
    (c) Ability to survive in aquatic environments and on land.
    (d) Ability to reproduce in aquatic environments.

36. Name the vertebrate group that made a first attempt to live on land.
    (a) Amphibia.
    (b) Reptilia.
    (c) Sarcropterygii.
    (d) Chondrichthyes.

37. Indicate the sub groups of Amphibia
    (a) Eosuchia, cotylosauria, Anapsida.
    (b) Thecodontia, Archosauria, Sauria.
    (c) Anura, Urodela. Gymnophiona.
    (d) Ichtyosauria, Sauropterygia, Protorosauria.

38. Name the group of Gnathostomata with the most efficient respiratory system.
    (a) Amphibia.
    (b) Reptilia.
    (c) Aves.
    (d) Chorichthyes.

39. In the evolution of vertebrates, what characteristic has enabled them to colonize terrestrial environment?
    (a) Ability to use lungs for respiration.
    (b) Development of the amniotic egg.
    (c) Development of cuticle to prevent excessive water loss.
    (d) Development of feathers and hair to regulate body temperature.

PROCEED TO THE NEXT PAGE

40. Indicate the list that constitute present day living Reptiles.
    (a) Cecelians Aponda Anura.
    (b) Ichtyosauria, Sauropterygia, Protorosauria
    (c) Cruinformes Colombiformes Coraciiformes.
    (d) Squamata, Chelonia, Crocodilia.

41. Name the Group of vertebrates where Chimaeras are found.
    (a) Chondrichthyes.
    (b) Reptilia.
    (c) Aves.
    (d) Cyclostomata.

42. Name the group of vertebrates in which Anseriformes are found.
    (a) Amphibia.
    (b) Reptilia.
    (c) Aves.
    (d) Cyclostomata.

43. Name the group of vertebrates where are Salamanders found.
    (a) Amphibia.
    (b) Reptilia.
    (c) Aves.
    (d) Cyclostomata.

44. Name the group where sub group Monotremata are found.
    (a) Amphibia.
    (b) Eutheria.
    (c) Metatheria.
    (d) Prototheria

45. Select the Genus name for African Lungfish.
    (a) Genus *Tilapia.*
    (b) Genus *Clarias.*
    (c) Genus *Henterbrachus.*
    (d) Genus *Protopterus*

46. Name the group where sub group Marsupialia are found.
    (a) Amphibia.
    (b) Eutheria.
    (c) Metatheria.
    (d) Prototheria.

47. Name the group where sub group Pholidota are found.
    (a) Amphibia.
    (b) Eutheria.
    (c) Metatheria.
    (d) Prototheria

TURN OVER

48. Indicate the group that shows the list of Aeluroids.
    (a) *Panthera leo, Panthera. pardus, Panthera tigris*
    (b) *Octocyon mega lotic, Lycan pictus, Canis mesomelas*
    (c) *Oryx gazelle, Syncerus caffer, Tragelaphus strepsicero.*
    (d) *Lepus saxatis, Hystrix afrcaeaustralis, Xerus inauris.*

49. Select a group of animals that represent Artiodactyles
    (a) Goats, sheep Giraffe Antelops.
    (b) Rhino, Zebra, Donkey Horse.
    (c) Lions Tiger Leopard Hyena
    (d) Fox, Wild Dog, Jackal Honey Badger

50. Which of the following is distinguishing characteristics for Primates
    (a) Parental care involving both parents
    (b) Separation of the circulatory system of the embryo from that of the parent
    (c) Ability to communicate with other members of the population.
    (d) Ability to maintain body temperature independent of the environment.

SECTION B

1. Summarise each of the following:
    (a) Encystment in protozoans.
    (b) Body forms in the Phylum Cnidaria.
    (c) Lifecycle of filaroid nematodes.
    (d) Tagmatisation in arthropods.

2. Describe the major distinguishing features of the classes Polyplacophora, Gastropoda, Bivalvia and Cephalopoda.

SECTION C

3. Summarise four of the following:
    (a) Petromyzoniformes.
    (b) Selachii.
    (c) Sarcopterygii.
    (d) Sauria.
    (e) Urochordata.

4. Demonstrate how the respiratory system of the class Amphibia is representative of the Sub Phylum Gnathostomata.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2020 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 3022: BIOLOGY OF SEED PLANTS
THEORY PAPER

TIME: THREE HOURS

INSTRUCTIONS: ANSWER **FIVE** QUESTIONS; **TWO** FROM EACH SECTION AND THE FIFTH FROM EITHER SECTION. ILLUSTRATE YOUR ANSWER WHERE NECESSARY. USE **SEPARATE ANSWER BOOKS** FOR EACH SECTION.

SECTION A

1. Explain the roles of cell wall functional proteins in seed plants.

2. Discuss plant meristem classification.

3. Describe spermatophyte vascular organisation in relation to phyllotaxy.

4. (a) Describe the occurrence of stomata in eudicots, monocots and conifers.
   (b) Explain the significance of stomatal positions in relation to the epidermal layer and side of leaf.

SECTION B

5. (a) Discuss how photoperiod regulates flowering in plants.
   (b) Explain how long-day periods induce flowering in Long-Day plants.

6. (a) Draw a diagram of a longitudinal section of the shoot apical meristem to show patterns of tissue growth and differentiation in the shoot apical meristem.
   (b) Discuss how the shoot apical meristem pattern relates to localized differences in auxin/cytokinin activity for its formation and maintenance.

7. (a) Explain how the endosperm is formed in angiosperm seeds.
   (b) Discuss the significance of abscisic acid activity during the last phase of seed maturation.

8. Draw labelled diagrams illustrating the formation of male gametophyte (microsporogenesis) and in the second phase, the mature microspore (microgametogenesis), in the anther of a flower.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2020 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 3031: INVERTEBRATES
THEORY PAPER

TIME: THREE HOURS

INSTRUCTIONS: ANSWER **FIVE** QUESTIONS, **TWO** QUESTIONS FROM EACH SECTION AND THE **FIFTH** FROM EITHER SECTION. USE **SEPARATE ANSWER BOOKS** FOR EACH SECTION. ILLUSTRATE YOUR ANSWERS WHERE NECESSARY.

SECTION A

1. Describe the hemal system and gas exchange in bilaterians.

2. Summarise each of the following:
   (a) Intracellular digestion in protozoans.
   (b) Structures of flagella and cilia in protozoans.
   (c) Filter feeding and digestion in the phylum Porifera.
   (d) Life cycle of cestodes.

3. (a) Describe the structure and significance of coelenteron in cnidarians.
   (b) Compare and contrast the skeletal system in phylum Cnidaria and phylum Porifera.

4. Discuss the life cycles of four named nematode parasites.

SECTION B

5. Discuss the economic importance of the class Insecta in the phylum Arthropoda.

6. Summarise each of the following:
   (a) Segmentation in phylum Annelida.
   (b) Water vascular system in phylum Echinodermata.
   (c) Nervous system in phylum Arthropoda.
   (d) Protostomes and Deuterostomes.

7. Discuss the characteristics which makes the molluscs to be more advanced than the Platyhelminthes.

8. Outline the characteristics which distinguish the six classes in the phylum Echinodermata.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2020 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 3201: INTRODUCTION TO ENTOMOLOGY
THEORY PAPER

TIME: THREE HOURS

INSTRUCTIONS: ANSWER **FIVE** QUESTIONS. ILLUSTRATE YOUR ANSWER WHERE NECESSARY.

---

1. Compare and contrast image formation in apposition and superposition types of Ommatidia in insect compound eyes.

2. Describe leg modifications exhibited by members of Class Pterygota which are directly related to modes of life they have adapted to during the evolution of this group.

3. The obvious function of insect wings is flight but these structures are also known to serve other purposes in these animals. Discuss the other functions that wings are known to perform among named insects and/or insect groups.

4. (a) State where cuticular intima is found in the insect body.
   (b) Explain the biological significance of cuticular intima to the development of the insect.
   (c) Explain how the limitation of cuticular intima to insect growth is overcome during insect Post embryonic development.

5. (a) Discuss the kinds of specialized morphological structures that are associated with leg modifications in named insect species or insect groups.
   (b) Explain the functions of the structures in 5(a).

6. Insects bear an open-type of circulatory system. Explain what is meant by this and the functions of named cell types found in the haemolymph.

7. (a) Discuss asexual reproduction in insects.
   (b) Explain how diploidy is established in diploid females in those insect groups where no males exist.

TURN OVER

8. (a) Compare and contrast image formation in an insect Ocellus and Stema.
   (b) Explain the significance of ocelli in insects where these simple eyes are said not to be capable of forming disenable images when compared to the Ommatidia units of compound eyes or the stemata.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2020 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 3312: BACTERIOLOGY AND VIROLOGY
THEORY PAPER

TIME: THREE HOURS

INSTRUCTIONS: ANSWER **FIVE** QUESTIONS; **TWO** FROM EACH SECTION AND THE FIFTH FROM EITHER SECTION. ILLUSTRATE YOUR ANSWER WHERE NECESSARY. **USE SEPARATE ANSWER BOOKS** FOR EACH SECTION.

SECTION A

1. Summarise each of the following:
   (a) Fredrick-Griffith experiment.
   (b) Robert Koch's postulates.
   (c) Sterilization methods in bacteriology.
   (d) Pasteurization.

2. Explain each of the following:
   (a) Uses of differential medium.
   (b) Characteristics of nitrogen fixing bacteria.
   (c) Characteristics of bacterial plant pathogens.
   (d) Methods of enumeration of bacteria.
3. Discuss the characteristics and roles of Methanogens in the treatment of waste water.

4. Describe the following bacteria based on Bergey's Determinative and Systematic Bacteriology:
   (a) *Staphylococcus aureus.*
   (b) *Escherichia coli.*
   (c) *Vibrio cholera.*
   (d) *Neisseria gonorrhea.*

TURN OVER

SECTION B

5. Discuss Severe acute respiratory syndrome coronavirus-2 (SARS-Cov-2) with reference to:
   (a) Virion structure and host variability.
   (b) Genome and gene organization.
   (c) Virus tropism and disease symptoms.
   (d) Three vaccine technologies for the virus.
6. Contrast the biological characteristics of the families Geminiviridae and Orthomyxoviridae with reference to:
   (a) Virion particle structure,
   (b) Genome organization,
   (c) Mode of virus transmission and
   (d) Host organisms.
7. Summarise each of the following aspects of virus genomes using specific examples:
   (a) Structure and functions of long terminal repeats.
   (b) Genome segmentation and its challenges.
   (c) Genome-linked viral proteins (Vpgs).
8. Discuss the biology of Marburg and Ebola viruses under the following headings:
   (a) Virion particle structure,
   (b) Genome organization and
   (c) Virus disease mechanisms and symptoms.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2020 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 3421: MOLECULAR BIOLOGY
THEORY PAPER

TIME: THREE HOURS

INSTRUCTIONS: ANSWER **FIVE** QUESTIONS. QUESTIONS **ONE** AND **TWO ARE COMPULSORY**. ILLUSTRATE YOUR ANSWER WHERE NECESSARY.

---

1. Figure 1 shows compartments A and B of a eukaryotic cell. Answer the questions with reference to Figure 1.

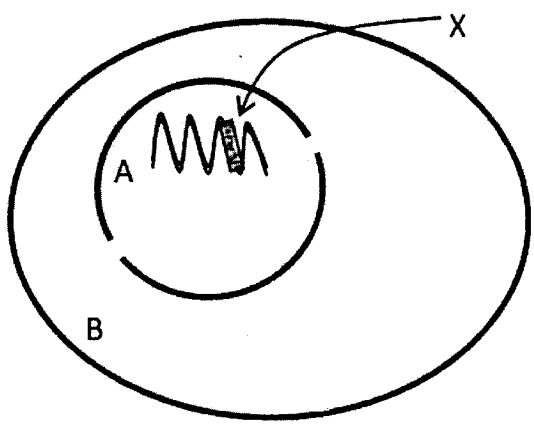


Figure 1. Representation of a eukaryotic cell.

(a) Suppose that the letter X represents a micro RNA (miRNA) gene, explain the molecular events that occur in compartments A and B leading to the production of effective products of gene X.

(b) Using your understanding of the biogenesis of different types of small RNAs, describe the molecular events that may accompany mirtron production. .

(c) Explain the biological significance of miRNAs and uses of siRNAs.

TURN OVER

2. Figure 2 shows a model of events at a DNA replication fork with details of polypeptides and DNA strands labeled by various letters. Study Figure 2 and answer the questions below it.

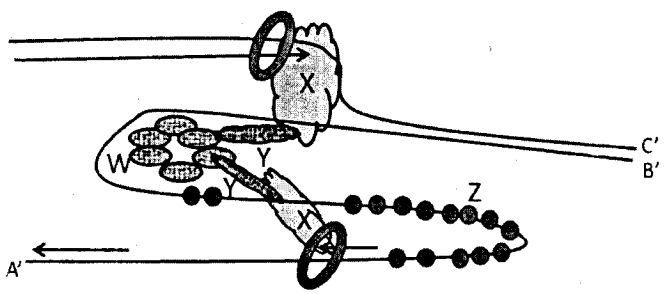


Figure 2. A model of events at a DNA replication fork.

(a) State the model presented in Figure 2 and describe its main features.

(b) Suppose that the letters W, X and Y represent the various polypeptide components of the DNA synthesizing polypeptide complex, state the DNA synthesizing complex and describe the biological functions of each of the three components.

(c) Describe the functions of the polypeptide represented by the letter Z.

(d) Considering that DNA strands are antiparallel, state the polarity represented by the letters B' and C'.

3. Study Figure 3 and answer the questions below it.

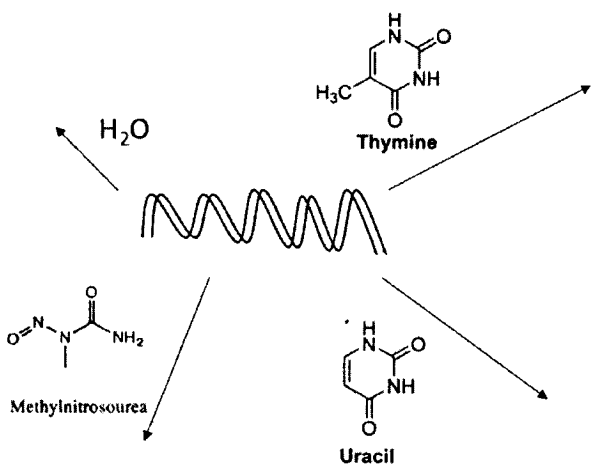


Figure 3. Examples of molecules that may cause DNA damage.

PROCEED TO NEXT PAGE

With reference to figure 3 explain:

(a) The potential damaging effects of water on cellular DNA.

(b) The various enzymatic processes for different types of DNA damage repair.

(c) The medical and agricultural significance of DNA damage and repair.

4. Explain the mechanism, genetic elements and polypeptides involved in gene imprinting of specified gene loci.

5. Summarise each of the following:

(a) The roles of sigma factors and functions of four named sigma factors in prokaryotes.

(b) The roles of adenylyl cyclase, CRP and two relevant mutations in *lac* operon gene regulation.

(c) The phosphotransferase mechanism in prokaryotic gene expression regulation for monosaccharide metabolism.

6. Explain the molecular and enzymatic processes of mRNA maturation via capping and exon splicing.

7. Draw the structure of the arabinose operon showing the various regulatory elements and structural genes and use your drawings to explain the regulation of the operon in the presence of arabinose.

8. Compare and contrast translation initiation events in prokaryotic and eukaryotic cells.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2020 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 3501: MYCOLOGY
PRACTICAL PAPER

TIME: TWO HOURS

INSTRUCTIONS: ANSWER **ALL** QUESTIONS.

---

1. Examine the provided illustration of specimen A and
   (a) Draw and label parts
   (b) State the following taxa of specimen A
      i. kingdom
      ii. phylum
      iii. genus name
2. Make a microscopic preparation of specimen B and
   (a) Sate its phylum
   (b) State its genus name
   (c) Draw and label parts of the specimen B
3. Make a microscopic preparation of specimen C and assign it to the following taxa,
   (a) kingdom
   (b) phylum
   (c) order
   (d) family
      v. its genus name
4. Examine the specimen D and,
   (a) draw and label it
   (b) assign it to its phylum
   (c) state its common name.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2020 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 3501: MYCOLOGY
THEORY PAPER

TIME: THREE HOURS

INSTRUCTIONS: ANSWER **FIVE** QUESTIONS. ILLUSTRATE YOUR ANSWER WHERE NECESSARY.

---

1. Describe sexual structures and the process of sexual reproduction in Ascomycota and the formation of ascocarps and their types.
2. (a) Describe vegetative structure in yeasts.
   (b) Explain the economic importance of yeasts.
3. With the aid of labelled diagrams des[redacted]e method of sexual reproduction in *Rhizopus*.
4. Describe salient features of the basidio[redacted]es and list three members of the group by giving their genus name.
5. Describe the process of promycelium development in a rust fungus and illustrate the nuclear events that occur in this structure.
6. Describe the morphology of *Pilobolus* sporangiophore and its sporangial discharge mechanism.
7. Describe habitats and methods of nutrition of fungi including their associations with plant parts and other organisms.
8. (a) Discuss asexual structures in Zygomycota.
   (b) Explain the significance of spore reduction in Zygomycota.

END OF EXAMINATION

UNIVERSITY OF ZAMBIA
DEPARTMENT OF BIOLOGICAL SCIENCES

2020 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 3512: PLANT PATHOLOGY
THEORY PAPER

TIME: THREE HOURS

INSTRUCTIONS: ANSWER **FIVE** QUESTIONS. ILLUSTRATE YOUR ANSWER WHERE NECESSARY.-

---

1. (a) Describe pathogenesis associated with biotrophs and necrotrophs.
   (b) Explain structural host changes caused by the pathogens in (a) and their significance.
2. (a) Identify and list six plant diseases that can be readily recognized on the basis of disease symptoms.
   (b) Give one example of each of the six diseases identified in 2 (a) with host and pathogen names.
3. Discuss the role of toxins in plant disease.
4. Discuss plant disease cycle and types of disease cycles and their epidemiological significance.
5. (a) Describe plant viroids with particular reference to their structure and mode of transmission.
   (b) Give four examples of viroid diseases.
6. (a) Describe salient features of plant pathogenic bacteria.
   (b) Describe vascular wilt of potato and tomato caused by a bacterium with its causal organism.
7. Describe structure and characteristic symptoms caused by phytoplasma.
8. Summarise any FOUR of the following:
   (a) Damping - off diseases
   (b) Phytoalexins.
   (c) Applied plant pathology.
   (d) Biological control of plant diseases.
   (e) Protectant fungicides.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2020 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 3601: PARASITOLOGY
PRACTICAL PAPER

TIME: THREE HOURS

INSTRUCTIONS: ANSWER **ALL** QUESTIONS. USE SEPRATE ANSWER BOOKS FOR EACH SECTION.

SECTION A

1. You are provided with specimens **A1 to A10**. For each specimen, state the following:
   (a) Species name.
   (b) The developmental/life cycle stage of the specimen.
   (c) Mode of transmission.
   (d) Disease caused by the parasite.
   (e) Infective stage of the parasite.

SECTION B

2. You are provided with specimens **B1 to B8**. For each specimen state the following
   (a) Species name.
   (b) Intermediate host.
   (c) Definitive host.
   (d) Disease caused by the parasite.
   (e) Infective stage.

3. You are provided with specimens **B9 to B13**. For each specimen:
   (a) State the species name.
   (b) Identify which one of the specimen is the intermediate host of *Schistosoma haematobium.*

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2020 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 3712: ANIMAL PHYSIOLOGY
THEORY PAPER

TIME: THREE HOURS

INSTRUCTIONS: ANSWER **FIVE** QUESTIONS. ILLUSTRATE YOUR ANSWER WHERE NECESSARY.

---

1. Compare and contrast ventilatory mechanisms and their efficiencies in birds and fish.

2. Discuss physiological challenges encountered by humans or animals that go from low to high altitude.

3. Summarise each of the following:
   (a) Excretion in two named invertebrate groups.
   (b) Urea formation by the liver.
   (c) Renal clearance.
   (d) Hormonal regulation of renal blood flow and glomerular filtration rate.

4. Discuss thermoregulatory pathways in vertebrates.

5. Describe each of the following:
   (a) Phases of action potentials in cardiac muscles.
   (b) Electrocardiography.

6. Discuss the different classes of cell membrane receptors based on the mechanisms used to transduce signals into cellular responses.

7. Discuss the different breeding patterns in mammals.

8. Explain the mode of action of steroid hormones, using estrogen as an example.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2020 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 3721: PLANT PHYSIOLOGY
PRACTICAL PAPER

TIME: THREE HOURS

INSTRUCTIONS: CARRY OUT THE FOLLOWING EXPERIMENT AND WRITE A REPORT ON IT AS REQUIRED IN SUB-PARAGRAPHS (a) TO (e).

You have been provided with **specimen A** (*Tradescantia* species) and dilute sucrose solutions with molarities 0.05 to 0.4 M. Place 10 ml of each solution in a petri dish, then peel several strips of the lower epidermis from the leaves of **specimen A** and float three epidermal strips in each of the dilute sucrose solutions, at intervals of five minutes between each sucrose concentration. Allow the epidermal strips to equilibrate with the solutions for one hour and thirty minutes before examining the epidermal strips from each solution under the microscope for count of plasmolysed and unplasmolysed cells.

1. Record all your data in a table.

2. Calculate the percentage of cells plasmolysed for each sucrose solution.

3. Answer the following:
   (a) Suggest;
      (i) title of the experiment
      (ii) the aim of the experiment.
   (b) Analyse the data collected and determine the solute potential of the cells of **specimen A** at incipient plasmolysis.
   (c) Describe the method you used to conduct the experiment.
   (d) Briefly discuss the results.
   (e) Draw a conclusion on the experiment.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2020 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 3841: EVOLUTIONARY BIOLOGY
THEORY PAPER

TIME: THREE HOURS

INSTRUCTIONS: ANSWER **FIVE** QUESTIONS. ILLUSTRATE YOUR ANSWER WHERE NECESSARY.

---

1. Summarise each of the following:
   (a) Mutation selection balance.
   (b) Random, or "drunken walk" in relation to alleles.
   (c) Microevolution.
   (d) Intersexual selection.

2. Explain how ring species provide evidence for evolution.

3. Discuss using an empirical example, the potential role of migration in the evolution of a population of organisms on an island.

4. (a) Explain the major goals of evolutionary biology.
   (b) Distinguish biological evolution from other types of evolution.

5. (a) Discuss the founder effect in genetically isolated human populations.
   (b) Explain how genetic drift can lead to loss or fixation of alleles.

6. With the help of a concept map, discuss the major concepts in evolutionary biology stating how each of these contribute to biological evolution.

7. Discuss the significance of the Cambrian period to:
   (a) The origin of life on earth
   (b) The diversity of life on earth.

8. (a) Describe the formation of the large igneous provinces on the surface of the earth.
   (b) Explain the role of igneous provinces in mass species extinction.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2020 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 4060: VERTEBRATE BIOLOGY
THEORY PAPER

TIME: THREE HOURS

INSTRUCTIONS: ANSWER **FIVE** QUESTIONS. ILLUSTRATE YOUR ANSWER WHERE NECESSARY.

---

1. Describe each of the following with respect to vertebrate embryology:
   (a) Morphogenesis.
   (b) Metamorphosis.

2. Discuss the evolutionary trends of the vertebrate integumentary systems.

3. Summarise each of the following:
   (a) Nerve plexus formation as a functional adaptation in tetrapods.
   (b) Functions of the mammalian corpus callosum.
   (c) Roles of vertebrate microglial cells.
   (d) Primary functions of five named cranial nerves in humans.

4. Compare and contrast structure and function of the muscular system in birds and mammals.

5. Discuss secondary sex determination in mammals.

6. Describe the hypothalamic neuroendocrine control of luteinising hormone secretion in female mice.

7. (a) Explain the various sources of cellular cholesterol used for steroidogenesis.
   (b) Describe the transport of cholesterol from the cytoplasm to the inner mitochondrial membrane for steroidogenesis.

8. Discuss the transport of gametes in the female reproductive tract prior to fertilisation in mammals.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2020 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 4321: ENVIRONMENTAL MICROBIOLOGY
THEORY PAPER

TIME: THREE HOURS

INSTRUCTIONS: ANSWER **FIVE** QUESTIONS; **TWO** FROM EACH SECTION AND THE **FIFTH** FROM EITHER SECTION. ILLUSTRATE YOUR ANSWERS WHERE NECESSARY. USE **SEPARATE ANSWER BOOKS** FOR EACH SECTION.

SECTION A

1. Explain the importance of microorganisms in the cleaning process of a water body which has been polluted by petroleum products from a shipwreck.

2. Explain the microbiology of waste water treatment process.

3. Summarise each of the following:
   (a) Open plumbing systems corrosion.
   (b) Bioremediation of chlorofluorocarbons.
   (c) Importance of microorganism in the nitrogen nutrient cycle.
   (d) Soil microbial biomass.

4. Explain the importance of microorganisms in the biodegradation and bioremediation of xenobiotics.

SECTION B

5. Discuss the impact of climate change and agricultural practices on microbial communities.

6. Describe the characteristics and role of the following microorganisms in sustaining soil health:
   (a) *Pseudomonas* spp.
   (b) *Nitrobacter* spp.

7. Discuss the role of microorganisms in regulating global temperatures.

8. Describe the production of compost manure and state its impact on the environment.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2020 ACADEMIC YEAR

FINAL EXAMINATIONS

BIO 4352: FOOD MICROBIOLOGY
THEORY PAPER

TIME: THREE HOURS

INSTRUCTIONS: ANSWER **FIVE** QUESTIONS: QUESTION **ONE** IS COMPULSORY.
ILLUSTRATE YOUR ANSWER WHERE NECESARY

---

1. Discuss the significance of proficiency testing in the food microbiology laboratory.

2. Describe the characteristics and public health significance of the following food spoilage organisms:
   (a) *Listeria monocytogenes.*
   (b) *Vibrio cholera.*

3. Summarise the following:
   (a) Production of clear beer
   (b) Eggs' microbial spoilage.

4. Describe the production of the following foods using microorganisms:
   (a) Yoghourt.
   (b) Amino acids.

5. Summarise the following:
   (a) Fermentation.
   (b) Microbial growth conditions.

6. Describe the determination of total coliforms in water meant for cleaning meat carcasses at the abattoir.

7. Discuss the isolation and characterisation of bacteria from ready-to-eat foods.

8. Summarise the significance of the following in the food industry:
   (a) Quality control.
   (b) Hazard analysis critical control points (HACCP).

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2020 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO4641: IMMUNOLOGY
THEORY PAPER

TIME: THREE HOURS

INSTRUCTIONS: ANSWER **FIVE** QUESTIONS. ILLUSTRATE YOUR ANSWER WHERE NECESSARY

---

1. Describe the major events of an inflammatory response that are initiated by the immune system as a protection against bacteria and tissue injury.

2. Describe the mechanisms by which foreign antigens are processed and presented to induce immune responses.

3. Describe the components of the first complement C1 and explain its binding to immunoglobulin gamma (IgG) to activate the classical pathway.

4. With the aid of diagrams, describe the morphology, structure and function of each of the following:
   (a) Natural Killer (NK) cells.
   (b) Neutrophil.
   (c) T-lymphocytes.

5. Discuss the composition and roles of Major Histocompatibility Complex (MHC) in the recognition of different antigens.

6. Discuss the roles of cells, receptors, costimulatory molecules and cytokines involved in the cell-mediated immunity.

7. With the aid of diagrams, describe the sequence of events in B-cell activation, proliferation and differentiation by soluble protein antigen.

8. (a) Describe immunotoxins.
   (b) Explain the production of immunotoxins and how they act to protect the human body against certain tumor cells.

END OF EXAMINATION

UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2020 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 5101: BIOSYSTEMATICS OF TROPICAL PLANT TAXA
PRACTICAL PAPER

TIME: THREE HOURS

INSTRUCTIONS: ANSWER **ALL** QUESTIONS.

---

1. You are provided with specimens **A to J**.
   (a) Use the dichotomous taxonomic key provided to identify each one of them.
   (b) List diagnostic features of each specimen identified in 1(a).

2. You are provided with specimens **K** to **O**.
   Construct a dichotomous taxonomic key for the identification of the specimens.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
2019 FINAL EXAMINATIONS

BIO 5421: INTEGRATED PEST AND VECTOR MANAGEMENT

THEORY PAPER

TIME: THREE HOURS

INSTRUCTIONS: ANSWER **FIVE** QUESTIONS. TWO QUESTIONS FROM EACH SECTION AND ONE QUESTION FROM EITHER SECTION A OR B. GIVE EXAMPLES OR ILLUSTRATIONS WHERE POSSIBLE.

SECTION A

1. Discuss two species of insects in the genus *Glossina* which are of medical and veterinary importance commonly found in Zambia.

2. Discuss the strategies used in integrated pest management (IPM).

3. Discuss the biology and bionomics of Culicidae (mosquitoes) in Zambia.

4. Summarise each of the following:
   (a) Epidemiology of vector-borne diseases
   (b) Classification of Diptera
   (c) Holometabo'ous insects
   (d) Invasive ins ect pests.

SECTION B

5. Discuss the importance of the book entitled, the Silent Spring (Carlson. 1962) and its impact on the development of Integrated Pest Management (IPM).

6. The statement "Integrated Pest and Vector Management (IPVM) is more of a myth than a reality". Discuss the strengths and weaknesses of this statement.

7. You have been requested to write an integrated vector management (IVM) manual for Zambia. Discuss with justification the main components of IVM you would include in this manual.

8. The fall army v orm (*Spodoptera frugiperda*, J.E. Smith) has been accidentally introduced in Zambia and is causing serious maize crop losses. Discuss some of the management approaches you would use to control this pest.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2019 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 5452: BIOTECHNOLOGY AND BIOSAFETY
THEORY PAPER

TIME: THREE HOURS

INSTRUCTIONS: ANSWER **FIVE** QUESTIONS; **ONE** FROM SECTION A, AND **TWO** FROM EACH OF THE SECTIONS B AND C. ILLUSTRATE YOUR ANSWER WHERE NECESSARY. USE SEPARATE ANSWER BOOKS FOR EACH SECTION.

SECTION A

1. Suppose that a biosafety officer was provided with an application for approval of a genetically modified maize variety ZEAma 1822 which was developed for resistance against insect pests and herbicide tolerance for use in making human foods.
   (a) Explain three potential risks that a biosafety officer would assess ZEAma 1822 for safety approval as a live genetically modified maize variety.
   (b) Suggest two alternative ways in which ZEAma1822 could have been developed.
   (c) Explain the various compositional analyses that a biosafety officer would conduct in assessing for safety of ZEAma 1822 as a food ingredient.
   (d) Explain how you would arrive at the conclusion as to whether to issue an approval permit or not based on your assessments in 1(a) and 1(b).

2. Explain each one of the following techniques could be relevant for assessment of a genetically-modified soybean variety constructed for production of high levels of a given fatty acid with proposed health benefits.
   (a) High performance liquid chromatography-mass spectrometry.
   (b) Southern blotting.
   (c) Western blotting.

SECTION B

3. (a) Explain the Precautionary Principle, giving examples of International Regulations that are using this principle.
   (b) Explain the three consistent elements in the use of the Precautionary Principle.

TURN OVER

4. Discuss with emphasis on Cartagena Protocol how the convention on Biological Diversity (CBD) regulates Genetically Modified Organisms (GMOs).

5. Using relevant examples and guidance by various international biosafety regulations, discuss the labelling vs. non-labelling of GMOs and genetically modified Foods.

SECTION C

6. (a) Discuss the environmental concerns of recombinant DNA technology.
   (b) Discuss the potential health risks and benefits of genetically modified maize.

7. Summarize each of the following.
   (a) Patents for biotechnology.
   (b) Methods of communicating biotechnology and biosafety information.
   (c) Testing for transgenes in genetically modified products in Zambia.
   (d) Monitoring field trials of genetically modified plants.

8. Discuss:
   (a) Intellectual properties and biotechnology.
   (b) Bioterrorism as a dark side of biotechnology.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2019 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 5612: MICROBIAL ECOLOGY
THEORY PAPER

TIME: THREE HOURS

INSTRUCTIONS: ANSWER **FOUR** QUESTIONS. ILLUSTRATE YOUR ANSWER WHERE NECESSARY.

---

1. Describe the important scientific contributions to the development of microbial ecology.

2. Explain the importance of microorganisms in the removal of heavy metals from waste water.

3. Summarise each of the following with reference to extremophiles:
   (a) Domain.
   (b) Energy transduction.
   (c) Physiology.
   (d) Biochemistry.

4. (a) Describe types of electron acceptors found in soil microbial cells.
   (b) Explain the importance of interactions among microbial units in the environment.

5. (a) Explain the significance of microorganisms in soil quality management.
   (b) Suggest safe agricultural methods to maintain a healthy soil microbial community.

6. Discuss the influence of microorganisms in indoor and outdoor air environments.

7. Discuss the biotechnological significance of various biosensors in element transformation in the environment.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2019/2020 ACADEMIC YEAR
FINAL EXAMINATIONS

CHE1000: INTRODUCTION TO CHEMISTRY

TIME: THREE (3) HOURS

INSTRUCTIONS TO THE CANDIDATES

1. Indicate your **student ID number** and **TG number** on **ALL** your answer booklets.
2. This examination paper consists of two (2) sections: **A** and **B**
3. Section **A** has ten **(10)** short answer questions. Questions carry equal marks. (Total marks = **40**).

   ANSWER ALL QUESTIONS IN SECTION A IN THE MAIN ANSWER BOOKLET
4. Section **B** has five **(5)** long answer questions. Questions carry equal marks. (Total marks = **60**).

   ANSWER QUESTION B1 AND ANY FOUR QUESTIONS, EACH QUESTION IN A SEPARATE ANSWER BOOKLET.
6. **YOU ARE REMINDED OF THE NEED TO ORGANISE AND PRESENT YOUR WORK CLEARLY AND LOGICALLY.**
7. Please be reminded that it is your responsibility to **ENSURE** that you have Ten (10) printed pages containing questions A1 to A10 and B1 to B5.

ADDITIONAL INFORMATION TO THE CANDIDATES:

Useful data is provided on page 11.
Periodic Table of Elements is on last page.

PLEASE TURN OVER

SECTION A

ANSWER ALL QUESTIONS IN THIS SECTION IN THE MAIN BOOKLET

Question A1

A 2.00 g sample of a compound gave 4.86 g CO_2 and 2.03 g H_2O upon combustion in oxygen. Find its empirical formula, if it only contained Carbon, Hydrogen and Oxygen.

[4 Marks]

Question A2

A sample of sodium azide (NaN_3), a compound used in automobile air bags, was thermally decomposed, and 15.3 mL nitrogen gas was collected over water at 25°C and 755 torr. Given the vapour pressure of water at 25°C is 23.6 torr, how many grams of nitrogen were collected?

[4 Marks]

Question A3

Ozone molecules in the upper atmosphere absorb radiation. If the radiation has a wavelength between 240 nm and 310 nm, the ozone molecules will decompose into oxygen molecules and oxygen atoms. The oxygen atoms then recombine with the oxygen molecules to make more ozone, releasing heat. This converts light energy into heat energy and insulates the Earth.

$O_3(g) \rightarrow O_2(g) + O_{(}g)$	light energy absorbed
$O_2(g) + O(g) \rightarrow O_3(g)$	heat energy released

a) What kind of electromagnetic radiation has a wavelength between 240 and 310 nm?

b) Which wavelength represents the minimum amount of energy required for this reaction to proceed: 240 nm or 310 nm?

c) Calculate the minimum amount of light energy that must be absorbed to convert 1 mole of ozone into oxygen molecules and atoms.
Report your answer in kJ/mol.

[4 Marks]

Question A4

The atoms of N_2O (nitrous oxide, laughing gas) are connected: N—N—O.

a) Draw all resonance structures for N_2O that have minimum formal charges. Explicitly show (using curved arrows) the electron movements that transform one resonance structure into the other. You must explicitly show all non-zero formal charges.

b) Predict the geometry of this molecule and draw its structure.

[4 Marks]

Question A5

Under standard conditions at 25 °C, Zn(*s*) reacts with $Co^{2+}(aq)$ to produce Co(*s*)

Co^{2+} (aq) + 2 e^- ⇌ Co(s) - 0.28 V
Zn^{2+} (aq) + 2 e^- ⇌ Zn(s) - 0.76 V

a) Write the balanced equation for the oxidation half reaction.

b) Write the balanced net-ionic equation for the overall reaction.

c) Calculate the standard potential, E^o, for the overall reaction at 25 °C.

[4 Marks]

Question A6

Use the following data to answer the questions about this reaction A (g) + 3B (g) → 2C (g), which is carried out in a 1.0 L container at 25°C

Run	[A] (M)	[B] (M)	Initial Rate of formation of C (M/min)
1	0.1	0.1	0.25
2	0.2	0.2	2.0
3	0.1	0.2	2.0

a) For experiment 1, give the initial rate of disappearance of A and B.

b) Determine the orders of reaction with respect to A and B.

[4 Marks]

Question A7

Given the following equations and their $\Delta H°$ values:

$2\ CH_3OH\ (l) + 3\ O_2\ (g) \rightarrow 2CO_2\ (g) + 4\ H_2O\ (g)$ $\quad \Delta H^c = -305.4$ kJ

$HCO_2H\ (l) + \frac{1}{2}\ O_2\ (g) \rightarrow CO_2\ (g) + H_2O\ (g)$ $\quad \Delta H^c = -65.2$ kJ

Calculate $\Delta H°$ for the reaction:

$$CH_3OH\ (l) + O_2\ (g) \rightarrow HCO_2H\ (l) + H_2O\ (g).$$

[4 Marks]

.....

Question A8

A recent analysis has shown that a certain variety of grapes contains 28 % sugar by mass. Assuming that sugar (formula $C_6H_{12}O_6$) is the only solute present and that water is the solvent, at what temperature will the grapes freeze? [Note: H_2O $K_f = 1.86\ °C \cdot kg/mol$]

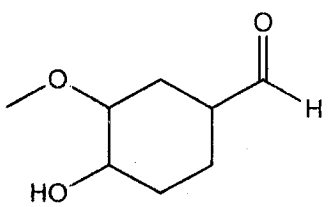
[4 Marks]

.....

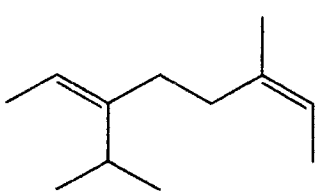
Question A9

Provide the IUPAC name for each of the molecules shown below:

(a)



(b)



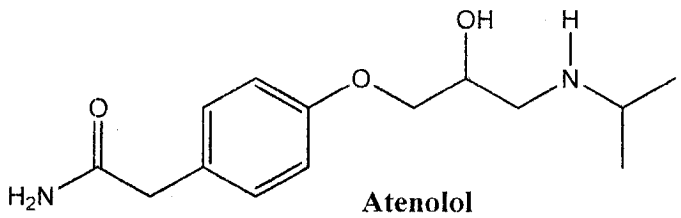
[4 Marks]

.....

Question A10

a) Write the bond line formulae corresponding to IUPAC names:
Ethyl 4-aminobutanoate

b) Consider the molecular structure of the drug Atenolol, used for treatment of hypertension (high blood pressure).



Atenolol

Redraw the structure of Atenolol molecule, **circle** all functional groups and **name** them.
[4 Marks]

SECTION B

ANSWER QUESTION B1 AND ANY THREE QUESTIONS

EACH IN A SEPARATE BOOKLET

Question B1

a) In one of the CHE1000 laboratory back titration was performed, a method in which the analyte (which is the limiting reagent) is not determined from the titration reaction with a primary standard, but by working back to the original reaction.

(i) In titration, what is meant by the term Primary standard? **[1 Mark]**

(ii) In three (3) lines or less, explain the principle involved in a back titration. **[2 Marks]**

(iii) An acid and a base were titrated, state the suitable indicator used and the end-point color expected. **[2 Marks]**

(iv) The mass of magnesium hydroxide, $Mg(OH)_2$, in an indigestion tablet was determined as follows:

Step 1 The tablet was crushed and dissolved in exactly 40.00 cm^3 of dilute Hydrochloric acid (an excess).

$$Mg(OH)_2(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + 2H_2O(l)$$

Step 2 The amount of hydrochloric acid remaining was measured by titration with 0.250 mol dm^{-3} sodium hydroxide solution.

22.80 cm^3 of this sodium hydroxide solution was required.

Calculate the mass of magnesium hydroxide in the tablet. **[4 Marks]**

b) In the redox titration, the weed killer solution was prepared by dissolving hydrated iron(II) sulphate, $FeSO_4.7H_2O$, in water. This was then titrated with 0.0200 mol dm^{-3} potassium manganate(VII) which had average titre of 25.60 cm^{-3}. The half-equations for the redox reactions occurring in the reaction between iron(II) and potassium manganate(VII) in acidic solution are shown below.

$$Fe^{2+} \rightarrow Fe^{3+} + e^-$$
$$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$$

(i) Give a reason why this titration does not need an indicator **[1 Mark]**

(ii) Deduce an overall equation for the reaction between iron(II) and manganate(VII) ions in acidic solution. **[2 Marks]**

(iii) Calculate the concentration, in g dm^{-3}, of hydrated iron(II) sulphate in the weed killer solution. **[3 Marks]**

[Total: 15 Marks]

Question B2

a) Explain the decrease in the atomic radii across the period from Na to Cl. **[2 Marks]**

b) Modern plasma television screens emit light when mixtures of noble gases, such as neon and xenon, are ionised. The first ionisation energies of neon and xenon are shown in the table below.

element	1st ionisation energy / kJ mol^{-1}
neon	+2081
xenon	+1170

Give 3 reasons why xenon has a lower first ionisation energy than neon. **[3 Marks]**

c) Calculate the maximum kinetic energy (in joules) and velocity of an electron ejected from zinc by a 275 nm photon. (Threshold energy for Zn 4.31eV).
Report the answer to 3 significant figures **[3 Marks]**

d) A water desalination plant is set up near a salt marsh containing water that is 0.10 *M* NaCl. Calculate the minimum pressure that must be applied at 20.8 °C to purify the water by reverse osmosis. Assume NaCl is completely dissociated. **[3 Marks]**

e) Diethyl ether ($CH_3CH_2OCH_2CH_3$) was one of the first chemicals used as an anaesthetic. At 34.68 °C, diethyl ether has a vapour pressure of 760. torr, and at 17.98 °C, it has a vapour pressure of 400. torr. What is the ΔH of vaporization for diethyl ether?

[3 Marks]

[Total: 15 Marks]

Question B3

a) Due to COVID-19 coupled with erratic power supply from ZESCO, you decide to play around with galvanic cells and you construct a zinc–copper battery operating at a zero resistant small light emitting diode (L.E.D) at 25^{O}C as follows:

$$Zn \mid Zn^{2+}(0.10\ M) \parallel Cu^{2+}\ (2.5\ M) \mid Cu$$

The mass of each solid electrode is 2.00 g.

The electrode potentials for the half reactions are:

$$Cu^{2+} + 2e^{-} \rightarrow Cu \qquad E^{o} = +0.3419\ V$$

$$Zn^{2+} + 2e^{-} \rightarrow Zn \qquad E^{o} = -0.7618\ V$$

(i) Which of the two is a reducing agent? **[1 Marks]**

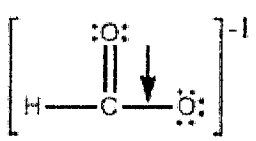
(ii) Calculate the cell potential when this battery is first connected. **[3 Marks]**

(iii) Calculate the cell potential after 10.0 A of current has flowed for 10.0 hours. (Assume each half-cell contains 1.00 L of solution.) **[3 Marks]**

(iv) Calculate the mass of each electrode after 10.0 hours. **[3 Marks]**

(v) What will cause the battery to die after some time? **[2 Marks]**

b) Using the table of mean bond enthalpies provided, predict the bond enthalpy (in kJ/mol) for the CO bond marked with an arrow in the molecule below. **[3 Marks]**



Bond	Mean Bond Enthalpy (in kJ/mol)
C-H	412
C-C	348
C=C	612
C-O	360
C=O	743

[Total: 15 Marks]

Question B4

a) Consider the following reaction in solution which was studied and gave the following data. Determine the rate law. **[5 Marks]**

$$2I^-(aq) + S_2O_8^{2-}(aq) \rightarrow I_2(aq) + 2SO_4^{2-}(aq)$$

$[I^-]_o$ (M)	$[S_2O_8^{2-}]_o$ (M)	Initial rates (mol. L^{-1}. s^{-1})
0.080	0.040	12.5×10^{-6}
0.040	0.040	6.25×10^{-6}
0.080	0.020	6.25×10^{-6}
0.032	0.040	5.00×10^{-6}
0.060	0.030	7.00×10^{-6}

b) At a particular temperature, 12 mol $SO_3(g)$ is placed into a 3.0 L rigid container, and the SO_3 dissociates by the reaction:

$$2SO_3(g) \rightleftharpoons 2SO_2(g) + O_2(g)$$

At equilibrium 3.0 mol SO_2 is present. Calculate the equilibrium constant, K for this reaction. **[3 Marks]**

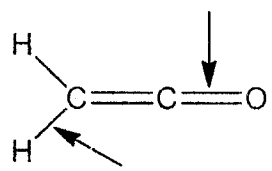
c) The activation energy for the decomposition of HI(g) to H_2 (g) and I_2(g) is 186 kJ/mol, and the rate constant at 555K is 3.52×10^{-7} L/mol. s.
What is the rate constant at 645 K? **[4 Marks]**

d) Calculate K_{sp} for $Pb_3(PO_4)_2(s)$ with a solubility of 6.2×10^{-12} mol/L. **[3 Marks]**

[Total: 15 Marks]

Question B5

a) Consider the ketene molecule shown below:



Identify the indicated bonds in terms of the types of bonds (**σ, π**) and the orbital overlaps Involved in bond formation. **[2 Marks]**

Bond	Bond description (σ, π)	orbital overlaps involved
C=O		
C-H		

b) Several constitutional (structural) isomers can be written for the molecular formula $C_4H_8O_2$.

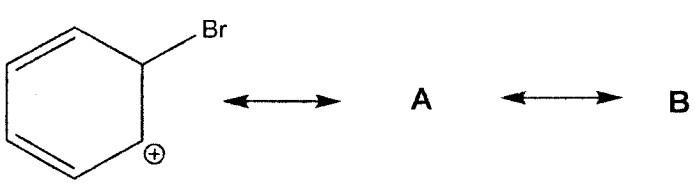
(i) Calculate the IHD and state all possible interpretations. **[3 Marks]**

(ii) One of the isomers, **B**, decolorizes bromine water. Does this isomer has a ring? Give a reason. **[2 Marks]**

(iii) Give the line (bond-line) formula and IUPAC name for another isomer **C**, a branched chain molecule, pH = 5.2. **[3 Marks]**

c) The compound with the molecular formula of C_4H_8 contains three structural isomers and two E/Z isomers. Draw the E isomers of C_4H_8, and give its IUPAC names. **[2 Marks]**

d) Draw two additional resonance structures A and B for the structure shown below, showing the movement of all electrons: **[3 Marks]**



[Total: 15 Marks]

USEFUL DATA

Physical contants

Avogadro constant, N_A	6.022×10^{23} mol^{-1}
Acceleration due to gravity	9.8 m s^{-2}
Faraday's constant, F	96485 C mol^{-1}
Mass of electron, m_e	9.11×10^{-31} kg
Planck's constant, h	6.626×10^{-34} J s
Rydberg constant, R_H	1.097×10^{7} m^{-1}
Speed of light, c	3.00×10^{8} m s^{-1}
Universal gas constant, R	8.3145 J mol^{-1} K^{-1}
	0.083145 L bar mol^{-1} K^{-1}
	0.08206 L atm mol^{-1} K^{-1}
	62.364 L torr mol^{-1} K^{-1}
	62.364 L mmHg mol^{-1} K^{-1}

Pressure conversions

1 atm = 1.01325×10^5 Pa = 1.01325×10^5 N m^{-2} = 760 torr = 760 mmHg = 1.01325 bar

1 bar = 1.00000×10^5 Pa
= 1.00000×10^5 N m^{-2}

Other conversion factors

V= J C^{-1} 1 eV = 1.602×10^{-19} J
I Joule = 1 J = 1 kg m^2 s^{-2} = 1 Pa m^3

Standard Reduction potentials

$ClO^-(aq) + H_2O(l) + 2e^- \leftrightharpoons Cl^-(aq) + 2OH^-$	$\varepsilon^o = +0.89$ V
$Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s)$	$\varepsilon^o = -0.76$ V
$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$	$\varepsilon^o = +0.80$ V
$Cl_{2(g)} + 2e^- \rightleftharpoons 2Cl^-_{(aq)}$	$\varepsilon^o = 1.36$ V
$2ClO_{2(g)} + 2e^- \rightleftharpoons 2\,ClO_2^-{}_{(aq)}$	$\varepsilon^o = 0.954$ V
$H^+(aq) + e^- \rightleftharpoons \frac{1}{2} H_2(g)$	$\varepsilon^o = 0.00$ V
$Mg^{2+}(aq) + 2e^- \rightleftharpoons Mg(s)$	$\varepsilon^o = -2.37$ V

PERIODIC TABLE OF ELEMENTS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18

hydrogen 1 **H** 1.00794																	helium 2 **He** 4.00260
lithium 3 **Li** 6.941	beryllium 4 **Be** 9.012182											boron 5 **B** 10.811	carbon 6 **C** 12.0107	nitrogen 7 **N** 14.00674	oxygen 8 **O** 15.9994	fluorine 9 **F** 18.9984	neon 10 **Ne** 20.1797
sodium 11 **Na** 22.98977	magnesium 12 **Mg** 24.3050											aluminium 13 **Al** 26.981538	silicon 14 **Si** 28.0855	phosphorus 15 **P** 30.97376	sulphur 16 **S** 32.065	chlorine 17 **Cl** 35.453	argon 18 **Ar** 39.984
potassium 19 **K** 39.0983	calcium 20 **Ca** 40.078	scandium 21 **Sc** 44.95591	titanium 22 **Ti** 47.867	vanadium 23 **V** 50.9415	chromium 24 **Cr** 51.9961	manganese 25 **Mn** 54.93805	iron 26 **Fe** 55.845	cobalt 27 **Co** 58.9332	nickel 28 **Ni** 58.6934	copper 29 **Cu** 63.546	zinc 30 **Zn** 65.409	gallium 31 **Ga** 69.723	germanium 32 **Ge** 72.64	arsenic 33 **As** 74.9216	selenium 34 **Se** 78.96	bromine 35 **Br** 79.904	krypton 36 **Kr** 83.798
rubidium 37 **Rb** 85.4678	strontium 38 **Sr** 87.62	yttrium 39 **Y** 88.90585	zirconium 40 **Zr** 91.225	niobium 41 **Nb** 92.90638	molybdenum 42 **Mo** 95.94	technetium 43 **Tc** [98]	ruthenium 44 **Ru** 101.07	rhodium 45 **Rh** 102.9055	palladium 46 **Pd** 106.42	silver 47 **Ag** 107.8682	cadmium 48 **Cd** 112.411	indium 49 **In** 114.818	tin 50 **Sn** 118.710	antimony 51 **Sb** 121.760	tellurium 52 **Te** 127.60	iodine 53 **I** 126.9045	xenon 54 **Xe** 131.293
caesium 55 **Cs** 132.90545	barium 56 **Ba** 137.327	lutetium 71 **Lu** 174.967	hafnium 72 **Hf** 178.49	tantalum 73 **Ta** 180.9479	tungsten 74 **W** 183.84	rhenium 75 **Re** 186.207	osmium 76 **Os** 190.23	iridium 77 **Ir** 192.217	platinum 78 **Pt** 195.078	gold 79 **Au** 196.96655	mercury 80 **Hg** 200.59	thallium 81 **Tl** 204.3833	lead 82 **Pb** 207.2	bismuth 83 **Bi** 208.980	polonium 84 **Po** [209]	astatine 85 **At** [210]	radon 86 **Rn** [222]
francium 87 **Fr** [223]	radium 88 **Ra** [226]	lawrencium 103 **Lr** [262]	rutherfordium 104 **Rf** [261]	dubnium 105 **Db** [262]	seaborgium 106 **Sg** [266]	bohrium 107 **Bh** [264]	hassium 108 **Hs** [269]	meitnerium 109 **Mt** [268]	darmstadtium 110 **Ds** [271]	roentgenium 111 **Rg** [272]	ununbium 112 **Uub** [285]		ununquadium 114 **Uuq** **[289]**				

key

element name
atomic number
symbol
atomic mass

lanthanum 57 **La** 138.9055	cerium 58 **Ce** 140.116	praseodymium 59 **Pr** 140.90765	neodymium 60 **Nd** 144.24	promethium 61 **Pm** [145]	samarium 62 **Sm** 150.36	europium 63 **Eu** 151.964	gadolinium 64 **Gd** 157.25	terbium 65 **Tb** 158.9253	dysprosium 66 **Dy** 162.50	holmium 67 **Ho** 164.930	erbium 68 **Er** 167.259	thulium 69 **Tm** 168.934	ytterbium 70 **Yb** 173.04
actinium 89 **Ac** [227]	thorium 90 **Th** 232.038	protactinium 91 **Pa** 231.0359	uranium 92 **U** 238.0289	neptunium 93 **Np** [237]	plutonium 94 **Pu** [244]	americium 95 **Am** [243]	curium 96 **Cm** [247]	berkelium 97 **Bk** [247]	californium 98 **Cf** [251]	einsteinium 99 **Es** [252]	fermium 100 **Fm** [257]	mendelevium 101 **Md** [258]	nobelium 102 **No** [259]

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
DEPARTMENT OF CHEMISTRY
2020/2021 ACADEMIC YEAR
FINAL EXAMINATIONS

CHE1010: INTRODUCTION TO CHEMISTRY FOR MEDICAL AND HEALTH SCIENCES

TIME: THREE (3) HOURS

INSTRUCTIONS TO THE CANDIDATES

1. Indicate your **student ID number** and **TG number** on **ALL** your answer booklets.
2. This examination paper consists of two (**2**) sections: **A** and **B**
3. Section **A** has ten **(10)** short answer questions. Questions carry equal marks.

   (Total marks = **40**).

   ANSWER ALL QUESTIONS IN SECTION A IN ONE SEPERATE MAIN ANSWER BOOKLET

4. Section **B** has five **(5)** long answer questions. Questions carry equal marks. (Total marks = **60**).

   ANSWER QUESTION B1 AND ANY THREE QUESTIONS IN ANOTHER SEPARATE MAIN ANSWER BOOKLET.

5. **YOU ARE REMINDED OF THE NEED TO ORGANISE AND PRESENT YOUR WORK CLEARLY AND LOGICALLY.**

6. Please be reminded that it is your responsibility to **ENSURE** that you have Ten (10) printed pages containing questions A1 to A10 and B1 to B5.

ADDITIONAL INFORMATION TO THE CANDIDATES:

Useful data is provided on page 11.
Periodic Table of Elements is on last page.

SECTION A

ANSWER ALL QUESTIONS IN THIS SECTION IN THE MAIN BOOKLET

Question A1

A 0.4108 g sample of $CaCO_3$ (M_r = 100.087 g/mol) is added to a flask along with 15.00 mL of 2.000 M HCl.

$$CaCO_3(aq) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

Enough water is then added to make a 250.0 mL solution. A 20.00 mL aliquot of this solution is taken and titrated with 0.1160 M NaOH.

$$NaOH(aq) + HCl(aq) \rightarrow H_2O(l) + NaCl(aq)$$

How many mL of NaOH are used?

[4 Marks]

Question A2

What is the De-Broglie wavelength of a Helium atom of 4.003 *amu* travelling at a velocity of 1000.0 ms^{-1}?

[4 Marks]

Question A3

Consider the following molecules; NH_3 and BF_3.

a) Draw a Lewis dot structure for each molecule.

b) Name the shape of each molecule.

[4 Marks]

Question A4

a) Explain the difference between dry-ashing and wet-ashing.

b) A 0.156 g sample of soil is analyzed for zinc and found to contain 0.203 mg Zn. Express the concentration of zinc in parts per million and parts per billion.

[4 Marks]

Question A5

A bottled soft drink contains CO_2 gas at a pressure of 5.0 bar over the liquid and after opening the partial pressure drops to 4.0×10^{-4} bar. Calculate the equilibrium concentration of CO_2 in the soft drink before and after the bottle is opened. Henrys constant, $= 3.1 \times 10^{-2}$ mol/L bar.

[4 Marks]

Question A6

When a 6.50 g sample of solid NaOH dissolves in 100.0 g of water in a coffee-cup calorimeter, the temperature rises from 21.6 °C to 37.8 °C. Calculate the ΔH (in kJ/mol NaOH) for the solution process. (Assume the specific heat of the solution formed is 4.18 J/g.K)

$$NaOH(s) \rightarrow Na^+(aq) + OH^-(aq)$$

[4 Marks]

Question A7

The decomposition of 0.500 M hydrogen peroxide to hydrogen and oxygen has a rate constant of 1.925×10^{-3} min^{-1} at 313.15 K. Determine the time it will take for 80.0 percent of the original concentration of hydrogen peroxide to decompose.

[4 Marks]

Question A8

A ^{60}Co source is labelled 4.00 mCi, but its present activity is found to be 1.85×10^7 Bq. (^{60}Co half-life is 5.271 years)

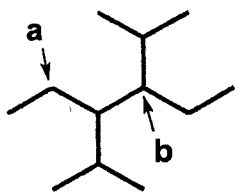
a) Write the equation for the beta decay of ^{60}Co.

b) How long ago did it actually have an activity of 4.00 mCi?

[4 Marks]

Question A9

Consider the compound given below.



a) Provide the IUPAC name.

b) State whether the two types of hydrogens located at carbons **a** and **b** are primary, secondary or tertiary.

[4 Marks]

Question A10

A compound with the molecular formula, (C_4H_8), has **six (6)** possible isomeric structures. When all these are subjected to aqueous bromine, **two (2)** out of the **six (6)** isomers do not decolorize aqueous bromine. Using the skeletal representation, draw the possible structures of these **two (2)** isomers.

[4 Marks]

SECTION B

ANSWER QUESTION B1 AND ANY THREE QUESTIONS IN ANOTHER SEPARATE MAIN ANSWER BOOKLET.

Question B1

a) According to Laboratory safety and rules, why should you never add water to an acid? **[2 Marks]**

b) In volumetric analysis, 25.00 cm^3 of a sodium hydroxide aqueous solution of concentration 0.10 mol/dm^3 was titrated against an aqueous solution of hydrochloric acid of unknown concentration.

(i) Write a balanced equation for the reaction between sodium hydroxide and hydrochloric acid including state symbols. **[2 Marks]**

(ii) Calculate the number of moles of sodium hydroxide in the titrated 25.00 cm^3. **[1 Mark]**

(iii) Determine the concentration of hydrochloric acid if you obtained the following set of titres (cm^3):

(1) 16.82 (2) 16.50 and (3) 16.63

Give your final answer to three significant figures. **[2 Marks]**

(iv) State the device or piece of apparatus used to ensure your safety when pipetting. **[1 Mark]**

(v) It is not advisable to load sodium hydroxide solution into the burette. However, in the back titration experiment, sodium hydroxide was put in the burette for the titration experiment. Mention the risk that this poses to the burette. **[1 Mark]**

c) In a gravimetric analysis experiment, a known mass of toothpaste was dissolved in 20 mL of water and the resulting solution was mixed with 50 mL of lead chloronitrate solution. The reaction below occurs:

$$F^-(aq) + PbClNO_3(aq) \rightarrow PbClF(s) + NO_3^-(aq)$$

In this experiment, the following results were obtained:

Mass of toothpaste weighed	0.50g
Mass of beaker used	108.42g
Mass of beaker + Product	108.57g

Calculate the percentage of the mass of Fluoride ions in the toothpaste sample analysed. **[6 Marks]**

[Total: 15 Marks]

Question B2

a) A student performed an analysis of a sample for its magnesium content and got the following results: 10.92%, 10.91%, 10.88% and 10.91%. The actual amount of magnesium in the sample is 10.91%. What conclusion can you draw about the accuracy and precision of these results? **[2 Marks]**

b) A reaction vessel contains 5.00 g of CO and 5.00 g of O_2.

$$2CO(g) + O_2(g) \longrightarrow 2CO_2(g)$$

(i) Which reactant is a limiting reagent? Show your working. **[3 Marks]**

(ii) How many grams of CO_2 could be produced? **[1 Marks]**

c) When 0.137 g of Mg is heated in a nitrogen (N_2) stream, a chemical reaction occurs. The product of the reaction has the mass of 0.189 g. Calculate its empirical formula? **[4 Marks]**

d) Consider the two redox half-equations given below.

1. $Mn^{2+}(aq) + 4H_2O(l) \longrightarrow MnO_4^-(aq) + 8H^+(aq)$
2. $6H^+(aq) + BiO_3^-(aq) \longrightarrow Bi^{3+}(aq) + 3H_2O(l)$

Balance the charges in each of the half-equations and provide the overall redox reaction equation

[5 Marks]

[Total: 15 Marks]

Question B3

a) Distinguish, with examples, between Bronsted – Lowry acid and Arrhenius acid.

[2 Marks]

b) What is a conjugate acid – base pair? Give two examples. **[2 Marks]**

c) Calculate the concentration of an aqueous solution of $Ca(OH)_2$ that has a pH of 10.05.
[3 Marks]

d) An acid, **HA**, has a concentration of 0.05 M and is 3% dissociated. What is the K_a of this acid? **[3 Marks]**

e) Morphine is a weak base having K_b value of $1.6\ 10^{-6}$. Find the pH of a 0.010 M solution of morphine. **[5 Marks]**

[Total: 15 Marks]

Question B4

a) An electrochemical cell consists of 1.0 L half-cells of Fe/Fe^{2+} and Cd/Cd^{2+} with the following initial concentrations: $[Fe^{2+}] = 0.800$ M, $[Cd^{2+}] = 0.200$ M.

(i) Write the overall cell reaction. **[3 Marks]**

(ii) What is the initial E_{cell} at 25 °C? **[5 Marks]**

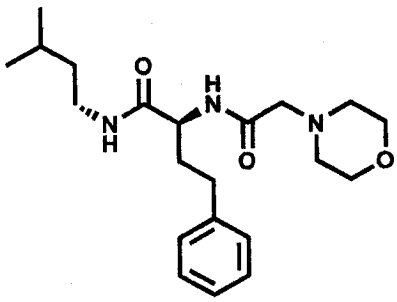
(iii) Calculate the ΔG^{o} of the reaction at 25 °C. **[3 Marks]**

b) How many minutes would be required to obtain 10.0 g of liquid mercury by passing a constant current of 0.17 A through a solution containing $Hg_2(NO_3)_2$ (aq)? **[4 Marks]**

[Total: 15 Marks]

Question B5

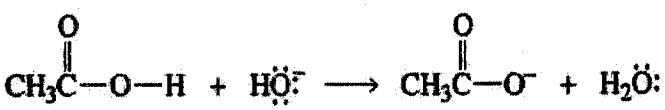
a) Give the molecular formula for the following compound. **[1 Mark]**



b) Draw the structure of (*Z*)-3-isopropyl-2-heptene. **[1 Mark]**

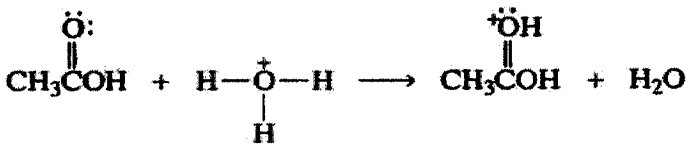
c) Use curved arrows to show the movement of electrons in each of the following reaction steps:

(i)



[1 Mark]

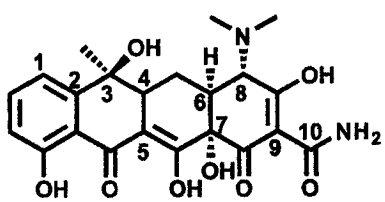
(ii)



[1 Mark]

d) Tetracycline is called a broad-spectrum antibiotic because it is active against a wide variety of bacteria. Which of the numbered carbon atoms are stereogenic centres?

[2 Marks]

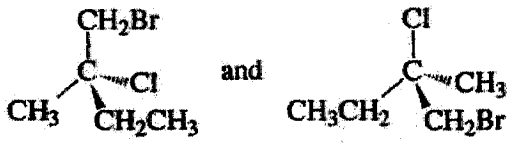


Tetracycline

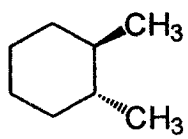
e) What is the expected observed rotation of a 1.0 x 10^{-4} M methanol solution of the potent anticancer drug paclitaxel (also called Taxol)? $[\alpha]_D^{20} = -49°$ (polarimeter tube length = 1 dm). Paclitaxel has a molecular weight of 853.93 g mol^{-1}.

[4 Marks]

f) Do the following structures represent identical molecules or a pair of enantiomers? Show your reasoning. **[3 Marks]**



g) Draw the more stable chair conformer of trans-1,2-dimethylcyclohexane. **[2 Marks]**



trans-1,2-dimethylcyclohexane

[Total: 15 Marks]

USEFUL DATA

Physical contants

Avogadro constant, N_A	6.022×10^{23} mol^{-1}
Acceleration due to gravity	9.8 m s^{-2}
Faraday's constant, F	96485 C mol^{-1}
Mass of electron, m_e	9.11×10^{-31} kg
Planck's constant, h	6.626×10^{-34} J s
Rydberg constant, R_H	1.097×10^{7} m^{-1}
Speed of light, c	3.00×10^{8} m s^{-1}
Universal gas constant, R	8.3145 J mol^{-1} K^{-1}
	0.083145 L bar mol^{-1} K^{-1}
	0.08206 L atm mol^{-1} K^{-1}
	62.364 L torr mol^{-1} K^{-1}
	62.364 L mmHg mol^{-1} K^{-1}

Other conversion factors

V= J C^{-1} 1 eV =1.602×10^{-19} J
1 Joule = 1 J = 1 kg m^2 s^{-2} = 1 Pa m^3
1 amu = $1.6605402 \times 10^{-27}$ kg

Nuclear Chemistry

1 Ci	3.70×10^{10} Bq
1 Ci	1000 mCi

Standard Reduction potentials

$Fe^{2+}(aq) + 2e^- \rightleftharpoons Fe(s)$	$\varepsilon^o = -0.44$ V
$H^+(aq) + e^- \rightleftharpoons \frac{1}{2} H_2(g)$	$\varepsilon^o = 0.00$ V
$Cd^{2+}(aq) + 2e^- \rightleftharpoons Cd(s)$	$\varepsilon^o = -0.40$ V

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18

hydrogen 1 **H** 1.00794																	helium 2 **He** 4.002602
lithium 3 **Li** 6.941	beryllium 4 **Be** 9.012182											boron 5 **B** 10.811	carbon 6 **C** 12.0107	nitrogen 7 **N** 14.00674	oxygen 8 **O** 15.9994	fluorine 9 **F** 18.9984	neon 10 **Ne** 20.1797
sodium 11 **Na** 22.98977	magnesium 12 **Mg** 24.3050											aluminium 13 **Al** 26.981538	silicon 14 **Si** 28.0855	phosphorus 15 **P** 30.97376	sulphur 16 **S** 32.065	chlorine 17 **Cl** 35.453	argon 18 **Ar** 39.984
potassium 19 **K** 39.0983	calcium 20 **Ca** 40.078	scandium 21 **Sc** 44.95591	titanium 22 **Ti** 47.867	vanadium 23 **V** 50.9415	chromium 24 **Cr** 51.9961	manganese 25 **Mn** 54.93805	iron 26 **Fe** 55.845	cobalt 27 **Co** 58.9332	nickel 28 **Ni** 58.6934	copper 29 **Cu** 63.546	zinc 30 **Zn** 65.409	gallium 31 **Ga** 69.723	germanium 32 **Ge** 72.64	arsenic 33 **As** 74.9216	selenium 34 **Se** 78.96	bromine 35 **Br** 79.904	krypton 36 **Kr** 83.798
rubidium 37 **Rb** 85.4678	strontium 38 **Sr** 87.62	yttrium 39 **Y** 88.90585	zirconium 40 **Zr** 91.225	niobium 41 **Nb** 92.90638	molybdenum 42 **Mo** 95.94	technetium 43 **Tc** [98]	ruthenium 44 **Ru** 101.07	rhodium 45 **Rh** 102.9055	palladium 46 **Pd** 106.42	silver 47 **Ag** 107.8682	cadmium 48 **Cd** 112.411	indium 49 **In** 114.818	tin 50 **Sn** 118.710	antimony 51 **Sb** 121.760	tellurium 52 **Te** 127.60	iodine 53 **I** 126.9045	xenon 54 **Xe** 131.293
caesium 55 **Cs** 132.90545	barium 56 **Ba** 137.327	lutetium 71 **Lu** 174.967	hafnium 72 **Hf** 178.49	tantalum 73 **Ta** 180.9479	tungsten 74 **W** 183.84	rhenium 75 **Re** 186.207	osmium 76 **Os** 190.23	iridium 77 **Ir** 192.217	platinum 78 **Pt** 195.078	gold 79 **Au** 196.96655	mercury 80 **Hg** 200.59	thallium 81 **Tl** 204.3833	lead 82 **Pb** 207.2	bismuth 83 **Bi** 208.980	polonium 84 **Po** [209]	astatine 85 **At** [210]	radon 86 **Rn** [222]
francium 87 **Fr** [223]	radium 88 **Ra** [226]	lawrencium 103 **Lr** [262]	rutherfordium 104 **Rf** [261]	dubnium 105 **Db** [262]	seaborgium 106 **Sg** [266]	bohrium 107 **Bh** [264]	hassium 108 **Hs** [269]	meitnerium 109 **Mt** [268]	darmstadtium 110 **Ds** [271]	roentgenium 111 **Rg** [272]	ununbium 112 **Uub** [285]		ununquadium 114 **Uuq** [289]				

key

element name
atomic number
symbol
atomic mass

lanthanum 57 **La** 138.9055	cerium 58 **Ce** 140.116	praseodymium 59 **Pr** 140.90765	neodymium 60 **Nd** 144.24	promethium 61 **Pm** [145]	samarium 62 **Sm** 150.36	europium 63 **Eu** 151.964	gadolinium 64 **Gd** 157.25	terbium 65 **Tb** 158.9253	dysprosium 66 **Dy** 162.50	holmium 67 **Ho** 164.930	erbium 68 **Er** 167.259	thulium 69 **Tm** 168.934	ytterbium 70 **Yb** 173.04
actinium 89 **Ac** [227]	thorium 90 **Th** 232.038	protactinium 91 **Pa** 231.0359	uranium 92 **U** 238.0289	neptunium 93 **Np** [237]	plutonium 94 **Pu** [244]	americium 95 **Am** [243]	curium 96 **Cm** [247]	berkelium 97 **Bk** [247]	californium 98 **Cf** [251]	einsteinium 99 **Es** [252]	fermium 100 **Fm** [257]	mendelevium 101 **Md** [258]	nobelium 102 **No** [259]

PLEASE TURN OVER

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2020/2021 ACADEMIC YEAR
FINAL YEAR EXAMINATIONS

CHE 2001: AGRICULTURAL AND VETERINARY CHEMISTRY

TIME ALLOWED: THREE (3) HOURS

INSTRUCTIONS:

1. This paper contains **SIX questions** and has seven (7) printed pages. Please ensure that you have all printed pages and the Periodic Table.
2. **Answer any FIVE (5) questions.**
3. All questions carry equal marks, twenty (20 marks) EACH.
4. Write your **Student Identity** number on all Answer booklets.
5. Please be reminded of the need to present your answers in a logical manner and try to be on point

QUESTION ONE

Directions: Answers to question 1(a) & (b) must be in essay form and labelled diagrams may be used to supplement discussions, but in no case will a diagram alone suffice. It is important that you read all two parts BEFORE you begin to write.

The unique properties of water make life possible on Earth. Approximately three-quarters of the Earth's surface are covered by water. Cells are made up of around 70-95% water. Water comprises roughly 70% of the human body.

(a) Describe the major physical and chemical properties of water that make it unique from other liquids.

(10 marks)

(b) Explain the properties of water that enable it to travel up through the roots and stems of plants to reach the leaves. **(10 marks)**

There is an overlap between the two questions. You do not have to repeat information in your answers as long as the answers refer to one essay question.

QUESTION TWO

(a) The pH in a solution of benzoic acid is 2.355. Determine the molar concentration of the benzoic acid. **(5 marks)**

(b) The pH in a 0.25 M solution of the acid HBrO is 4.65 . Using this, calculate the value of K_a for the acid HBrO. **(5 marks)**

(c) Calculate the pH of a 0.22 M solution of the salt $NaNO_2$. Show all of your steps clearly.

(5 marks)

(d) A 0.40 M solution of the lactate ion ($C_3H_5O_3^-$) (a weak base), has a pH of 8.728. Calculate the K_b of the lactate ion ($C_3H_5O_3$ **(5 marks)**

QUESTION THREE

(a) The standard heat of combustion of ethanol, C_2H_5OH, is 1372 kJ/mol ethanol. How much heat (in kJ) would be liberated by completely burning a 20.0 g sample? **(4 Marks)**

(b) How much heat is absorbed in a complete reaction of 3.00 grams of SiO_2 with excess carbon in the reaction shown below? ΔH° for the reaction is + 624.7 kJ. **(4 Marks)**

$$\mathbf{SiO_{2(s)} + 3C_{(s)} \rightarrow SiC_{(s)} + 2\ CO_{(g)}}$$

(c) A 28.5 g piece of metal at 99.8 °C is placed in a calorimeter containing 50.0 g of water at 22.3°C. The calorimeter itself has a heat capacity of 3.40 J/°C, and the temperature rises to 26.1°C. Calculate the specific heat of the metal (J/g °C). **(4 Marks)**

(d) The standard heat of combustion of benzene is −3271 kJ/mol, for CO_2 it is −394 kJ/mol, and for H_2O, it is −286 kJ/mol. Given the equations below, calculate the standard heat of formation of benzene. **(8 Marks)**

$\mathbf{6C_{(s)} + 3\ H_{2\ (g)} \rightarrow C_6H_{6\ (l)}}$	
$C_6H_{6\ (l)} + 15/2\ O_2 \rightarrow 6\ CO_2 + 3\ H_2O$	ΔH = -3271 kJ
$C + O_2 \rightarrow CO_2$	ΔH = -394 kJ
$H_2 + 1/2\ O_2 \rightarrow H_2O$	ΔH = -286 kJ

QUESTION FOUR

a) Given that 2500J of heat is added to a system, and 1800 J of work is done on the system. What is the change in internal energy of the system? **(4 Marks)**

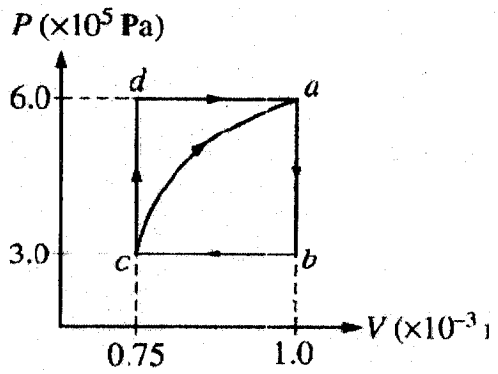
b) At a constant temperature, an ideal gas is compressed from 6.0 litres to 4.0 litres by a constant external pressure of 5.0 atm. How much work is done on the gas? **(4 Marks)**

c) Calculate the amount of work done for the conversion of 1.00 mole of Ni to $Ni(CO)_4$ in the reaction below, at 75°C. Assume that the gases are ideal. The value of R is 8.31 J/ K mol. **(4 Marks)**

$$Ni(s) + 4CO\ (g) \rightarrow Ni(CO)_4(g)$$

d) A cylinder with a movable piston contains 0.1 mole of a monatomic ideal gas. The gas, initially at state *a*, can be taken through either of two cycles, *abca* or *abcda*, as shown on the *PV* diagram below. The following information is known about this system. **(8 Marks)**

$Qc \rightarrow a$ = 685 J along the curved path
$Wc \rightarrow a$ = –120 J along the curved path
$Ua - Ub = 450$ J
$Wa \rightarrow b \rightarrow c = 75$ J

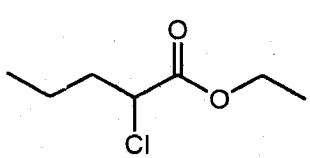


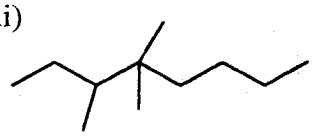
(i) Determine the change in internal energy, $Ua - Uc$, between states *a* and *c*.
(ii) Determine if the heat is added to or removed from the gas when the gas is taken along the path *abc*?
(iii) How much work is done on the gas in the process *cda*?

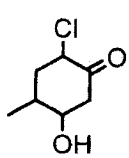
QUESTION FIVE

(a) Draw the structures of the following compounds
(i) 4-hydroxy-2-butanone **(1 mark)**
(ii) 2-methyl-4-oxo-pentanoic acid **(1 mark)**
(iii) 3-ethyl-,1,1-dimethylcyclopentane **(1 mark)**
(iv) 2-chloro-3,5-dimethyl hexane **(1 mark)**

(b) Give **IUPAC** names for the following compounds **(3 marks)**

(i) 

(ii) 

(iii) 

(c) Which of the following compounds show geometrical isomerism? **(3 marks)**

(i) 2-butene
(ii) 2-methyl-2-butene
(iii) 1-butene
(iv) 2,3-dibromo-2-pentene

(d) Consider the following reaction below:

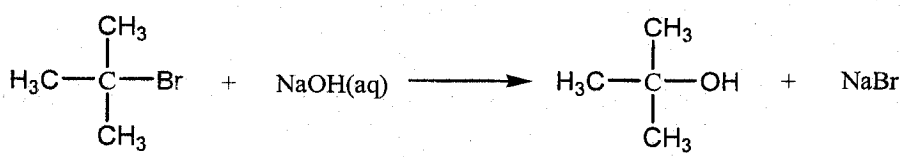
$$CH_3\text{-}Br + NaOH(aq) \rightarrow CH_3\text{-}OH + NaBr$$

(i) Identify the nucleophile, substrate and the leaving group in this reaction. **(3 marks)**

(ii) What is the name of this reaction? **(1 mark)**

(iii) Write the rate equation for this reaction, state whether second order or first order. **(3 marks)**

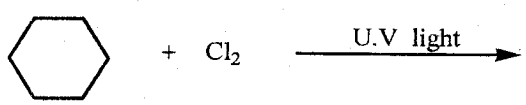
(e) Write the **mechanism** for the reaction of *tert*-butyl bromide with aqueous sodium hydroxide, (NaOH) to form *tert*-butyl alcohol. This is a **SN1** mechanism. **(3 marks)**

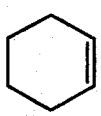


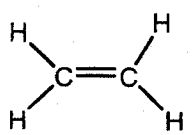
QUESTION SIX

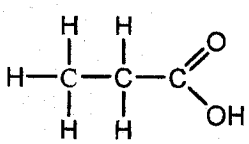
(a) Explain why 2-bromopropane is the major product, instead of 1-bromopropane when propene is reacted with HBr. **(2 marks)**

(b) Write the structure of the products of the following reactions and name the products of each reaction: **(10 marks)**

(i)  + Cl_2 —U.V light→ **Monosubstituted Product** + **?**

(ii)  + Br_2 —CCl_4→ **?**

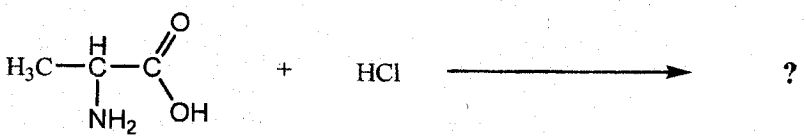
(iii)  —H_2/Ni→ **?**

(iv)  + $H_3C—OH$ —H^+→ **?**

(c) What are α-amino acids? How are they related to proteins? **(3 marks)**

(d) Name the type of bond uniquely found in proteins. **(1 mark)**

(e) When alanine, shown below is treated with HCl, write the structure of the ionic compound obtained. **(2 marks)**



(f) What process is used to convert vegetable oils into margarine and other solid or semi-solid vegetable shortenings? **(2 marks)**

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
hydrogen 1 **H** 1.00794																	helium 2 **He** 4.002602
lithium 3 **Li** 6.941	beryllium 4 **Be** 9.012182											boron 5 **B** 10.811	carbon 6 **C** 12.0107	nitrogen 7 **N** 14.00674	oxygen 8 **O** 15.9994	fluorine 9 **F** 18.9984	neon 10 **Ne** 20.1797
sodium 11 **Na** 22.98977	magnesium 12 **Mg** 24.3050											aluminium 13 **Al** 26.981538	silicon 14 **Si** 28.0855	phosphorus 15 **P** 30.97376	sulphur 16 **S** 32.065	chlorine 17 **Cl** 35.453	argon 18 **Ar** 39.984
potassium 19 **K** 39.0983	calcium 20 **Ca** 40.078	scandium 21 **Sc** 44.95591	titanium 22 **Ti** 47.867	vanadium 23 **V** 50.9415	chromium 24 **Cr** 51.9961	manganese 25 **Mn** 54.93805	iron 26 **Fe** 55.845	cobalt 27 **Co** 58.9332	nickel 28 **Ni** 58.6934	copper 29 **Cu** 63.546	zinc 30 **Zn** 65.409	gallium 31 **Ga** 69.723	germanium 32 **Ge** 72.64	arsenic 33 **As** 74.9216	selenium 34 **Se** 78.96	bromine 35 **Br** 79.904	krypton 36 **Kr** 83.798
rubidium 37 **Rb** 85.4678	strontium 38 **Sr** 87.62	yttrium 39 **Y** 88.90585	zirconium 40 **Zr** 91.225	niobium 41 **Nb** 92.90638	molybdenum 42 **Mo** 95.94	technetium 43 **Tc** [98]	ruthenium 44 **Ru** 101.07	rhodium 45 **Rh** 102.9055	palladium 46 **Pd** 106.42	silver 47 **Ag** 107.8682	cadmium 48 **Cd** 112.411	indium 49 **In** 114.818	tin 50 **Sn** 118.710	antimony 51 **Sb** 121.760	tellurium 52 **Te** 127.60	iodine 53 **I** 126.9045	xenon 54 **Xe** 131.293
caesium 55 **Cs** 132.90545	barium 56 **Ba** 137.327	lutetium 71 **Lu** 174.967	hafnium 72 **Hf** 178.49	tantalum 73 **Ta** 180.9479	tungsten 74 **W** 183.84	rhenium 75 **Re** 186.207	osmium 76 **Os** 190.23	iridium 77 **Ir** 192.217	platinum 78 **Pt** 195.078	gold 79 **Au** 196.96655	mercury 80 **Hg** 200.59	thallium 81 **Tl** 204.3833	lead 82 **Pb** 207.2	bismuth 83 **Bi** 208.980	polonium 84 **Po** [209]	astatine 85 **At** [210]	radon 86 **Rn** [222]
francium 87 **Fr** [223]	radium 88 **Ra** [226]	lawrencium 103 **Lr** [262]	rutherfordium 104 **Rf** [261]	dubnium 105 **Db** [262]	seaborgium 106 **Sg** [266]	bohrium 107 **Bh** [264]	hassium 108 **Hs** [269]	meitnerium 109 **Mt** [268]	darmstadtium 110 **Ds** [271]	roentgenium 111 **Rg** [272]	ununbium 112 **Uub** [285]		ununquadium 114 **Uuq** [289]				

key

element name
atomic number
symbol
atomic mass

lanthanum 57 **La** 138.9055	cerium 58 **Ce** 140.116	praseodymium 59 **Pr** 140.90765	neodymium 60 **Nd** 144.24	promethium 61 **Pm** [145]	samarium 62 **Sm** 150.36	europium 63 **Eu** 151.964	gadolinium 64 **Gd** 157.25	terbium 65 **Tb** 158.9253	dysprosium 66 **Dy** 162.50	holmium 67 **Ho** 164.930	erbium 68 **Er** 167.259	thulium 69 **Tm** 168.934	ytterbium 70 **Yb** 173.04
actinium 89 **Ac** [227]	thorium 90 **Th** 232.038	protactinium 91 **Pa** 231.0359	uranium 92 **U** 238.0289	neptunium 93 **Np** [237]	plutonium 94 **Pu** [244]	americium 95 **Am** [243]	curium 96 **Cm** [247]	berkelium 97 **Bk** [247]	californium 98 **Cf** [251]	einsteinium 99 **Es** [252]	fermium 100 **Fm** [257]	mendelevium 101 **Md** [258]	nobelium 102 **No** [259]

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

Department of Chemistry

2020/21 Academic year Final Examination

CHE2015 Analytical Chemistry and Basic Inorganic Chemistry

Instructions: Answer *both* questions from section A and any *three* questions from section B

Duration: 3 hours

Section A

Question 1.

(a) Complexes $K_2[PtCl_4]$ and $[AuCl_4]^-$ are diamagnetic. Predict their geometries using CFT.

(b) Give two reasons for anomalous behaviour of Boron. Mention two points of differences between Boron and Aluminium.

(c) Using Slaters rules determine Z_{eff} for a valence 3p electron in P, S, Cl and Ar. Are the calculated values of Z_{eff} consistent with the relative sizes of these atoms?

Question 2.

(a) The colour of coordination compounds can be readily explained in terms of

(i) Spectrochemistry (ii) chelate effect (iii) crystal field theory (iv) none of these

(b) The spin only magnetic moment value (in BM units) of $[NiCl_4]^{2-}$ is

(i) zero (ii) 2.84 (iii) 4.90 (iv) 5.92

(c) The bond order in NO is 2.5 while that is NO^+ is 3. Which of the following statements is true for these two species?

(i) Bond length in NO^+ is greater than in NO

(ii) Bond length in NO is greater than in NO^+

(iii) Bond length in NO^+ is greater than in NO

(iv) Bond length is unpredictable

Section B

Question 3.

(a) (i) Differentiate between a homogenous sample and heterogeneous sample.

(ii) How will you collect and analyse a heterogeneous sample?

(iii) Why is it essential to pre- treat a sample?

(b) A 0.156g sample of soil is analyzed for zinc and found to contain 0.203mg Zn. Express the concentration of zinc in parts per million and parts per billion

(c) A batch of cough mixture was weighed to determine if they fell within acceptable standard control guidelines. The individual weights were: 127.2; 128.4; 127.1, 129.0 and 131.1g.

(i) Determine whether the last weight is an outlier datum at 99% confidence level.

(ii) Compute the standard deviation of the mean

(d) A calibration curve for the calorimetric determination of phosphorus in urine is prepared by reacting standard solutions of phosphorus with molybdenum(vi) and reducing the phosphomolybdic acid complex to produce the characteristic blue colour. The measured absorbance A, is plotted against the concentration of phosphorus. From the following data, determine the least squares line and calculate the phosphorus concentration in the urine sample.

ppm, P	A
1.0	0.206
2.0	0.410
3.0	0.615
4.0	0.820
Urine sample	0.625

(e) Lead on leaves by the roadside was measured spectrophotometrically by reaction with dithizone. The standard deviation for a triplicate analysis was 2.3ppm. What is the 90% confidence limit?

(f) Below are two sets of data. Determine the mean, standard deviation, and relative standard deviation and 95% confidence interval of each data set. The B data set contains an outlier data point - should this datum be retained or dropped from the data set?

Set A: 45.6, 44.7, 46.3, 45.5, 46.0, 44.9, 47.1

Set B: 45.2, 47.1, 46.7, 47.1, 50.0, 46.2, 45.8

Question 4.

(a) List three types of errors that can occur during a chemical analysis and describe their effects on the analytical results.

(b) Distinguish between confidence limit, confidence interval and confidence level.

(c) Define a Gaussian error curve. Give four main features of a Gaussian curve. State the %of the area under a normalized Gaussian curve covered the following: $\mu\pm\sigma$, $\mu\pm2\sigma$, , $\mu\pm3\sigma$.

(d) (i) Distinguish between the F Test and the t- Test

(ii) The Manager of a Food Processing Company was trying to decide whether or not to keep a young recently hired food technologist. The Manager decided to see if the new food technologist's work was of the same quality as that of the other staff. She asked both a senior food technologist and the new food technologist to analyze the same food sample using the same procedure, reagents and instruments. They obtained the following results:

Senior Food Technologist (% Ca)	**New Food Technologist** (%Ca)
18.89	20.10
19.20	20.50
19.00	18.65
19.70	19.25
19.40	19.40
	19.99

Determine if there is a significant difference in the precision of the data at 95% confidence level. (7marks)

Question 5.

(a) In the following reactions, identify the species undergoing oxidation and reductions:

$$3Fe_3O_4\,(s) + 8Al(s) \leftrightarrow Fe(s) + 4\,Al_2O_3\,(s).$$

(b) Use Acetic acid as an exmple to highlight an acid or base and its conjugate pair in accordance with bronsted -lowry acid base theory.

(c) Calculate the pH of 0.050 M NH_3, state any assumptions in simplifying the calculation and verify that the error is lesser than 5%.

(d) Balance the following redox reactions.

$$MnO_4^-\,(aq) + H_2SO_3\,(aq) \leftrightarrow Mn^{2+}\,(aq) + SO_4^{2-}\,(aq)\ \text{(acidic solution)}$$

(e) Find the pH at each of the following points in the titration of 25 mL of 0.3 M HF (Ka value is 6.6×10^{-4}) with 0.3 M NaOH

(i) The initial pH
(ii) After adding 10 mL of 0.3 M NaOH
(iii) After adding 25 mL of 0.3 M NaOH
(iv) After adding 26 mL of 0.3 M NaOH

Question 6.

(a) Calculate the pH of a 0.100 M H_3PO_4 solution

(b) How does the von Weimarn Ratio used to produce good precipitate in precipitation

(c) By an aid of the diagram differentiate galvinc cell form the electrolytic cell

(d) What is the pH in a cell in which Mg^{2+} = 1.00 M and pressure of H_2 =1.00 atm, if the E of the cell =2.099 V?

$$Mg(s) + 2H{+}(aq) \leftrightarrow Mg^{2+}(aq) + H_2(g)\ E^o\ \text{cell} = 2.363\ V$$

(e) Consider the following reaction taking place at 25°C

$$Cd_{(s)} + 2Ag^{+}_{(aq)} \leftrightarrow Cd^{2+}_{(aq)} + 2Ag_{(s)}$$

Calculate

(i) The standard -state potential
(ii) The equilibrium constant
(iii) The potential when [Ag^{+}Marks] = 0.020 M and [Cd^{2+}Marks] = 0.050 M

END OF EXAMINATION

Universal Statistical Tables:

1. Rejection Quotient, Q, at Different Confidence Limits.

Number of Observations	Confidence Level Q_{90}	Q_{95}	Q_{99}
3	0.941	0.970	0.004
4	0.765	0.829	0.926
5	0.642	0.710	0.821
6	0.560	0.625	0.740
7	0.507	0.568	0.680
8	0.468	0.526	0.634
9	0.437	0.493	0.598
10	0.412	0.466	0.568
15	0.338	0.384	0.475
20	0.300	0.342	0.425
25	0.277	0.317	0.393
30	0.260	0.298	0.372

2. Values of t for v Degrees of Freedom at Different Confidence Limits.

Number of Degrees of Freedom	Confidence Level 90%	95%	99%	99.5%
1	6.314	12.706	63.657	127.32
2	2.920	4.303	9.925	14.089
3	2.353	3.182	5.841	7.453
4	2.132	2.776	4.604	5.598
5	2.015	2.571	4.032	4.773
6	1.943	2.441	3.707	4.317
7	1.895	2.365	3.500	4.029
8	1.860	2.306	3.355	3.832
9	1.833	2.262	3.250	3.690
10	1.812	2.228	3.169	3.581
15	1.753	2.131	2.947	3.252
20	1.725	2.086	2.845	3.153
25	1.708	2.060	2.787	3.078
Infinite	1.645	1.960	2.576	2.807

3. Values of F at the 95% Confidence Level

v_1 =	2	3	4	5	6	7	8	9	10	15	20	3
v_2 = 2	19.0	19.2	19.2	19.3	19.3	19.4	19.4	19.42.	19.4	19.4	19.4	1
3	9.55	9.28	9.12	9.01	8.94	8.89	8.85	8.81	8.79	8.70	8.66	8
4	6.94	6.59	6.39	6.26	6.16	6.09	6.04	6.00	5.96	5.86	5.80	5
5	5.79	5.41	5.19	5.05	4.95	4.88	4.82	4.77	4.74	4.62	4.56	4
6	5.14	4.76	4.53	4.39	4.28	4.21	4.15	4.10	4.06	3.94	3.87	3
7	4.74	4.35	4.12	3.97	3.87	3.79	3.73	3.68	3.64	3.51	3.44	3
8	4.46	4.07	3.84	3.69	3.58	3.50	3.44	3.39	3.35	3.22	3.15	3
9	4.26	3.86	3.63	3.48	3.37	3.29	3.23	3.18	3.14	3.01	2.94	2
10	4.10	3.71	3.48	3.33	3.22	3.14	3.07	3.02	2.98	2.85	2.77	2
15	3.68	3.29	3.06	2.90	2.79	2.71	2.64	2.59	2.54	2.40	2.33	2
20	3.49	3.10	2.87	2.71	2.60	2.51	2.45	2.39	2.35	2.20	2.12	2
30	3.32	2.92	2.69	2.53	2.42	2.33	2.27	2.21	2.16	2.01	1.93	1

USEFUL DATA

Avogadro's constant, N_A	6.022×10^{23} mol^{-1}
Molar volume of gas at S.T.P	22.4 dm^3 mol^{-1}
Planck Constant, h	6.626×10^{-34} Js
Rydberg constant, R_H	1.097×10^7 m^{-1}
Speed of light in vacuum, c	3.00×10^8 ms^{-1}
Mass of an electron	9.11×10^{-31} kg
1 electron volt (1 eV)	1.602×10^{-19} J

I Joule = 1 J = 1 kg m^2 s^{-2} = 1 Pa m^3
1 Faraday (F) = 96485 C mol^{-1}

Universal Gas constant R

8.3145 J mol^{-1}K^{-1}
8.314 k Pa L K^{-1} mol^{-1}
0.083145 L bar mol^{-1} K^{-1}
0.08206 L atm mol^{-1} K^{-1}
62.364 L torr mol^{-1} K^{-1}
62.364 L mmHg mol^{-1} K^{-1}

Pressure

1 atm = 1.01325×10^5 Pa
= 1.01325×10^5 N m^{-2}
= 760 torr
= 760 mmHg
= 1.01325 bar

1 bar = 1.00000×10^5 Pa
= 1.00000×10^5 N m^{-2}

PERIODIC TABLE

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
hydrogen 1 H 1.00794																	helium 2 He 4.002602
lithium 3 Li 6.941	beryllium 4 Be 9.012182											boron 5 B 10.811	carbon 6 C 12.0107	nitrogen 7 N 14.00674	oxygen 8 O 15.9994	fluorine 9 F 18.9984	neon 10 Ne 20.1797
sodium 11 Na 22.98977	magnesium 12 Mg 24.3050											aluminium 13 Al 26.981538	silicon 14 Si 28.0855	phosphorus 15 P 30.97376	sulphur 16 S 32.065	chlorine 17 Cl 35.453	argon 18 Ar 39.984
potassium 19 K 39.0983	calcium 20 Ca 40.078	scandium 21 Sc 44.95591	titanium 22 Ti 47.867	vanadium 23 V 50.9415	chromium 24 Cr 51.9961	manganese 25 Mn 54.93805	iron 26 Fe 55.845	cobalt 27 Co 58.9332	nickel 28 Ni 58.6934	copper 29 Cu 63.546	zinc 30 Zn 65.409	gallium 31 Ga 69.723	germanium 32 Ge 72.64	arsenic 33 As 74.9216	selenium 34 Se 78.96	bromine 35 Br 79.904	krypton 36 Kr 83.798
rubidium 37 Rb 85.4678	strontium 38 Sr 87.62	yttrium 39 Y 88.90585	zirconium 40 Zr 91.225	niobium 41 Nb 92.90638	molybdenum 42 Mo 95.94	technetium 43 Tc [98]	ruthenium 44 Ru 101.07	rhodium 45 Rh 102.9055	palladium 46 Pd 106.42	silver 47 Ag 107.8682	cadmium 48 Cd 112.411	indium 49 In 114.818	tin 50 Sn 118.710	antimony 51 Sb 121.760	tellurium 52 Te 127.60	iodine 53 I 126.9045	xenon 54 Xe 131.293
caesium 55 Cs 132.90545	barium 56 Ba 137.327	lutetium 71 Lu 174.967	hafnium 72 Hf 178.49	tantalum 73 Ta 180.9479	tungsten 74 W 183.84	rhenium 75 Re 186.207	osmium 76 Os 190.23	iridium 77 Ir 192.217	platinum 78 Pt 195.078	gold 79 Au 196.96655	mercury 80 Hg 200.59	thallium 81 Tl 204.3833	lead 82 Pb 207.2	bismuth 83 Bi 208.980	polonium 84 Po [209]	astatine 85 At [210]	radon 86 Rn [222]
francium 87 Fr [223]	radium 88 Ra [226]	lawrencium 103 Lr [262]	rutherfordium 104 Rf [261]	dubnium 105 Db [262]	seaborgium 106 Sg [266]	bohrium 107 Bh [264]	hassium 108 Hs [269]	meitnerium 109 Mt [268]	damstadium 110 Ds [271]	roentgenium 111 Rg [272]	ununbium 112 Uub [285]		ununquadium 114 Uuq [289]				

key element name / atomic number / symbol / atomic mass

lanthanum 57 La 138.9055	cerium 58 Ce 140.116	praseodymium 59 Pr 140.90765	neodymium 60 Nd 144.24	promethium 61 Pm [145]	samarium 62 Sm 150.36	europium 63 Eu 151.964	gadolinium 64 Gd 157.25	terbium 65 Tb 158.9253	dysprosium 66 Dy 162.50	holmium 67 Ho 164.930	erbium 68 Er 167.259	thulium 69 Tm 168.934	ytterbium 70 Yb 173.04
actinium 89 Ac [227]	thorium 90 Th 232.038	protactinium 91 Pa 231.0359	uranium 92 U 238.0289	neptunium 93 Np [237]	plutonium 94 Pu [244]	americium 95 Am [243]	curium 96 Cm [247]	berkelium 97 Bk [247]	californium 98 Cf [251]	einsteinium 99 Es [252]	fermium 100 Fm [257]	mendelevium 101 Md [258]	nobelium 102 No [259]

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

2019/2020 ACADEMIC YEAR FINAL EXAMINATIONS

CHE 2112: INTRODUCTORY BIOCHEMISTRY

NOVEMBER 2021

INSTRUCTIONS TO CANDIDATES:

Time: three (3) hours

All questions carry **equal marks** (20 marks each)

Answer **any FIVE (5)** questions

Write your computer number on all answer booklets

This examination consists of **SIX (6)** questions and **SIX (6)** printed pages

QUESTION 1

A weak acid may be represented by the term HA.

a) **Write** an equation for its equilibrium constant for the dissociation of such a weak acid. **[2 marks]**

b) **What** does the equilibrium constant indicate. **[3 marks]**

c) (i) **Define** the term buffer. **[2 marks]**

(ii) A buffer whose mixture is 6 mL of 0.1mol/L sodium acetate and 4 mL of 0.1 mol/L acetic acid. (pKa for acetic acid is 4.76). **Calculate** the hydrogen concentration in this buffer. **[4 marks]**

(iii) **Calculate** the pH after adding 1mL of 0.01 mol/L sodium hydroxide to this buffer mixture. **[5 marks]**

(iv) **Is** this buffer an effective buffer. **[4 marks]**

QUESTION 2

a) **Calculate** the pI for histidine given that the pKa values are 1.82, 6.0 and 9.17 for the α-carboxyl, imidazole ring and α-amino groups respectively. **[4 marks]**

b) **State** whether each of the following statement is **True (T)** or **False (F).**

i.) Amino acid configuration is with respect to glyceraldehyde. **[1 mark]**

ii.) Desmosine is not a derived amino acid. **[1 mark]**

iii.) Proline gives a purple colour with ninhydrin. **[1 mark]**

iv.) Glycine is chiral. **[1 mark]**

c) **Explain** the salient features of the secondary structural elements, α-helix and β-pleated sheets. **[6 marks]**

d) **Calculate** the axial length of an α-helix containing 78 amino acyl residues. How long would the polypeptide chain be if it were fully extended? **[6 marks]**

QUESTION 3

*a) **How** many aldohexose isomers are possible excluding anomers?* ***[2 marks]***

b) **State** whether the statement is **True(T) or False(F)**

i.) Carbohydrates are not genetically encoded. **[1 mark]**

ii.) Mannose is an epimer of glucose on carbon atom number 2. **[1 mark]**

iii.) Erythrose is a ketotetrose. **[1 mark]**

iv.) Trehalose is a disaccharide. **[1 mark]**

v.) Cleavage of a vicinal diol consumes 1 mole of HIO 4 . **[1 mark]**

c) A 4 th year student in CHE 4102 isolated a new and unknown disaccharide from one of the weeds growing on the Goma lakes. After exhaustive methylation and acid hydrolysis, the student performed gas chromatography and detected 3,4,6-trimethylglucose and 2,3,4,6-tetramethylglucose only. **What** is the likely structure of the original disaccharide? **[8 marks]**

d) **Give** a brief description of how can you distinguish a furanose from a pyranose ring structure.(Hint: you may use structures to help you explain) **[5 marks]**

QUESTION 4

a) **What** is acute respiratory distress syndrome (ARDS)? **[2 marks]**

i) **What** cause the ARDS? **[2 marks]**

ii) **List** three uses of spingolipids? **[3 marks]**

b) Figure 1 below shows a structure of a lipid molecule

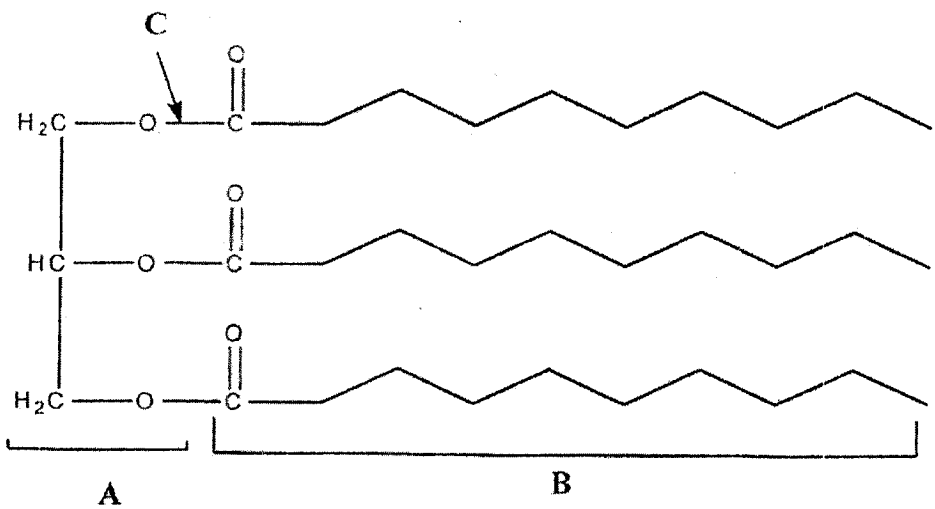


Figure 1: Structure of a lipid molecule

P.T.O.

i) **What** are the features of this type of a lipid? **[3 marks]**

ii) **What** is saponification? **[2 marks]**

iii) **Distinguish** between fats and oils. **[3 marks]**

iv) Comparing this lipid and the corresponding carbohydrate, **which** one yield more energy? **Why?** **[5 marks]**

QUESTION 5

In your answer book, **draw a table 1** and then **match** the reaction on the left with the appropriate enzyme on the right:

Table 1

Reaction	**Enzyme**
Transfer of functional group	Oxidoreductases
Oxidation-reduction reaction	Transferases
Bond formation coupled with ATP hydrolysis	Lyases
Group elimination to form double bond	Isomerases
Hydrolysis reaction	Ligases
Isomerisation	hydrolyases

[6 marks]

i) **Rearrange** the Michaelis-Menten equation to give initial velocity (v) as a function of v/[S] and **draw** the shape of the curve you would obtain with this equation. **[8 marks]**

ii) Look at the following reaction and answer the questions that follow:

D-glyceraldehyde 3-phosphate +NAD^+ + H_3PO_4 ⟶ 1,3-bisphosphoglyceric acid + NADH + H^+

$\Delta G^{0'}$ = +1,500 cal/mol

In vivo (pH 7.0, temperature 37 ^{0}C), the following concentrations are observed:

[D-glyceraldehyde 3-phosphate] = 10^{-4} M

[1,3-bisphosphoglyceric acid] = 10^{-5} M

[Inorganic phosphate] = 0.01M

As the reaction stands ($\Delta G^{0'}$ is +ve), 1,3-bisphosphoglycerate will not form. One way to make the formation of 1,3-bisphosphoglycerate possible is to change the ratio of NAD^+/NADH. **What** must ratio of NAD^+/NADH be in order for the reaction to proceed spontaneously from left to right? **Show** your calculation. (**R = 1.987 cal/K.mol)**

[6 marks]

QUESTION 6

a) **State** the Chargaff's Rules. **[2 Marks]**

b) **What** are salient features of β-DNA structure. **[4 Marks]**

c) **Draw** the chemical structure of any cytidine nucleoside analogue used in treatment of HIV. **[3 Marks]**

d) A sample of double stranded DNA was found to have guanylate as 29% of the nucleotide residues.

(i) **What** is the %AT of this DNA? **[5 Marks]**

(ii) **Draw** a structure showing hydrogen bonds between adenine and thymine. **[6 Marks]**

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

2020/2021 ACADEMIC YEAR FIRST TERM FINAL EXAMINATIONS

CHE2219 CHEMICAL ANALYSIS

TIME: THREE HOURS

INSTRUCTIONS

1 There are **five** questions in this paper.
2 Answer any **four** questions.
3 Questions carry equal marks.

Question 1

(a) (i) Differentiate between a homogenous sample and heterogeneous sample.

(ii) How will you collect and analyse a heterogeneous sample?

(iii) Why is it essential to pre- treat a sample?

(b) A 0.156g sample of soil is analyzed for zinc and found to contain 0.203mg Zn. Express the concentration of zinc in parts per million and parts per billion

(c) A batch of cough mixture was weighed to determine if they fell within acceptable standard control guidelines. The individual weights were: 127.2; 128.4; 127.1, 129.0 and 131.1g.

(i) Determine whether the last weight is an outlier datum at 99% confidence level.

(ii) Compute the standard deviation of the mean

(d) A calibration curve for the calorimetric determination of phosphorus in urine is prepared by reacting standard solutions of phosphorus with molybdenum(vi) and reducing the phosphomolybdic acid complex to produce the characteristic blue colour. The measured absorbance A, is plotted against the concentration of phosphorus. From the following data, determine the least squares line and calculate the phosphorus concentration in the urine sample.

ppm, P	A
1.0	0.206
2.0	0.410
3.0	0.615
4.0	0.820
Urine sample	0.625

(d) Lead on leaves by the roadside was measured spectrophotometrically by reaction with dithizone. The standard deviation for a triplicate analysis was 2.3ppm. What is the 90% confidence limit?

(e) Zinc analysis (%) in a soil sample gave the following results: 33.27, 33.37 and 33.34. calculate the coefficient of variation

Question 2

(a) List three types of errors that can occur during a chemical analysis and describe their effects on the analytical results.

(b) Distinguish between confidence limit, confidence interval and confidence level.

(c) Define a Gaussian error curve. Give four main features of a Gaussian curve. State the %of the area under a normalized Gaussian curve covered the following: $\mu\pm\sigma$, $\mu\pm2\sigma$, , $\mu\pm3\sigma$.

(d) ZEMA limits the amount of lead in drinking water to .015 mg/L. Express this concentration in Molarity, ppm, and ppb.

(e) A second year B.Sc student is on trial, suspected of second degree burglary. Broken pieces of glass were found on his jacket, which he claims were from broken glassware from CHE2219 labortoy sessions. Laboratory glassware is a special borosilicate glass and so determination of the boron content of the glass in the jacket and also from the crime scene was done. Each analysis was replicated 5 times. The results from the analyses are presented in the table below;

Boron concentration (ppm)	
From crime scene	From jacket
14.0	15.4

The population or pooled standard deviation for the test was found to be 0.7ppm. would you be 99% confident that indeed the student committed the said offence?

Question 3

(a) Explain the difference between:

(i) Primary sampling and secondary sampling

(ii) Dry ashing and wet ashing

(iii) Limit of detection and limit of quantification

(iv) Primary standard and secondary standard.

(b) State and explain the errors that would affect the accuracy and precision of experimental results. How would you correct them?

(c) Define an outlier and how can it be identified?

(d) .Below are two sets of data. Determine the mean, standard deviation, and relative standard deviation and 95% confidence interval of each data set. The B data set contains an outlier data point - should this datum be retained or dropped from the data set?
Set A: 45.6, 44.7, 46.3, 45.5, 46.0, 44.9, 47.1

Set B: 45.2, 47.1, 46.7, 47.1, 50.0, 46.2, 45.8

(e) (i) The concentration of chloride in a sample: 0.1015, 0.0991, 0.1016, and 0.1017. What is the mean, the 95% confidence interval, and the relative standard deviation for this data set.

(ii) One value that looks like a ringer. Calculate Q for this one bad value and determine if it can be rejected from the date set

Question 4

(a) Highlight the limitation of anherrius acid base theory and how was it corrrected

(b) In the following reactions, identifyn the species undergoing oxidation and reductions:

$H_2S\ (g) + Cl_2(g) \leftrightarrow 2HCl(g) + S\ (s)$

(c) Calculate the pH of a buffer that is 0.020 M in NH_3 and 0.030 M in NH_4Cl. What is the pH after adding 1.00 mL of 1.0 mL of 0.10 M NaOH to 0.10 L of this buffer. $Ka = 5.6 \times 10^{-1}$

(d) Calculate the volume of concentrated ammonia and the weight of ammonium chloride you would have to take to prepare 100 mL of a buffer at pH 10.00 if the final concentration of salt is to be 0.200 M.

(e) EDTA is a polyprotic acid with four protons (H_4Y); Calculate the hydrogen ion concentration of a 0.0100 M solution of Na_2EDTA (Na_2H_2Y).

Questin 5

(a) An ore is analyzed for the manganese content by converting the manganese to Mn_3O_4 and weighing it. If a 1.52-g sample yields Mn_3O_4 weighing 0.126 g, what would be the percent Mn_2O_3 in the sample? The percent Mn?

(b) Calculate the potential for the following redox reatcion whcen the $[Fe^{3+}] = 0.050$ M, $[Fe^{2+}] = 0.030$ M, $[Sn^{2+}] = 0.015$M and $[Sn^{4+}] = 0.020$ M

$$2Fe^{3+}_{(aq)} + Sn^{2+}_{(aq)} \leftrightarrow Sn^{4+}_{(aq)} + 2Fe^{2+}_{(aq)}$$

0.77 V

0.15 V

$Sn^{4+} \rightarrow Sn^{2+} = 0.15V$

$Fe^{3+} \rightarrow Fe^{2+} + 1e^- = 0$

(c) Balance the following redox reactions

$$ClO^-(aq) + I^- \leftrightarrow IO_3^-(aq) + Cl^-(aq) \text{ (basic soultion)}$$

(d) A solution is 10^{-3} M in $Cr_2O_7^{2-}$ and 10^{-2} M in Cr^{3+}. If the pH is 2.0, what is the potential of the half-reaction at 298K?

1.33

(e) The Cu^{2+} ion concentration in a copper-silver electrochemical cell is 0.1M. If E^o (Ag+/Ag) =0.8V, E^o (Cu^{2+}/Cu) = 0.34V, and Cell potential (at 25°C) = 0.422V, find the silver ion concentration.

END OF EXAMINATION

Universal Statistical Tables:

1. Rejection Quotient, Q, at Different Confidence Limits.

Number of Observations	Confidence Level Q_{90}	Q_{95}	Q_{99}
3	0.941	0.970	0.004
4	0.765	0.829	0.926
5	0.642	0.710	0.821
6	0.560	0.625	0.740
7	0.507	0.568	0.680
8	0.468	0.526	0.634
9	0.437	0.493	0.598
10	0.412	0.466	0.568
15	0.338	0.384	0.475
20	0.300	0.342	0.425
25	0.277	0.317	0.393
30	0.260	0.298	0.372

2. Values of t for v Degrees of Freedom at Different Confidence Limits.

Number of Degrees of Freedom	Confidence Level 90%	95%	99%	99.5%
1	6.314	12.706	63.657	127.32
2	2.920	4.303	9.925	14.089
3	2.353	3.182	5.841	7.453
4	2.132	2.776	4.604	5.598
5	2.015	2.571	4.032	4.773
6	1.943	2.441	3.707	4.317
7	1.895	2.365	3.500	4.029
8	1.860	2.306	3.355	3.832
9	1.833	2.262	3.250	3.690
10	1.812	2.228	3.169	3.581
15	1.753	2.131	2.947	3.252
20	1.725	2.086	2.845	3.153
25	1.708	2.060	2.787	3.078
Infinite	1.645	1.960	2.576	2.807

3. Values of F at the 95% Confidence Level

v_1 =	2	3	4	5	6	7	8	9	10	15	20	30
v_2 = 2	19.0	19.2	19.2	19.3	19.3	19.4	19.4	19.42.	19.4	19.4	19.4	19.5
3	9.55	9.28	9.12	9.01	8.94	8.89	8.85	8.81	8.79	8.70	8.66	8.62
4	6.94	6.59	6.39	6.26	6.16	6.09	6.04	6.00	5.96	5.86	5.80	5.75
5	5.79	5.41	5.19	5.05	4.95	4.88	4.82	4.77	4.74	4.62	4.56	4.50
6	5.14	4.76	4.53	4.39	4.28	4.21	4.15	4.10	4.06	3.94	3.87	3.81
7	4.74	4.35	4.12	3.97	3.87	3.79	3.73	3.68	3.64	3.51	3.44	3.38
8	4.46	4.07	3.84	3.69	3.58	3.50	3.44	3.39	3.35	3.22	3.15	3.08
9	4.26	3.86	3.63	3.48	3.37	3.29	3.23	3.18	3.14	3.01	2.94	2.86
10	4.10	3.71	3.48	3.33	3.22	3.14	3.07	3.02	2.98	2.85	2.77	2.70
15	3.68	3.29	3.06	2.90	2.79	2.71	2.64	2.59	2.54	2.40	2.33	2.25
20	3.49	3.10	2.87	2.71	2.60	2.51	2.45	2.39	2.35	2.20	2.12	2.04
30	3.32	2.92	2.69	2.53	2.42	2.33	2.27	2.21	2.16	2.01	1.93	1.84

PERIODIC TABLE OF ELEMENTS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
hydrogen 1 **H** 1.00794																	helium 2 **He** 4.002602
lithium 3 **Li** 6.941	beryllium 4 **Be** 9.012182											boron 5 **B** 10.811	carbon 6 **C** 12.0107	nitrogen 7 **N** 14.00674	oxygen 8 **O** 15.9994	fluorine 9 **F** 18.9984	neon 10 **Ne** 20.1797
sodium 11 **Na** 22.98977	magnesium 12 **Mg** 24.3050											aluminium 13 **Al** 26.981538	silicon 14 **Si** 28.0855	phosphorus 15 **P** 30.97376	sulphur 16 **S** 32.066	chlorine 17 **Cl** 35.453	argon 18 **Ar** 39.984
potassium 19 **K** 39.0983	calcium 20 **Ca** 40.078	scandium 21 **Sc** 44.95591	titanium 22 **Ti** 47.867	vanadium 23 **V** 50.9415	chromium 24 **Cr** 51.9961	manganese 25 **Mn** 54.93805	iron 26 **Fe** 55.845	cobalt 27 **Co** 58.9332	nickel 28 **Ni** 58.6934	copper 29 **Cu** 63.546	zinc 30 **Zn** 65.409	gallium 31 **Ga** 69.723	germanium 32 **Ge** 72.64	arsenic 33 **As** 74.9216	selenium 34 **Se** 78.96	bromine 35 **Br** 79.904	krypton 36 **Kr** 83.798
rubidium 37 **Rb** 85.4678	strontium 38 **Sr** 87.62	yttrium 39 **Y** 88.90585	zirconium 40 **Zr** 91.225	niobium 41 **Nb** 92.90638	molybdenum 42 **Mo** 95.94	technetium 43 **Tc** [98]	ruthenium 44 **Ru** 101.07	rhodium 45 **Rh** 102.9055	palladium 46 **Pd** 106.42	silver 47 **Ag** 107.8682	cadmium 48 **Cd** 112.411	indium 49 **In** 114.818	tin 50 **Sn** 118.710	antimony 51 **Sb** 121.760	tellurium 52 **Te** 127.60	iodine 53 **I** 126.9045	xenon 54 **Xe** 131.293
caesium 55 **Cs** 132.90545	barium 56 **Ba** 137.327	lutetium 71 **Lu** 174.967	hafnium 72 **Hf** 178.49	tantalum 73 **Ta** 180.9479	tungsten 74 **W** 183.84	rhenium 75 **Re** 186.207	osmium 76 **Os** 190.23	iridium 77 **Ir** 192.217	platinum 78 **Pt** 195.078	gold 79 **Au** 196.96655	mercury 80 **Hg** 200.59	thallium 81 **Tl** 204.3833	lead 82 **Pb** 207.2	bismuth 83 **Bi** 208.980	polonium 84 **Po** [209]	astatine 85 **At** [210]	radon 86 **Rn** [222]
francium 87 **Fr** [223]	radium 88 **Ra** [226]	lawrencium 103 **Lr** [262]	rutherfordium 104 **Rf** [261]	dubnium 105 **Db** [262]	seaborgium 106 **Sg** [266]	bohrium 107 **Bh** [264]	hassium 108 **Hs** [269]	meitnerium 109 **Mt** [268]	darmstadtium 110 **Ds** [271]	roentgenium 111 **Rg** [272]	ununbium 112 **Uub** [285]		ununquadium 114 **Uuq** [289]				

key

element name
atomic number
symbol
atomic mass

lanthanum 57 **La** 138.9055	cerium 58 **Ce** 140.116	praseodymium 59 **Pr** 140.90765	neodymium 60 **Nd** 144.24	promethium 61 **Pm** [145]	samarium 62 **Sm** 150.36	europium 63 **Eu** 151.964	gadolinium 64 **Gd** 157.25	terbium 65 **Tb** 158.9253	dysprosium 66 **Dy** 162.50	holmium 67 **Ho** 164.930	erbium 68 **Er** 167.259	thulium 69 **Tm** 168.934	ytterbium 70 **Yb** 173.04
actinium 89 **Ac** [227]	thorium 90 **Th** 232.038	protactinium 91 **Pa** 231.0359	uranium 92 **U** 238.0289	neptunium 93 **Np** [237]	plutonium 94 **Pu** [244]	americium 95 **Am** [243]	curium 96 **Cm** [247]	berkelium 97 **Bk** [247]	californium 98 **Cf** [251]	einsteinium 99 **Es** [252]	fermium 100 **Fm** [257]	mendelevium 101 **Md** [258]	nobelium 102 **No** [259]

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2020/2021 ACADEMIC YEAR

FINAL EXAMINATIONS

CHE 2522: FUNCTIONAL GROUP AND ARENE CHEMISTRY

TIME ALLOWED: THREE (3) HOURS

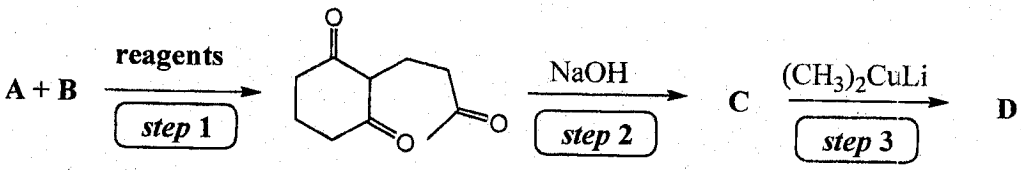
INSTRUCTIONS:

1. This paper contains **five questions** and has eight (8) printed pages. Please ensure that you have all printed pages.
2. **Answer any four (4) questions.**
3. Questions carry equal marks; twenty five (25) marks EACH.
4. Write your TG number (example: TG 9) on the cover page of each Answer booklet.
5. Please be reminded of the need to present your answers in a logical manner and try to be on point.

QUESTION 1

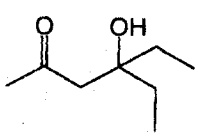
(a) Provide the reagents for ***step* 1** and structures of the reactants **A** and **B**, intermediate **C** and product **D**.

(9 marks)

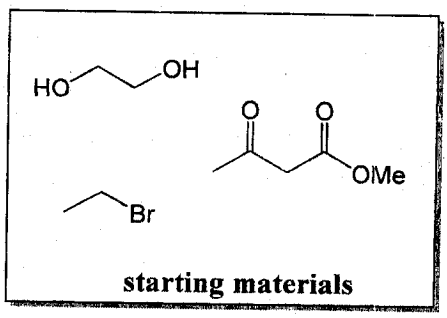


(b) Give a detailed synthetic plan of obtaining product **E** from the given **starting materials** (additional reagents will be necessary). Each step in your synthesis must be clearly shown, ***but no mechanism is required.***

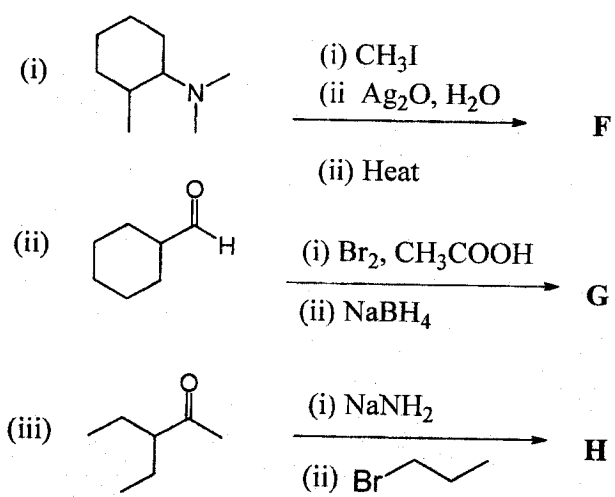
(6 marks)



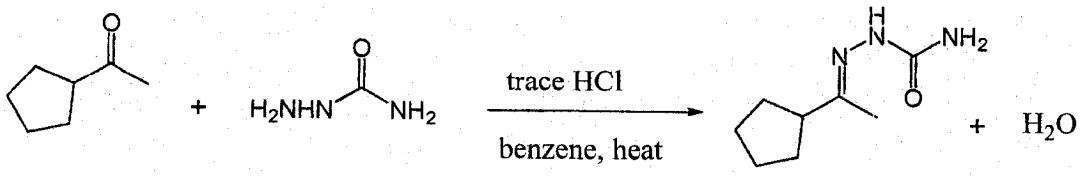
E



(c) Draw the major products of each reaction, ***but no reaction mechanism is required.*** **(6 marks)**

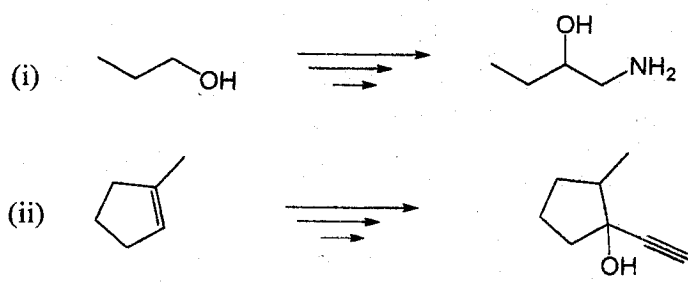


(d) Propose a stepwise detailed mechanism for the reaction below. **(4 marks)**

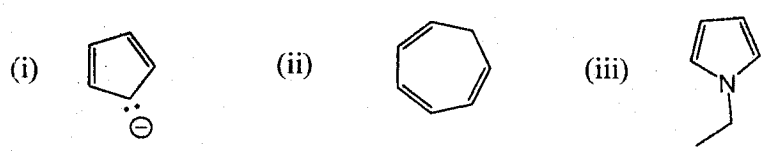


QUESTION 2

(a) Provide a synthetic plan on how the following transformations can be carried out in good yield. More than 1 step is required. Show all steps clearly, including the intermediates, ***but no reaction mechanism is required*** **(10 marks)**

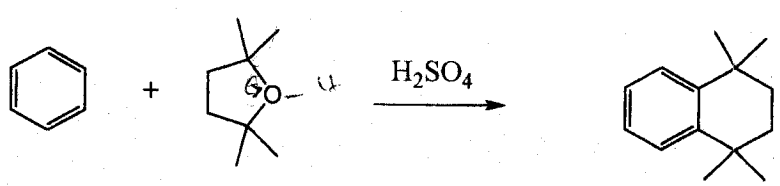


(b) Consider the following molecules and state, with a reason, which ones are aromatic, non-aromatic, or antiaromatic. **(6 marks)**

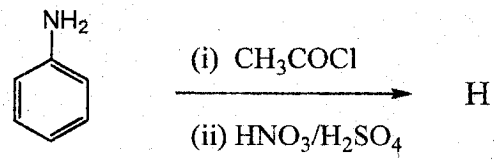


(c) Provide a plausible mechanism to account for the product of the following reaction.

(5 marks)



(d) Consider the following reaction sequence.

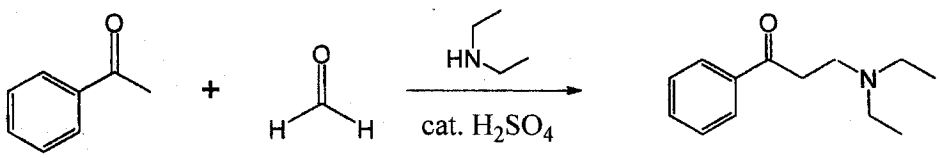


(i) Predict the major product, ***but no reaction mechanism is required.*** **(2 marks)**

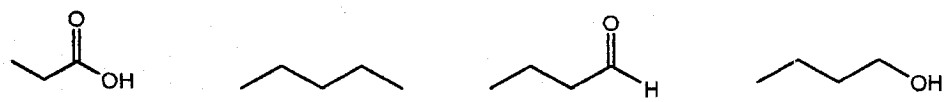
(ii) In not more than two sentences, explain the purpose of step (i) in the above given reaction scheme. **(2 marks)**

QUESTION 3

(a) The process shown below is an example of a "Mannich reaction". Nature uses this reaction to synthesize alkaloids (natural product that contain a basic nitrogen). Suggest a stepwise detailed mechanism. **(7 marks)**

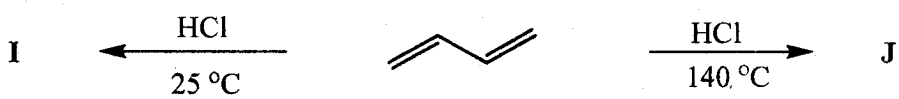


(b) Rank the following compounds in order of increasing boiling point. **(3 marks)**

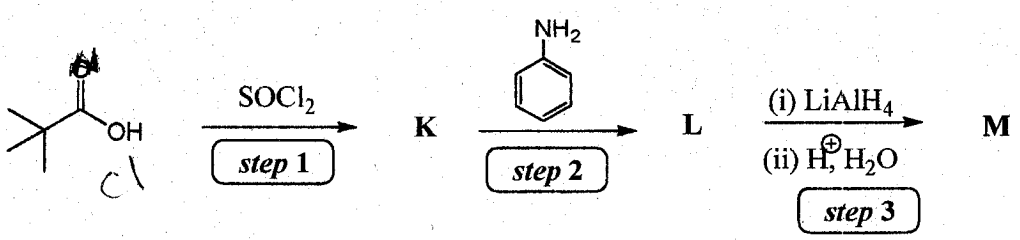


propanoic acid pentane butanal butan-1-ol

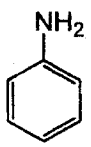
(c) Consider the following reaction between 1,3-butadiene and HCl. The following products are obtained depending on the reaction conditions. Predict the products in the given conditions and give the mechanism for each pathway: **(6 marks)**



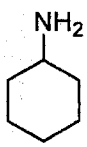
(d) Provide the intermediates **K** and **L**, and product **M**. **(6 marks)**



(e) Using appropriate structural representation, demonstrate why the hydrogens in aniline are more acidic compared to the hydrogens in cyclohexanamine. **(3 marks)**



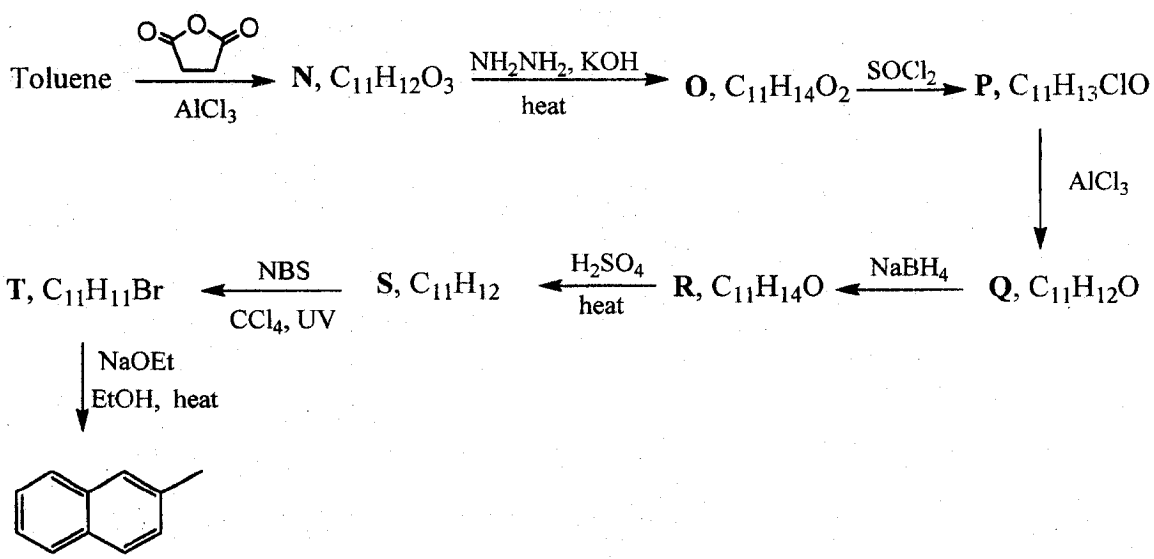
aniline



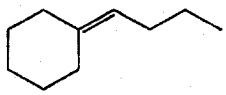
cyclohexanamine

QUESTION 4

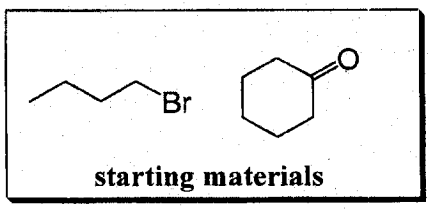
(a) 2-methylnaphthalene can be synthesized from toluene through the following sequence of reactions. Write the structure of each intermediate: **(7 marks)**



(b) Give a detailed synthetic plan of obtaining product **U** "via the Wittig reaction" from the given **starting materials** (additional reagents will be necessary). Each step in your synthesis must be clearly shown, ***but no reaction mechanism is required.*** **(4 marks)**



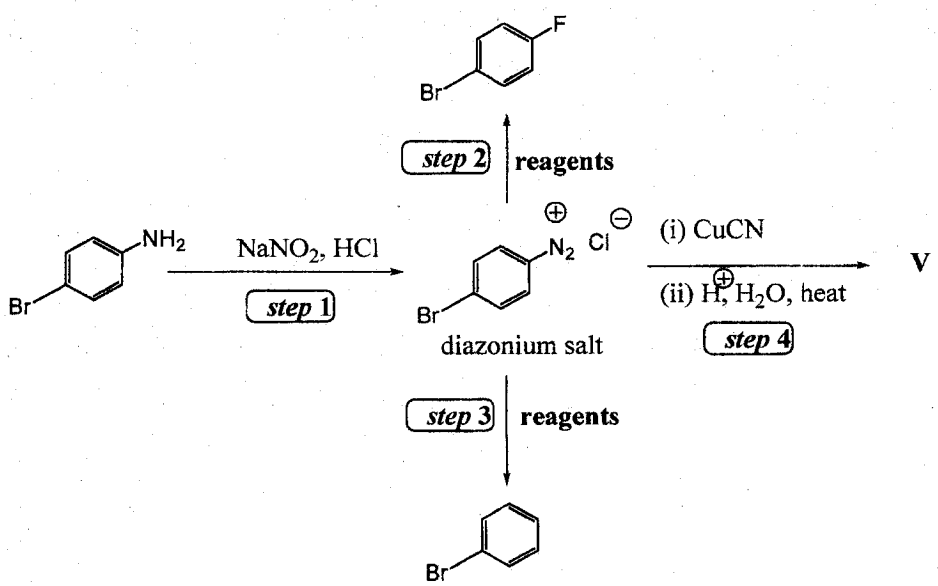
U



starting materials

(c) Quantum mechanical principles are used to combine the atomic *p* orbitals to form π-molecular orbitals in conjugated systems. Draw the shapes of the π-molecular orbitals of 1,3-butadiene and label HOMO and LUMO. **(5 marks)**

(d) Consider the following sequence of reactions.

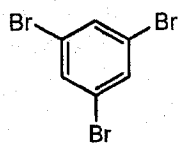


(i) Propose a stepwise detailed mechanism for ***step* 1** leading to the formation of diazonium salt starting with NO^+ as the electrophilic specie. **(5 marks)**

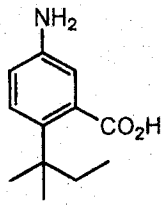
(ii) Provide the **reagents** for ***steps* 2** and **3** and product **V**. **(4 marks)**

QUESTION FIVE

(a) Outline the preparation of the following compounds, **1** and **2** in a reasonable pure state and good yields from benzene by electrophilic aromatic substitution, ***but no reaction mechanism is required.*** **(10 marks)**

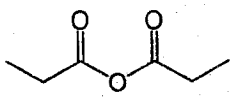


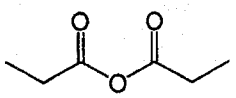
1



2

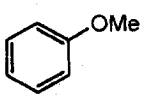
(b) Consider the following reactions.

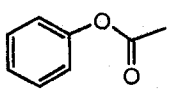
(i)  NaCl ⟶ ?

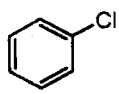
(ii)  EtONa ⟶ ?

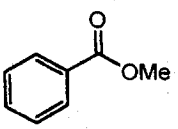
State whether each of the reaction above will **occur** to produce the desired product or **not**. In not more **three** sentences briefly explain your choice. **(3 marks)**

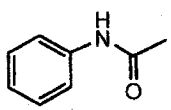
(c) Label the following aromatic rings as activated or deactivated based on the substituent attached to and state whether the group is an ortho-para or meta director. **(6 marks)**

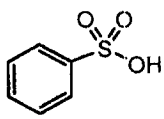
(i) 

(ii) 

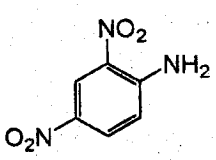
(iii) 

(iv) 

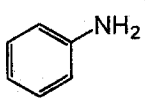
(v) 

(vi) 

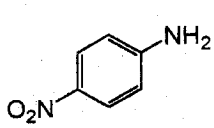
(d) Rank the following compounds in order of increasing basicity. **(4 marks)**



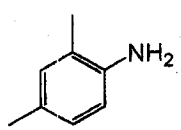
2,4-dinitroaniline



aniline

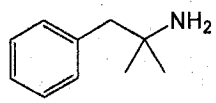


4-nitroaniline



2,4-dimethylaniline

(e) Can the amine shown below be prepared by a Gabriel Method or not? Briefly explain your choice. **(2 marks)**



amine

END OF EXAMINATION!!

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
DEPARTMENT OF CHEMISTRY

Lib Copy

2020/2021 ACADEIMC YEAR
FINAL EXAMINATIONS

COURSE: **CHE2615 (BASIC PHYSICAL CHEMISTRY)**

DATE: **09:00 HOURS THURSDY 25 NOVEMBER 2021**

DURATION: **THREE HOURS**

Instructions:

There are **six (06) questions** in this paper and each question is **20 marks**.

You are required to answer any **five (05) questions.**

You are reminded to answer questions in a clear and logical manner, showing all your calculations for maximum point.

Useful Information and Constants:

$R = 8.314\ J\ mol^{-1}\ K^{-1} = 0.08206\ L\ atm\ Jmol^{-1}\ K^{-1}$,

1 atm = 101.325 J,

1 cal = 4.187 J,

$F = 9685\ C\ mol^{-1}$,

$N = 6.02 \times 10^{23}\ mol^{-1}$,

Molar volume of gas at STP = $22.4\ dm^3mol^{-1}$,

STP = 273 K and 1 atm,

Avogadro's constant = $6.02 \times 10^{23}\ mol^{-1}$

Question 1

(a) Determine the pressure in atm exerted by 1 mole of methane placed into a bulb with a volume of 244.6 cm^3 at 25 °C. Carry out two calculations:

(i) In the first calculation, assume that methane behaves as an ideal gas. **[4 marks]**

(ii) In the second calculation, assume that methane behaves as a real gas and obeys the van der Waals equation. The values of the constants a and b for methane are: $a = 2.303$ L^2 atm mol^{-2} and $b = 0.0431$ L mol^{-1}. **[4 marks]**

(iii) Is the gas in the repulsive or attractive region of the molecule-molecule potential **[2 marks]**

(b) Three moles of an ideal gas expand isothermally from 50 to 300 L at 500 K. If the expansion is carried out reversibly, calculate: ΔU, w, q, and ΔS. **[10 marks]**

Question 2

(a) The molar heat capacity of solid gold is given by the relation

$$C_{p,m} = 25.69 - 7.32 \times 10^{-4} T + 4.58 \times 10^{-6} T^2,$$

in units of J mol^{-1} K^{-1}. Calculate the entropy change for heating 2.50 moles of gold from 22 °C to 1000 °C at constant pressure. **[8 marks]**

(b) Consider that the following enthalpy changes are known for the stated reactions below.

$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$	$\Delta H° = -286$ kJ	.....(1)
$CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(s)$	$\Delta H° = -64$ kJ	.....(2)
$Ca(s) + \frac{1}{2}O_2(g) \rightarrow CaO(s)$	$\Delta H° = -634$ KJ	.....(3)

(i) What is the enthalpy change for the reaction shown known below? **[5 marks]**

$$Ca(s) + O_2(g) + H_2(g) \rightarrow Ca(OH)_2(s)$$

(ii) Draw a fully labeled enthalpy diagram for the reaction depicted in (i) above. **[4 marks]**

(c) Calculate the quantity of heat required to heat a 1 kg block of aluminum from 30 °C to 60 °C. Assume that the specific heat of aluminum is 1 cal g^{-1} $°C^{-1}$. **[3 marks]**

Question 3

(a) Consider the dissociation of an initial amount, n_o = 1 mole, of N_2O_5 to NO_2 according to the reaction:

$$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$

At 55 °C and 1 bar the average molar mass of partially dissociated N_2O_4 is 61.2 g mol^{-1}.

(i) Write an expression for K_P in terms of the extent of the reaction. **[8 marks]**

(ii) Determine the value of the extent of the reaction, ξ. **[3 marks]**

(iii) Hence calculate K_P. **[2 marks]**

(b) The value of $\Delta_r H°$ is –12.93 kJ mol-1 at 800 K for

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

Assuming the $\Delta_r H°$ is independent of temperature, calculate K_P at 700 K given that K_P = 29.1 at 1000 K **[4 marks]**

(c) What is the value of the standard Gibbs energy for reaction in part (b) at 1000 K. **[3 marks]**

Question 4

(a) At l000 °C, cyclobutane (C_4H_8) decomposes in a first order reaction, with a very high rate constant of 87 s^{-1} to two molecules of ethylene (C_2H_4).

(i) If the initial C_4H_8 concentration is 2.00 M, what is the concentration after 0.010 s? **[3 marks]**

(ii) What fraction of C_4H_8 has decomposed in this time? **[2 marks]**

(b) What is the half-life of a radioisotope that has a rate constant of 0.225 d^{-1}? **[5 marks]**

(c) The nitrogen dioxide (NO_2) produced during driving is a health hazard. Chemists attempting to remove it have investigated the effect of heating it to high temperatures. At 300 °C the concentration of NO_2 drops with time as in the table below.

Time (minutes)	$[NO_2]$ (M)
0	2.40
5	2.60×10^{-1}
10	1.28×10^{-1}
20	7.58×10^{-2}
30	5.38×10^{-2}
40	4.17×10^{-2}
50	3.40×10^{-2}
60	$2.87 \quad 10^{-2}$

(i) This reaction is thought to be either 1st order or second order. Plot the appropriate graphs and find the order of reaction. **[7 marks]**

(ii) Calculate the rate constant. **[3 marks]**

Question 5

(a) A saturated solution of Ag_2CO_3 had an electrical resistance of 3529.6 Ω when measured in a conductance cell with a cell constant of 38.54 m^{-1} at 25 °C. The specific conductance of water was 0.00760 Ω^{-1} m^{-1}. The limiting molar conductance, Λ_m°, of Ag_2CO_3 is 0.02624 $\Omega^{-1} m^2 mol^{-1}$, at a temperature of 25 °C.

(i) Calculate the specific conductance of Ag_2CO_3 corrected for the specific conductance of water. **[5 marks]**

(ii) Determine the solubility of Ag_2CO_3. **[5 marks]**

(b) The limiting molar conductance, Λ_m°, of NaI, $NaCH_3CH_2$, $MgCH_3CH_2$, are 12.69 × 10^{-3} S m^2 mol^{-1}, 9.10 × 10^{-3} S m^2 mol^{-1}, and 18.78 × 10^{-3} S m^2 mol^{-1} respectively, all at 25 °C. Use Kohlraush's law of the independence of migration of ions to calculate the limiting molar conductance of MgI. **[5 marks]**

(c) The mobility of the acetate ion.CH_3COO in aqueous solution at 25 °C is 4.24 x10^{-8} m^2 s^{-1} V^{-1}. Calculate the molar ionic conductance of the ions. **[5 marks]**

Question 6

(a) Consider a cell, below at a temperature of 25 °C,

$$Pt(s)|H_2(g,1bar)|HCl)(aq,0.0100\,mol\,L^{-1})\|AgCl(s)|Ag(s)$$

The standard half-cell reduction potentials are:

$$AgCl(s) + e^- \rightleftharpoons Ag(s) + Cl^-(aq) \qquad E^\circ = 0.2224\,V$$

$$H^+(aq) + e^- \rightleftharpoons \frac{1}{2}H_2(g) \qquad E^\circ = 0.0\,V$$

The cell reaction is

$$AgCl(s) + \tfrac{1}{2}H_2(g) \rightleftharpoons Ag(s) + H^+(aq) + Cl^-(aq)$$

(i) Use the Debye-Hückel limiting law to calculate the mean ionic activity coefficient of HCl. **[4 marks]**

(ii) Apply the Nernst equation determine the emf of the cell. **[7 marks]**

(b) An electrochemical cell:

$$Pb(s)\left|PbCl_2(aq).a_1\right\|Hg_2Cl_2(ag), a_2\left|Hg(s)\right.$$

has an emf of 0.5357 V and $\partial E/\partial T = 1.45 \times 10^{-4}$ V K^{-1} at 25 °C.

(i) Calculate ΔG of the cell reaction. **[3 mark]**

(ii) Determine the entropy change, ΔS of cell reaction. **[3 mark]**

(iii) What is ΔH of the cell reaction? **[3 mark]**

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

2020 ACADEMIC YEAR FINAL EXAMINATIONS

CHE 3111: **CELLULAR BIOCHEMISTRY**

TIME: **THREE HOURS**

INSTRUCTIONS:
1. Answer any **FIVE (5)** questions
2. There are **FOUR (4)** printed pages in this examination paper
3. Each question carries **TWENTY (20)** marks

QUESTION 1

a) **Explain** why protein structure determination is essential. **[5 marks]**

b) **List** three common chemical reagents used to analyse N-terminal of a peptide. **[3 marks]**

c) **What** are the pros and cons of methods listed in Question 1 part (b)? **[3 marks]**

d) **A** biochemistry student was given the following peptide AspProMetMetHisArgCysTyrLeuLysThrGlu. In one experiment the student subjected this peptide to chymotrypsin and in another separate experiment the student subjected a different sample of the same peptide to trypsin. The resultant fragments in the second experiment were treated with β-mercaptoethanol and hydrolyzed.

(i) **How** many fragments were produced in the second experiment? **[2 marks]**

(ii) **What** is the difference between chymotrypsin and trypsin with reference to the site where they act? **[2 marks]**

(iii) **Describe** the detailed chemical mechanism of action of β-mercaptoethanol in the reaction mentioned above (Include chemical structures). **[5 marks]**

QUESTION 2

Protein folding and conformations are essential for protein function. The protein conformations are affected by various interactions and these properties of proteins are well illustrated by in haemoglobin molecule.

a) **Describe** specific protein-protein chain interactions that exists in haemoglobin. **[10 marks]**

b) **What** is meant by chloride shift? **[2 marks]**

c) (i) **Draw** oxygen dissociation curves at two different pH say at pH=7.4 and pH=7.6 on the same catesian plane. **[5 marks]**

(ii) **Explain** the curves that you have drawn. **[3 marks]**

QUESTION 3

a) **Write** a brief note on how the active site of chymotrypsin was elucidated giving the catalytic triad amino acid residues. **[5 marks]**

b) In a bisubstrate reaction, a small amount of the first product P is isotopically labelled (P*) and added to the enzyme and the first substrate A. No B or Q is present. **Will** A (= P—X) become isotopically labelled (A*) if the reaction follows a Ping Pong mechanism? **[5 marks]**

c) A reaction, in the presence of a certain amount of enzyme, was found to have a Vmax of 61.7 $nmols^{-1}$ at 25°C. In the presence of the same amount of enzyme at 37°C, the Vmax was 120.8 $nmols^{-1}$. Using sensitive detection techniques it was possible to follow the course of the uncatalysed reaction, which had a rate of 30.2 $x10^{-3}$ $nmols^{-1}$ at 25 °C and 88.4 $x\ 10^{-3}$ $nmols^{-1}$ at 37 °C. **Calculate** the activation energy for the catalysed and unanalysed reactions.

[10 marks]

QUESTION 4

a) During the preparatory stages of glycolysis, glucose is converted to glyceraldehyde-3-phosphate.

i) Using full chemical structures, **outline** the steps for conversion of glucose into glyceraldehyde. Include the names of the enzymes and cofactors. **[10 marks]**

ii) If you start off with $8.0x10^{-9}$ micrograms of glucose, **how many** moles of ATP would be used if all the glucose is converted to glyceraldehyde-3-phosphate? (molar mass of glucose is 180.156 g/mol) **[5 marks]**

b) **Discuss** the biochemical basis and symptoms of lactose intolerance. **How** can it be avoided? **[5 marks]**

QUESTION 5

a) **Discuss** the biological importance of the two important products of the pentose phosphate pathway. **[5 marks]**

b) **Discuss** the following with reference to amino acid metabolism:

i. The difference between non-essential amino acids and essential amino acids. Give two (2) examples for each group.

ii. The difference between glucogenic amino acids and ketogenic amino acids. Give two (2) examples for each group.

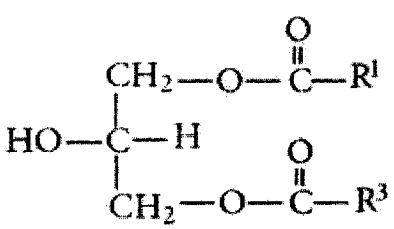
iii. The general reaction catalyzed by aminotransferases and their biological importance.

[15 marks]

QUESTION 6

a) "Fat acids are not just fuel molecules". Briefly **explain** this statement (not longer than half a page). **[4 marks]**

b) Consider the following structure:



Where $R^1 = R^3 = -(CH_2)_2CH_3$

i) **Identify** all the final products of lipase enzyme reaction for this lipid.

[6 marks]

ii) **Calculate** the total number of ATP that can be obtained from the complete oxidation of this lipid to CO_2 and H_2O **(<u>DO NOT WRITE DOWN THE PATHWAY</u>).** Assume you have all the enzymes and cofactors needed in addition to the lipase mentioned in 3 a) above. **[10 marks]**

<u>END OF EXAMINATION</u>

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

2019 ACADEMIC YEAR FINAL YEAR DEFFERED EXAMINATIONS

CHE 3122: ENERGY TRANSDUCTION SYSTEMS

INSTRUCTIONS:

TIME: THREE HOURS

1. Answer any **FOUR (4)** questions
2. All questions carry **EQUAL MARKS** (25 marks each question)
3. There are **FOUR (4)** printed pages in this examination

P.T.O

Question 1

a) Describe with the functions of the proteins found of the cell membrane **15 marks]**

b) Describe is details endocytosis. **[5 marks]**

c) Write short notes on secondary transport. **[5 marks]**

Question 2

a) **What** is meant by the term oxidative phosphorylation? **[3 marks]**

b) **Draw** a neat diagram of the ATP synthase complex labelling all components clearly. **[10 marks]**

c) **Explain** in detail how ATP is formed by the ATP synthase in (b). **[8 marks]**

d) **List any** two substances that would uncouple oxidative phosphorylation.**[2 marks]**

e) **How** many ATP molecules are formed when 3 protons are pumped into the mitochondrial matrix? **[2 marks]**

Question 3

a) **Explain** cyclic photophosphorylation using a neat diagram. **[10 marks]**

b) Assuming a light source has speed of 2.998×10^{8} ms^{-1}, Planks constant of 6.626×10^{-34} J.s and Avogadro's number of 6.022×10^{23} mol^{-1}, $\Delta G^{o'}$ for ATP synthesis is +30.5 kJ mol^{-1}

i) **How** many moles of ATP can be synthesized at 100% efficiency by a photosynthetic organism upon absorption of 1 mol of photons of red light of 700 nm? **[8 marks]**

ii) **How** many molecules of ATP can be produced from 1 photon?**[1 mark]**

iii) **Calculate** the overall efficiency of energy conversion if 1 mole of ATP is formed per 2 equivalents of electrons excited by red light (i.e per 2 mol photons). **[6 marks]**

P.T.O

Question 4

a) **Explain** the first three Calvin cycle reactions with clear chemical structures. **[10 marks]**

b) **True** or **False**

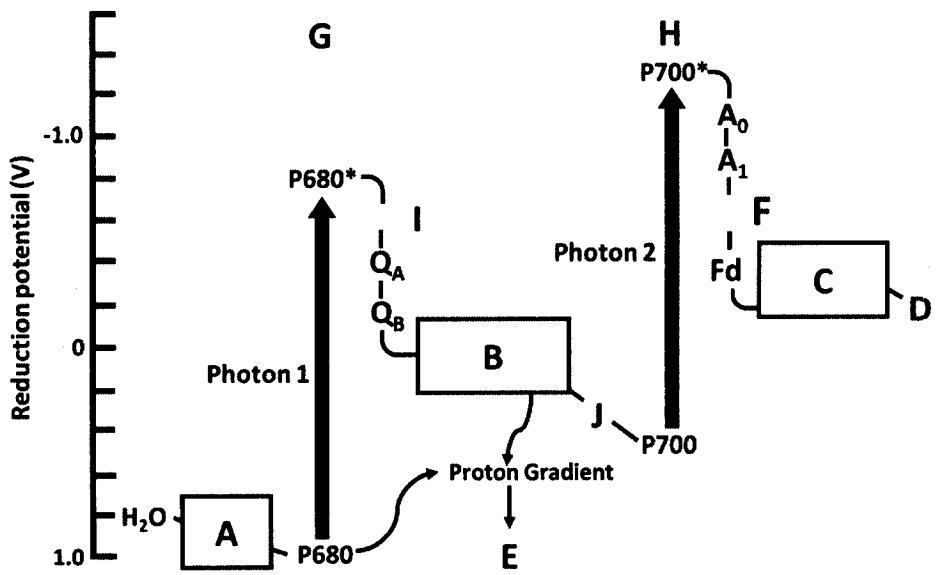
i) Atrazine inhibits PS II by blocking the transfer of electrons to QH_2 **[1 mark]**

ii) Dark reactions occur in the stroma **[1 mark]**

iii) The catalytic efficiency of rubisco low **[1 mark]**

iv) 2-carboxyarabinitol-1-phosphate is a regulator of PSII **[2 marks]**

c) In tabular form, **Identify** the species or process in the diagram labelled A to J **[10 marks]**



P.T.O

Question 5

a) **Explain** in detail the cycle of skeletal muscle contraction using a diagram. **[10 marks]**

b) **Give** an estimated composition of the myosin heavy chains **[10 marks]**

c) **Write** a short note on effect of nerve gas on muscle contraction? **[5 marks]**

END OF FINAL EXAMINATION

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

CHEMISTRY DEPARTMENT

2020/21 ACADEMIC YEAR

FINAL EXAMINATION

CHE3211: SPECTROSCOPIC METHODS OF ANALYSIS

22nd NOVEMBER 2021

TIME: 14:00 -17: 00 HRS

DURATION: 3 HOURS **TOTAL MARKS: 100**

INSTRUCTIONS TO THE CANDIDATES

1. Indicate your **student ID number** on the answer scripts provided.
2. There are a total of **SIX (6)** questions in this paper. **Answer any FOUR**
3. All questions carry **25 marks** each.
4. **The graph paper, periodic and spectroscopic standard tables (NMR, IR, MS, UV-VIS) copies attached to this exam paper.**
5. **YOU ARE REMINDED OF THE NEED TO ORGANISE AND PRESENT YOUR WORK CLEARLY AND LOGICALLY.**

DO NOT TURN THE PAGE UNTIL YOU ARE TOLD TO DO SO.

Question One

(a) Draw full labelled schematic diagrams of the interferometer and highlight it's significance in spectroscopy. **[4 Marks]**

(b) Draw and describe the basic instrumental components in spectroscopic methods. **[4 Marks]**

(c) Describe the effect of Microwave, IR, UV-vis and X-ray radiation on matter. **[4 Marks]**

(d) Differentiate a line and continuum spectrum in spectroscopy and describe how it can be related qualitative and quantitative analysis. **[4 Marks]**

(e) IR spectroscopic analysis is mid infrared region of 2.5 μm - 15 μm. Calculate the.....associated with this region.

i) wavelength number in cm^{-1} **[3 Marks]**

ii) frequency **[2 Marks]**

iii) energy in joule and kJ/mol **[4 Marks]**

Question two

(a) How many absorptions would you expect each of the following compounds to show in its ^{1}H and ^{13}C NMR spectra? **[2 x 3 Marks]**

i) Cyclohexane

ii) $(CH_3)_3COH$

iii) Chloroethane

(a) A calibration curve for the colorimetric determination of phosphorous in urine is prepared by reacting standard solutions of phosphate with molybdenum (VI) and reducing the phosphomolybdic acid complex to produce the characteristic blue color. The measured absorbance A is plotted against the concentration of phosphorous. From the following data plot the curve and, determine **[5 Marks]**

i) the linear least-squares line **[3 Marks]**

ii) correlation coefficient **[2 Marks]**

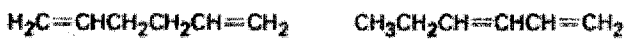
iii) the phosphorous concentration in the urine sample **[4 Marks]**

iv) what is the molar absorptivity if the length of the cuvette is 1 cm **[5 Marks]**

ppm	P A
1.00	0.205
2.00	0.410
3.00	0.615
4.00	0.820
Urine sample	0.625

Question Three

(a) Hexa-1,5-diene and hexa-1,3-diene are isomers. How can you distinguish them by UV spectroscopy? **[3 Marks]**



Hexa-1,5-diene

Hexa-1,3-diene

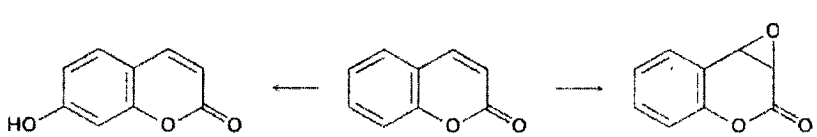
(b) Chloroaniline in a sample is determined as the amine picrates, which absorb strongly at 359 nm *(£* (molar absorptivity) = 1.25×10^4*)*. A 0.0265-g sample is reacted with picric acid and diluted to 1 L. The solution exhibits an absorbance of 0.368 in a 1-cm cell. What is the percentage chloroaniline in the sample? **[4 Marks]**

(c) The active metabolite of the antiviral drug abacavir has a UV molar absorptivity of 13,260 L/(mol · cm). What absorbance would you expect for a sample in a cell with a pathlength of 1.00 cm at a concentration of 42 M? (1 M = 1 x 10^{-6} M) [4 **Marks**]

(d) What is the concentration of a sample of abacavir in mg/mL if the UV absorbance measured in a cell with 1.00 cm pathlength is A 0.93 and the molar absorptivity is 13,260 L/(mol · cm). **[4 Marks]**

(e) The pathway for metabolism of a drug depends on the species doing the metabolizing. Coumarin, an anticoagulant, metabolizes to a toxic compound in rats but not in humans. Using Woodward -Fieser Rules How would the UV spectra differ between the different metabolites?

[10 Marks]



(Human metabolite) Coumarin (Rat metabolite)

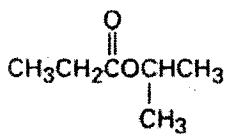
Question Four

(a) How does the energy of infrared radiation with = 1.0×10^{-6} m compare with that of an X ray having = 3.0×10^{-9} m? **[3 Marks]**

(b) Which is higher in energy, radiation with = 4.0×10^{9} Hz or radiation with = 9.0×10^{-6} m? **[3 Marks]**

(c) How many signals would you expect *p*-dimethylbenzene to show in its ^{1}H and ^{13}C NMR spectra? **[2 Marks]**

(d) Predict the splitting patterns for each proton in the following molecules: **[3 x 2 Marks]**

i) 

ii) $ClCH_2CH_2CH_2Cl$

iii) $CH_3OCH_2CH_2Br$

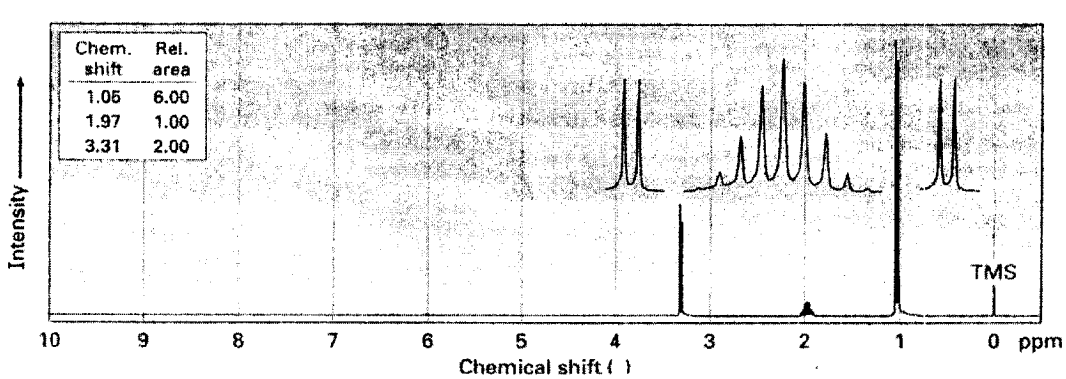
(e) Propose structures for compounds that show the following ^{1}H NMR spectra: **[3 x 2 Marks]**

i) C_2H_6O; one singlet

ii) $C_3H_6O_2$; two singlets

iii) C_3H_7Cl; one doublet and one septet

Propose a structure for a compound with formula C_4H_9Br that has the following ^{1}H NMR spectrum: **[5 Marks]**



Question Five

(a) What are the major sources of interferences in AAS and how can they be corrected?

[4 Marks]

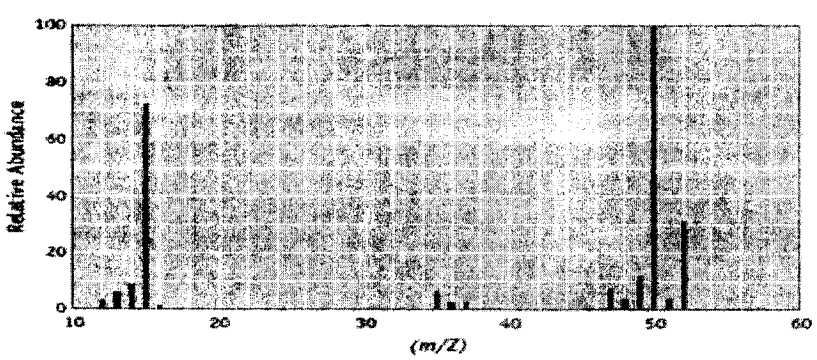
(b) Give two examples of flames (fuel/oxidant) with their associated temperature range.

[4 Marks]

(c) Draw schematic diagrams of the quadruple and time of flight mass analyzers and explain the basic principle of operation principles. **[5 Marks]**

(d) Draw the molecular structure and mass (*m/z*) for the base peak you would anticipate for methylbenzene and methoxybenzene. **[4 Marks]**

(e) The mass spectrum of CH_3Cl is illustrated here. You know that carbon has two stable isotopes, ^{12}C and ^{13}C with relative abundances of 98.9% and 1.1%, respectively, and chlorine has two isotopes, ^{35}Cl and ^{37}Cl with abundances of 75.77% and 24.23%, respectively.



m/z	Relative ion Abundance
14	17.2
15	67
35	17.2
37	3.6
38	9.4
50	100
41	1.1
52	25

i) What molecular species gives rise to the lines at m/z of 50 and 52? Why is the line at 52 about 1/3 the height of the line at 50? **[4 Marks]**

ii) What species might be responsible for the line at m/Z = 51? **[2 Marks]**

iii) Propose an explanation for the low abundance of the peak at *m/z* 35. **[2 Marks]**

Question Six

(a) Predict the how many possible vibration modes ethanol (C_2H_5O) will have in IR spectroscopy. **[4 Mark]**

(b) Describe the mechanism in which gaseous atoms are generated in AAS. **[5 Marks]**

(c) Describe electron impact and chemical spray ionization, and explain which one you would prefer. **[4 Marks]**

(d) Draw a Hollow cathode Lamp and mechanism to produce a discrete line spectrum. **[5 Marks]**

(e) What are the advantages of electrothermal atomization from Flames AAS? **[3 Marks]**

(f) Halogenated compounds are particularly easy to identify by their mass spectra because both chlorine and bromine occur naturally as mixtures of two abundant isotopes. Chlorine occurs as ^{35}Cl (75.8%) and ^{37}Cl (24.2%); bromine occurs as ^{79}Br (50.7%) and ^{81}Br (49.3%). At what masses do the molecular ions occur for the following formulas? What are the relative percentages of each molecular ion?

ii) Bromomethane, CH_3Br **[2 Marks]**

iii) 1-Chlorohexane, $C_6H_{13}Cl$ **[2 Marks]**

SUPPLEMENTARY DATA

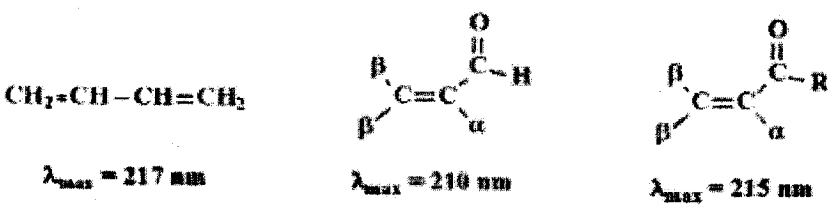
CONSTANT

Planck constant(h) = 6.626×10^{-34} J.s

Speed of light (c) $= 3 \times 10^{-8}$ m/s

TABLES

Woodward–Fieser table



To the base add:

i. 30 for each extra conjugted double bond

ii. 5 each time a conjugated double beond is an exocyclic double bond

iii. 36 for each conjugated double bond frozon *s*-cis

iv. 5 for each alkyl group or halogen bonded to conjugated system of polyene

v. 10 for an α-substitution of a conjugated aldehyde or ketone

vi. 12 for a β-subsitutuent of a conjugated aldehyde or ketone

Mass Spectrometry fragmentation

A partial list of fragments follows:

PEAK at:	REMOVAL of:	FROM:	PEAK at:	FRAGMENT:	FROM:
M - 1	H		15	CH_3^+	
M - 2	H_2		18	H_2O^+	
M - 15	CH_3		26	$C_2H_2^+$	
M - 17	OH		28	CO^+, $C_2H_4^+$	
M - 18	H_2O	ROH, RCHO,	30	$CH_2N^+H_2$	RNH_2 RCOR'
M - 28	C_2H_4	$RCOOC_2H_5$	31	CH_2O^+H	ROH
M - 29	C_2H_5	$RCOC_2H_5$	43	CH_3CO^+	CH_3COX
M - 31	OCH_3	$RCOOCH_3$	43	$C_3H_7^+$	C_3H_7X
M - 32	CH_3OH	$RCOOCH_3$	44	$C_2H_6N^+$	Some amines
M - 42	CH_2CO	$RCOCH_3$	44	$CH_2CH(OH)^+$	Some RCHO
M - 43	C_3H_7	$RCOC_3H_7$	45	$CH_2O^+CH_3$	Some ROR', ROH
M - 43	CH_3CO	$RCOCH_3$	45	CH_3CHO^+H	Some ROR', ROH
M - 44	CO_2	RCOOR'	57	$C_4H_9^+$	C_4H_9X
M - 45	CO_2H	RCOOH	57	$C_2H_5CO^+$	C_2H_5OR, C_2H_5COOR
M - 45	OC_2H_5	$RCOOC_2H_5$	59	$COOCH_3^+$	$RCOOCH_3$
M - 46	C_2H_5OH	$RCOOC_2H_5$	60	$CH_2C(OH)OH^+$	Some RCOOH

^{1}H Chemical shifts

Type of Hydrogen	Chemical Shift (δ)	Type of Hydrogen	Chemical Shift (δ)
$(CH_3)_4Si$	0 (by definition)	$RCOCH_3$	3.7-3.9
RCH_3	0.8-1.0	$RCOCH_2R$	4.1-4.7
RCH_2R	1.2-1.4	RCH_2I	3.1-3.3
R_3CH	1.4-1.7	RCH_2Br	3.4-3.6
$R_2C=CRCHR_2$	1.6-2.6	RCH_2Cl	3.6-3.8
$RC\equiv CH$	2.0-3.0	RCH_2F	4.4-4.5
$ArCH_3$	2.2-2.5	$ArOH$	4.5-4.7
$ArCH_2R$	2.3-2.8	$R_2C=CH_2$	4.6-5.0
ROH	0.5-6.0	$R_2C=CHR$	5.0-5.7
RCH_2OH	3.4-4.0	ArH	6.5-8.5
RCH_2OR	3.3-4.0	$RCHO$	9.5-10.1
R_2NH	0.5-5.0	$RCOH$	10-13
$RCCH_3$	2.1-2.3		
$RCCH_2R$	2.2-2.6		

Chemical Shift - ^{13}C-NMR

Characteristic Carbon-13 Chemical Shift (ppm)					
RCH_3	0 – 40	RCH_2Cl	35 – 80	benzene ring	110 – 160
RCH_2R	15 – 55	R_3COH	40 – 80	C=O ester	160 – 180
R_3CH	20 – 60	R_3COR	40 - 80	C=O amide	165 – 180
RCH_2I	0 – 40	$RC\equiv CR$	65 – 85	C=O carboxylic acid	175 – 185
RCH_2Br	25 - 65	$R_2C=CR_2$	100 - 150	C=O aldehyde, ketone	180 – 210

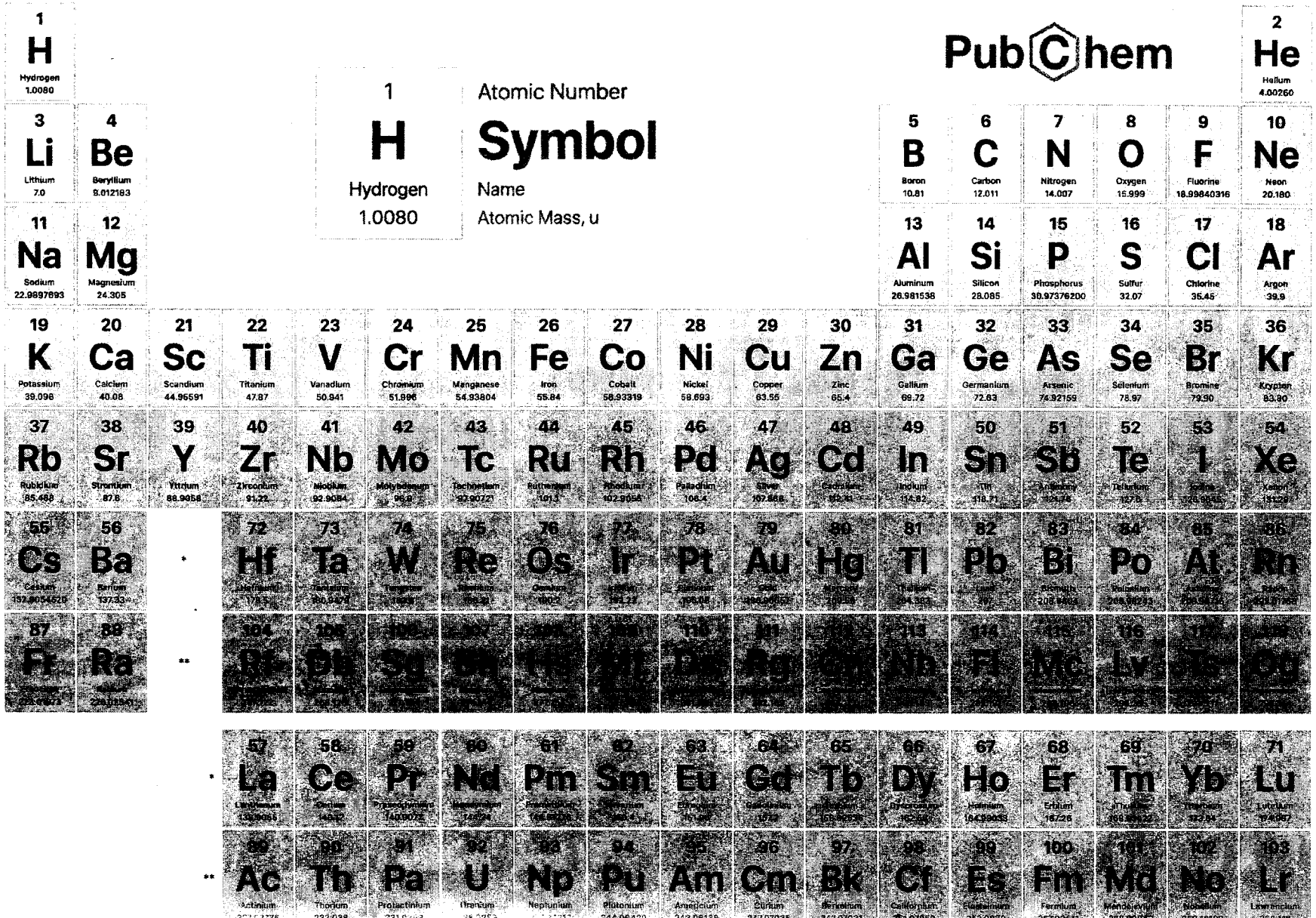
Trends

- $RCH_3 < R_2CH_2 < R_3CH$
- Electronegative atoms cause downfield shift
- Pi bonds cause downfield shift
- C=O 160-210 ppm

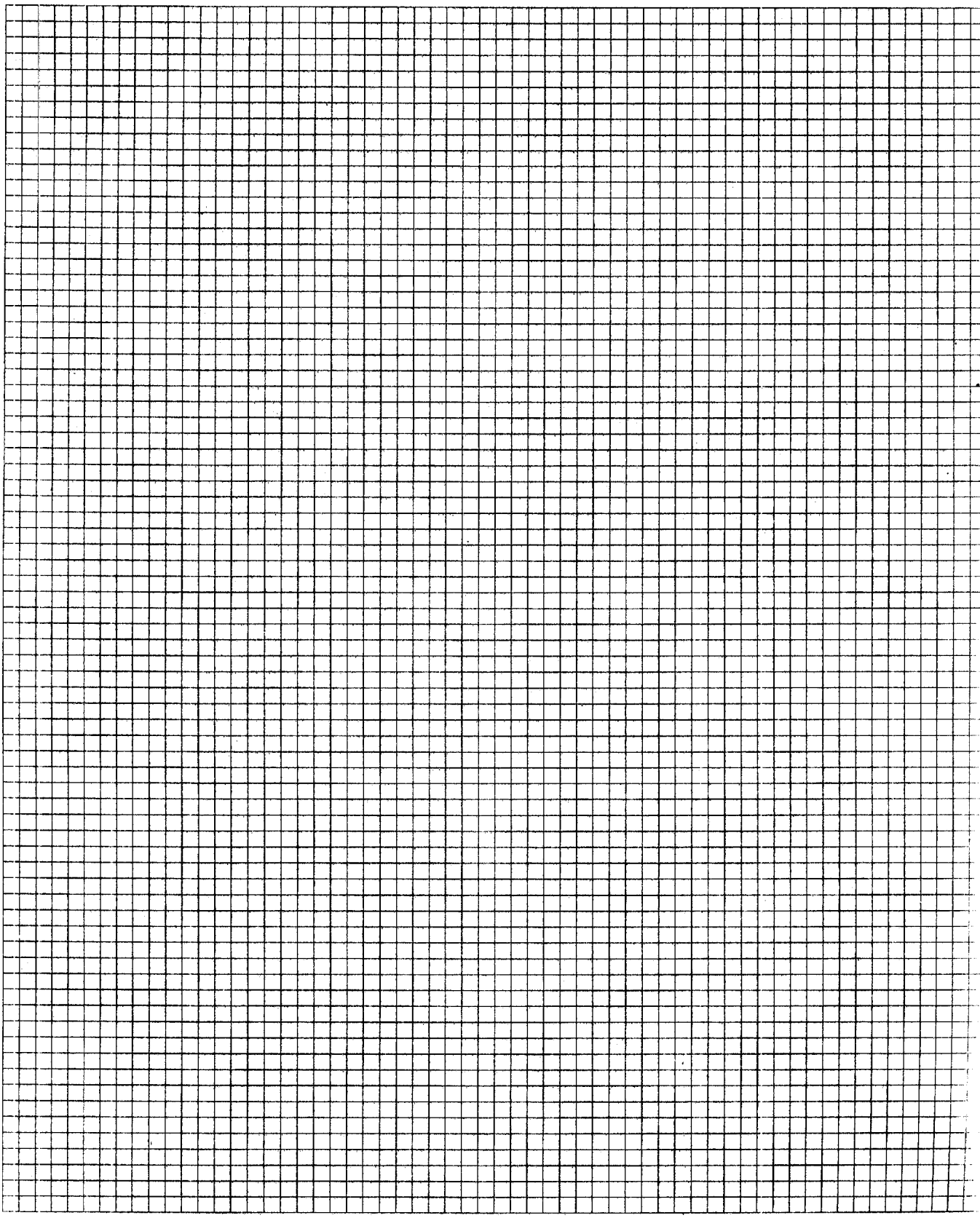
IR Spectrum

IMPORTANT IR ABSORPTIONS (cm^{-1}) IN THE RANGE 1000 cm^{-1}–4000 cm^{-1}		
C — C	(alkane)	1200
C = C	(aromatic)	1600 & 1450–1500 (*strong*)
C = C	(alkene)	1640–1680
C ≡ C	(alkyne)	2180
C — Cl	(organic chloride)	600–830 (*strong*)
C — H	(alkane)	2850–2960 (*med–strong*)
C — H	(alkene)	3000–3100 (*med–strong*)
C — H	(aromatic)	3030–3050 (*med*)
C ≡ N	(nitriles)	2210–2260
C — O	(alcohols)	1050–1150
C = O	(acids, esters, aldehydes)	1680–1750 (*strong*)
C = O	(amide)	1630–1690 (*strong*)
N — H	(amines)	3300–3500
O — H	(acid)	2500–3100 (*broad, strong*)
O — H	(phenol)	3200 (*broad, strong*)
O — H	(alcohol)	3400–3650 (*broad, strong*)

PERIODIC TABLE OF ELEMENTS



1/8" Graph Paper



UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

CHEMISTRY DEPARTMENT

2020 ACADEMIC YEAR FINAL EXAMS

CHE 3222: ANALYTICAL CHEMISTRY

INSTRUCTIONS TO THE CANDIDATES

Time: Three (3) hours.

All questions carry equal marks (20 marks each).

Answer **any four (4)** questions.

Indicate your student ID number on the provided answer scripts.

This examination consists of five (5) questions and five (5) printed pages.

QUESTION ONE

a) A chromatogram has two peaks, A and B. The area measured for peak A is 2 cm^2 and the area measured for peak B is 3 cm^2. Assuming that the detector response is the same for both substances, calculate the mol% of A in the mixture. **(1 mark)**

b) The van Deemter equation relates the column efficiency (measured as H) to the mobile phase flow rate (u), Sketch a typical van Deemter plot that shows how H depends on u. Clearly label the axes. **(2 marks)**

c) There are three terms in the van Deemter equation: the A term, the B term, and the C term, each describing a different type of contribution to the band broadening. Explain the type of band broadening described by 2 of the 3 terms. **(2 marks)**

d) Define (a) elution (b) mobile phase (c) stationary phase (d) distribution constant (e) retention time (f) selectivity factor (g) plate height (h) eddy diffusion (I) eluent (j) size exclusion chromatography. **(10 marks)**

e) What is the difference between liquid-liquid and liquid-solid chromatography? **(1 mark)**

f) A chromatogram of a mixture of A, B, C, and D resulted in the following data:

I. The length of the column is 10 m.

	Retention time	Width of peak base
Nonretained	3.1	-
A	5.4	0.41
B	13.3	1.07
C	14.1	1.16
D	21.6	1.72

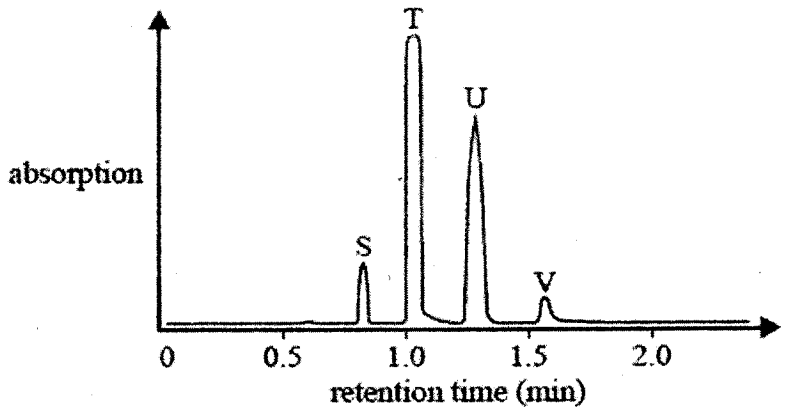
Calculate:

i. the number of plates from each peak. **(2 marks)**

ii. the plate height for the column. **(2 marks)**

QUESTION TWO

Four straight chain alkanols, S, T, U, V, with a general formula ROH, were analysed using a gas chromatograph combined with a mass spectrometer. The following chromatogram was produced.



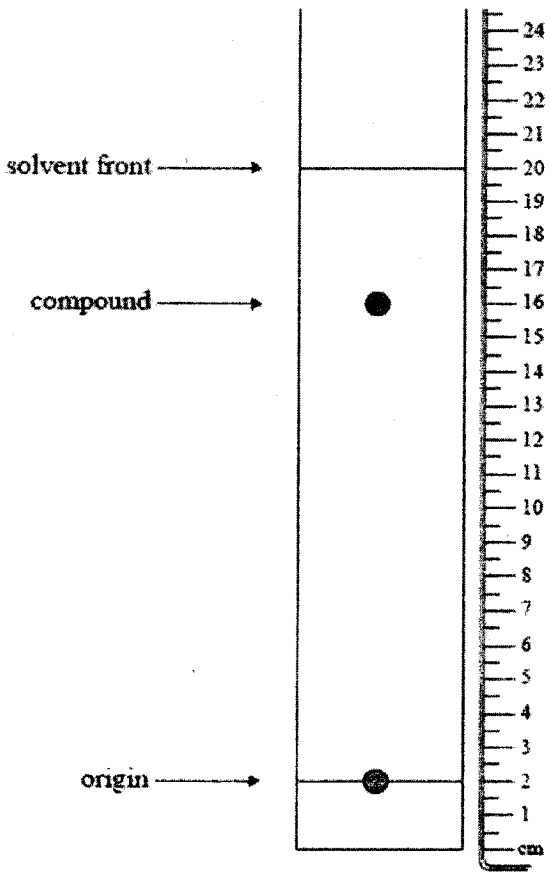
a) What is the order of the alkanols from the highest molar mass to the lowest molar mass? **(5 marks)**

b) Mixtures of coloured substances can be separated by paper chromatography.

i. Give a reason why the start line is drawn in pencil rather than in ink. **(4 marks)**

ii. A student investigates mixtures of food colourings using paper chromatography. One of the substances in a food colouring does not move during the experiment. Explain one change that could be made to the experiment to obtain an R_f value for this substance. **(2 marks)**

c) A thin layer chromatography (TLC) plate was set up with a non-polar solvent, hexane, and a polar stationary phase, silica gel. The chromatogram below was obtained. A ruler as then placed next to the plate.



The Rf value for the compound would be: **(5 marks)**

d) This diagram from the Chemguide page shows the results of a simple thin layer chromatography experiment: Describe briefly, but precisely, what you would have done in order to get to this stage. You can assume that you have been given a suitable thin layer chromatography plate. **(4 marks)**

QUESTION THREE

a) From potentials listed in the Table, determine the reaction between the following half-reactions, and calculate the corresponding cell voltage: **(6 marks)**

Fe3+ + e- = Fe2+ Eo = 0.771V
I3- + 2e- =3I- Eo = 0.5355V

b) A solution of 10^{-3} M in $Cr_2O_7^{2-}$ and 10^{-2} M in Cr^{3+}. If the pH is 2.0 what is the potential of the half-reaction: **(6 marks)**

$Cr_2O_7 + 14H^+ + 6e = 2Cr^{3+} + 7H_2O$

c) What do you understand by potentiometric titration? **(4 marks)**

d) What are the two disadvantages of potential metric titration? **(4 marks)**

QUESTION FOUR

a) What is thin layer chromatography? **(5 marks)**

b) How can thin layer chromatography be used? **(5 marks)**

c) Discuss four (4) advantages of thin layer chromatography. **(4 marks)**

d) Discuss what liquid, gas, paper and thin-layer chromatography each separate. **(6 marks)**

QUESTION FIVE

a) What are potentiometric titrations? **(4 marks)**

b) Draw a typical potentiometric titration curve (potential difference against volume). **(3 marks)**

c) What is amperometric titration? **(4 marks)**

d) Draw three typical amperometric titration curves (1. Analyte is reduced 2. Reagent is reduced, analyte is not 3. Both reagent and analyte are reduced). **(9 marks)**

1,b(copy)

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

Department of Chemistry

2020/21 Academic year Final Examination

CHE3411 Main group elements and Transition metal chemistry

Instructions: Answer any *four* questions

All questions carry equal marks **Duration: 3 hours**

Question 1

a) Nitric acid HNO_3 is an important industrial chemical. State the two major industrial uses of nitric acid.

b) Describe briefly the key major steps for the production of sulphuric acid by the contact process (Include the key chemical equations involved)

c) Some elements in the periodic table exist as allotropes.
   (i) Define what an allotrope is.
   (ii) Draw Lewis structures for each of the allotropes of oxygen
   (iii) Mention any two allotropes of Phosphorus
   (iv) Graphite and diamond are allotropes of Carbon. Explain the difference in properties of diamond and graphite on the basis of their structures as diamond been use as on abrasives and graphite been used in lubricants

Question 2

a) Explain briefly the following statements
   i) How is excessive content of CO_2 responsible for global warming.
   ii) Why nitrogen exists as diatomic molecule and phosphorus as P_4
   iii) Why has it been difficult to study the chemistry of radon

a) Oxygen is the most abundant of all the elements on earth. However, it can also be prepared in the laboratory and on major scale production in industries.
   (i) State one laboratory preparation of oxygen gas with the chemical equation involved
   (ii) How is oxygen gas is obtained Industrially?

b) Nitric acid (HNO_3) is a strong acid. Nitrous acid (HNO_2) is a weak acid.
   (i) Draw a Lewis diagram for each of these acids
   (ii) With calculation shown, how does the oxidation state of the central atom of an oxoacid relate to its strength (compared to other oxoacids with the same central atom)?

Question 3

(a) Write the formula of tetramine dithiocyanato chromium (III) complex. What is the net charge on the complex?

(b) Name the complex ion and indicate the oxidation state of metal: $[Ag(S_2O_3)_2]^{3-}$

(c) Glycine is an aminoacid, NH_2-CH_2-COOH. Sketch the cis and trans isomers of $[Pt(Gly)_2]$

Question 4

(a) A compound with Mr. 112 is transparent in the UV spectra. In the IR spectra it shows two bands 2941 cm^{-1} and 1464 cm^{-1} corresponding to C-H and C-C stretching vibrations. In the NMR it forms a singlet at 8.48 τ. Interpret the given data and propose a structure for the compound.

(b) The complex $[Cr(C_2O_4)_3]^{3-}$ is of the type $M(AA)_3$, where, AA is a bidentate ligand. Draw the possible isomers of the complex. What kind of isomerism do they exhibit?

(c) State and explain the type of isomerism exhibited by the given pair of complexes.
$[Cr(H_2O)_5Cl]Cl_2.H_2O$ & $[Cr(H_2O)_4Cl_2]Cl.2H_2O$

Question 5

(a) (i) Given the complexes $[Ni(H_2O)_6]^{2+}$, $[Mn(H_2O)_6]^{2+}$, $[Cr(H_2O)_6]^{3+}$, $[Ti(H_2O)_6]^{3+}$, which one/s will not show ideal O_h geometry and explain why?
(ii) In the crystal structure of $[CuF_6]^{4-}$, the Cu^{2+} ion is six coordinate with four F^- ions at a distance of 1.93 Å and two F^- ions at a distance of 2.27 Å. Explain.

(b) The pairing energy (P) is 28000cm^{-1} for Mn^{+3} and 30,000cm^{-1} for Fe^{+2} ion. Δ_o value for $[Mn(H_2O)_6]^{+3}$ is 21, 000 cm^{-1} and for $[Fe(CN)_6]^{3-}$ is 36000cm^{-1}. Predict and explain the correct d-electron configuration in the d-orbitals of the complexes $[Mn(H_2O)_6]^{+3}$ and $[Fe(CN)_6]^{3-}$ respectively.

(c) Predict and explain the transitions responsible for the light pink colour of $Co(H_2O)_6]^{2+}$ and the deep blue colour of $[CoCl_4]^{2-}$complexes respectively.

Question 6

(a) Show using valence bond theory whether the Ni^{2+} ion can have two unpaired electrons in Octahedral geometry only or Square-planar geometry only or Tetrahedral geometry only or both octahedral and tetrahedral geometries.

(b) Mn^{2+} forms a complex with Br^- ion. The magnetic moment of complex is 5.92 BM. Predict the probable formula and geometry of the complex.

(c) (i) Label the molecular orbital diagram below fully to show how metal–ligand σ-bond molecular orbitals form in an octahedral complex according to the ligand field theory.
(ii) Populate the diagram drawn in (i) above for the octahedral complex $V(NH_3)_6^{+3}$.
(iii) Indicate the crystal field splitting energy, Δ_o, on the diagram.

PERIODIC TABLE OF THE ELEMENTS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1 **H** 1.01 Hydrogen																1 **H** 1.01 Hydrogen
3 **Li** 6.94 Lithium	4 **Be** 9.01 Beryllium											5 **B** 10.81 Boron	6 **C** 12.01 Carbon	7 **N** 14.01 Nitrogen	8 **O** 16.00 Oxygen	9 **F** 19.00 Fluorine
11 **Na** 23.00 Sodium	12 **Mg** 24.31 magnesium											13 **Al** 26.98 Aluminium	14 **Si** 28.09 Silicon	15 **P** 30.99 Phosphorus	16 **S** 32.07 Sulphur	17 **Cl** 35.45 Chlorine
19 **K** 39.10 Potassium	20 **Ca** 40.08 Calcium	21 **Sc** 44.96 Scandium	22 **Ti** 47.88 Titanium	23 **V** 50.94 Vanadium	24 **Cr** 52.00 Chromium	25 **Mn** 54.94 Manganese	26 **Fe** 55.85 Iron	27 **Co** 58.93 Cobalt	28 **Ni** 58.69 Nickel	29 **Cu** 63.55 Copper	30 **Zn** 65.39 Zinc	31 **Ga** 69.72 Gallium	32 **Ge** 71.61 Germanium	33 **As** 74.92 Arsenic	34 **Se** 78.96 Selenium	35 **Br** 79.90 Bromine
37 **Rb** 85.47 Rubidium	38 **Sr** 87.62 Strontium	39 **Y** 88.91 Yttrium	40 **Zr** 91.22 Zirconium	41 **Nb** 92.91 Niobium	42 **Mo** 95.94 Molybdenum	43 **Tc** 97.91 Technetium	44 **Ru** 101.07 Ruthenium	45 **Rh** 102.91 Rhodium	46 **Pd** 106.42 Palladium	47 **Ag** 107.87 Silver	48 **Cd** 112.41 Cadmium	49 **In** 114.82 Indium	50 **Sn** 118.71 Tin	51 **Sb** 121.76 Antimony	52 **Te** 127.60 Tellurium	53 **I** 126.90 Iodine
55 **Cs** 132.91 Caesium	56 **Ba** 137.33 Barium	57 – 71	72 **Hf** 178.49 Hafnium	73 **Ta** 180.95 Tantalum	74 **W** 183.84 Tungsten	75 **Re** 186.21 Rhenium	76 **Os** 190.23 Osmium	77 **Ir** 192.22 Iridium	78 **Pt** 195.08 Platinum	79 **An** 196.97 Gold	80 **Hg** 200.59 Mercury	81 **Tl** 204.38 Thallium	82 **Pb** 207.2 Lead	83 **Bi** 208.98 Bismuth	84 **Po** 208.98 Polonium	85 **At** 209.99 Astatine
87 **Fr** (223.02) Francium	88 **Ra** 226.03 Radium	89 - 103	104 **Unq** 261.11	105 **Unp** 262.11	106 **Unh** 263.12	107 **Uns** 262.12	108 **Uno** 265.00	109 **Une** 265								

KEY

Atomic number
X
Atomic mass
Name of the element X

57 **La** 138.91 Lanthanum	58 **Ce** 140.12 Cerium	59 **Pr** 140.91 Praseodymium	60 **Nd** 144.24 Neodymium	61 **Pm** 144.91 Promethium	62 **Sm** 150.36 Samarium	63 **Eu** 151.97 Europium	64 **Gd** 157.25 Gadolinium	65 **Tb** 158.93 Terbium	66 **Dy** 162.50 Dysprosium	67 **Ho** 164.93 Holmium	68 **Er** 167.26 Erbium	69 **Tm** 168.93 Thulium	70 **Yb** 173.04 Ytterbium	71 **Lu** 174.97 Lutetium
89 **Ac** 227.03 Actinium	90 **Th** 232.04 Thorium	91 **Pa** 231.04 Protactinium	92 **U** 238.03 Uranium	93 **Np** 237.05 Neptunium	94 **Pu** 244.0 Plutonium	95 **Am** 243.06 Americium	96 **Cm** 247.07 Curium	97 **Bk** 247.07 Berkelium	98 **Cf** 251.08 Californium	99 **Es** 252.08 Einsteinium	100 **Fm** 257.10 Fermium	101 **Md** 260 Mendelevium	102 **No** 259.10 Nobelium	103 **Lr** 262.11 Lawrencium

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

Department of Chemistry

2020/21 Academic year Final Examination

CHE3422 Organometallics and Inorganic Reaction Mechanisms

Instructions: Answer any *two* questions from section A and any *two* from section B

All questions carry equal marks **Duration: 3 hours**

SECTION A

Question 1

(a) Given the series of complexes $[CpMn(CO)_2L]$, with L=CO $[CpMn(CO)_2(CO)]$, L=PPh_3 $[CpMn(CO)_2(PPh_3)]$, L=C_2H_4 $[CpMn(CO)_2(C_2H_4)]$, arrange these complexes in order of decreasing electron density on Mn. What is the most easily oxidizable complex?

(b) Order the following phosphines from the strongest to weakest σ-donor phosphine and justify your answer: $P(OEt)_3$ PPh_3 PCl_3 $P(OMe)_3$

(c) Electron count the following metal complexes using either the ionic or covalent methods, showing clearly the oxidation state of the metal centre and ligand charges if present.
(i) $[Co(CH_3)_3Cl_3]^{3-}$
(ii) $Cp_2Ta(CCH_3)$

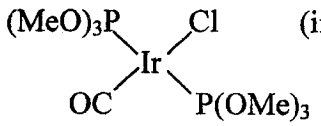
(d) Which of the following complexes will have the highest CO infrared stretching frequency? Briefly explain your reasoning. $Cr(CO)_3(PMe_3)_3$ or $MnCl(CO)_5$

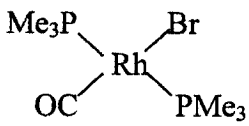
(e) For the reaction, Trans-$[IrCl(CO)(PPh_3)_2]$ + Cl_2 → Trans-$[IrCl_3(CO)(PPh_3)]$ the stretching frequency ν_{co}(Product) > ν_{co}(reactant). Explain why this is so.

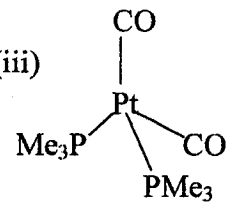
Question 2

(a) Ligand substitution can occur either by an *associative* or *dissociative* mechanism. What will determine the exact pathway the substitution takes in a metal complex?

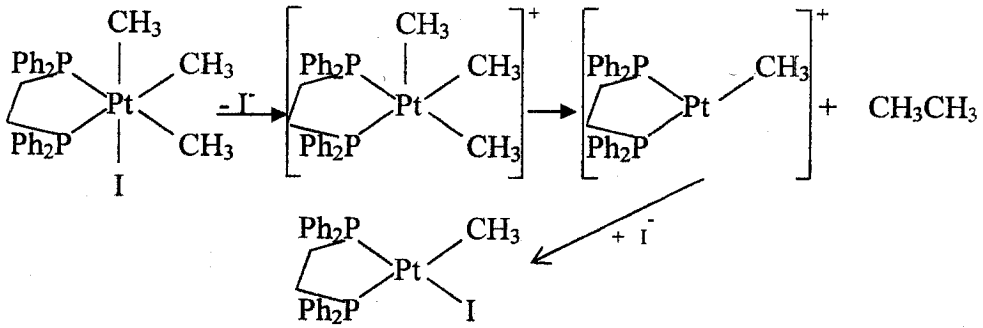
(b) Applying the conditions that favour oxidation addition to take place, to which of the following complexes will H_2 undergo oxidative addition most readily and why?

(i) 

(ii) 

(iii) 

(c) Given the reaction below:



(i) Explain step by step what is happening in this reaction.

(ii) Why doesn't CH_3I fall off instead of CH_3CH_3?

Question 3

(a) Given a reaction equation as follows: $M + 2L \rightleftharpoons ML_2$:

(i) Write expressions for the stepwise formation constants for the above equation.

(ii) Write an expression for the cumulative formation constant for this equation.

(iii) Successive stability constants for the formation of an octahedral complex show the following trend: $K_1 > K_2 > ... > K_n$. Explain why.

(b) Define the meanings of the terms stable/unstable and labile/inert in reference to the thermodynamics of complex formation. Illustrate your answer with an example.

(c) State and interpret the relationship among free energy, cumulative stability constant, enthalpy and entropy changes of a reaction.

(d) Given the trans-directing series in order of increasing ability: $H_2O < OH^- < py \approx NH_3 < Cl^- < Br^- < I^- < NO_2^- < C_6H_5^- < CH_3^- < H^-$, $PR_3 \approx SH_2 << CO \approx C_2H_4 \approx CN^-$, complete the following reaction and explain the quantities of product/s formed.

$PtCl_3NO_2 + NH_3 \rightarrow$

(e) The reactions of $[Ni(CO)_4]$ with the ligand (L = $P(Me)_3$ or $P(OMe)_3$, L yields $[Ni(CO)_3L]$. Show that this reaction occurs by a dissociative mechanism.

SECTION B

QUESTION 4

(a) Most of lanthanide complexes are with oxygen containing ligands like acetylacetone, citric acid, EDTA etc. Suggest a reason for this.

(b) A number of lanthanide minerals like monazite are usually deficient in Europium, which is found among calcium minerals. Justify the statement.

(c) Many of the oxides of actinides e.g U_3O_8, AmO_2 are non-stoichiometric, but this is true of few Lanthanide oxides. Why?

QUESTION 5

(a) Extraction of uranium involves both chemical and physical separation techniques. Briefly outline the steps involved in separation of nuclear fuel grade uranium from its ore.
(b) Explain the major reactions involved in breeder reactor. How is it more useful than ordinary nuclear reactor?
(c) What is the principle behind neutron activation analysis? How is it useful?

QUESTION 6

(a) Using isotopic labelling how can you furnish information concerning the possible path of oxidation of SO_3^{2-} by ClO^- involving the transfer of oxygen atom from chlorate to sulphate.

(b) Equivalent conduction of metal NH_3 solutions decrease first and then increase with increase in concentration. Discuss the above observation.

(c) Write down the auto-ionisation reaction of non- aqueous liquid SO_2. Hence write a balanced equation of its typical neutralization reaction. How does SO_2 react with KBr?

END OF EXAMINATION

PERIODIC TABLE OF THE ELEMENTS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

KEY

Atomic number
X
Atomic mass
Name of the element X

1 **H** 1.01 Hydrogen																1 **H** 1.01 Hydrogen
3 **Li** 6.94 Lithium	4 **Be** 9.01 Beryllium											5 **B** 10.81 Boron	6 **C** 12.01 Carbon	7 **N** 14.01 Nitrogen	8 **O** 16.00 Oxygen	9 **F** 19.00 Fluorine
11 **Na** 23.00 Sodium	12 **Mg** 24.31 magnesium											13 **Al** 26.98 Aluminium	14 **Si** 28.09 Silicon	15 **P** 30.99 Phosphorus	16 **S** 32.07 Sulphur	17 **Cl** 35.45 Chlorine
19 **K** 39.10 Potassium	20 **Ca** 40.08 Calcium	21 **Sc** 44.96 Scandium	22 **Ti** 47.88 Titanium	23 **V** 50.94 Vanadium	24 **Cr** 52.00 Chromium	25 **Mn** 54.94 Manganese	26 **Fe** 55.85 Iron	27 **Co** 58.93 Cobalt	28 **Ni** 58.69 Nickel	29 **Cu** 63.55 Copper	30 **Zn** 65.39 Zinc	31 **Ga** 69.72 Gallium	32 **Ge** 71.61 Germanium	33 **As** 74.92 Arsenic	34 **Se** 78.96 Selenium	35 **Br** 79.90 Bromine
37 **Rb** 85.47 Rubidium	38 **Sr** 87.62 Strontium	39 **Y** 88.91 Yttrium	40 **Zr** 91.22 Zirconium	41 **Nb** 92.91 Niobium	42 **Mo** 95.94 Molybdenum	43 **Tc** 97.91 Technetium	44 **Ru** 101.07 Ruthenium	45 **Rh** 102.91 Rhodium	46 **Pd** 106.42 Palladium	47 **Ag** 107.87 Silver	48 **Cd** 112.41 Cadmium	49 **In** 114.82 Inidum	50 **Sn** 118.71 Tin	51 **Sb** 121.76 Antimony	52 **Te** 127.60 Tellurium	53 **I** 126.90 Iodine
55 **Cs** 132.91 Caesium	56 **Ba** 137.33 Barium	57 – 71	72 **Hf** 178.49 Hafnium	73 **Ta** 180.95 Tantalum	74 **W** 183.84 Tungsten	75 **Re** 186.21 Rhenium	76 **Os** 190.23 Osmium	77 **Ir** 192.22 Iridium	78 **Pt** 195.08 Platinum	79 **Au** 196.97 Gold	80 **Hg** 200.59 Mercury	81 **Tl** 204.38 Thallium	82 **Pb** 207.2 Lead	83 **Bi** 208.98 Bismuth	84 **Po** 208.98 Polonium	85 **At** 209.99 Astatine
87 **Fr** (223.02) Francium	88 **Ra** 226.03 Radium	89 - 103	104 **Unq** 261.11	105 **Unp** 262.11	106 **Unh** 263.12	107 **Uns** 262.12	108 **Uno** 265.00	109 **Une** 265								

57 **La** 138.91 Lanthanum	58 **Ce** 140.12 Cerium	59 **Pr** 140.91 Praseodymium	60 **Nd** 144.24 Neodymium	61 **Pm** 144.91 Promethium	62 **Sm** 150.36 Samarium	63 **Eu** 151.97 Europium	64 **Gd** 157.25 Gadolinium	65 **Tb** 158.93 Terbium	66 **Dy** 162.50 Dysprosium	67 **Ho** 164.93 Holmium	68 **Er** 167.26 Erbium	69 **Tm** 168.93 Thulium	70 **Yb** 173.04 Ytterbium	71 **Lu** 174.97 Lutetium
89 **Ac** 227.03 Actinium	90 **Th** 232.04 Thorium	91 **Pa** 231.04 Protactinium	92 **U** 238.03 Uranium	93 **Np** 237.05 Neptunium	94 **Pu** 244.0 Plutonium	95 **Am** 243.06 Americium	96 **Cm** 247.07 Curium	97 **Bk** 247.07 Berkelium	98 **Cf** 251.08 Californium	99 **Es** 252.08 Einsteinium	100 **Fm** 257.10 Fermium	101 **Md** 260 Mendelevium	102 **No** 259.10 Nobelium	103 **Lr** 262.11 Lawrencium

THE UNIVERSITY OF ZAMBIA
INSTITUTE OF DISTANCE EDUCATION
SCHOOL OF NATURAL SCIENCES

2020/2021 ACADEMIC YEAR
DEFERRED FINAL YEAR EXAMINATIONS

CHE 3511: ORGANIC SPECTROSCOPY AND AROMATIC CHEMISTRY

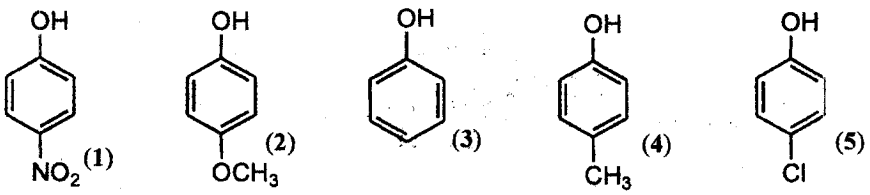
TIME ALLOWED: THREE (3) HOURS

INSTRUCTIONS TO CANDIDATES:

1. This paper contains **five questions** and has eight (7) printed pages. Please ensure that you have all printed pages.
2. **Answer any four (4) questions.**
3. Each question carries twenty five (**25**) marks.
5. Please be reminded of the need to present your answers in a logical manner and try to be on point.

QUESTION ONE

(a) Arrange the following molecules in order of decreasing acidity (most acidic to least acidic) and explain your answer: **[5 marks]**.

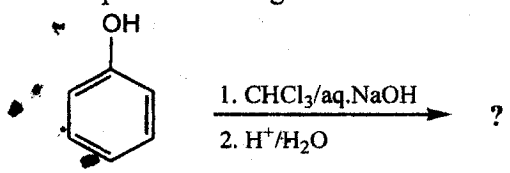


(b) p-Nitrophenol is more acidic than phenol, give an explanation for this statement. **[4 marks]**

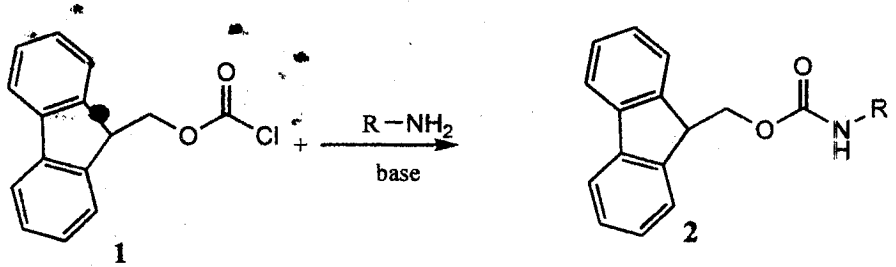
(c) Describe the bonding in pyrrole **[4 marks]**

(d) Predict the products and give the mechanism of the reaction shown below. **[6 marks]**

(i)



(e) Consider the following transformation:



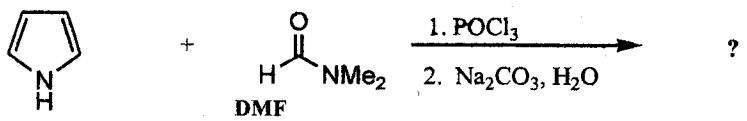
(i) Name the protecting group in this transformation. **[1 mark]**

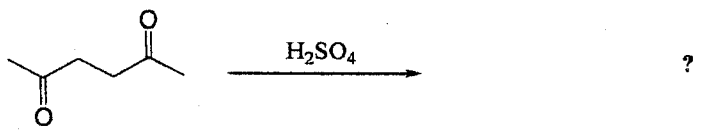
(ii) Write the mechanism for the deprotection of the amine in base. **[3 marks]**

(iii) Explain why it is difficult to substitute at the primary carbon next to the cyclopentyl ring? **[2 marks]**

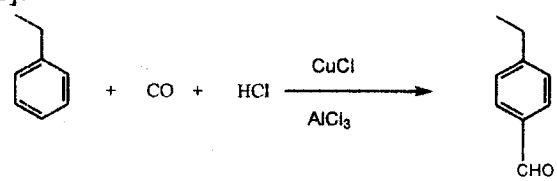
QUESTION TWO

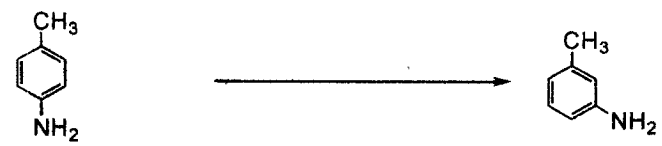
(a) Predict the major products of the following reactions and give the reaction mechanisms. **[10 marks]**

(i) 

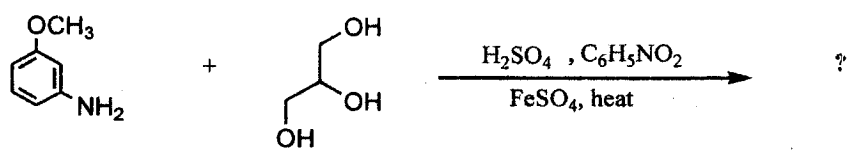
ii) 

(b) Outline the mechanism of the following reactions **[10 marks]**:

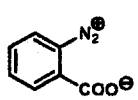
(i) 

(ii) 

(c) Propose a plausible mechanism for the following reaction. **[5 marks]**

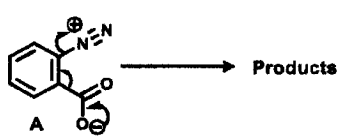
(ii) 

(d) The dry diazonium salt **A**, shown below, was subjected to flash discharge and the reaction was monitored by mass spectrometry. After about 50 microseconds, three peaks at *m/z* 28, 44 and 76 were seen.



A

(i) By following the flow of electrons shown below, predict all the resulting products of this decomposition reaction. **[6 marks]**



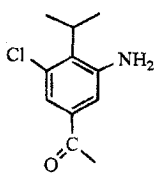
(ii) Assign the structures to the MS peaks at *m/z* 28, 44 and 76? **[6 marks]**

QUESTION THREE

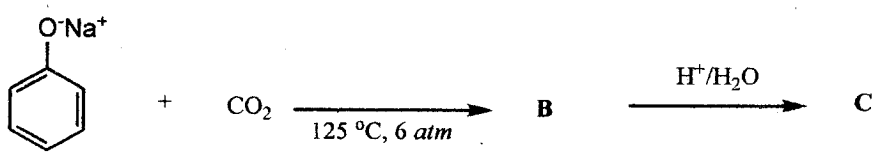
(a) Discuss the structure and bonding of naphthalene. **[5 marks]**

(b) Which position does Nitration and Halogenation occur predominantly? Explain your answer. **[6 marks]**

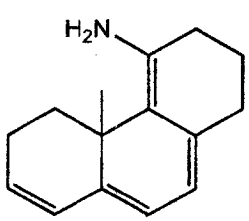
(c) Propose a synthesis route for the following target molecule from benzene: **[6 marks]**



(d) Write the structure of **B** and **C** in the following reactions. **[2 marks]**



(e) Calculate the expected λ_{max} for the following compound in ethanol. **[4 marks]**

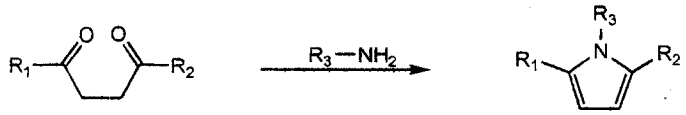


(f) Acrolein (H_2C=CHCHO) absorbs at 217 nm ($\varepsilon_{max} = 1.6 \times 10^4$ L mol^{-1} cm^{-1}). What concentration in g/mL of acrolein is required to observe an absorbance of 0.8 when the cell length is 0.2 dm? **[4 marks]**

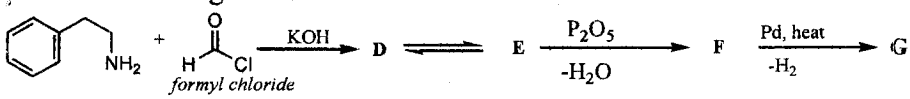
(g) The proton decoupled ^{13}CNMR spectrum of a triiodobenzene ($C_6H_3I_3$) shows only two signals. With a reason, identify the exact structure of this triiodobenzene. **[4 marks]**

QUESTION FOUR

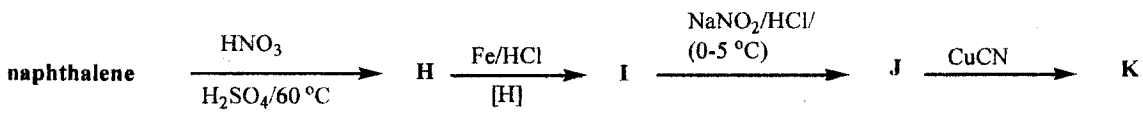
(a) Furan and pyrrole can be prepared via the Paal-Knorr synthesis. Provide a mechanistic explanation for each of the following reactions below: **[10 marks]**



(b) Provide structures for **D-G** and provide a mechanistic explanation for the following reaction scheme given below:

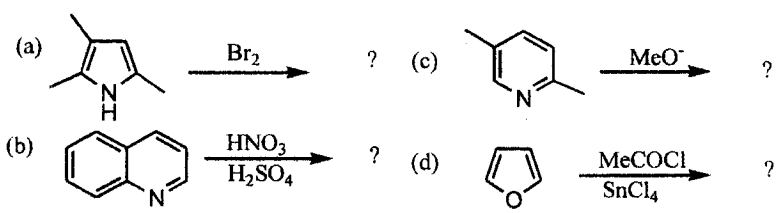


(c) Complete the following scheme of reactions: **[5 marks]**

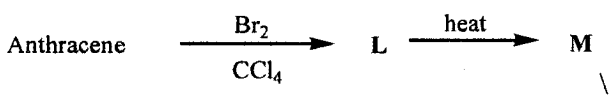


(d) For each of the following reactions:

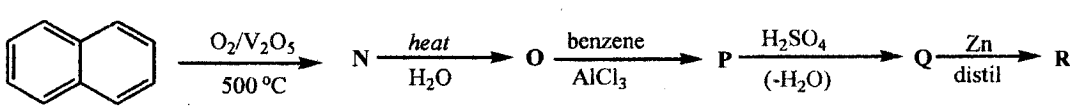
(i) State what kind of substitution is suggested? **[4 marks]**
(ii) Predict the product(s) formed: **[4 marks]**



(e) Provide the products of the following reactions. **[3 marks]**



(f) Complete the following reaction scheme by providing the structure of **N-R** **[5 marks]**

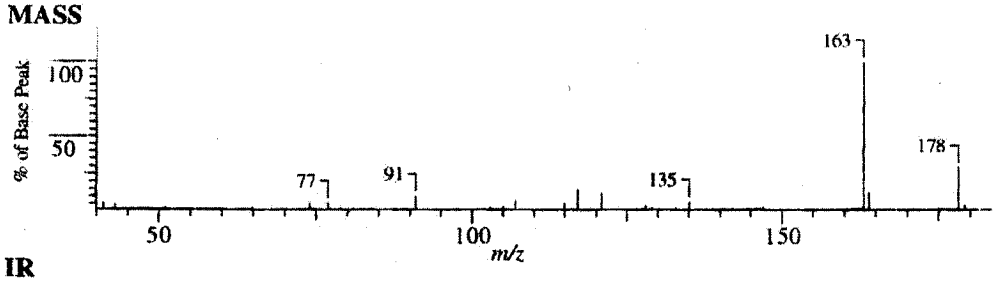


QUESTION FIVE

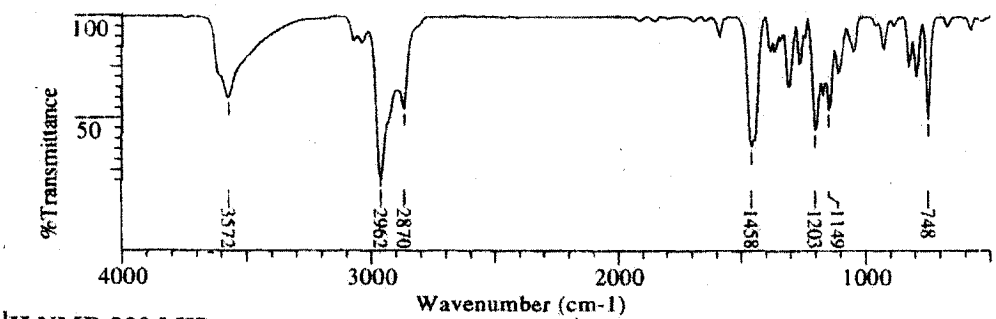
Deduce the structures of the compounds given the following spectroscopic data:

(a)

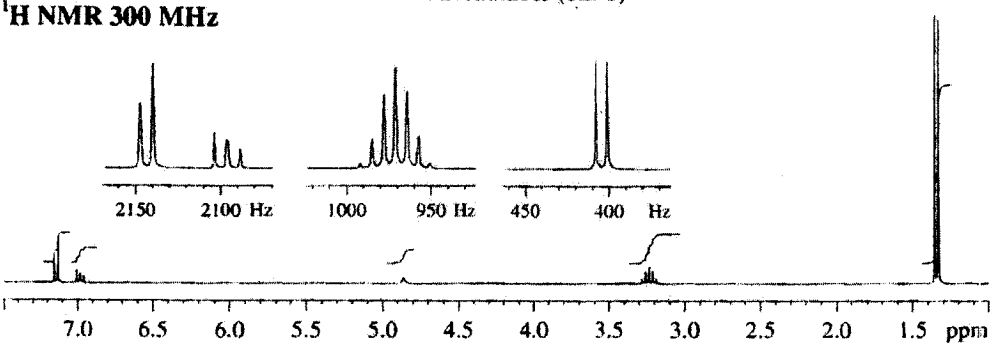
MASS



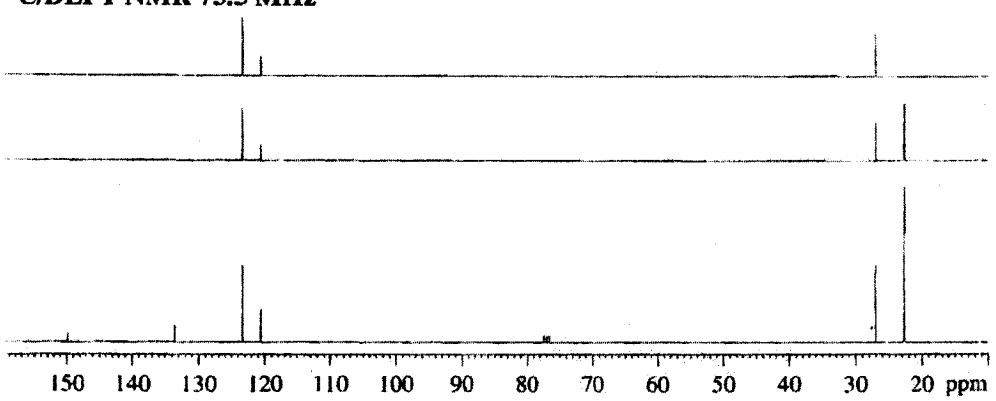
IR



^{1}H NMR 300 MHz

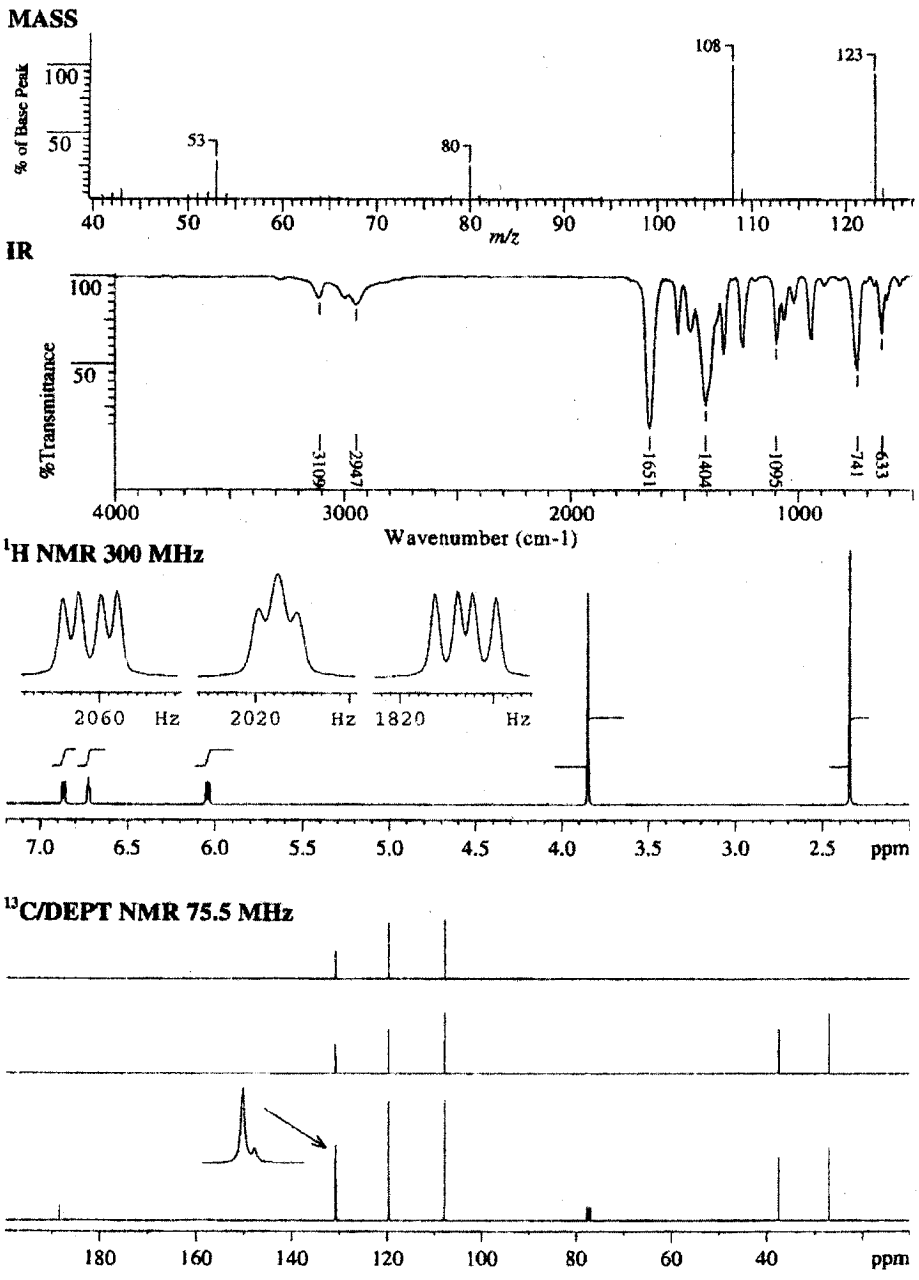


^{13}C/DEPT NMR 75.5 MHz



[12.5 marks]

(b)



[12.5 marks]

END OF EXAMINATION
GOOD LUCK!

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2020/21 ACADEMIC YEAR
FINAL YEAR EXAMINATIONS

CHE 3522: POLYFUNCTIONAL COMPOUNDS, MOLECULAR REARRANGEMENTS AND ORGANIC SYNTHESIS

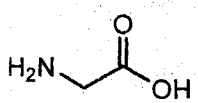
TIME ALLOWED: THREE (3) HOURS

INSTRUCTIONS:

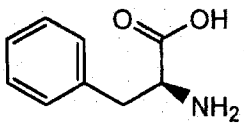
1. This paper contains **five questions** and has six (7) printed pages. Please ensure that you have all printed pages.
2. **Answer any four (4) questions.**
3. Questions carry equal marks; twenty five (25) marks EACH.
4. Write your Student Identity Number on ALL Answer booklets
5. Please be reminded of the need to present your answers in a logical manner and try to be on point.

QUESTION ONE

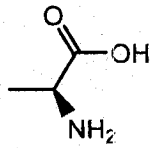
(a) Consider the structures of the three amino acids given below:



glycine



phenylalanine



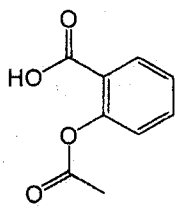
alanine

(i) Draw the tripeptide obtained from Gly-Ala-Phe. **(3 marks)**

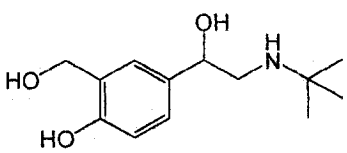
(ii) Show the N-terminal and C-terminal residues. **(2 marks)**

(iii) Draw the structure of product obtained when the tripeptide N-terminal residue reacts with acetic anhydride. **(3 marks)**

(b) By using the retrosynthetic analysis, provide a synthetic plan on how **Salbutamol**, a drug used to treat asthma, may be synthesised in good yields using **acetyl salicylic acid** as the starting material. Show all the steps clearly; including the intermediates, ***but no mechanism is required.*** **(10 marks)**

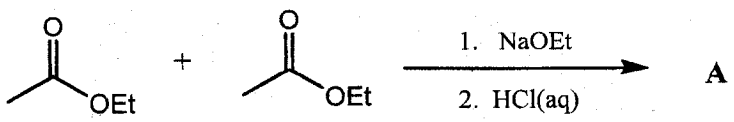


Actetyl salicylic acid

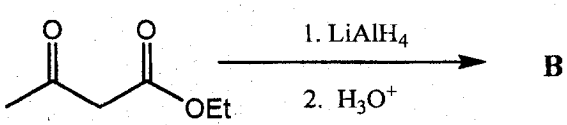


Salbutamol

(c) Write the structure of **A** in the following reaction below: **(2 marks)**

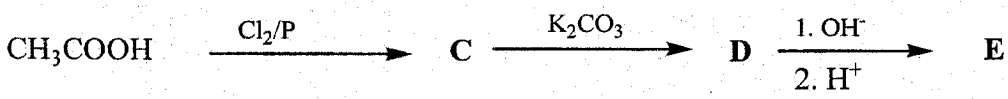


(d) Provide the structure and name product **B**. **(2 marks)**



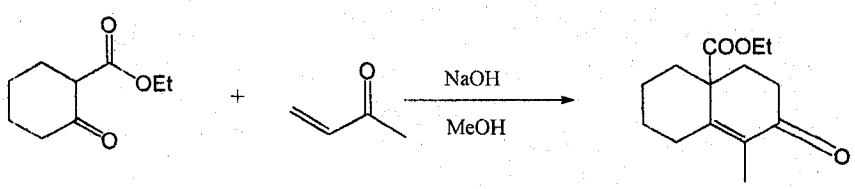
(e) Provide the structures of **C, D** and **E** in the following reaction scheme given below:

(3 marks)

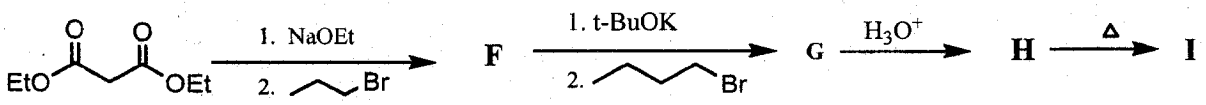


QUESTION TWO

(a) Write reaction mechanisms for each of the following reactions: **(6 marks)**

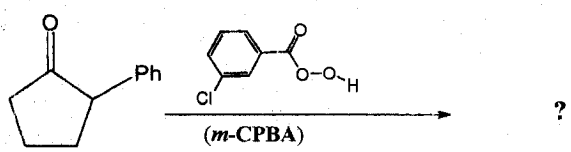


(b) Malonic esters are used in the synthesis of a variety of compounds. Write the structure of compounds/intermediates **F, G, H** and **I**. **(4 marks)**

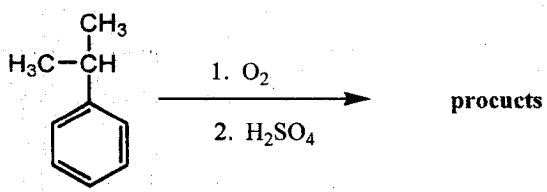


(c) Predict and give the structure of the products of the reactions shown below: **(4 marks)**

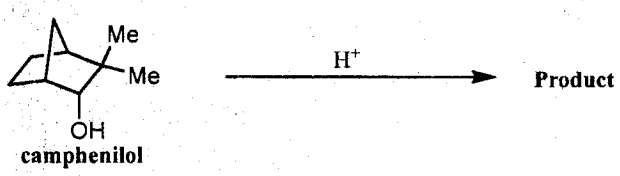
(i)



(ii)

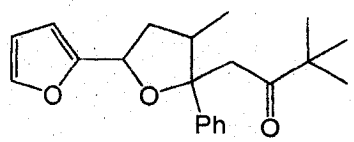


(iii)

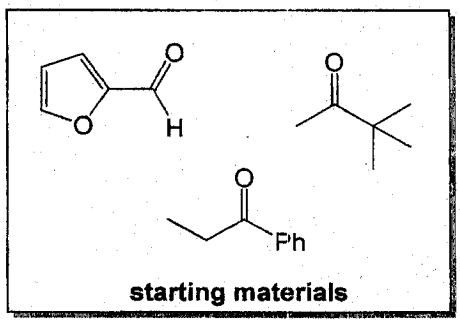


camphenilol

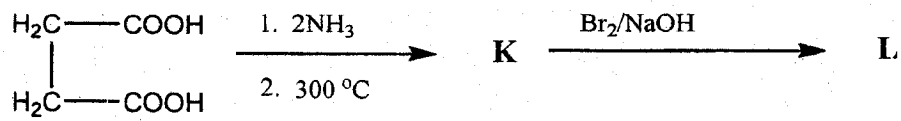
(d) Give a detailed synthetic plan of obtaining product **J** from the given **starting materials** (additional reagents will be necessary). Show all the steps clearly; including the intermediates, ***but no mechanism is required.*** **(8 marks)**



J

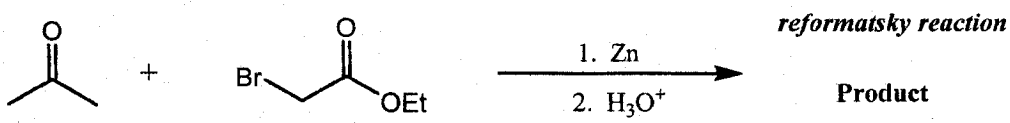


(e) Write the structures of **K** and **L** in the following reaction: **(3 marks)**

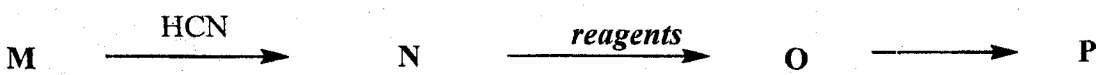


QUESTION THREE

(a) Predict the product of the following reaction and write a plausible mechanism for it. **(6 marks)**



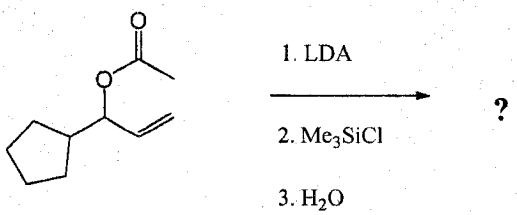
(b) Using the Strecker method, outline the synthesis of 2-amino-3-methylbutanoic acid; provide the structures of **M**, intermediates, **N** & **O**, and give the reagents between **N** & **O**. **(4 marks)**



(c) Briefly explain the following terms and give an example. **(5 marks)**

(i) Retrosynthetic analysis
(ii) Synthetic equivalent

(d) The reaction below proceeds by Ireland-Claisen rearrangement. Predict the major product of the following reaction. **(2 marks)**

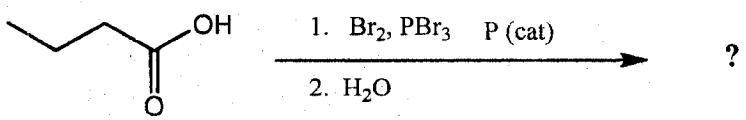


(e) A compound (**Q**), $C_3H_6O_4$, when heated with acetic anhydride gives (**R**), $C_4H_4O_3$. Compound (**R**) reacts with ammonia to give (**S**), $C_4H_{12}O_4N_2$. Compound (**S**) on heating to 300 °C forms (**T**), $C_4H_5O_2N$. Both (**R**) and (**S**) can be hydrolyzed to (**Q**). Identify (**Q**), (**R**), (**S**) and (**T**). **(4 marks)**

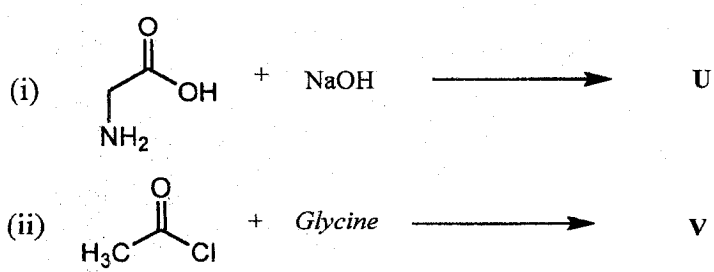
(f) What are reducing sugars? How will you distinguish glucose from fructose? **(4 marks)**

QUESTION FOUR

(a) Predict the product of the following reaction and give a detailed reaction mechanism: **(6 marks)**

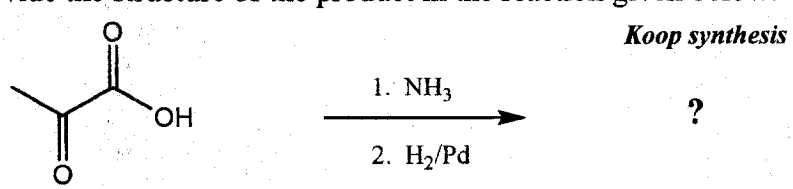


(b) Write the structure and name of molecules, **U** and **V** in the following reactions: **(2 marks)**



(c) Provide the structure of the product in the reaction given below: **(2 marks)**

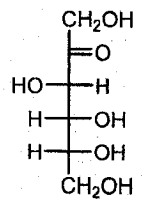
Koop synthesis



α-ketopropanoic acid

(d) Write down the open chain structure of the aldaric acid (mannaric acid that would be obtained by nitric acid oxidation of D-mannose. Would you expect mannaric acid to be optically active? **(2 marks)**

(e) D-fructose is not an epimer of glucose or mannose but all three yield the same phenylosazone. D-fructose structure is given below:



D-Fructose

(i) Using Fisher projection formulas, write equation for the reaction of fructose with phenyl hydrazine. **(6 marks)**

(ii) Based on the information from (i), write the structures of *D*-Mannose and *D*-Glucose. **(2 marks)**

(iii) What information about the stereochemistry of *D*-fructose does this experiment yield? **(1 mark)**

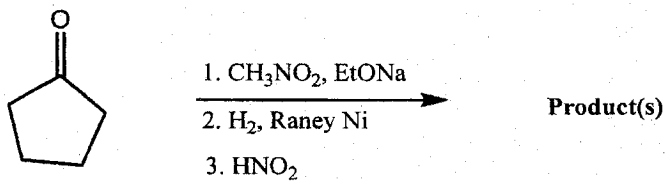
(f) A compound (**W**) ($C_4H_8O_4$) gives a positive test with Tollens' reagent. Treatment of A with bromine water produces an optically active compound (**X**). Oxidation of (A) with nitric acid gives an optically inactive compound (**Y**). Compound (**W**) can be prepared from L-glyceraldehyde by Kiliani-Fischer synthesis. What are the structures of (**W**), (**X**), and (**Y**)? **(4 marks)**

QUESTION FIVE

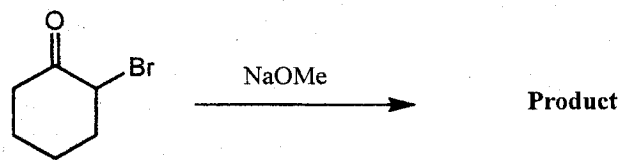
(a) Show how periodic acid could be used to distinguish between and aldohexose and ketohexose. What products would you obtain from each, and how many molar equivalents of HIO_4 would you consume. **(6 marks)**

(b) Consider the following transformations given below. Provide a plausible reaction mechanism for each one of them: **(11 marks)**

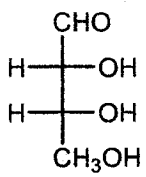
(i)



(ii)



(c) Outline a Killian-Fischer synthesis of epimeric aldopentoses starting with D-Erythrose (use Fischer projections). **(8 marks)**



D-Erythrose

(i) The two epimeric aldopentoses that one obtains are D-arabinose, D-Ribose.

(ii) Nitric acid oxidation of D-ribose yields an optically inactive aldaric acid whereas similar oxidation of D-arabinose yields and optically active product. On the basis of this information alone which Fischer projection represents D-Arabinose and which one represents D-Ribose.

END OF EXAMINATION!!!!!

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
DEPARTMENT OF CHEMISTRY

2020/2021 ACADEIMC YEAR
FINAL EXAMINATIONS

COURSE: **CHE3611 (COLLOIDS AND ELECTROCHEMISTRY)**

DATE: **09:00 HOURS FRIDAY 22 NOVEMBER 2021**

TIME: **THREE HORS**

INSTRUCTIONS TO CANDIDATES

1. THEY ARE SIX QUESTIONS IN THIS PAPER AND ALL QUESTIONS CARRY EQUAL MARKS.
2. ANSWER ANY FIVE OF THE SIX QUESTIONS.
3. YOU WILL BE PROVIDED WITH GRAPH PAPERS.
4. YOU ARE REMINDED OF THE NEED TO ORGANIZE AND PRESENT YOUR WORK CLEARLY AND LOGICALY.

USEFUL DATA

- $R = 8.314\ J\ K^{-1}\ mol^{-1}$;
- $N_A = 6.022141 \times 10^{23}\ mol^{-1}$
- $1u = 1.6605 \times 10^{-27}\ kg = 931.481\ MeV$
- $1eV = 1.602 \times 10^{-19}\ J$
- $1Ci = 3.7 \times 10^{10}\ Bq$
- $m_n = 1.00866544\ u$
- $m_p = 1.007277\ u$
- $m_e = 0.000548593\ u$

Question 1

Consider the first-order decomposition of cyclobutane at 438°C at constant volume:

$$C_4H_8(g) \rightarrow 2C_2H_4(g)$$

a) Assuming ideal gas behavior, write an expression of the rate of the reaction in terms of the change in total pressure as a function of time.

b) The rate constant for the reaction is $2.48 \times 10^{-4}\ s^{-1}$. What is the half-life?

c) After initiation of the reaction, how long will it take for the initial pressure of C_4H_8 to drop to 90% of its initial value?

d) Given that At 552.3 K, the rate constant for the reaction is $1.02 \times 10^{-6}\ s^{-1}$. If the activation energy is 210 kJ mol^{-1}, calculate the Arrhenius preexponential factor

Question 2

Bacteriorhodopsin is a protein found in *Halobacterium halobium* that converts light energy into a transmembrane proton gradient that is used for ATP synthesis. After light is absorbed by the protein, the following consecutive first-order reaction occurs:

$$Br \xrightarrow{k_1 = 2.0 \times 10^{12}\ s^{-1}} J \xrightarrow{k_2 = 3.3 \times 10^{11}\ s^{-1}} K$$

a) Derive an expression for the concentration of [Br], [J] and [K] as a function of time for the reaction sequence above.

b) Sketch a graph of the concentration of each species versus time for an initial concentration of $[Br]_o = 1.0$ M.

c) At what time will the maximum concentration of the intermediate J occur?

Question 3

(a) The rate of reaction can be determined by measuring the change in optical rotation of the sample as a function of time if a reactant or product is chiral. This technique is especially useful for kinetic studies of enzyme catalysis involving sugars. For example, the enzyme

invertase catalyzes the hydrolysis of sucrose, an optically active sugar. The initial reaction rates as a function of sucrose concentration are as follows:

$[Sucrose]_o$ *M*	Initial rate (R_o) Ms^{-1}
0.029	0.182
0.059	0.266
0.088	0.310
0.117	0.330
0.175	0.362
0.234	0.361

Use these data to determine the Michaelis constant for invertase

Question 4

For a type II second-order reaction, the reaction is 60% complete in 60 seconds when $[A]_o = 0.1$ M and $[B]_o = 0.5$ M

a) What is the rate constant for this reaction?

b) Will the time for the reaction to reach 60% completion change if the initial reactant concentrations are decreased by a factor of 2?

c) Using the steady state approximation, Devise the rate law for the decomposition of N_2O_5,

$$2\ N_2O_5(g) \rightarrow 4\ NO_2(g) + O_2(g)$$

On the basis of the following mechanism:

$N_2O_5 \rightarrow NO_2 + NO_3$ k_1

$NO_2 + NO_3 \rightarrow N_2O_5$ k_2

$NO_2 + NO_3 \rightarrow NO_2 + O_2 + NO$ k_3

$NO + N_2O_5 \rightarrow NO_2 + NO_2 + NO_2$ k_4

Question 5

(a) Polonium, $^{212}_{84}Po$, of activity of 925 MBq, α-decay 97 % to ground state, α-decay 1 % to 2.6148 MeV first excited state, α-decay 2 % to 3.1977 MeV second excited state of $^{208}_{82}Pb$. The mass excess of $^{212}_{84}Po$, $^{208}_{82}Pb$ and $^{4}_{2}He$ are -10.381, -21.759 and 2.4249 MeV respectively.

(i) Write the decay reaction.

(ii) Draw a sketch of decay scheme diagram described in the above process.

(iii) Calculate Q_α.

(iv) Determine the maximum kinetic energy of emitted alpha particle.

(b) $^{30}_{15}P(t_{1/2} = 2.50\,m)$ of activity 50 MBq decays both by EC and β^+ 99.94% to the ground state of $^{30}_{14}Si$. The mass excess of $^{30}_{15}P$ and $^{30}_{14}Si$ are -20.2045 and -24.4317 MeV respectively.

(i) Write the radioactive decay reaction of $^{30}_{15}P$ to $^{30}_{14}Si$ by EC and β^+.

(ii) Calculate $Q_{EC.}$, Q_{β^+} and $E_{\beta^+ max.}$

Question 6

a) Consider a decay sequence:

$$^{239}_{92}U \xrightarrow{t_{1/2}=23.54\,m} {}^{239}_{93}Np \xrightarrow{t_{1/2}=2.346\,d} {}^{239}_{94}Pu \xrightarrow{t_{1/2}=2.41\times10^4\,y}$$

The mass excess of $^{239}_{92}U$ and $^{239}_{93}Np$ are 50.5722 and 49.306 MeV respectively and an initial pure $^{239}_{92}U$ of activity of 1.00 mCi

(i) Identify and write the radioactive decay modes involved in the above sequence of reactions.

(ii) Calculate the Q value of the decay of $^{239}_{92}U$ to $^{239}_{93}Np$

(iii) Determine the activity of $^{239}_{92}U$ after the decay time of 1.00 day in Bq.

(c) Calculate the mass defect and nuclear binding energy per nucleon (in MeV) for C-16, a radioactive isotope of carbon with a mass of 16.014701 amu.

(d) Calculate the isotopic mass of U-238. The mass excess of U-238 is 47.3070 MeV.

(e) How many α and β particles are emitted in passing down from $^{232}_{90}Th$ to $^{208}_{82}Pb$.

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

2020 ACADEMIC YEAR FINAL EXAMINATIONS

CHE4111 INFORMATION STORAGE AND BIOCHEMICAL GENETICS

TIME: THREE (3) HOURS

INSTRUCTIONS:

1. ANSWERS ANY **FOUR (4) QUESTIONS**
2. THERE ARE **FOUR (4) PRINTED PAGES** IN THIS EXAMINATION PAPER
3. EACH QUESTION CARRIES **TWENTY (25) MARKS**

QUESTION 1

Gene expression involves two main processes, that is, transcription and translation. Translation process may be divided into activation of amino acids, initiation, elongation, termination and post translation modification. In HIV particle post translation modification is very essential for proper functioning of the virus.

a) **What** is translation? **[3 marks]**

b) **Describe** in detail the process of activation of amino acids during translation in *E. coli*. **[6 marks]**

c) **Explain** post translation modification of products of GAG and POL gene in HIV particle. **[6 marks]**

d) **Describe** in detail the process of initiation of translation in *E. coli*. **[10 marks]**

QUESTION 2

a) **Describe** the experiments that Avery and his colleagues conducted in 1944 to determine which molecule was most important for the transformation that was observed in Griffiths experiment. **Discuss** the results of the experiments? **[7 marks]**

b) With reference to the process of DNA replication, **write** short notes on the following (you can use diagrams to support your answers): **[12 marks]**

i. The distinctive roles of type I and II topoisomerases
ii. The mechanism of DNA chain elongation as observed in *E. coli* DNA pol I
iii. The dispersive model of DNA replication

c) **Compare and contrast** DNA nucleotide excision repair and DNA base excision repair. **[6 marks]**

QUESTION 3

a) **Describe** in detail the sequential steps of packaging used to condense linear DNA in a eukaryotic cell. **[10 marks]**

b) A student extracted DNA from a eukaryotic cell that approximately weighs 1.63 $x10^{-7}$ micrograms.

i. **Calculate** how many nucleosomes would be present. [Average weight of a DNA base pair is 650 Daltons; there is 1 nucleosome per 200 base pairs of DNA; 1 Dalton = 1.67×10^{-24} grams]. **[6 marks]**

ii. **What** will be the number of core histone molecules and linker histone H1 molecules in the extracted DNA? **[4 marks]**

c) Assume you are studying the *rII* region of phage T4. Three mutant T4 strains are obtained, identified as A, B and C. Each has a point mutation. When mixed infections are performed in *E. coli*, the following results are obtained:

Strains in mixture	**Observation**
A and B	Lysis of bacterial cells occurred
A and C	No lysis of bacterial cells occurred
B and C	Lysis of bacterial cells occurred

Based on the above observations, **which** two strains have a mutation on the same gene? **Explain** your answer. Note that the ***rII* mutant phenotype** is inability to lyse bacterial cells. **[5 marks]**

QUESTION 4

a) **Distinguish** the following:

i. Pancreatic deoxyribonuclease and restriction endonuclease
ii. gDNA and cDNA
iii. Staggered ends and blunt ends **[12 marks]**

b) Bacteria such *Escherichia coli* (*E. coli)* have mechanisms that ensure that a foreign DNA molecule that gets inside them is degraded and yet numerous bacterial systems including *E. coli* are frequently used to carry recombinant DNA in biotechnology applications. **How** is this possible? **Explain**. **[5 marks]**

c) **How** has treatment of the following diseases been assisted by recombinant DNA technology? **a)** diabetes, **b)** malaria **[8 marks]**

QUESTION 5

Assuming you a government DNA specialist, explain you might produce a human malaria parasite hypoxanthine guanine phosphoribosyl transferase (HGPRT) enzyme for drug trials. Your employers want you to have this enzyme expressed in *E. coli* cells.

a) **Describe** in detail how you might produce the enzyme assuming the gene is found in *P. Falciparum,* a malaria parasite.
b) **Suggest** how your protein might be purified.

[25 marks]

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2020/2021 ACADEMIC YEAR
FINAL EXAMINATIONS

NOVEMBER 26, 2021

CHE 4522: PHYSICAL ORGANIC AND NATURAL PRODUCTS CHEMISTRY

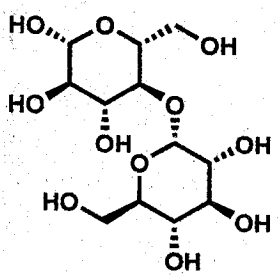
TIME ALLOWED: THREE (3) HOURS

INSTRUCTIONS:

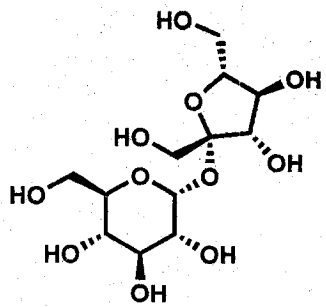
1. Answer any FOUR (4) questions.
2. Each question carries 25 marks.
3. Ensure you have seven (7) printed pages and five questions.
4. Present your answers in a concise and logical manner.
5. Useful physical constants are given on page 7
6. Spectral data tables are provided.

QUESTION ONE

(a) Consider the structures of maltose and sucrose shown below:



Maltose



Sucrose

Which one would you expect to reduce Fehling's solution and briefly explain why? **(3 marks)**

(b) Match the following ρ values with the appropriate reactions. Explain your reasoning:
Reaction constants: + 2.45, +0.75, -7.29:

(i) Nitration of substituted benzenes **(2 marks)**

(ii) Ionization of substituted benzenethiols **(2 marks)**

(iii) Ionization of substituted benzene phosphonic acid **(2 marks)**

(c) Starch is the most widely distributed polysaccharide in the vegetable kingdom with its rich sources being potatoes, wheat, maize, rice, barley and arrow root.

(i) Give the names of two different polysaccharides that make up starch. **(2 marks)**

(ii) State which of these two polysaccharides in starch is responsible for the blue black color during the test for starch and briefly explain how the color arises. **(6 marks)**

(d) Sucrose undergoes hydrolysis according to the reaction shown below:

$$\underset{[\alpha]_D = +66.5^\circ}{C_{12}H_{22}O_{11}} + H_2O \longrightarrow \underset{\substack{\textbf{Glucose} \\ [\alpha]_D = +52.7^\circ}}{C_6H_{12}O_6} + \underset{\substack{\textbf{Fructose} \\ [\alpha]_D = -92.4^\circ}}{C_6H_{12}O_6}$$

With the aid of some calculations, suggest a reason why this hydrolysis reaction is referred to as inversion. **(5 marks)**

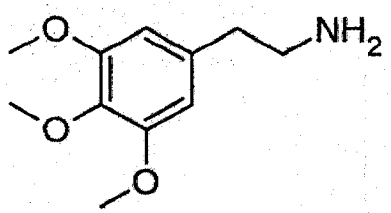
(e) Explain the meaning of the terms primary and secondary kinetic Isotope effect **(3 marks)**

QUESTION TWO

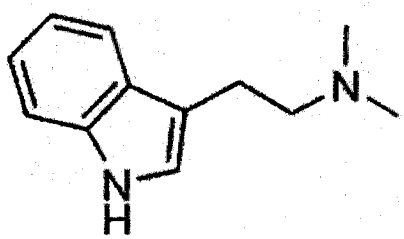
(a) Distinguish between primary and secondary metabolites. Give two examples of each. **(5 marks)**

(b) Classify the following as true or proto alkaloids and give a reason for your classification. **(4 marks)**

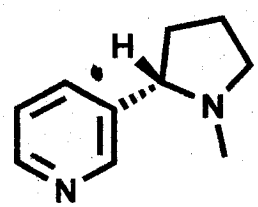
(i)



(ii)



(iii)



(c) (a) In the process of isolating alkaloids from a plant, a CHE 4522 student shade-dried some plant material, crushed and ground it into powder. It was then soaked in hexane after which the mixture was filtered and the filtrate discarded. The residue obtained was then subjected to further extraction procedures. Briefly explain why this initial extraction with hexane was required. **(5 marks)**

(d) (b) Targeted extraction of alkaloids can be achieved with the help of hydrochloric acid. Outline, in bullet point form, the steps involved in this method. **(11 marks)**

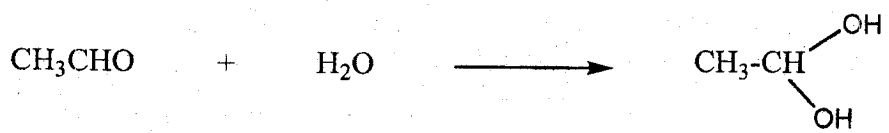
QUESTION THREE

(a) An alkaloid is isolated from a plant harvested from the Namib Desert and is found to be highly soluble in water. From its high water solubility, a CHE 4522 student suggests it contains carboxylic acid groups.

(i) Describe a chemical test you would carry out to confirm the existence of the carboxylic acid groups. Give the expected results **(6 marks)**

(ii) Once the presence of carboxylic acid groups has been confirmed, the actual number of such groups is determined. Describe an experiment you would carry out to determine this number. **(6 marks)**

(b) Consider that, in aqueous solution acetaldehyde is slowly hydrated:



In acetate buffer the reaction is subject to acid and base catalysis. The first order rate constants (k_{obs}) in two different acetate buffers, of known hydrogen ion concentration, were measured with the following results (r= buffer ratio) [$CH_3CO_2H/CH_3CO_2^-$]).

(a) $[H^+]$ = 3.36 x 10^{-6} M					r= **0.118**
10^{-3} $[CH_3CO_2H]$	2.7	4.9	6.9	9.0	10.9
10^{-2} k_{obs} (min^{-1})	6.6	8.7	9.9	11.6	12.7

(b) $[H^+]$ = 8.78 x 10^{-6} M					r = **0.308**	
10^{-3} $[CH_3CO_2H]$ M	3.0	4.7	7.4	8.7	11.3	15.2
10^{-2} k_{obs} (min^{-1})	8.2	9.3	10.2	10.6	12.3	13.4

Catalysis by hydroxide ion is known to be negligible but there is catalysis by hydrogen ions, acetic acid and acetates ions, as well as spontaneous reaction, the rate expression given as below:

$$k_{obs} = \mathbf{k_o} + \mathbf{k_1}[H^+] + \mathbf{k_2}[CH_3CO_2H] + \mathbf{k_3}[CH_3CO_2^-] \quad \text{.....Equation 1}$$

$$\text{Buffer ratio } (\mathbf{r}) = \frac{[CH_3COOH]}{[CH_3COO^-]} \quad \text{.....Equation 2}$$

NOTE:

You are not required to plot any graphs, use the following value for the calculation of rate constants in **equation 1**: for values set (**a**) = 4.6 is the slope and for set of values in (**b**); the slope = 7.5; the intercepts are for (**a**) = 47 x 10^{-3} and for (**b**) = 69 x 10^{-3}.

(i) Simplify the rate expression from **equation 1** above to the one below:

$$k_{obs} = k_o + k_1[H^+] + k_2 + k_3/r\,[CH_3CO_2H]$$ **(5 marks)**

(ii) Calculate the values of the rate constants; k_3, k_2, k_1 & k_o in that order. **(8 marks)**

(**Hint:** treat this as a simultaneous equation to calculate k_3 and k_2 from given slopes)

QUESTION FOUR

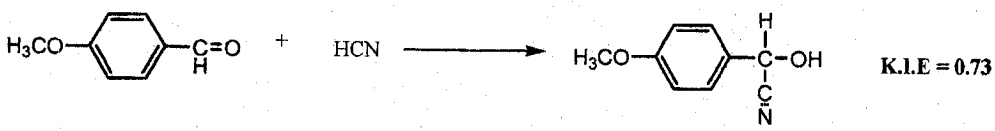
(a) Consider the following reactions 1 and 2 with the observed kinetic isotope effects values.

Reaction 1

1. 

K.I.E = 1.30

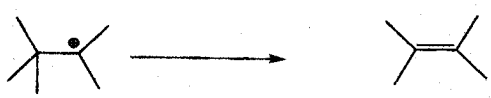
Reaction 2

2. 

K.I.E = 0.73

(i) Explain the meaning of the observed K.I.E for the reactions shown above in reaction (1) and (2). **(4 marks)**

(ii) Explain why you would expect a normal K.I.E for the transformation given below: **(2 marks)**



(b) Consider the following equation:

$$k_r = \frac{k_B\,T}{h}\, e^{\frac{-\Delta H^{\ddagger}}{RT}} . e^{\frac{\Delta S^{\ddagger}}{R}}$$

(i) Name this equation **(2 marks)**

(ii) Name each term given in the equation **(4 marks)**

(iii) Write the linear form of this equation and show the linear plot indicating what the slope and intercept is. **(4 marks)**

(c) The sulphonation of tritium –labelled bromobenzene is much slower than of normal benzene, while nitration of nitrobenzene is unaffected by isotopic substitution on the aromatic ring. Explain these observations. **(5 marks)**

(d) Explain the meaning of the term general acid and base catalysis. **(4 marks)**

QUESTION FIVE

(a) Consider the following reaction scheme:

step 1: $A \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} P_1 + I$

step 2: $I + B \xrightarrow[slow]{k_2} P_2$

(i) Use the stead state theory to drive a rate expression for this reaction scheme. **(5 marks)**

(ii) Explain what the terms in the numerator and denominator represent. **(3 marks)**

(b) Consider the following reaction scheme:

$$R + H_3O^+ \rightleftharpoons RH^+ \xrightarrow{slow} PH^+ \xrightarrow{fast} P + H_3O^+$$

(i) Carry out a kinetic analysis and derive a kinetic rate expression for this reaction scheme given above. **(5 marks)**

(ii) Is this a specific acid or general acid catalysis? Briefly explain your answer. **(2 marks)**

(iii) Has the concentration of the acid changed over the course of the reaction or not. Briefly explain your answer. **(2 mark)**

(c) After determination of empirical formula from combustion analysis experiments, the molecular weight of a compound can then be determined through experiments such as freezing-point-depression experiments using the relationship:

$\Delta T_f = K_f m.$

Where:
ΔT_f = difference in freezing point between that of pure solvent and the solution.
K_f = molal freezing point depression constant in °C/*m*.
m = molality of the solution formed by dissolving the compound in a suitable solvent.
Derive an expression for the molecular weight of the solute compound. **(8 marks)**

END OF EXAMINATION
GOOD LUCK!

APPENDIX

Substituent	HAMMETT CONSTANTS		
	Σ	σ^+	σ-
p-MeO	-0.27	-0.78	-0.27
m-MeO	0.12	0.05	
p-Me	-0.17	-0.31	-0.17
m-Me	-0.07	--0.07	-0.07
p-Bu^t	-0.20	-0.26	
m-Bu^t	-0.10	-0.06	
p-F	0.06	-0.07	
m-F	0.34	0.35	
p-Br	0.23	0.15	0.22
m-Br	0.39	0.41	
p-Cl	0.23	0.11	
m-Cl	0.37	0.40	0.38
p-CO_2Et	0.45	0.48	0.68
p-NO_2	0.78	0.79	1.27
m-NO_2	0.71	0.67	0.70

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

DEPARTMENT OF CHEMISTRY

END OF 2020/21 ACADEMIC YEAR FINAL EXAM

CHE4411 Inorganic Spectral techniques and its application in group theory

Answer any four questions

All questions carry equal marks **Time allowed: 3 hours**

Some Useful Data

Planck's constant = 6.6×10^{-34} Js

Speed of light = 3×10^{8} m/s

Avogadro number = 6.02×10^{23}/mol

Boltzmann Constant, K = 1.380×10^{-16} erg/K

1 eV = 1.6×10^{-19} joules

1 BM = 0.927×10^{-20} erg/gauss

Magnetic field strength, $\beta = 9.27 \times 10^{-24}$ J/T

Question 1

(a) What are the symmetry species of the vibrational modes of a C_{6v} molecule that are neither IR nor Raman active?

(b) What symmetry element do the following have:

i) A molecule cannot be polar.

ii) A molecule cannot be chiral.

iii) A molecule has none of its modes which can be both IR and Raman active.

(c) The character has characteristic features. Using the C_{2h} character table:

(i) Determine the order of the group

(ii) Verify that the $\mathbf{B_u}$ irreducible representation is orthogonal to **any one** of the other irreducible Representations.

(iii) The P_z orbital transform as A_u irreducible representation, prove this by carrying out the symmetry operations on the P_z orbital.

(iv) Reduce the following representations to their component irreducible representation

C_{2h}	E	C_2	i	σ_h
Γ	4	0	0	0

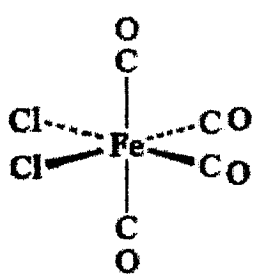
Question 2

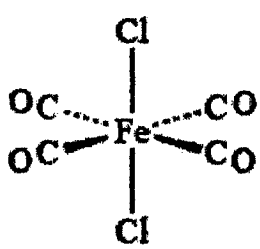
(a) Group theory is often used by chemists as an aid in the interpretation of infrared and Raman spectra. Considering the molecule of water H_2O with the C_2v point group
(i) Determine the number of normal modes of vibrations and their representation
(ii) Identify the stretching and bending modes
(iii)Which of the normal modes is in (i) are IR-active and which are Raman-active

(b) Using the group theory can be used to come up with the molecular orbital energy diagram for H_2O:
(i) Determine the symmetry allowed hybridization schemes for the valence orbitals of the central atom. Ignore the contribution of d orbitals.
(ii) Reduce the ligand group orbitals (LGO) to their irreducible representations
(iii)Hence draw the MO diagram for H_2O

Question 3

(a) The following isomer molecules, are the cis-$Fe(CO)_4Cl_2$ with C_2v symmetry and trans-$Fe(CO)_4Cl_2$ has D_{4h} symmetry.



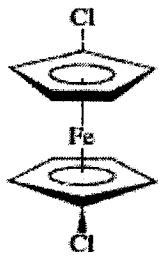


(i) Use group theory to determine the number of IR-active and Raman-active C-O stretching vibrations for each isomer.
(ii) How many peaks do you expect to observe in the IR and Raman spectra, respectively for each isomer
(iii) How can the basis C-O stretching vibrations be used to distinguish this two isomer.

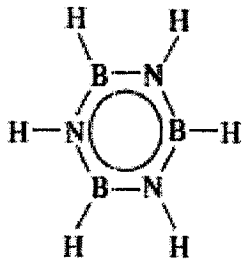
(b) Assign the point groups of following compounds, and determine any of the species is optically active

(i) H_2O_2 (ii) CBrClFI (iii) $XeOF_2$

(iv) 1,1 – Dichloroferrocene



(v) Borazine (planar)



Question 4

(a) Sketch the stick diagram of the peaks observed in the mass spectrum of CH_2Br_2 , if Br^{79} and Br^{81} are of 50 % abundance.

(b) At 25°C, the molar magnetic susceptibility, χ_m of NH_3 is -18.3×10^{-6} cm^3 /mol and its density is 0.86 g/cm^3. Calculate its specific magnetic susceptibility, χ and magnetic permeability, μ.

(c) In an ESR spectrometer, the ESR frequency of the free electron is 9.5 GHz. Calculate the magnetic field at which the spectrometer is operating. Values of g and β are 2.0023 and 9.273×10^{-24} J/T

Question 5

(a) The energy difference between $^{57}Fe^*$ & ^{57}Fe is 14.4 KeV. In a Mossbauer experiment if the relative velocity of source and the absorber is 100 ms^{-1}, calculate the shift in frequency.

(b) Gallium has two naturally occurring isotopes, ^{69}Ga and ^{71}Ga, with masses of 68.92577 u and 70.9249 u, respectively. Calculate the percent abundance of ^{69}Ga.

(c) What is magnetic hysteresis? What are soft and hard magnets? Draw the hysteresis loop for soft and hard magnets.

END OF EXAMINATION

PERIODIC TABLE OF THE ELEMENTS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

KEY

Atomic number
X
Atomic mass
Name of the element X

1 **H** 1.01 Hydrogen																1 **H** 1.01 Hydrogen
3 **Li** 6.94 Lithium	4 **Be** 9.01 Beryllium											5 **B** 10.81 Boron	6 **C** 12.01 Carbon	7 **N** 14.01 Nitrogen	8 **O** 16.00 Oxygen	9 **F** 19.00 Fluorine
11 **Na** 23.00 Sodium	12 **Mg** 24.31 magnesium											13 **Al** 26.98 Aluminium	14 **Si** 28.09 Silicon	15 **P** 30.99 Phosphorus	16 **S** 32.07 Sulphur	17 **Cl** 35.45 Chlorine
19 **K** 39.10 Potassium	20 **Ca** 40.08 Calcium	21 **Sc** 44.96 Scandium	22 **Ti** 47.88 Titanium	23 **V** 50.94 Vanadium	24 **Cr** 52.00 Chromium	25 **Mn** 54.94 Manganese	26 **Fe** 55.85 Iron	27 **Co** 58.93 Cobalt	28 **Ni** 58.69 Nickel	29 **Cu** 63.55 Copper	30 **Zn** 65.39 Zinc	31 **Ga** 69.72 Gallium	32 **Ge** 71.61 Germanium	33 **As** 74.92 Arsenic	34 **Se** 78.96 Selenium	35 **Br** 79.90 Bromine
37 **Rb** 85.47 Rubidium	38 **Sr** 87.62 Strontium	39 **Y** 88.91 Yttrium	40 **Zr** 91.22 Zirconium	41 **Nb** 92.91 Niobium	42 **Mo** 95.94 Molybdenum	43 **Tc** 97.91 Technetium	44 **Ru** 101.07 Ruthenium	45 **Rh** 102.91 Rhodium	46 **Pd** 106.42 Palladium	47 **Ag** 107.87 Silver	48 **Cd** 112.41 Cadmium	49 **In** 114.82 Inidum	50 **Sn** 118.71 Tin	51 **Sb** 121.76 Antimony	52 **Te** 127.60 Tellurium	53 **I** 126.90 Iodine
55 **Cs** 132.91 Caesium	56 **Ba** 137.33 Barium	57 – 71	72 **Hf** 178.49 Hafnium	73 **Ta** 180.95 Tantalum	74 **W** 183.84 Tungsten	75 **Re** 186.21 Rhenium	76 **Os** 190.23 Osmium	77 **Ir** 192.22 Iridium	78 **Pt** 195.08 Platinum	79 **Au** 196.97 Gold	80 **Hg** 200.59 Mercury	81 **Tl** 204.38 Thallium	82 **Pb** 207.2 Lead	83 **Bi** 208.98 Bismuth	84 **Po** 208.98 Polonium	85 **At** 209.99 Astatine
87 **Fr** (223.02) Francium	88 **Ra** 226.03 Radium	89 - 103	104 **Unq** 261.11	105 **Unp** 262.11	106 **Unh** 263.12	107 **Uns** 262.12	108 **Uno** 265.00	109 **Une** 265								

57 **La** 138.91 Lanthanum	58 **Ce** 140.12 Cerium	59 **Pr** 140.91 Praseodymium	60 **Nd** 144.24 Neodymium	61 **Pm** 144.91 Promethium	62 **Sm** 150.36 Samarium	63 **Eu** 151.97 Europium	64 **Gd** 157.25 Gadolinium	65 **Tb** 158.93 Terbium	66 **Dy** 162.50 Dysprosium	67 **Ho** 164.93 Holmium	68 **Er** 167.26 Erbium	69 **Tm** 168.93 Thulium	70 **Yb** 173.04 Ytterbium	71 **Lu** 174.97 Lutetium
89 **Ac** 227.03 Actinium	90 **Th** 232.04 Thorium	91 **Pa** 231.04 Protactinium	92 **U** 238.03 Uranium	93 **Np** 237.05 Neptunium	94 **Pu** 244.0 Plutonium	95 **Am** 243.06 Americium	96 **Cm** 247.07 Curium	97 **Bk** 247.07 Berkelium	98 **Cf** 251.08 Californium	99 **Es** 252.08 Einsteinium	100 **Fm** 257.10 Fermium	101 **Md** 260 Mendelevium	102 **No** 259.10 Nobelium	103 **Lr** 262.11 Lawrencium

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2020/2021 ACADEMIC YEAR
UNIVERSITY MIDYEAR EXAMINATIONS

November 25, 2021

CHE 4715: ESSENTIALS OF MEDICINAL CHEMISTRY

TIME ALLOWED: THREE (3) HOURS

INSTRUCTIONS:

1. **Answer any four (4) questions.**
2. Each question carries 25 marks.
3. Present your answers in a logical manner.
4. Ensure that you have 6 printed pages and 5 questions.
5. A graph paper is provided.

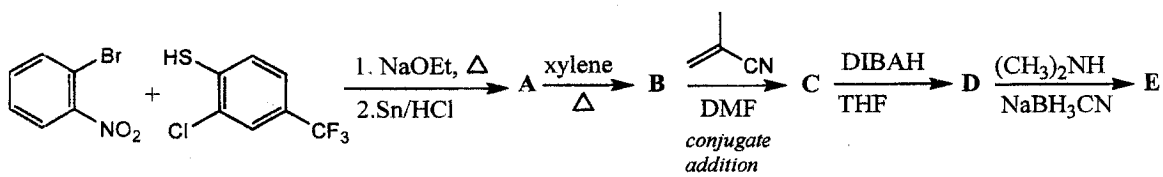
QUESTION ONE

(a) Provide a scientific rationale for the use of plant materials and aqueous decoctions prepared from them as traditional medicine for treatment of human diseases. **(3 marks)**

(b) Briefly describe a laboratory test for detection of alkaloids and flavonoids in herbal medicines. **(4 marks)**

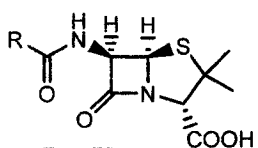
(c) State the principal ethno medicinal uses of the following: **(6 marks)**
(i) Wine Grape *(Vitis vinifera)*
(ii) Green Tea *(Camellia sinensis)*
(iii) Ginger *(Zingiber officinale)*

(d) Deduce the structure of an antidepressant drug **E** from the following synthesis. Identify the intermediates **A-D.** **(6 marks)**

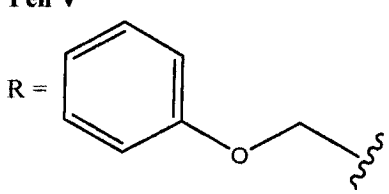


(e) Naturally occurring penicillins are orally ineffective for treatment of bacterial infections. Explain. **(3 marks)**

Naturally Occurring Penicillins:



Pen V



(f) Define the term *neurotransmitter* and give the structure and name of a neurotransmitter which is implicated in the etiology of depression. **(3 marks)**

QUESTION TWO

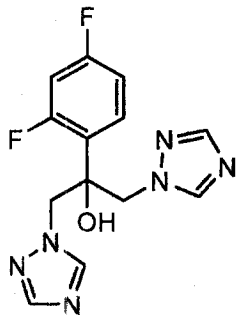
(a) Briefly explain the mechanism of antifungal action of amphotericin B (AMB). **(3 marks)**

(b) State the principal medicinal application and briefly explain the mechanism of action of the following drugs: **(9 marks)**

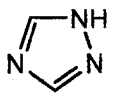
(i) Primaquin
(ii) Gabapentin

(iii) AZT

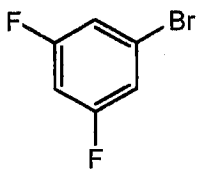
(c) Propose an efficient synthesis for an antifungal drug, fluconazole, from 1*H*-1,2,4-triazole and **(1),** assuming that all needed reagents are available. Show all steps, including intermediates clearly. **(6 marks)**



fluconazole



1*H*- 1,2,4-triazole



(1)

(d) (i) What is meant by drug synergism? **(2 marks)**

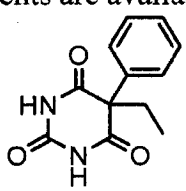
(ii) Briefly explain synergistic action of antimicrobial drugs sulfamethoxazole and trimethoprim. **(4 marks)**

(iii) State two clinical applications of trimethoprim. **(1 mark)**

QUESTION THREE

(a) (i) Provide a synthesis for phenobarbital from non-heterocyclic starting materials. Assume that all needed reagents are available. **(5 marks)**

Phenobarbital:



(ii) Briefly explain the mechanism of anticonvulsant action of phenobarbital. **(3 marks)**

(b) Briefly explain how β-lactam antibiotics are inactivated by Gram negative cocci. **(3 marks)**

(c) In the following pairs of species, identify the stronger hydrogen bond donor (HBD) or hydrogen bond acceptor (HBA). Justify your choice. **(6 marks)**

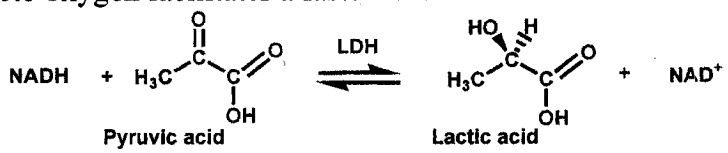
(i) Carboxylate (CO_2^-) ion or Carboxylic acid (CO_2H) (identify stronger HBA)

(ii) Methylamine or Trimethylamine (identify stronger HBA)

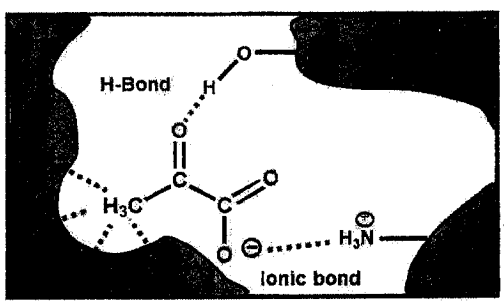
(iii) CH_3NH_2 or $CH_3NH_3^+$ (identify stronger HBD)

(d) In **not more than three sentences**, explain how protein quaternary structure differs from tertiary structure. **(3 marks)**

(e) Pyruvic acid is converted to lactic acid via a Lactate dehydrogenase (LDH)-catalyzed reduction as shown below. Prior to reduction, pyruvic acid binds to the binding site of the LDH enzyme via intermolecular interactions shown below. Explain how hydrogen bonding to the keto oxygen facilitates a faster reaction. **(5 marks)**

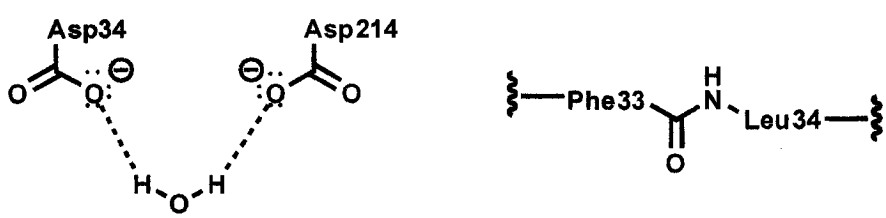


NADH = Nicotinamide adenosine dinucleotide (reducing agent & cofactor)



QUESTION FOUR

(a) Plasmepsin II is an aspartic protease expressed during the asexual blood stage of the malaria parasite development and is said to be involved in the degradation of host haemoglobin. This involves the hydrolysis of the peptide bond mediated by two aspartic acid residues Asp34 and Asp214 (see structures below) in its catalytic site. The first step is the generation of a hydroxide ion through deprotonation of a water molecule by Asp214. On this basis, give a full push-arrow mechanism for the hydrolysis of the shown peptide bond. **(5 marks)**



(b) The Michaelis-Menten equation is given below:

$$v = \frac{v_{max}[S]}{(K_M + [S])}$$

Where
[S]: substrate concentration
v: velocity of the reaction

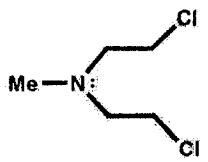
v_{max}: maximum velocity of the reaction
K_M: Michaelis-Menten constant or enzyme affinity

(i) Show that $K_M = [S]$ when v is 2-times lower than v_{max}. **(4 marks)**

(ii) Derive the linear form of the Michaelis-Menten's equation (Lineweaver–Burk plot). Show your working clearly. **(4 marks)**

(iii) Assume that the reaction catalyzed by an enzyme follows Michaelis-Menten kinetics. If at a substrate concentration of 100 nM, the reaction proceeds at 98% of v_{max}, calculate the K_M for this substrate? **(4 marks)**

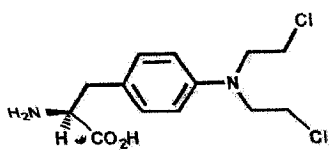
(c) Chlormethine (structure shown below), an anticancer agent, is a nitrogen mustard first used medicinally in 1942.



(i) With the aid of push-arrow mechanistic details, briefly describe the mechanism of action behind its anticancer properties. **(4 marks)**

(ii) Chlormethine is associated with toxic side effects. Judging from its structure, explain why this is expected. **(2 marks)**

(iii) Analogues designed later such as Melphalan (shown below) are less toxic. Suggest why this is the case. ***(2 marks)***



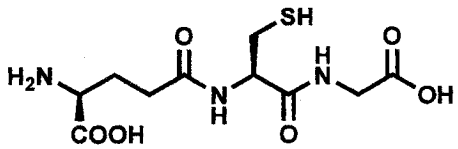
Melphalan

QUESTION FIVE

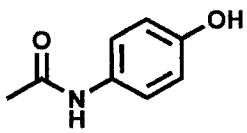
(a) After an IV bolus dose of 500 mg, the following data was collected. Determine the elimination rate constant and the apparent volume of distribution. **(20 marks)**

Time (h)	1	2	3	4	6	8	10
C_p (mg/L)	72	51	33	20	14	9	4

(b) Glutathione (shown below) is a tripeptide which contains a cysteine residue with a nucleophilic thiol group. Glutathione reacts with electrophilic species in the body from phase I reactions which would otherwise damage biomolecules. An example is the detoxification of the reactive metabolite of acetaminophen (also known as paracetamol, shown below).



Glutathione (GSH)



Acetaminophen

(i) Draw the structure of the toxic quinone imine metabolite of acetaminophen. **(1 mark)**

(ii) Use the push arrow mechanism to show how glutathione detoxifies the toxic quinone imine metabolite of acetaminophen. **(4 marks)**

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
School of Natural Sciences
Department of Computer Science

FINAL EXAMINATION

CSC 2000
Computer Programming

Date: 19th November 2021
Time: 09:00hrs – 12:00hrs
Duration: 3 Hours
Venue: NSLT

Instructions

1. There are **two (2) sections** in this exam paper.
2. Only the java programming language should be used in this exam
3. *Answer all* the questions in **Section A** and choose *any three (3)* questions from **Section B**

SECTION A. Short answers (40 marks)

You are required to answer all questions in this section.

1. It is often argued that one can only claim to have grasped the key concepts of Object Oriented Programming if they understand inheritance. Shapes are often used to demonstrate inheritance. In this question you are required to develop an inheritance hierarchy that is built on a Polygon class.

   a. Write code for the polygon base class which has abstract methods area() and perimeter(). **[3 marks]**

   b. Write code for class Triangle, which extend the Polygon base class, with mathematically valid implementations of the area() and perimeter() methods. **[6 marks]**

   c. Isosceles and Equilateral triangles are special kinds of triangles. An Isosceles triangle is a triangle that has two sides of equal length and Equilateral triangle is one with all sides being equal. Write classes for the two types of triangles exhibiting the appropriate inheritance relationships. **[6 marks]**

   d. In a triangle, the sum of any two sides is always greater than the other side. The Triangle class must adhere to this rule. Create an IllegalTriangleException class, and modify the constructor of the Triangle class to throw an IllegalTriangleException when a triangle is created with sides that violate the rule. **[5 marks]**

2.

   a. What is an Object and a Class? **[4 marks]**

   b. Clearly explain what each part of the method declaration below implies. **[4 marks]**

   ```
   public static void main(String args[])
   ```

   c. How does Java achieve platform independence? **[4 marks]**

   d. Briefly discuss any four key characteristics of Java. **[4 marks]**

   e. What are the four access modifiers in Java **[4 marks]**

SECTION B (40 marks)

Answer any three (3) of the five (5) questions in this section. Each question carries **20 marks**

1. You have been tasked to write code for a class called GradesCount.
   a. What is an array? **[2 marks]**
   b. The class reads a list of scores from the keyboard (integer numbers in the range 0 to 100). It prompts a user with a "---Please enter a score between 0 and 100 or -1 to quit --- " message each time before reading the next integer. **[4 marks]**
   c. Store the scores in one array and the grades in a corresponding parallel array. Each score is graded as either A, B, C, D or F as follows: 90 to 100 = A, 80 to 89 = B, 70 to 79 = C, 60 to 69 = D, and 0 to 59 = F. **[6 marks]**
   d. It has a method that outputs the total number of each type of grade i.e the number of As, Bs, Cs, Ds and Fs. **[4 marks]**
   e. It also has a method that computes the average score and grade. **[4 marks]**

For example, if the input is:
38
86
92
55
83
42
90
-1

For example, if the input is:
then the output should be:
Total number of grades = 7
Number of A = 2
Number of B = 2
Number of C = 0
Number of D = 0
Number of F = 3
The A grades are: 92, 90

2. Consider the following problem from a requirement specification:

   "If a customer enters a store with the intention of buying a toy for a child, then advice must be available within a reasonable time concerning the suitability of the toy for the child. This will depend on the age range of the child and the attributes of the toy. If the toy is a dangerous item, then it is unsuitable."

   Identify the classes and their members (fields and methods/behaviours) from this requirement. Write a simple java program that simulates/implements the above specification.

3. More often than not, one is required to repeat a task until some condition is met or broken. For this most programming languages have constructs for looping.
   a. What is a loop? **[2 marks]**
   b. How are conditions related to loops? **[2 marks]**

c. Write code that demonstrates at least two different ways of implementing loops in Java. **[4 marks]**
d. Write a program that prints numbers from 1 to 10 on the screen. **[4 marks]**
e. A Fibonacci sequence is defined as a series of numbers in which each number (Fibnacci number) is the sum of the two preceding numbers. The simplest is the series 0 1, 1, 2, 3, 5, 8, etc. This is the set of the first 7 numbers in the Fibonnaci sequence. Write a program to print a Fibonacci series of n terms where n is input by user. In our sample series n is 7. **[8 marks]**

4. Good programming requires that one develops conventional skills and norms. With such skills a good programmer can write code that is easier to understand thereby maintain by other programmers.
   a. List all the Java primitive data types? **[4 marks]**
   b. Write the commands you would use to compile and execute code contained in a file name *"HelloWorld.java"*. **[4 marks]**
   c. What are the simple rules to giving a valid identifier name? **[3 marks]**
   d. What are the conventions used to name Classes, constants and variables? **[3 marks]**
   e. Why is it important to properly comment your code? **[2 marks]**
   f. What is wrong with the following code? **[4 marks]**

```
public class String Programs {
      static void main(String[10] args){
            String s = "abc"
            System.out.println(s);
      }
}
```

5.
   a. Illustrate and explain state transitioning of a java thread. **[6 marks]**
   b. In Java programming an object is said to have both state and behavior. What does Java use to define state and behavior? **[4 marks]**
   c. While designing a program, a programmer notes that variable a needs to accessible to all classes in the same package only, variable b can be accessed from anywhere, variable c should only be accessed from inside the same class and variable d is accessible only to classes in the same package and to its subclasses. All variables are of type integer. Write code to declare the variables clearly showing the access modifiers. **[4 marks]**
   d. Briefly explain the types of programming errors a programmer may encounter in java. **[6 marks]**

The end of this examination paper

THE UNIVERSITY OF ZAMBIA

School of Natural Sciences

Department of Computer Science

CSC 2101
COMPUTER SYSTEMS

FINAL EXAMINATION

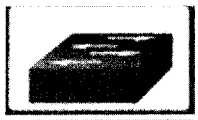
Date: 22th NOVEMBER, 2021
Time: 09:00 – 12:00 HOURS
Duration: 3 Hours
Venue: SPORTS HALL

INSTRUCTIONS

1. This exam paper has **Seven (7)** questions.
2. Answer **ANY FIVE (5)** questions.
3. Clearly identify the problem being solved.
4. Use the marks as a guide to the detail required in your answers while keeping your answers concise and relevant.

QUESTION ONE

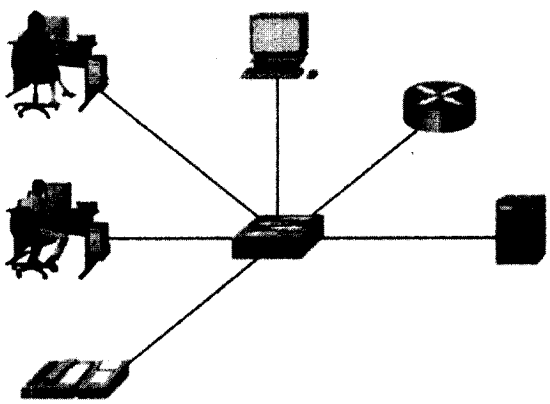
1. Computer networks connect devices and users to one another.
   a. What is the role of an intermediary device in a network? [**1 mark**]
   b. For each of the following, name the intermediary device and state its function.[**3 marks**]

i. 

ii. 

iii. 

   c. Consider the following network diagram. State the network topology name and outline its characteristics. **[3 marks]**



2. The TCP/IP model consists of layers that perform functions necessary to prepare data for transmission over a network.
   a. What does the acronym TCP/IP stand for? [**1 mark**]
   b. Outline the three basic operations of reliability with respect to TCP. [**3 marks**]
   c. Name the layers on the TCP/IP model and identify the layers where TCP and IP protocols are located. [**3 marks**]
3. When you use a web browser, you can have more than one tab open at a time. Explain how your computer knows which browser tab to deliver the web content to. [**3 marks**]
4. Distinguish between DHCP and DNS servers. [**3 marks**]

QUESTION TWO

1. All motherboards need BIOS to operate.
    a. What does the acronym BIOS stand for? [**1 mark**]
    b. Outline three (3) settings/features that are identified by BIOS. [**3 marks**]
    c. Name the component that is used to save BIOS settings. [**1 mark**]
    d. *LoJack* is a BIOS security feature that consists of two programs.
        i. Name the two (2) programs. [**2 marks**]
        ii. State the three (3) functions that a device owner can perform by using LoJack. [**3 marks**]

2. Match the term to the description: Noise, Spike, Power surge, Blackout, Brownout. [**4 marks**]
    a. Can be caused by a downed power line.
    b. Occurs when electrical circuits are overloaded.
    c. Sudden increase in voltage that exceeds 100 percent of the normal voltage on a line.
    d. Reduced voltage level of AC power that lasts for a period of time.
    e. Interference from generators and lightning.
    f. Can be caused by a damaged transformer.
    g. Can be caused by lightning strikes.
    h. Lasts for a few nanoseconds, or one-billionth of a second.
3. Distinguish between Pixel and Dot Pitch computer monitor terms. [**2 marks**]
4. Distinguish between Stripping and Mirroring in RAID storage technology. [**2 marks**]
5. Distinguish between Thick and Thin client computers. [**2 marks**]

QUESTION THREE

1. Organisations, both large and small, are investing heavily in virtualisation computing.
    a. Outline four (4) advantages of server virtualisation. [**4 marks**]
    b. The hypervisor, also called the Virtual Machine Manager (VMM), is the brain of virtualization.
        i. Why is a hypervisor termed the brain of virtualization? [**1 mark**]
        ii. With the aid of a diagram, distinguish between a Type 1 (native) hypervisor and Type 2 (hosted) hypervisor. [**5 marks**]
2. Organisations, both large and small, are investing heavily in cloud computing.
    a. Explain how each of the following cloud services operates. [**6 marks**]
        i. Software as a Service (SaaS)
        ii. Platform as a Service (PaaS)
        iii. Infrastructure as a Service (IaaS)
    b. Outline four (4) characteristics of cloud computing models. [**4 marks**]

QUESTION FOUR

1. Identify the steps in the troubleshooting process of computer problems, including a brief description and **ONE** example activity for each step. Use the table format below to organise your answer. [**12 marks**]

Step	Description	Activity

2. Answer **True** or **False**
   a. Less computer downtime is a benefit of doing frequent preventive maintenance on a desktop PC.
   b. Fewer security breaches are a benefit of doing frequent preventive maintenance on a desktop PC.
   c. Longer equipment life is a benefit of doing frequent preventive maintenance on a desktop PC.
   d. Fewer spam emails is a benefit of doing frequent preventive maintenance on a desktop PC.
   e. System access to more RAM is a benefit of doing frequent preventive maintenance on a desktop PC.
   f. Elimination of hardware component failure is a benefit of doing frequent preventive maintenance on a desktop PC.
   g. Cost saving is a benefit of doing frequent preventive maintenance on a desktop PC.
   h. Elimination of updating operating software is a benefit of doing frequent preventive maintenance on a desktop PC.
   i. A technician would require the use of an anti-static wrist strap during preventive maintenance on a desktop PC.
   j. A technician would require the use of a lint-free cloth during preventive maintenance on a desktop PC.
   k. A technician would require the use of a can of compressed air during preventive maintenance on a desktop PC.
   l. A technician would require the use of cotton swabs during preventive maintenance on a desktop PC.
   m. A technician would require the use of an industrial vacuum cleaner during preventive maintenance on a desktop PC.
   n. A technician would require the use of a screw driver during preventive maintenance on a desktop PC.
   o. A technician would require the use of a hammer during preventive maintenance on a desktop PC.
   p. A technician would require the use of a duster during preventive maintenance on a desktop PC.

QUESTION FIVE

1. Answer **True** or **False. [5 marks]**
    a. iOS allows both automatic and scheduled Antivirus scans.
    b. Running apps in a sandbox helps mitigate damage to mobile devices by malicious software.
    c. Rooting is a method for removing restrictions on modifying code on an iOS device.
    d. Jailbreaking exploits vulnerabilities on iOS devices and is completely reversible.
    e. Updates and patches for Android devices are not released as one package for all devices.
    f. The swipe lock is considered the most secure method of preventing unauthorised access to a mobile device.
    g. Requiring the user to draw a pattern on the careen with their finger is a feature of the fingerprint lock.
    h. Some mobile devices can be unlocked by scanning a user's facial features.
    i. The iOS Erase Data feature will delete all data on the device after 3 failed passcode attempts.
    j. iOS devices store passcodes in plain text in flash memory.

2. State the function performed by each of the following CLI Commands. [**5 marks**]
    a. cp
    b. mkdir
    c. rm
    d. pwd
    e. cd
3. A good change management process can prevent business functions from being negatively impacted by the updates, upgrades, replacements, and reconfigurations that are a normal part of IT operations.

    Identify the steps in a typical change management process, including **TWO** example questions for each step. Use the table format below to organise your answer. [**10 marks**]

Step	**Question**

QUESTION SIX

1. Distinguish between a virus and a trojan horse. [**2 marks**]
2. Outline the seven-step best practice procedure for malware-removal. [**7 marks**]
3. Explain how each of the following types of TCP/IP attacks works. [**3 marks**]
    a. Denial of service

b. Spoofing
c. DNS poisoning

4. One of the first tasks of a technician is to identify a customer's problem. Explain each of the following general rules for talking with customers. **[3 marks]**
   a. Know
   b. Relate
   c. Understand
5. Outline the five major phases of a disaster recovery plan. **[5 marks]**

QUESTION SEVEN

1. Electrostatic Discharge (ESD) can cause permanent damage to electrical components of a computer.
   a. Explain how ESD is caused? **[1 mark]**
   b. Approximately how many volts of static electricity must build up before a person can feel ESD? **[1/2 mark]**
   c. Approximately how many volts of static electricity can damage a computer component? **[1/2 mark]**
   d. Outline four (4) recommendations to help prevent ESD damage. **[2 marks]**
2. The computer case is an important component of a computer.
   a. Outline any three (3) functions of computer cases **[3 marks]**
   b. Mention two (2) other terms used to refer to computer cases. **[1 mark]**
3. The power supply includes several different connectors, which are said to be *"keyed"*.
   a. What does the term *keyed* mean? **[1 mark]**
   b. Name the component powered by each of the connectors listed below.**[3 marks]**
      i. A 20-pin or 24-pin slotted connector
      ii. Molex keyed connector
      iii. Berg keyed connector
4. Distinguish between Pin Grid Array (PGA) and Land Grid Array (LGA) CPU architectures. **[2 marks]**
5. Distinguish between the Northbridge and Southbridge motherboard chipsets. **[2 marks]**
6. Distinguish between active and passive cooling solutions in computers. **[2 marks]**
7. Distinguish between LCD and LED monitor technologies in computers. **[2 marks]**

The End

THE UNIVERSITY OF ZAMBIA
School of Natural Sciences
Department of Computer Science

CSC 2111
COMPUTER ARCHITECTURE

FINAL EXAMINATION

Date: 16th NOVEMBER, 2021
Time: 14:00 – 17:00 HOURS
Duration: 3 Hours
Venue: GLT

INSTRUCTIONS

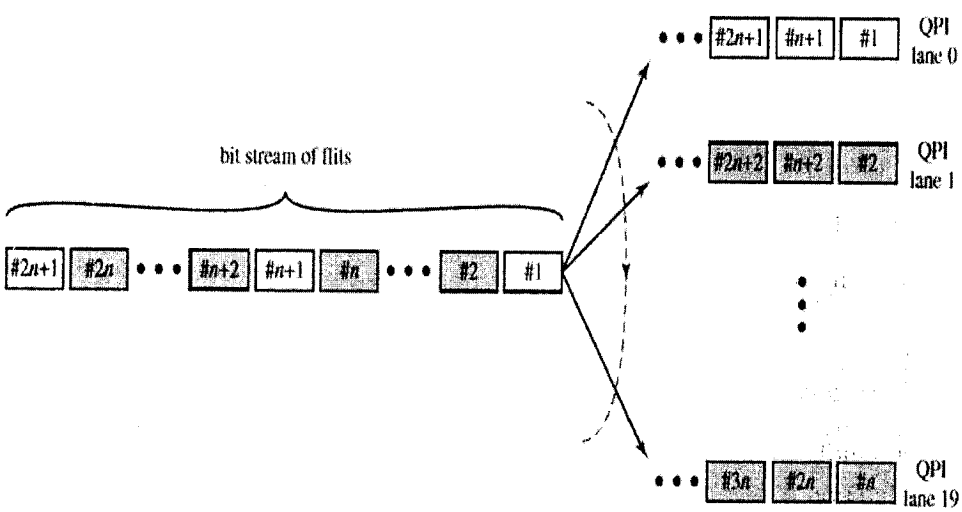
1. This exam paper has **Seven (7)** questions.
2. Answer **ANY FIVE (5)** questions.
3. Clearly identify the problem being solved.
4. Use the marks as a guide to the detail required in your answers while keeping your answers concise and relevant.

QUESTION ONE

1. Distinguish among multicore, MIC, and GPGPU organisations. [**5 marks**]
2. Consider a processor having four types of instruction classes, A, B, C and D, with the corresponding CPI values 1.1, 1.7, 2.8 and 3.5 respectively. The processor runs at a clock rate of 2 GHz. For a given program, the instruction counts for the four types of instructions are 20, 15, 12 and 5 million respectively.
    a. Define the following terms:
        a. Instruction Count. [**2 marks**]
        b. Average Cycles per Instruction. [**2 marks**]
        c. Clock rate. [**2 marks**]
    b. Calculate the overall CPI of the processor for this program. [**3 marks**]
    c. Calculate the processor time needed to execute this program? [**3 marks**]
    d. Calculate the MIPS rating of the processor for this program. [**3 marks**]

QUESTION TWO

1. Provide a detailed explanation as to why arbitration is found in Bus interconnection and not in Point-to-Point systems. [**4 marks**]
2. Consider the figure below and answer the questions that follow:



    a. What is a flit? [**2 marks**]
    b. What distribution technique is shown in the figure? [**2 marks**]
    c. Provide a detailed explanation as to why the bit stream of flits is being distributed as shown in the figure. [**4 marks**]

3. Assuming a CPU and memory share an 8-bit data and address bus running at 250MHz. The memory needs 20 nanoseconds (ns) to access a 16-bit value from one address.

   a. What is the amount of memory that can be addressed by this system? **[2 marks]**

   b. What is the bus transfer speed of this system? **[2 marks]**

   c. How many cycles does the memory need to access one address? **[4 marks]**

QUESTION THREE

1. Consider a simple computer in which both instructions and data are 8 bits long: (Opcode = 4 bits and memory location or I/O device = 4 bits).

Address	Memory
0000	0100 0100
0001	0101 0101
0010	0110 0110
0011	0111 0000
0100	0001 1000
0101	0001 0001
0110	0000 0000

Its opcodes are as follows:

```
4 = Load AC from memory
5 = Add to AC from memory
6 = Store AC to memory
7 = Halt
```

   a. Using the format below to keep track of the state of the registers while the programme loaded into memory is executing, SIMULATE the fetch/execute process **[10 marks]. NOTE:** Use decimal notation in your solution.

	Fetch	Execute
Step 1	PC: 0	PC:
	IR:	IR:
	AC:	AC:
	MAR:	MAR:
	MBR:	MBR:

2. Consider the point in program execution at which the opcode `6 = Store AC to memory` is executed. Generate the error correcting code for the data that is to be stored in the memory **[10 marks]**

QUESTION FOUR

1. With the aid of a diagram, discuss the hierarchy of the memory subsystem in terms of:
   a. How it is structured. **[2 marks]**
   b. The features of the hierarchy. **[4 marks]**
   c. The trade-offs that it addresses. **[2 marks]**
2. Methods of accessing units of data in the memory include *direct* and *random*.
   a. Explain how the two methods work. **[4 marks]**
   b. Explain how the performance parameter ***access time*** differs for the methods. **[2 marks]**
   c. Explain what the performance parameter **Transfer rate** measures? **[2 marks]**
   d. Hence, show the transfer rate formula for random access method. **[4 marks]**

QUESTION FIVE

1. Based on the presented memory address, outline how direct mapping works. **[2 marks]**
2. A computer system uses 16-bit memory addresses. It has a 2K-byte cache organised in a direct-mapped manner with 64 bytes per cache block. Assume that the size of each memory word is 1 byte.
   a. Calculate the number of bits in each of the Tag, Line, and Word fields of the memory address. **[6 marks]**
   b. When a program is executed, the processor reads data sequentially from the following word addresses:

      Access # 1: 128
      Access # 2: 144
      Access # 3: 2176
      Access # 4: 2180
      Access # 5: 128
      Access # 6: 2176

      All the above addresses are shown in decimal values. Assume that the cache is initially empty.

      Task: For each of the above addresses, indicate whether the cache access will result in a hit or a miss. **Show your working [12 marks]**

QUESTION SIX

1. Match items from the following list of computing inventions to the statements below: **Abacus, Pascaline, Schickard's Calculator, Harvard Mark I, ENIAC. [5 marks]**
    a. The first calculator in which each number inputted modified others as gears would interact with each other mechanically.
    b. The first adding machine produced in modest quantity.
    c. The world's first general purpose electronic digital computer.
    d. Credited as the earliest recognised device for computing.
    e. Was built from both electronic components such as relays and mechanical components.
2. State the three (3) different types of technology by which electronic computer inventions can be organised. **[3 marks]**
3. In computing history, the IAS computer is credited as the prototype of all subsequent general-purpose computers.
    a. Explain why the IAS was credited as such? **[4 marks]**
    b. What was the capacity of the IAS's main memory? **[4 marks]**
    c. Explain how an IAS instruction was designed. **[4 marks]**

QUESTION SEVEN

Only two fundamental types of small electronic components are required for performing the storage, movement, processing, and control functions of a computer: ***logic gates*** and ***memory cells.***

1. Match the electronic components to the function they perform, i.e., storage, movement, processing and control. **[2 marks]**
2. Draw the symbol and truth table for the following three (3) gates:
    a. AND Gate **[3 marks]**
    b. XOR Gate **[3 marks]**
    c. NAND Gate **[3 marks]**
3. Outline the properties of a memory cell. **[3 marks]**
4. With the aid of a diagram, describe the operations of a memory cell. **[6 marks]**

The End

THE UNIVERSITY OF ZAMBIA
School of Natural Sciences
Department of Computer Science

OPERATING SYSTEMS
CSC2202

FINAL EXAMINATION

Date: Thursday, 28th November 2021
Venue: NSLT
Time: 09 – 12hrs
Duration: 3hrs

Instructions

1. This exam has two sections A and B.
2. Answer **ALL** the questions from **Section A.**
3. Answer any **three (3)** questions from **Section B.**
4. **Total number of questions answered should be 5.**
5. Write your answers on a separate answer sheet.

SECTION A (Answer all questions)

QUESTION 1 (20 marks)

A. **[2 marks]** What other hardware mechanism can be used on a uniprocessor to achieve mutual exclusion?

B. **[3 marks]** What are the three main purposes of an operating system?

C. **[2 marks]** List two reasons why an operating system designer might choose not to have user threads map 1:1 with kernel threads.

D. **[3 marks]** For each of the following traps, indicate whether the trap is synchronous or asynchronous with respect to a user-level program.

   i. System call
   ii. Exception
   iii. Interrupt

E. **[2 marks]** Why might it be advantageous to keep a process running on the same processor on which it last ran (this is called processor affinity)?

F. **[4 marks]** Imagine that you've been asked to build an operating system for a simple embedded processor. The processor has no virtual memory and no memory translation unit. What functionality must you build into your process loader if you wish to have multiple programs resident in memory?

G. **[4 marks]** In a system with virtual memory, how can you share memory between two processes?

QUESTION 2 (20 marks)

For each synchronization problem described below, select the best synchronization primitives to solve the problem. You may use each primitive as many times as you need to. Briefly, explain why you chose the primitive you did. Select the synchronization primitive from the following list:

1. Counting semaphore
2. Binary semaphore
3. Lock (w/out a CV)
4. Lock and condition variable

A. **[4 marks]** A common problem in soccer collisions between players jumping for headers (this often leads to concussions). They've decided that clever CSC2202 students could easily solve this problem with a synchronization primitive that would arbitrate which player got to jump up for the header (such primitives would have to be very high performance). Which primitive would you suggest?

B. **[4 marks]** Mrs. Kumar was making pancakes for hungry teenagers. The pancakes come out in batches of three. She'd like a synchronization primitive that would allocate pancakes to teenagers without fighting. (There is no need to worry about leftovers between batches all pancakes are consumed pretty much instantly.) Suggestions?

C. **[4 marks]** You are competing in a new Olympic event called a distributed relay. One team member must run one lap at the UNZA track. The next team member must run a lap at the CBU track. The third team member runs a lap at Mulungushi track and the last team member runs a lap at the UNILUS track. Each runner must not start until the previous runner has completed his/her lap. Naturally, the traditional passing of the baton or slapping of the hands won't work, so they've turned to you, to provide the proper synchronization. What mechanism do you use?

D. **[4 marks]** Competition for parking in UNZA carpark has become brutal due to the massive quantities of potholes accumulating on our streets. The traditional use of space savers (things like cones or lawn chairs that mark a spot as being "owned" because someone invested the physical labor in shoveling it out) has become too contentious and the UNZA Department of Engineering is looking for a better solution. They've decided to have security hand out parking tokens and any car without a visible token will be towed to the far reaches of the universe. Each security has a token check-in point and cars must drive to the check-in point to obtain a token for a specific spot and return a token when they leave a spot (cars that do not return tokens within seven minutes of leaving a spot are subject to enormous fines). They would like the check-in points to operate as efficiently as possible, allocating and deallocating spots in parallel as much as possible. What synchronization primitive(s) should they use?

E. **[4 marks]** It is well known that graduate students (as well as many others) are motivated by free food. After the first couple of years (once classes are complete), a graduate student's day consists mostly of doing research and periodically checking email to determine if anyone has announced any free food lately. Unfortunately, the better research is going, the less likely students are to check email, and by the time they get to the location of the free food, it's often gone. (While they could configure their mail to alert them every time a new message comes in, most messages do not concern free food, so this would be quite distracting.) There must be a better way can you propose use of a synchronization primitive that would let them receive/see messages only when they concerned free food?

SECTION B (Choose any three)

QUESTION 3 (20 marks)

A. **[5 marks]** Consider a machine with a physical memory of 8 GB, a page size of 8 KB, and a page table entry size of 4 bytes. How many levels of page tables would be required to map a 46-bit virtual address space if every page table fits into a single page? Be explicit in your explanation.

B. **[4 marks]** List the fields of a Page Table Entry (PTE) in your scheme.

C. **[3 marks]** Without a cache or TLB, how many memory operations are required to read or write a single 32-bit word?

D. **[6 marks]** Briefly describe two approaches to avoiding deadlock.

E. **[2 marks]** List two events that may take a process to a ready state.

QUESTION 4 (20 marks)

A. **[6 marks]** How much physical memory is needed for a process with three pages of virtual memory (for example, one code, one data, and one stack page)?

B. Think of the various deadlock detection and prevention algorithms we've discussed in this course and consider the following snapshot of a system with five processes (P1, P2, P3, P4, P5) and four resources (R1, R2, R3, R4). There are no current outstanding queued unsatisfied requests.

Currently Available Resources

R1	R2	R3	R4
2	1	2	0

	Current Allocation				Max Need				Still Needs			
Process	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R
P1	0	0	1	2	0	0	3	2	0	0	2	0
P2	2	0	0	0	2	7	5	0	0	7	5	0
P3	0	0	3	4	6	6	5	6	6	6	2	2
P4	2	3	5	4	4	3	5	6	2	0	0	2
P5	0	3	3	2	0	6	5	2	0	3	2	0

1. **[5 marks]** Is this system currently deadlocked, or can any process become deadlocked? Why or why not? If not deadlocked, give an execution order.

2. **[3 marks]** If a request from a process P1 arrives for (0, 4, 2, 0), can the request be immediately granted? Why or why not? If yes, show an execution order.

3. **[3 marks]** If a request from a process P2 arrives for (0, 1, 2, 0), can the request be immediately granted? Why or why not? If yes, show an execution order.

C. **[3 marks]** Explain why mobile operating systems such as iOS and Android do not support swapping?

QUESTION 5 (20 marks)

A. For each of the following pairs of terms, identify the context(s) in which they occur. Then define each term and clarify the key difference(s) between the two terms.
   1. "host OS" and "guest OS" **[3 marks]**
   2. "page" and "frame" **[3 marks]**
   3. "reference bit" and "dirty bit" **[3 marks]**
   4. "file" and "directory" **[3 marks]**
   5. "disk partition" and "file system volume" **[3 marks]**

B. **[5 marks]** When multiple processes need to cooperate, there is a choice between shared memory and inter-process communication (IPC). Compare and contrast these two techniques. Make sure to clarify the role of the operating system in each.

QUESTION 6

A. **[4 marks]** What is a process? What is a thread? How are they similar/different?

B. **[6 marks]** There are many system processes active on any Linux system. These are typically created at system startup, and operate in the background as daemon processes. Give three examples of system (daemon) processes in a Linux system, and briefly state their role in the operation of the system.

C. **[4 marks]** One of the design decisions in OS memory management is the choice between swapping and paging. Define each of these terms, and clarify their respective roles in OS memory management.

D. **[6 marks]** Below are three different techniques for organizing the data blocks for each file in a file system. Briefly describe each approach, identifying the strengths and weaknesses of each.

1. Contiguous allocation
2. Linked allocation
3. Indexed allocation.

QUESTION 7

A. **[6 marks]** The readers and writers problem can be formulated in several ways with regard to which category of processes can be started when. Carefully describe ***three*** different variations of the problem, each one favoring (or not favoring) some category of processes. For each variation, specify what happens when a reader or a writer becomes ready to access the database, and what happens when a process is finished.

B. **[4 marks]** Two computer science students, Keziah and Haward, are having a discussion about inodes. Keziah maintains that memories have gotten so large and so cheap that when a file is opened, it is simpler and faster just to fetch a new copy of the i-node into the inode table, rather than search the entire table to see if it is already there. Haward disagrees. Who is right and why?

C. **[5 marks]** A typical printed page of text contains 50 lines of 80 characters each. Imagine that a certain printer can print 6 pages per minute and that the time to write a character to the printer's output register is so short it can be ignored. Does it make sense

to run this printer using interrupt-driven I/O if each character printed requires an interrupt that takes 50 μ sec all-in to service?

D. **[2 marks]** In which of the four I/O software layers is each of the following done.
   a. Computing the track, sector, and head for a disk read.
   b. Writing commands to the device registers.
   c. Checking to see if the user is permitted to use the device.
   d. Converting binary integers to ASCII for printing.

E. **[3 marks]** RAID level 3 is able to correct single-bit errors using only one parity drive. What is the point of RAID level 2? After all, it also can only correct one error and takes more drives to do so.

END OF EXAM

Omnium Optimi!!!

THE UNIVERSITY OF ZAMBIA

School of Natural Sciences

Department of Computer Science

FINAL EXAMINATION

DATABASES AND INFORMATIONS MANAGEMENT SYSTEMS
CSC 2702

Date:	26th NOVEMBER 2021
Time:	14:00hrs – 17:00hrs
Duration:	3 Hours
Venue:	NSLT

Instructions

1. *Answer **all** the questions in Section A.*
2. Choose ***any THREE** (3) questions in Section B.*

SECTION A

Answer ALL Questions in this section. Both questions carry an equal weight of **20 Marks**.

Question 1 [20 Marks]

i. Define the following terms briefly in not more than 3 lines: [**5 Marks**]
   a. *Database*
   b. *Database program*
   c. *Database System*
   d. *Record*
   e. *Attribute*

ii. What is a DBMS, and what are its functions? (list at least 3 functions) [**5 Marks**]

iii. Describe the main components you are likely to find in a DBMS environment? [**5 Marks**]

iv. Give at least 5 reasons why the file based system approach is desirable over the database approach. [**5 Marks**]

Question 2 [20 Marks]

i. Explain what it means to say a database displays both *entity integrity* and *referential integrity*? [**4 Marks**]

ii. Define the following terms in relation to the database: [**4 Marks**]
   a. Intentions
   b. Extension

iii. Draw a well labelled diagram of the ANSI-SPARC DBMS architecture and describe the different aspect of it. [**6 Marks**]

iv. In relation to databases, explain what a data model is. Also state three components that describe a data model? [**3 Marks**]

v. State three categories in which you can classify data models? [**3 Marks**]

SECTION B

There are FOUR questions in this section. All questions carry an equal weight of **20 Marks**. Choose only **three** (**3**) question!

Question 3

i. In relation to Relational Database Model, list at least five (5) attributes that differentiate relations from tables. [**5 Marks**]

ii. Suppose you wanted to apply for a Job in a database computing environment, what are the five (5) different roles you may likely find? [**5 Marks**]

iii. What do you mean when you say "cardinality of the relation" and "degree of the relation" when you are talking about relational databases? [**4 Marks**]

iv. What two conditions must be met before an entity can be classified as a weak entity? Give an example of a weak [**2 Marks**]

v. Discuss the difference between a composite key and a composite attribute. How would each be indicated in an Entity Relationship Diagram? [**4 Marks**]

Question 4

i. Define the following terms: [**5 Marks**]

   a. *Composite key*
   b. *Super key*
   c. *Candidate key*
   d. *Foreign key*
   e. *Primary key*

ii. Briefly describe the four (4) integrity constraints that are associated with relational database model? [**4 Marks**]

iii. What is the difference between a "view" and "base relation"? [**2 Marks**]

iv. Give at least 3 reasons why the file based system approach is undesirable over manual filing system? [**3 Marks**]

v. What three data anomalies are likely to be the result of data redundancy? [**6 Marks**]

Question 5

i. What is a partial dependency? With what normal form is it associated? [**4 Marks**]

ii. Explain the difference between "Functional Dependency" and "Transitive Dependency". [**4 Marks**]

iii. When is a relationship in ER modelling said to be "recursive"? [**2 Marks**]

iv. Define the following attributes and give example of each: [**6 Marks**]

   a. Derived
   b. Simple
   c. Composite
   d. Multi-valued

v. Briefly, but precisely, explain the difference between single-valued attributes and simple attributes. Give an example of each. [**4 Marks**]

Question 6

i. In database development process, what does the term "fact-finding" mean? [**2 Marks**]

ii. State when "fact-finding" in Q6 (i) is particularly important during database development life cycle? [**2 Marks**]

iii. Explain why "fact-finding" is crucial to the database development process? Especially to phase you have stated in Q6 (ii). [**4 Marks**]

iv. State and briefly explain the five (5) most used fact-finding techniques you may adopt for your database design.[**10 Marks**]

v. Why is a table whose primary key consists of a single attribute automatically in 2NF when it is in 1NF? [**2 Marks**]

---- End of Exam ----

THE UNIVERSITY OF ZAMBIA

School of Natural Sciences

Department of Computer Science

FINAL EXAMINATION

CSC 2901
DISCRETE STRUCTURES

Date	:	23RD NOVEMBER 2021
Time	:	14:00HRS – 17:00HRS
Duration	:	3 HOURS
Venue	:	NSLT

Instructions

1. There are **two (2) Sections** in this exam, **Section A** and **Section B**.
2. **Answer ALL the questions** in Section A and **choose any three (3) questions** in Section B

SECTION A. ANSWER ALL QUESTIONS

1) Let A and B be subsets of the U.
   a) Define
      i) $A \subseteq B$ [2 Marks]
      ii) $|A|$ [2 Marks]
      iii) The difference set, $A - B$ [2 Marks]
      iv) The symmetric difference set, $A \otimes B$ [2 Marks]
   b) State, without proof, the sum rule for two sets A and B. [2 Marks]

2) Let A be set and R be a relation defined on A. Define the following properties of R
   a) Reflexive [2 Marks]
   b) Symmetric [2 Marks]
   c) Antisymmetric [2 Marks]
   d) Transitive [2 Marks]
   e) R is a partial order [2 Marks]

3) Show that the Boolean algebra identity $x + x'y = x + y$ is true using
   a) The truth table [4 Marks]
   b) Analytical methods [4 Marks]
   c) K-map [4 Marks]

4) State the following rules of inference
   a) Modus Ponens [4 Marks]
   b) Modus Tollens [4 Marks]

SECTION B. ANSWER THREE (3) OF THE FOUR QUESTIONS

1)

a) Prove that

i) if $A \subseteq B$ then $|A - B| = |A| - |B|$ [4 Marks]

ii) $A \cap B \subseteq A \cup B$ [4 Marks]

iii) $A \otimes B = (A \cup B) - (A \cap B)$ [4 Marks]

b) Hence or otherwise, show that $|A \otimes B| = |A| + |B| - 2|A \cap B|$. [8 Marks]

2) Let $A = \{1, 2, 6, 12, 16, 24\}$ and R be a relation defined on A as follows if x and y are in A

$$xRy \; iff \; x \; is \; a \; factor \; of \; y$$

a) List the elements of R [6 Marks]

b) Show that R is a partial order on A [8 Marks]

c) Draw the Hasse diagram for R. [6 Marks]

3)

a) You are requested to design a password policy for your organization. You suggest that the passwords will consist of alphabetical letters and decimal digits. How many possible combinations of the passwords can you have, if you set

i) Password length = 8 characters with repetition [4 Marks]

ii) Password length = 8 without repletion [4 Marks]

b) A Discrete Structures class has 45 students, 27 male and 18 female. A team of 3 is to be picked from the class, to go for a completion.

i) In how many was can the team be formed? [4 Marks]

ii) In how many was can the team of both males and females be formed? [4 Marks]

iii) In how many was can the team of all males or all females? [4 Marks]

4)

a) Alice and Bob wish to have their messages encrypted using the RSA algorithm. Alice picks the following prime numbers $p = 11$ and $q = 3$ for use in this operation.

i) Suppose Alice's public key is $(7, 33)$, what is her private key? [6 Marks]

ii) Suppose Bob wants to send a plaintext message $M = 14$. What will be the ciphertext that Bob sends to Alice? [6 Marks]

b) Alice and Bob wish to share a secret key using the Diffie-Hellman (DH) key exchange algorithm. They agree to use $a = 3$ and $n = 11$. Alice picks a secret prime $p = 3$ and Bob picks his secret prime $q = 5$. What is the value the key DH will generate for them? [8 Marks]

5)

a) Given the following Boolean expression with variables x and y.

$$x' + y + x'y$$

i) Draw the logic network for the expression. [4 Marks]

ii) Simplify the expression using the K-map. [6 Marks]

iii) Draw the simplified logic network. [2 Marks]

b) Given the following propositions in the premises

[I]. $p \vee q \rightarrow r$

[II]. $\neg p \wedge r \rightarrow s$

[III]. $\neg p \wedge q$

i) Derive s [8 Marks]

**********END OF EXAMINATION**********

THE UNIVERSITY OF ZAMBIA
School of Natural Sciences
Department of Computer Science

FINAL EXAMINATION

CSC 2912
NUMERICAL ANALYSIS

Date	:	15TH NOVEMBER 2021
Time	:	14:00HRS – 17:00HRS
Duration	:	3 HOURS
Venue	:	NSLT

Instructions

1. There are **two (2) Sections** in this exam, **Section A** and **Section B.**
2. **Answer ALL the questions** in Section A and **choose any three (3) questions** in Section B

SECTION A. ANSWER ALL QUESTIONS [40 Marks]

A.1. Define the following

A.1.1. Continuity of a function [3 Marks]

A.1.2. Differentiability of a function [3 Marks]

A.1.3. Absolute error [3 Marks]

A.1.4. Relative error [3 Marks]

A.2. State without proof

A.2.1. The Taylor theorem [3 Marks]

A.2.2. Mean-value theorem [3 Marks]

A.2.3. Intermediate value theorem [3 Marks]

A.3. Explain why $f(x) = 3x^2 + 2x - 1$ has exactly one root in [0, 1] [5 Marks]

A.4. Suppose $P_{1,2}(x) = 2x$ and $P_{0,1}(x) = x^2 - 3x + 1$. What is $P_{0,1,2}(0.5)$, if $x_0 = 1.0, x_1 = 1.2$ and $x_2 = 1.4$? [7 Marks]

A.5. Suppose it is known that the function f has a unique root in the interval $[a, b]$ and you want to usr the Bisection method to approximate the solution of f to 10^{-k}. In terms of a, b and k, how many iterations of the Bisection method are required to achieve this? [7 Marks]

SECTION B. ANSWER THREE (3) OF THE FOUR QUESTIONS. ALL QUESTIONS HAVE 20 MARKS

B.1. Given the function defined on R by $f(x) = e^{\frac{x-1}{2}}$

B.1.1. Derive $P_4(x)$, the fourth Taylor polynomial approximating f at a point $x = 1$.

B.1.2. Use P to estimate $\frac{1}{\sqrt{e}}$

B.1.3. What is the error bound for this estimation?

B.1.4. What is the relative error of this estimation?

B.2. In class we derived the three-point formulae for $f'(x_0), f'(x_1)$ and $f'(x_2)$. Consider a four-point case with $(x_0, y_0), (x_1, y_1), (x_2, y_2)$ and (x_3, x_0). Derive the four-point formulae for $f'(x_0), f'(x_1), f'(x_2)$ and $f'(x_3)$.

B.3. Consider the $f(x) = x^2e^x$

B.3.1. Generate $P_4(x)$, the Lagrange polynomial using Newton's divided difference method where $x_0 = 0.2$, and h = 0.2

B.3.2. Use $P_4(x)$ to estimate $f(0.5)$

B.4. Consider the function defined on R as $f(x) = x^2e^x$

B.4.1. Use three-point numerical differentiation formula to estimate $f'(0.4)$ with $h = 0.2$

B.4.2. Estimate

$$\int_{0.0}^{1.0} f(x)dx$$

Using the composite Simpson rule with $h = 0.2$

**********END OF EXAMINATION**********

THE UNIVERSITY OF ZAMBIA

School of Natural Sciences

Department of Computer Science

FINAL EXAMINATION

CSC 3011
ALGORITHMS & COMPLEXITY

Date	:	25TH NOVEMBER 2021
Time	:	14:00HRS – 17:00HRS
Duration	:	3 HOURS
Venue	:	GLT

Instructions

1. There are **two (2) Sections** in this exam, **Section A** and **Section B**.
2. **Answer ALL the questions** in Section A and **choose any three (3) questions** in Section B

SECTION A. ANSWER ALL QUESTIONS

1)
   a) Define what an algorithm is [2 Marks]
   b) Explain why algorithm analysis is important [8 Marks]

2)
   a) Suppose you are given that $a^x = b^y$, what is x in terms of a, d and y? [2 Marks]
   b) Suppose $log(x) = 0.2$ and $log(y) = 0.8$, what is
      i) $\log(xy)$ [2 Marks]
      ii) xy [2 Marks]

3)
   a) Define what a collision in hashing is
   b) In hashing explain how
      i) A search operation works [2 Marks]
      ii) A deletion is handled [2 Marks]

4)
   a) Define recursion. [2 Marks]
   b) Describe the following four rules of recursion. [8 Marks]

5) What is the maximum number of swaps in the following sorting algorithms
   a) Bubble sort [2 Marks]
   b) Insertion sort [2 Marks]
   c) Selection sort [2 Marks]

6) What is the difference between the following
   a) AVL tree and Minheap [2 Marks]
   b) Full binary tree and perfect tree [2 Marks]

SECTION B. ANSWER THREE (3) OF THE FOUR QUESTIONS

1)
   a) Using the principle of mathematical induction to prove that [8 Marks]

$$\sum_{i=1}^{n} i = \frac{n(n+1)}{2}$$

   b) Hence, or otherwise,
      i) Evaluate the sum of all even numbers between 1000 and 4000 [4 Marks]

$$\sum_{i=1}^{n}(2i-1)$$

2) Consider the pseudocode below in which a and b are integers.

```
algorithm mystery(a,b)
    if b = 0 then
        return 0
    else
        if b is odd then
            return a + mystery(a, b-1)
        else
            return mystery(a, b/2) + mystery(a, b/2)
        end if
    end if
end
```

a) What will be returned by mystery if it is given $a = 3$ and $b = 4$? [6 Marks]

b) What does mystery do? [2 Marks]

c) What is the asymptotic analysis of this algorithm? [10 Marks]

3)

a) Design an algorithm for $dec2Bin$, which takes as input a positive integer n and returns the binary representation of a using recursion. [10 Marks]

b) Give a asymptotic analysis of you algorithm [10 Marks]

4)

a) Devise an algorithm, which takes in an expression postfix and returns an infix equivalent of the expression. [10 Marks]

b) Show how your algorithm transforms [10 Marks]

$$a\ b\ c\ *\ d\ +\ e\ /\ -$$

5) Given the following list of numbers. Insert them, showing the state of the data structure, to an initially empty

a) AVL Tree [6 Marks]

b) Minheap [6 Marks]

c) Hashtable, with the initial size of 7, hash function $h(x) = x\%7$, rehash at 80% and quadratic probing. [8 Mars]

6)

a) Simulate the sorting of the array below using the algorithms below. In each case, indicate the number of comparisons and swaps.

23	12	69	5	3

i) Selection sort [10 Marks]

ii) Insertion sort [10 Marks]

**********END OF EXAMINATION**********

Essential Formulas

For constants a and b

$$\sum_{i=1}^{n}(ai+b) = a\sum_{i=1}^{n} i + \sum_{i=1}^{n} b$$

$$\sum_{i=1}^{n} 1 = n$$

THE UNIVERSITY OF ZAMBIA
Institute of Distance Education

CSC 3070
PROGRAMMING CONCEPTS

DEFERRED FINAL EXAMINATION

Date:	20TH DECEMBER, 2021
Time:	14:00 HRS – 17:00 HRS
Duration:	3 HOURS
Venue:	CL2 COMPUTER SCIENCE BUILDING

INSTRUCTIONS

1. This exam has two sections A and B.
2. Answer **ALL** the questions from **Section A**.
3. Answer **ANY three (3)** questions from Section B.
4. **Total number of questions answered should be five (5).**

Section A (Compulsory) [40 Marks]

1. What are the values of the following variables? **[5 marks]**
   a) double var1 = 10 / 3;
   b) int var2 = (int) (2.5 * 2.6);
   c) boolean var3 = !(3 > 3);
   d) boolean var4 = (121 % 11 == 0) || (5 == 5);
   e) int var5 = 11 % 3;

2. Assuming that a and b are both int type variables. Describe the differences between "a = b", "a == b" and "a += b". **[3 marks]**

3. Suppose you have the variable str of type String with data "How are you?" Write out the data stored in str and place the index of each character below the string.
   [2 marks]

4. Study a piece of a java code below and answer all the questions below;

```
int i = 30;
while(i >= 0)
{
   if(i % 2 > 0)
   {
     continue;
   }
   System.out.println(i);
   i--;
}
```

   a) What is the output of the above code? **[2 Marks]**
   b) Rewrite the above code using the for loop **[2 Marks]**
   c) Rewrite the above code using the do while loop **[2 Marks]**

5. What is wrong with this piece of code? **[3 marks]**

```
int count = 0;
   while (count < 100)
        if (count % 5 == 0)
           System.out.println(count);
           count++;
```

6. What is wrong with this piece of code? (Circle the error and tell me why it's wrong)
   [3 marks]

```
do {
        System.out.print("The programming language, "Java", ");
   }
while (false);
   System.out.println("is named after the Java coffee");
```

7. What is wrong with this piece of code? (Circle two errors and tell me why they're wrong) [**4 marks**]

```
public int absoluteValue(int num)
    {
      if (num < 0);
            return -num;
      else if (num > 0)
            return num;
    }
```

8. Write the output for the piece of code. **[8 marks]**

```
int a = 2, b = 2, c = 2;
for (int i = 0; i < 3; i++)
{
  a += a;
  b *= b;
  c /= c;
}
System.out.println(a + ", " + b + "," + c + ".");
```

9. Write the output of the method doSomething(). **[8 marks]**

```
public void swap(int a, int b)
{
   int temp = a;
   a = b;
   b = temp;
}

public void doSomething()
{
    int a = 2, b = 3;
    a = b;
    b = a;
   System.out.println(a + "," + b);
   int c = 2, d = 3;
   int temp = c;
   c = d;
   d = temp;
  System.out.println(c + "," + d);
  int e = 2, f = 3;
  swap(f, e);
  System.out.println(e + "," + f);
}
```

Section B [Answer any three [3] question. Each question is worth 20 Marks]

1. Write a program in Java that displays the grade of a mark. The grade system is as follows;
   90 – 100 A+
   80 – 89 A
   70 – 79 B+
   60 – 69 B
   50 – 59 C+
   45 – 49 C
   0 – 44 D
   Your program must not allow marks below 0 and above 100. Use the command line both for prompting the user for a mark and displaying the grade **[20 Marks]**

2.
   a) Create a class that holds 10 grades in an array data structures. **[2 Marks]**
   a) Loop through the data structure and compute the sum of grades **[2 Marks]**
   b) Loop through the data structure and compute the average of grades **[4 Marks]**
   c) Loop through the data structure and print the biggest grade **[4 Marks]**
   d) Loop through the data structure and print the lowest grade **[4 Marks]**
   e) Print the grades in the descending order of indexes **[4 Marks]**

3. Write an instantiable class called Counter that has:
   a) An integer instance variable called *numClicks* **[2 Marks]**
   b) A constructor that sets *numClicks* to 0 **[2 Marks]**
   c) A method called click() that adds 1 to *numClicks* **[4 Marks]**
   d) A method called getClicks() that returns *numClicks* **[4 Marks]**

   Write a driver program called TestCounter that
   e) Creates a counter object **[2 Marks]**
   f) Calls the click method 2 times **[4 Marks]**
   g) Calls the getClicks() method and prints its value **[2 Marks]**

4. Write a main method that
   a) prompts a user to enter an integer **[2 Marks]**
   b) passes that integer to a method called cube **[2 Marks]**
   c) receives the cube of that integer back from the method **[2 Marks]**
   d) displays the return value **[2 Marks]**

   Write a method called cube that
   e) accepts an integer, cubes it and returns the result **[4 Marks]**
   f) Change the preceding code so the main method has a *for* loop **[4 Marks]**
   g) It passes the numbers 0 to 3 to the cube method, one at a time **[2 Marks]**
   h) It receives back the result from the cube method and displays it **[2 Marks]**
   i) The cube method is unchanged

*******************END OF EXAMINATION*******************

THE UNIVERSITY OF ZAMBIA
Institute of Distance Education

CSC 3080
INFORMATION MANAGEMENT SYSTEMS

DEFERRED FINAL EXAMINATION

Date:	21TH DECEMBER, 2021
Time:	09:00 HRS – 12:00 HRS
Duration:	3 HOURS
Venue:	CL2 COMPUTER SCIENCE BUILDING

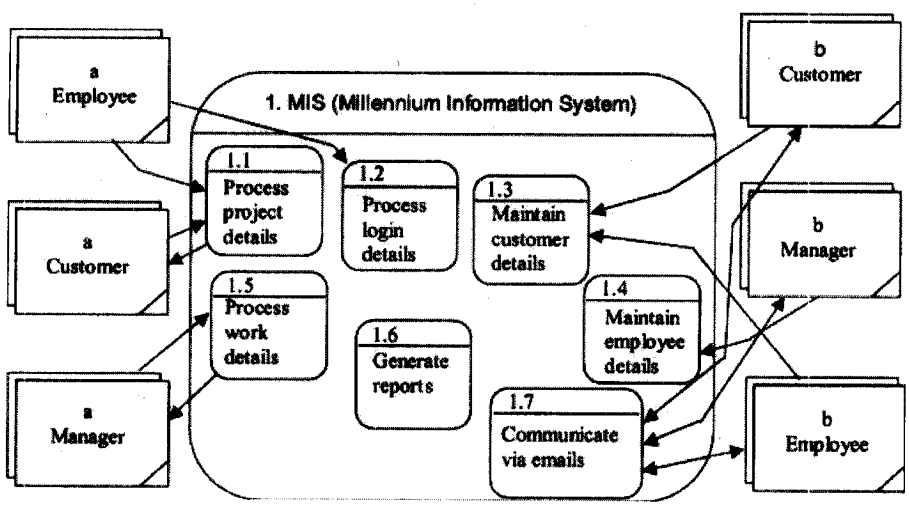
INSTRUCTIONS

1. This exam has two sections A and B.
2. Answer **ALL** the questions from **Section A**.
3. Answer **ANY three (3)** questions from Section B.
4. **Total number of questions answered should be five (5).**

SECTION A [COMPULSORY] [40 MARKS]

Question 1

i. Consider the following data flow diagram for the millenium information system.



Interpret what the diagram is describing about the system and other entities. [20]

ii. Lincoln Pizza is a small restaurant on Lincoln Ave. Most of its customers are EIU students. In the current manual ordering system, the restaurant employees have to go through three different activities in order to process a pizza order. The first activity, called Receiving the order, consists in getting customers' information (such as name, phone number, and address), and getting orders' information (such as the pizza size, the type of crust, and the ingredients needed to make the pizza). The same process also checks the availability of the ingredients needed before setting the status of the pizza order as "valid". When a pizza order is valid, the employee in charge of Receiving the order provides the valid order information to the cooks who make the pizza. The second activity, Making the pizza, consists in getting the ingredients needed (from containers in the kitchen) and actually cooking the pizza. At the end of that process, the cooks have to update the manual file that keeps track of the ingredients. They, then, provide the drivers in charge of delivering the pizza with the (completed) status of the order. The final activity, Delivering the pizza, done by the drivers consists in getting address and payment information from the employee in charge of Receiving the order, and actually delivering the pizza. The drivers provide the customers with a receipt and get the payment.

a) Name all the processes in the Data Flow Diagram of the system. [4]

b) Name all the external entities to be found in the Data Flow Diagram of the system.[4]

c) Name all the data stores to be found in the Data Flow Diagram of the system.[4]

d) Draw the Data Flow Diagram for the new Lincoln Pizza's ordering system. [8]

**********END OF SECTION A**********

SECTION B [60 MARKS]

Question 1

i. Briefly explain the functions of an information systems? [4]

ii. Briefly explain any three (3) strategic business objectives of information systems? [6]

iii. Briefly explain the three types of information systems

a. Management Information Systems [2]

b. Decision Support Systems [2]

c. Executive Support Systems [2]

iv. What are the benefits of collaboration and teamwork? [4]

Question 2 [20 marks]

i. You are advising the owner of Smalltown Computer, a new, local computer repair store that also builds custom computers to order. What competitive strategies could Smalltown Computer exert? [5]

ii. List and describe the Porter's competitive forces model? [5]

iii. What are the basic concepts for ethical analysis? [4]

iv. Identify and describe six ethical principles? [6]

Question 3 [20 marks]

i. Explain any four main components in the IT Infrastructure?[8]

ii. Give any two drawbacks of cloud computing?[2]

iii. What are the problems in managing data resources in a traditional file environment? [5]

iv. What are the contemporary tools and technologies in business intelligence infrastructure? [5]

Question 4 [20 marks]

i. Write short notes on Client/server computing, Packet switching and TCP/IP and connectivity?[6]

ii. List the pros and cons of social media?[4]

iii. Define computer crime. Provide two examples of crime in which computers are targets and two examples in which computers are used as instruments of crime? [6]

iv. What are the four types of firewall? [4]

Question 5 [20 marks]

i. You have been hired by Croydon Visiting Nurse Services, whose business processes are all manual, paper-based processes. How might a Customer Relationship Management system benefit them? [4]

ii. Explain the following

a. Enterprise Systems [3]

b. Supply Chain Management Systems [3]

iii. Describe the following principal e-commerce business models?

a. Business to Business (B2B)[2]

b. Business to Customer (B2C)[2]

c. Customer to customer (C2C) [2]

iv. Define behavioral targeting and explain how it works at individual Web sites and on advertising networks? [4]

Question 6 [20 marks]

i. Describe the stages in the knowledge management value chain? [4]

ii. Describe fuzzy logic, genetic algorithms, and intelligent agents. Explain how each works and the kinds of problems for which each is suited? [6]

iii. What are the four stages in decision making process? [4]

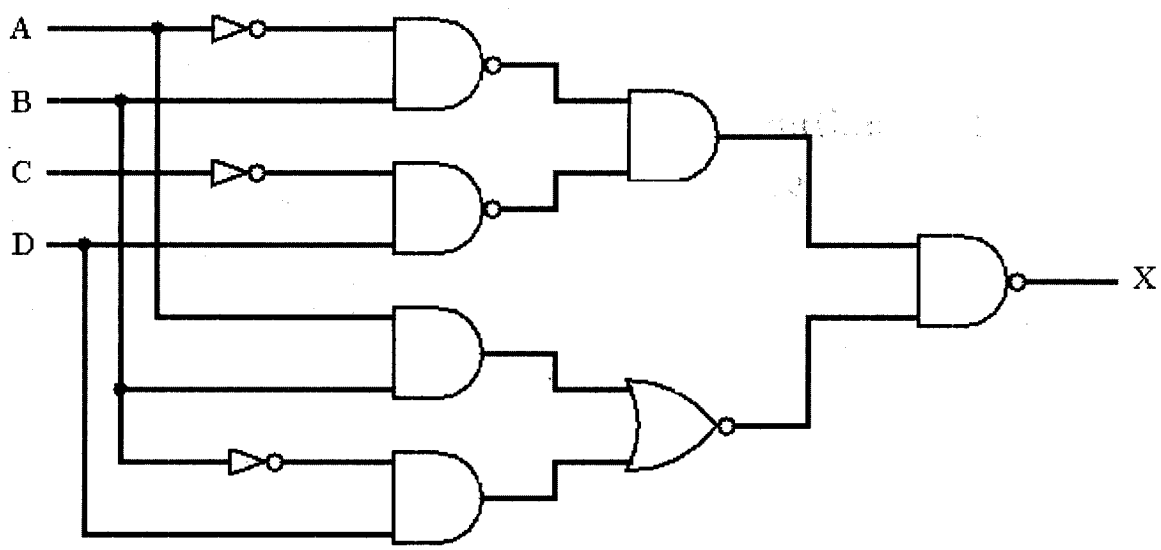
iv. List and describe the analytic functionalities provided by Business Intelligent systems? [6]

*****************END OF EXAMINATION***************

The University of Zambia Examination 2021
School of Natural Science
Digital Electronics CS3120

Time: 3 Hours
Instructions: Answer any 4 questions
All questions carry 25 marks

Q1. a) Write the Boolean equation for the circuit below. **[4]**



b) Convert the Boolean equation into SOP. **[5]**

c) Use Boolean rules to simplify the Boolean equation. Draw the simplified equation. **[8]**

d) Use a K-Map to simplify the SOP Boolean equation in part b) to confirm the result of c) [8]

Q2.

a)

i) Convert the decimal number 26294 to hexadecimal. **[3]**

ii) Convert the hexadecimal number to binary. **[2]**

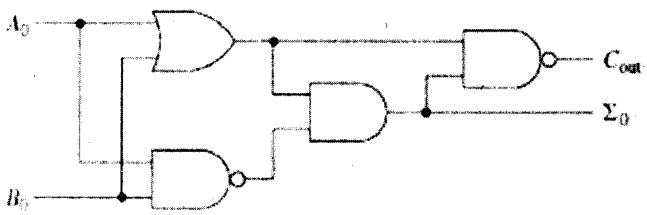
b) Perform the following 8 bit twos complement arithmetic **[5][5]**

i) 89 – 120 = _____

ii) -53 – 45 = _____

c) The circuit in the figure below is an attempt to build a half-adder. Will the C_{out} and Σ_0 function properly? Write the Boolean equation for C_{out} and Σ_0 and create a truth table to verify whether is performs as a half adder.

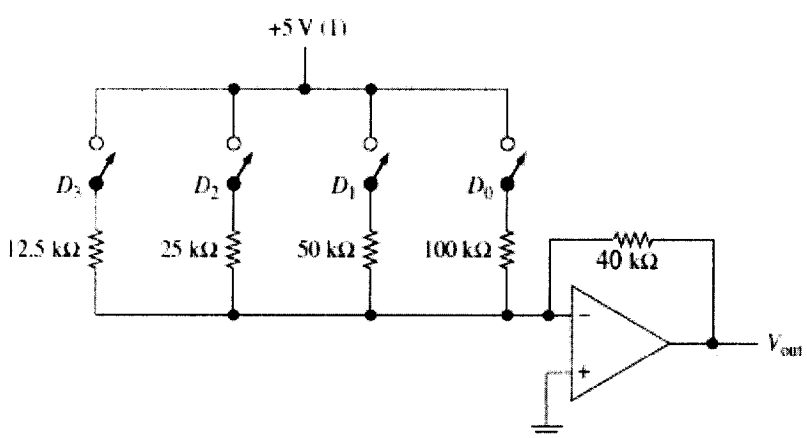
[10]



Q 3. a) Draw an active low comparator that compares two 4 bit binary numbers. Show the gates.

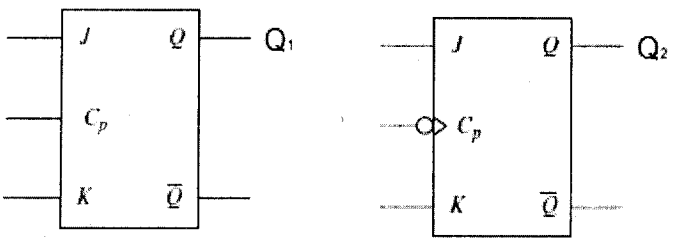
[14]

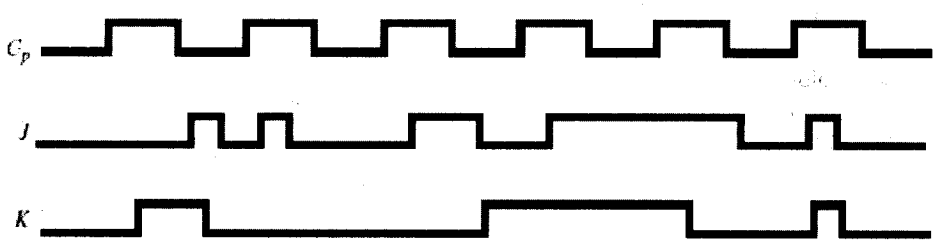
b) For the digital to analog converter below calculate the output V_{out} if the input digital input is 0101_2 (or 5_{10}). ($D_0 = 1$, $D_1 = 0$, $D_2 = 1$, $D_3 = 0$) **[11]**



Q4. a) What is the difference a pulse triggered and an edge triggered flip flop? **[3]**

b) Draw the Q output waveforms for each of the J-K flip flops below given the input waveforms. (Assume the initial value of each Q output is LOW). **[12][12]**

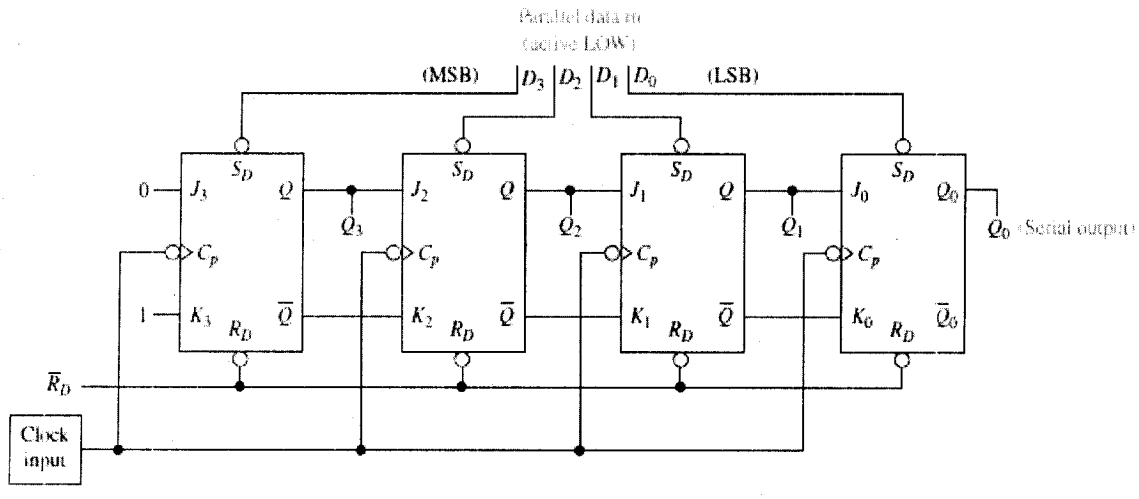




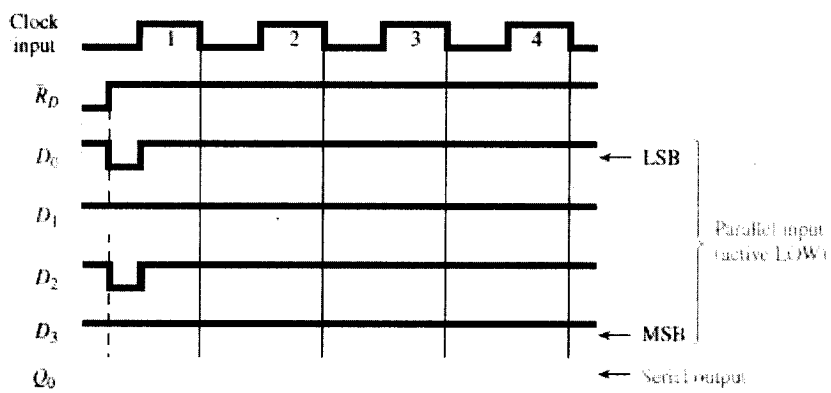
Q_1

Q_2

Q5. a) Given the shift register given below draw the output waveform Q_0. (Note: The $\overline{R}$ resets a flip flop to low) **[14]**



(a)



b) Draw a two input NAND gate using CMOS gates. Clearly label each transistor and indicate its type. Make a truth table for the NAND gate indicating the state of each transistor for each input state. **[11]**

END OF EXAM

THE UNIVERSITY OF ZAMBIA
Institute of Distance Education

CSC 3150
APPLICATION PACKAGES

DEFERRED FINAL EXAMINATION

Date:	22ND DECEMBER, 2021
Time:	09:00 HRS – 12:00 HRS
Duration:	3 HOURS
Venue:	CL2 COMPUTER SCIENCE BUILDING

INSTRUCTIONS

1. This exam has two sections A and B.
2. Answer **ALL** the questions from **Section A**.
3. Answer **ANY three (3)** questions from Section B.
4. **Total number of questions answered should be five (5).**

SECTION A

Answer ALL Questions in this section. Both questions carry an equal weight of **20 Marks**.

Question 1 [20 Marks]

i. Define the following terms briefly in not more than 3 lines: [**5 Marks**]
   a. *Database*
   b. *Database program*
   c. *Database System*
   d. *Record*
   e. *Attribute*

ii. Explain why MS-Access is considered as a database management system. [**5 Marks**]

iii. List at five (5) examples of popular database management systems [**5 Marks**]

iv. What is the difference between a field and a tuple in relation to databases and MS Access? [**5 Marks**]

Question 2 [20 Marks]

i. In MS Access, what are the elements that are considered to be major or core in managing [**6 Marks**]

ii. Explain the difference between a table and a relation in database context [**4 Marks**]

iii. Define the following terms: [**5 Marks**]
   a. Field
   b. Record
   c. Query
   d. Form
   e. Report

iv. Explain the difference between a form and report in MS Access software. [**2 Marks**]

v. Explain what a macro is in MS Access and why they are important. **[3 Marks]**

******************END OF SECTION A *****************

SECTION B

There are FOUR questions in this section. All questions carry an equal weight of **20 Marks**. Choose only **three (3)** questions!

Question 1

i. State the five (5) different number field types in MS Access. [**5 Marks**]

ii. What are the front-end and back-end components of the database? [**5 Marks**]

iii. What are referred to as objects of Access database? List six (6) [**6 Marks**]

iv. Discuss the difference between a composite key and a composite attribute. How would each be indicated in an Entity Relationship Diagram? [**4 Marks**]

Question 2

i. Explain the meaning of the following field properties in Access database. [**10 Marks**]

   a. *Field Size*
   b. *Format*
   c. *Input Mask*
   d. *Caption*
   e. *Default Value*
   f. *Validation Rule*
   g. *Validation Text*
   h. *Required*
   i. *Decimal Places*
   j. *Indexed*

ii. What is referred to as a datasheet view in MS Access? [**3 Marks**]

iii. What is the difference between a "view" and "base relation"? [**2 Marks**]

iv. What are the advantages of normalizing database designs [**5 Marks**]

Question 3

i. Explain how the following constraints are implemented in MS Access. [**6 Marks**]
   a. No nulls
   b. No Changes
   c. No duplicates

ii. Explain five ways by which you can add a table in the Access database. [**10 Marks**]

iii. What does it mean by "default value" for a field in the Access table? [**4 Marks**]

Question 4

i. What do the following formatting symbols mean in the Format properties of fields? [**6 Marks**]
   a. <
   b. >
   c. $

ii. What is the use of the Validation Test property of a field? [**4 Marks**]

iii. State the three different forms of auto forms. [**6 Marks**]

iv. What are controls? How do you use them and give examples? [**2 Marks**]

v. What is referred to as a form view? [**2 Marks**]

***********END OF EXAMINATION*********

THE UNIVERSITY OF ZAMBIA

School of Natural Sciences

Department of Computer Science

FINAL EXAMINATION

PROGRAMMING LANGUAGE PARADIGMS
CSC 3301

Date:	17th NOVEMBER 2021
Time:	14:00hrs – 17:00hrs
Duration:	3 Hours
Venue:	NSLT

Instructions

1. *Answer **all** the questions in Section A.*
2. Choose ***any THREE** (3) questions in Section B.*

SECTION A: ANSWER ALL QUESTIONS IN THIS SECTION.[40 MARKS]

QUESTION 1 [20 Marks]

i. In not more than five (5) lines, enumerate why studying concepts of programming languages is important in your career as a computer scientist. [2 Marks]

ii. Imagine after graduating you are employed in a reputable organization – let's say – AIRTEL. As a fresh graduate, you are put on a software development project so you can gain some experience as well as provide some technical assistance need be. If you are tasked to choose an appropriate programming language for a given project, what factors would you consider in your decision making process. [5 Marks]

iii. Explain how the VON NEUMAN computer architecture influences programming language design. Be sure to sketch the architecture with focus on main components.[3 Marks]

iv. Enumerate the four programming languages categories. And for each category, state at least two examples. [4 Marks]

v. Upon successful completion of CSC 3301 course, you decide to put your knowledge to test by implementing your own programming language, enumerate the strategies you have at your disposal to realize your plans. [6 Marks]

QUESTION 2 [20 Marks]

i. Consider the following grammar:

<S> → a <S> c <B> | <A> | b

<A> → c <A> | c

<B> → d | <A>

Which of the following sentences are in the language generated by this grammar?

a. Abcd

b. Acccbd

c. Acccbcc

d. Acd

e. Accc

(NOTE: Show how you will be arriving at your solutions.)

SECTION B: ANSWER ANY THREE (3) OF THE QUESTIONS IN THIS SECTION [60 MARKS]

QUESTION 3 [20 Marks]

i. Consider the following context free grammar:

<assign> → <id> = <expr>
<id> → A | B | C
<expr> → <expr> + <term> | <term>
<term> → <term> * <factor> | <factor>
<factor> → (<term>) | id

a. Show whether the grammar above violates the precedence rule of operators.

b. Rewrite the following BNF to give + precedence over * and force + to be right associative.

c. Generate the parse tree of the sentence, **A = A * (A + (C))**, using the grammar above.

QUESTION 4 [20 Marks]

i. What is the distinction between *type checking* and *coercion*?

ii. Convert the following context free grammar into EBNF:

<expr> → <expr> + <term> | <expr> - <term> | <term>

<term> = <term> * <factor> | <term> / <factor> | <factor>

<factor> = <exp> ** <factor> | <exp>

<exp> → (<expr>) | id

QUESTION 5 [20 Marks]

i. Write a grammar for the language consisting of strings that have *n* copies of the letter a followed by the same number of copies of the letter b, where $n > 0$. For example, the strings ab, aaaabbbb, and aaaaaaaabbbbbbbb are in the language but a, abb, ba, and aaabb are not.

ii. Draw parse trees for the sentences aabb and aaaabbbb, as derived from the grammar in (i) above.

QUESTION 6 [20 Marks]

i. List *six (6) attributes* that characterise a variable in programming languages.

ii. State and explain the *three models* of parameter passing in subprograms. Also, for each model, give an example of *parameter passing method* that is implemented using that model.

iii. Modify the grammar in Question 3 to add a unary minus operator that has higher precedence than either + or *.

END OF EXAM

THE UNIVERSITY OF ZAMBIA

School of Natural Sciences

Department of Computer Science

CSC3600 – Software Engineering

2020/2021 FINAL EXAM

Date:	Tuesday 22nd November 2021
Venue:	NSLT
Time:	14:00 – 17:00 hrs
Duration:	3 Hours

Instructions

1. This exam has two sections A and B.
2. Answer **ALL** questions in **Section A.**
3. Answer **any three (3)** questions in **Section B.**
4. **Total number of questions answered should be 5.**

SECTION A

Answer all questions in this section. Each question carries 20 marks.

QUESTION 1

a) Why are iterations usually limited when the waterfall model is used? **[2 Marks]**

b) What are the three benefits of incremental development, compared to the waterfall model? **[3 Marks]**

c) What are the development stages in reuse-based development? **[4 Marks]**

QUESTION 2

a) List the 5 principles of agile methods. **[5 marks]**

QUESTION 3

a) What is the distinction between functional and non-functional requirements? **[3marks]**

b) What should be included in a scenario. **[5 marks]**

QUESTION 4

a) What perspectives may be used for system modelling? **[4 marks]**

b) What is described in a context model? **[2 marks]**

QUESTION 5

a) List 4 fundamental questions that should be addressed in architectural design? **[4 marks]**

QUESTION 6

a) What is the purpose of an activity diagram? **[2 marks]**

b) What are the three types of events? **[3 marks]**

c) What are the three key parts of an entity relationship diagram (ERD)? **[3 marks]**

SECTION B

Answer three (3) questions in this section. Each question carries 20 marks.

QUESTION 1 [20 marks]

Lusaka City Council (LCC) have hired your company to build a bus reservation system for all bus trips taken from Intercity Bus Terminal (IBT).

a) Outline in one paragraph the information you would need to gather in order to perform domain analysis for the LCC IBT bus reservation system. **[7 marks]**

b) Requirements can be divided into four major types functional, quality, platform and process. Describe quality requirements and give 2 examples of main categories for quality requirements. **[3 marks]**

c) Classify the following aspects of the LCC IBT bus reservation system into F for functional, Q for quality, PL for platform, PR for process, and X for 'should not be a requirement'. Also indicate the subcategory of requirement. For something that should not be a requirement, explain why not. **[5 marks]**

i. What information appears on tickets and reports.
ii. How fares are calculated.
iii. The system must be available at all times. Only 2 minutes' downtime a week is to be permitted.
iv. The system must run on any Linux system.
v. A merge-sort algorithm must be used to sort the flights by departure time.

d) What are the two techniques used to identify use cases? **[5 marks]**

QUESTION 2 [20 marks]

For this question, read through the MoveYourBooksNow.com case study and answer the questions that follow.

MoveYourBooksNow.com is a book exchange that does business entirely on the Internet. The company acts as a clearinghouse for buyers and sellers of used books.

To offer books for sale, a person must register with MoveYourBooksNow.com. The person must provide a current physical address and telephone number as well as a current e-mail address. The system maintains an open account for this person. Access to the system as a seller is through a secure, authenticated portal.

A seller can list books on the system through a special Internet form. Information required includes all the pertinent information about the book, its category, its general condition, and the asking price. A seller may list as many books as desired. The system maintains an index of all books in the system so buyers can use the search engine to search for books. The search engine allows searches by title, author, category, and keyword.

People who want to buy books come to the site and search for the books they want. When they decide to buy, they must open an account with a credit card to pay for the books. The system maintains all this information on secure servers.

When a request to purchase is made and the payment is sent, MoveYourBooksNow.com sends an e-mail notice to the seller of the book. It also marks the book as sold. The system maintains an open order until it receives notice that the book has been shipped. After the seller receives notice that a listed book has been sold, the seller must notify the buyer via e-mail within 48 hours. Shipment of the order must be made within 24 hours of the seller sending the notification e-mail. The seller sends a notification to the buyer and MoveYourBooksNow.com when the shipment is made.

After receiving notice of shipment, MoveYourBooksNow. com maintains the order in shipped status. At the end of each month, a check is mailed to each seller for the book orders that have been in shipped status for 30 days. The 30-day waiting period allows the buyer to notify MoveYourBooksNow.com if the shipment doesn't arrive for some reason or if the book isn't in the same condition as advertised.

If they want, buyers can enter a service code for the seller. The service code is an indication of how well the seller is servicing book purchases. Some sellers are very active and use MoveYourBooksNow.com as a major outlet for selling books. Thus, a service code is an important indicator to potential buyers.

For case study above, develop the following diagrams:

a) A domain model class diagram **[5 marks]**

b) A list of uses cases and a use case diagram **[5 marks]**

c) A fully developed description for two use cases: *Add a seller* and *Record a book order* **[5 marks]**

d) An SSD for each of the two use cases in question (c) **[5 marks]**

QUESTION 3 [20 marks]

For this question, read through the case study and answer the questions that follow.

The purpose of the State Patrol ticket-processing system is to record moving violations, keep records of the fines paid by drivers when they plead guilty or are found guilty of moving violations, and notify the court that a warrant for arrest should be issued when such fines are not paid in a timely manner.

A separate State Patrol system records accidents and the verification of financial responsibility(insurance). A third system uses ticket and accident records to produce driving record reports for insurance companies. Finally, a fourth system issues, renews, or suspends driver's licenses. These four systems are obviously integrated in that they share access to the same database; otherwise, they are operated separately by different departments of the State Patrol.

When an officer gives a ticket to a driver, a copy of the ticket is turned in and entered into the system. A new ticket record is created, and relationships to the correct driver, officer, and court are established in the database. If the driver pleads guilty, he or she mails in the fine in a preprinted envelope with the ticket number on it. In some cases, the driver claims innocence and wants a court date. When the envelope is returned without a check and the trial request box has an "X" in it, the system does the following: notes the plea on the ticket record; looks up driver, ticket, and officer information; and sends a ticket details report to the appropriate court. A trial date questionnaire form is also produced at the same time and is mailed to the driver. The instructions on the questionnaire tell the driver to fill in convenient dates and mail the questionnaire directly to the court. Upon receiving this information, the court schedules a trial date and notifies the driver of the date and time.

When the trial is completed, the court sends the verdict to the ticketing system. The verdict and trial date are recorded for the ticket. If the verdict is innocent, the system that produces driving record reports for insurance companies will ignore the ticket. If the verdict is guilty, the court gives the driver another envelope with the ticket number on it for mailing in the fine. If the driver fails to pay the fine within the required period, the ticket-processing system produces a warrant request notice and sends it to the court. This happens if the driver does not return the original envelope within two weeks or does not return the court-supplied envelope within two weeks of the trial date. What happens then is in the hands of the court. Sometimes, the court requests that the driver's license be suspended, and the system that processes drivers' licenses handles the suspension.

a) To what events must the ticket-processing system respond? List each event, the type of event, and the resulting use case. **[5 marks]**

b) Write a brief use case description for each use case. **[5 marks]**

c) The portion of the database used with the ticket processing system involves driver data, ticket data, officer data, and court data. Driver data, officer data, and court data are read by the system, and the ticket processing system creates and updates ticket data. In an integrated system like the ticket-processing system, some domain

classes are created by and updated by other systems, as described in this case. Create a table with systems down the rows and the four types of data (domain classes) across the columns. Indicate C, R, U, or D for each domain class and each system. **[10 marks]**

QUESTION 4 [20 marks]

a) What is a generalization/specialization relationship, and what object-oriented terms does it illustrate? **[5 marks]**

b) Compare/contrast aggregation with composition for a whole part relationship. **[5 marks]**

c) Draw an entity-relationship diagram, including minimum and maximum cardinality, for the following: The system stores information about two things: cars and owners. A car has attributes for make, model, and year. The owner has attributes for name and address. Assume that a car must be owned by one owner and an owner can own many cars, but an owner might not own any cars (perhaps she just sold them all, but you still want a record of her in the system). **[5 marks]**

d) Draw a class diagram for the cars and owners described in question c, but include subclasses for sports car, sedan, and minivan, with appropriate attributes.

[5 marks]

- END -

THE UNIVERSITY OF ZAMBIA

School of Natural Sciences

Department of Computer Science

IT PROJECT MANAGEMENT
CSC 3612

2020-2021 FINAL EXAM

Date:	19th November 2021
Venue:	NSLT
Time:	14:00hrs – 17:00hrs
Duration:	3 Hours

Instructions

1. *This examination has one section A*
2. *Section A comprises six [6] questions. Answer any five [5] questions. Each question carries 20 marks.*

Section A

Answer any five [5] questions. Each question carries 20 Marks

Question 1

a) List and explain the ten knowledge areas of project management? [10]

b) List the project management tools and techniques that assist the project manager and their teams? [5]

c) How do you define the success or failure of the Project? [2] What factors helps project succeed? [3]

Question 2

a) What is the role of the project manager? [2] What are suggested skills of project managers? [3] Why is leadership so important for project managers? [2]

b) Explain the five main project management process groups? [10]

c) who creates project charter? What is the purpose of the project charter? [3]

Question 3

a) XYZ Corporation is using weighted scoring model to select one project out of four projects. The importance criteria as well as ratings of four projects are given below. Which of the following projects will be selected? [4]

Criteria	Weight	Project 1	Project 2	Project 3	Project 4
Supports business objectives	35%	90	80	80	85
Customer support	22%	65	70	15	5
Shorter implementation period	18%	85	60	40	15
Tax incentives	25%	50	60	55	40

b) What are the processes involved in project integration management? [6]

c) Describe the different methods that organizations have for selecting projects? [10]

Question 4

a) Explain in detail about Work Breakdown Structure (WBS), WBS dictionary and Scope baseline? [6] Describe different ways to develop a WBS? [5] Give some advice for creating a WBS and WBS dictionary? [5]

b) List and describe any four methods of collecting requirements? [4]

Question 5

a) Consider the following table, Network Diagram Data for a Small Project. All duration estimates or estimated times are in days; and the network proceeds from Node 1 to Node 9.

Activity	Initial Node	Final Node	Estimated Duration
A	1	2	2
B	2	3	2
C	2	4	3
D	2	5	4
E	3	6	2
F	4	6	3
G	5	7	6
H	6	8	2
I	6	7	5
J	7	8	1
K	8	9	2

i. Draw an AOA network diagram representing the project. Put the node in numbers in circles and draw arrows from node to node, labelling each arrow with the activity letter and estimated time [3]

ii. Identify all of the paths on the network diagram and note how long they are [3]

iii. What is the critical path for this project and how long is it? [1]

iv. What is the shortest possible time it will take to complete this project? [1]

b) Explain the following schedule development tools and concepts: Gantt charts, PERT, Critical path method, Critical chain scheduling? [12]

Question 6

a) Explain about earned value management and its terms? [8]

b) Given the following information for a one-year project, answer the following questions.

Planned Value (PV)	= $35,000
Earned Value (EV)	= $30,000
Actual Cost (AC)	= $40,000
Budget at completion (BAC)	= $150,000

i. What is the cost variance, schedule variance, cost performance index (CPI), and schedule performance index (SPI) for the project? [4]

ii. How is the project doing? Is it ahead of schedule or behind of schedule? Is it under budget or over budget? [2]

iii. Use the CPI to calculate the estimate at completion (EAC) for this project, Is the project performing better or worse than planned? [2]

iv. Use the SPI to estimate how long it will take to finish this project. [2]

v. Sketch the earned value chart based for this project. [2]

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
DEPARTMENT OF COMPUTER SCIENCE
CSC4035 WEB PROGRAMMING AND TECHNOLOGIES
FINAL EXAM

Friday 12th July, 2019

Time: 14:00 - 17:00HOURS

Duration: 3 HOURS

Venue: P207

INSTRUCTIONS

- This paper has a total of SIX(6) questions
- You must answer a total of FOUR(4) questions
- All questions carry equal marks (25 marks each)
- Clearly number all your answers
- Use the marks as a guide to the detail required in your answers while keeping your answers concise and relevant

Question 1 [25 marks]

1. (a) (6 points) Assume you have joined a hot Silicon Valley web application startup that has Photo Sharing App headed to a billion users and growing. One complaint of the app users is the user registration process is painful since you have a try a bunch of different user names before finding one that hasn't been taken already. The user interface designers have come up with a fix that makes the user registration view update an indication of the availability of the user name as the user name is inputted key-by-key into the view.

   i. Your job is to implement the backend API for the key-by-key checking if an user name is available. Your initial implementation which runs a query of the User collection to see if the name exists gives the right answer but the query consumes significant resources and is growing the the number of users. Describe what you could do to the database to make this query not scale directly with the number of users.

   ii. Although you are now a hero for fixing that user check problem, you hear complaints that another API has got much slower. The API allows for bulk loading of new accounts that are known to be unique has slowed down significantly with your change. Describe what is happening here.

   (b) (2 points) One risk to network security is packet sniffing. Briefly describe the attack, and explain why this is a particularly important risk to wireless networks.

   (c) (2 points) Users often access Internet services using other devices such as mobile phones and home video games consoles (e.g. mobile phones, tablets).
   State ONE risk specific to accessing Internet services using mobile phones, and ONE risk specific to Internet services using home video games consoles.

   (d) Some people believe that web services should not require users to log in or authenticate in any way, and should instead be open for all to use.

   i. (1 point) With a suitable example, briefly explain why authentication may be necessary.

   ii. (2 points) One traditional method of restricting user access to web pages is the use of `htaccess` and `htpasswd`. State TWO features that `htaccess` offers for restricting access to pages.

   iii. (6 points) A company is currently using `htaccess` files to restrict access to sensitive pages, but a recent visit from an IT consultant has suggested this technique is old fashioned and insecure. Your manager would like to understand some alternatives.
   Briefly explain the following three methods of authentication, and provide a drawback of using each method.
   A) Biometric data alone
   B) 2-factor authentication (not using biometric data)
   C) Personal digital certificates using public key infrastructure

   (e) (6 points) Wireshark software allows anyone with a network adapter to capture and examine wireless packets. This means an attacker could use their laptop near a user of your photo sharing app and see all the requests the user sends along with the cookie attached to that request.

   i. This is a problem because the attacker is able to see all of this information. Using cryptography we can encrypt the connection to the web server, but to do so we need both the user's environment and our web server to know a shared secret (i.e. encryption key). Describe in detail how we could setup the shared secret even with the attacker running Wireshark on our network?

   ii. Since the attacker sees our HTTP request/response traffic they will also see the Express session cookies on the requests. Describe in detail why we need to worry about the attacker using the session cookie to impersonate the current user, but wouldn't need to worry about the attacker being able to modify a session cookie to impersonate a different user.

Question 2 [25 marks]

2. Web developers face a number of technical choices when developing a website.

(a) A solution stack is a complete set of software components required to run an application.

i. (4 points) LAMP is a well-known solution stack for dynamic web sites. Give the name of every component in this stack, and explain their role within the stack.

ii. (1 point) Give an example of an alternative to LAMP

(b) Server-side scripting can be performed using a variety of programming languages.

i. (2 points) Give the names of FOUR different server-side scripting languages.

ii. (3 points) Give THREE distinct factors which may lead a web developer to choose (or avoid) a particular server-side scripting language when embarking on a brand new project. Clearly explain the impact (risk/cost or benefit) of each factor on the project.

iii. (2 points) Are there any different factors that must be considered when choosing a client-side scripting language? Justify your answer with a clear explanation.

(c) i. (2 points) Describe two different ways information such as parameters can be sent from the browser to a web server using a HTTP POST request.

ii. (3 points) Describe how a browser decides how long it can cache a web page it fetched with a HTTP GET request.

(d) (8 points) Content distribution networks (CDNs) provide an interface where web application developers give them content and the CDN gives them an URL that will return the content if a HTTP GET request is issued to that URL.
For each the following parts of a web application, state if using a CDN to serve the part would be appropriate. Provide a short justification for your answer.

i. Company logo that is shown on every view.

ii. Model data for popular views of the web application.

iii. Controller code of popular views of the web application.

Question 3 [25 marks]

3. You are developing a simple web-based application to manage a collection of web bookmarks.
N.B. This question involves server-side scripting. The preferred language is PHP. Clearly state which server-side scripting language you will be using for the whole question (if you decide to use another languauge), and make sure all relevant files are named accordingly.

(a) Web addresses are often referred to as "URL".

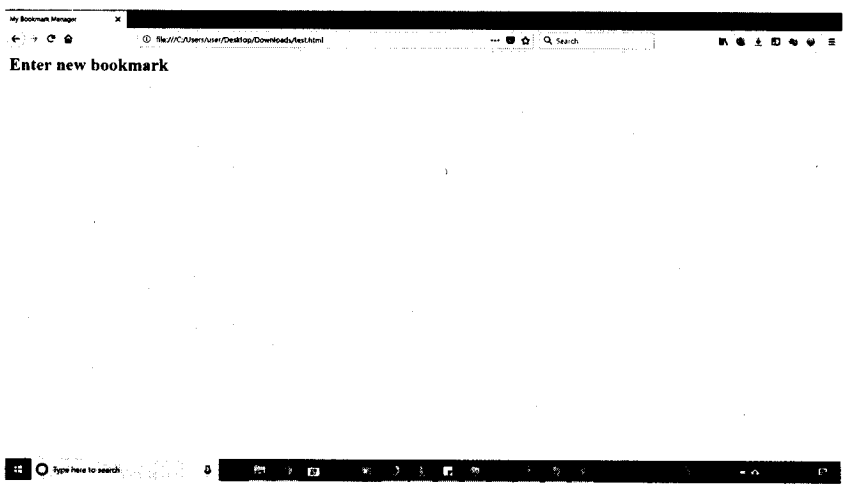
i. (1 point) What does this abbreviation mean?

ii. (2 points) A typical URL takes the following format:
`http://www.example.com/products/index.php?ref=4263&cur=gbp`
Briefly explain what each of the following parts represent:

- `http://`
- `www.example.com`
- `/products/index.php`
- `?ref=4263&cur=gbp`

(b) First, you will build a simple front-end in a file named bookmarkinput.html

i. (1 point) Write HTML to construct the page as indicated in the figure?



ii. (3 points) Add a simple form to your code. This form must take the following input parameters:
- a single-line string representing the location of a web page, named `address`
- a single-line text description, named `title`

These two parameters must be sent to a script named `savebookmarks.php`. When doing so, the parameters should not be visible in the address bar of the web browser.

(c) The URL entered in the `address` field might be incorrect.

i. (3 points) We wish to add some basic client-side validation to the address field. The validator should check that:
- the first part of the URL is present (`http://` or `https://`)
- the second part contains at least one character

Write the corresponding code.

ii. (1 point) If you were to write code to check the existence of a URL, should it be written on the client side, or on the server side? Explain why.

(d) (3 points) You have access to a database called `BOOKMARKMANAGER`, which contains a single table named `Bookmarks`. The database is hosted remotely at `mywebhost.com`. The administrator username is `db_admin` and the password is `foobar4263` Using the server-side scripting language of you choice, write a function called `connectToDatabase`, which:

- takes no input parameters
- establishes an authorised connection with the database host
- gets access to the database itself
- displays relevant error messages when necessary
- returns a connection handle, to be used in future database queries

This function will be saved in a file called `myfunctions.inc`

(e) You will now write the back-end of your application.

i. (3 points) In a file called `savebookmark.php`, write a function called `savebookmark`, which:
- takes 2 strings called `myAddress` and `myTitle` as an input
- gets access to the `Bookmarks` table described earlier, by referring, via an appropriate mechanism, to the function `connectToDatabase` defined in d)
- saves `myAddress` and `myTitle` in the `Bookmarks` table
- returns `true` if the operation was a success, `false` if it failed

ii. (3 points) Still in `savebookmark.php`, write code to:
- generate a full, valid web page entitled "Saving Bookmark"
- check that the input parameters obtained from the form in `bookmarkinput.html` (see question b) ii)) have been set; if not, display an error message linking back to `bookmarkinput.html`

- use the `savebookmark` function to save the input parameters in the database
- display a relevant message regarding the success or failure of the operation

(f) (5 points) Write another file called `displaybookmarks.php`:

- the page should display, ordered by `id`, all the web addresses contained in the database
- the results should appear as a HTML table
- the first column of the table should contain the title of each bookmark
- the second column should contain the corresponding address, formatted as a hyperlink

The following SQL syntax may be useful to accomplish some this question's tasks:

```
INSERT INTO tbl_name (col1, ...) values (val1, ...);
SELECT * FROM tbl_name WHERE col1 = val1;
```

where `tbl_name`, `col1`, `val1` are replaced with appropriate values.

Question 4 [25 Marks]

4. (a) (3 points) Explain, with reference to XML, the purpose of the Document Type Definition and the Document Type Declaration.

(b) (3 points) Explain how an XML document would call:

i. an internal DTD

ii. an external DTD

iii. an XML schema

(c) (4 points) The XML document in figure 4.2 contains precisely FOUR errors when validated against the DTD in figure 4.1. Identify all the errors, and provide a solution for each one.
(Note: the line numbers are for your benefit and are not part of the XML code.)

Figure 4.1 - Simple XML DTD

```
1: <?xml version = "1.0" encoding="ISO-8859-1"?>
2 : <!ELEMENT JournalCatalogue (Journal*)>
3 : <!ELEMENT Journal (Journal_title,Journal_url)>
4 : <!ATTLIST Journal ISBN CDATA "0-000-0000-0">
5 : <!ELEMENT Journal_title (#PCDATA)>
6 : <!ELEMENT Journal_url EMPTY>
7 : <!ATTLIST Journal_url page CDATA #REQUIRED>
```

Figure 4.2 - XML doument with Errors

```
1 : <?xml version="1.0" encoding="ISO-8859-1" standalone="no"?>
2 : <!DOCTYPE JournalCatalogue SYSTEM "journal-initial.dtd">
3 : <?xml-stylesheet type="text/xsl" href="journal.xsl"?>
4 : <JournalCatalogue>
5 : <Journal IBSN="0-123-4567-1">
6 : <Journal_Title>Nature</Journal_Title>
7 : <Journal_url>
8 : </Journal>
9 : </JournalCatalogue>
```

(d) (15 points) Write an external DTD for the XML file in figure 4.3:

- The element `trainlog` may contain, in any order, one or more `session` and `progress_report` elements.

- A `session` element must first contain a `duration` element, followed by `distance` element, followed by a `location` element, followed optionally by a `comment` element, followed by zero or more `photo` elements.
- The `date` and `heartrate` attributes in `session` are optional.
- The `type` attribute in `session` must be present but allow only 3 values – running, swimming, cycling - with default set to running.
- A `photo` element must contain a `url` attribute, but may not contain any text.
- A `progress_report` element must contain one or more comment elements.

Figure 4.3 - XML trainlog document

```
<?xml version="1.0"?>
<trainlog>
   <session date="11/01/10" type="running" heartrate="158">
      <duration units="minutes">50</duration>
      <distance units="miles">5.5</distance>
      <location>Hyde Park</location>
      <comment>Mid-morning run, a little winded throughout.</comment>
      <photo url="http://www.bcs.org/cloud.jpg" />
      <photo url="http://www.bcs.org/london.jpg" />
   </session>
   <session date="16/01/10" type="cycling" heartrate="153">
      <duration units="hours">1.5</duration>
      <distance units="miles">26.4</distance>
      <location>Crystal Palace</location>
      <comment>Hilly ride, felt strong as an ox.</comment>
   </session>
   <session date="23/01/10" type="running" heartrate="156">
      <duration units="hours">2.5</duration>
      <distance units="miles">16.8</distance>
      <location>Regents Park</location>
      <comment>Afternoon run, felt reasonably strong.</comment>
   </session>
   <progress_report>
      <comment> Performance improved significantly</comment>
   </progress_report>
</trainlog>
```

Question 5 [25 marks]

5. (a) (5 points) Internet of things (IoT) is defined as "the infrastructure of the information society." Briefly explain what this means using appropriate examples.

   (b) (3 points) In a MEAN stack applications state, what is the order that the Model, View, and Controller (MVC) components typically arrive at the browser? It is OK to answer that one or more of them arrive at the same time.

   (c) (5 points) Explain why we frequently end up validating input in a web app twice: once in browser and then again in the web server.

   (d) (8 points) REST API's are frequently described as doing CRUD. What does CRUD mean in this context? Give details on each term

   (e) (4 points) Explain how indexes make database queries go faster

Question 6 [25 marks]

6. (a) (3 points) Define the term API and state the purpose it serves.

(b) An Object Relational Mapping (ORM) system maps an object system onto a relational database. For each of the following parts of a relational database, what is the corresponding part in an object system.

i. (4 points) relational table

ii. (4 points) table column.

iii. (4 points) table row

Hint: Object systems typically have a class structure with inheritance containing objects that have properties/attributes and methods.

(c) (8 points) Assume you are given a correctly functioning database with several secondary indexes. You delete one of the secondary indexes. For each of the following effects the index deletion could have, state if the effect is either possible or impossible. Provide a justification for your answer. If possible, describe a scenario in which it would happen. If impossible, describe why.

i. The database continues to correctly function with performance unchanged.

ii. The database continues to correctly function with performance increased.

iii. The database continues to correctly function with performance decreased.

iv. The database stops correctly functioning.

(d) (2 points) Explain how JavaScript running in a Node.js webserver can read a file from disk and send it out over the network to a browser without all the bytes of the file being brought into JavaScript variables.

Omnium Optimi

THE UNIVERSITY OF ZAMBIA

School of Natural Science

Department of Computer Science

DEFERRED FINAL EXAMINATION

CSC 4130: ADVANCED HARDWARE DESIGN AND IMPLEMENTATION

Date:	Friday, 19th November 2021
Time:	14:00hrs – 17:00hrs
Duration:	3 Hours
Venue:	NSLT

Instructions

1. There are **five (5) questions** and **two (2) sections** in this paper.
2. Each question carries **25 marks,**
3. *You are required to answer a total of **Four (4) Questions***
    a. *Answer **all** the questions in **Section A***
    b. Choose ***One (1)** question from **Section B***

SECTION A

This Section has Three Questions. Answer all the questions

Question I

a) Von Neumann architecture has four functional units namely Memory, Input/Output, Arithmetic/Logic unit and Control unit [5 Marks].
   i. Draw a well labelled diagram of the Von Neumann architecture
   ii. Briefly discuss each of the following none Von Neumann architectures
      1. SIMD architecture
      2. MIMD architecture

b) Describe each of the following categories of processor classifications [5 Marks]
   i. Categorized by memory organization
      1. Von-Neumann architecture
      2. Harvard architecture
   ii. Categorized by instruction type
      1. CISC
      2. RISC
      3. VLIW

c) Computer memory can be defined as any physical device capable of storing information temporarily or permanently. Sequential circuits all depend upon the presence of memory. Briefly describe each of the following in relation to computer memory [3 Marks]
   i. Bit
   ii. Word
   iii. Memory Module

d) Draw a well labelled diagram showing the following memory units. Discuss how each memory unit store a bit. [6 Marks]
   i. DRAM
   ii. SRAM

e) The 8085-instruction set is classified into the following three groups according to word size [6 Marks]
   i. One-word or 1-byte instructions
   ii. Two-word or 2-byte instructions
   iii. Three-word or 3-byte instructions

   Briefly discuss each of the above Intel 8085 instruction set above

Question II

a) The intel 8085 uses Machine language which is a set of instructions executed directly by the processing unit. Each instruction of the intel 8085 performs a very specific task, such as LOAD, JUMP, or an ALU operation on a unit of data in a CPU register or memory. **Write the machine code** for the Intel 8085 microprocessor used to [6 Marks]

i. Add two numbers (11010011 and 10001010)

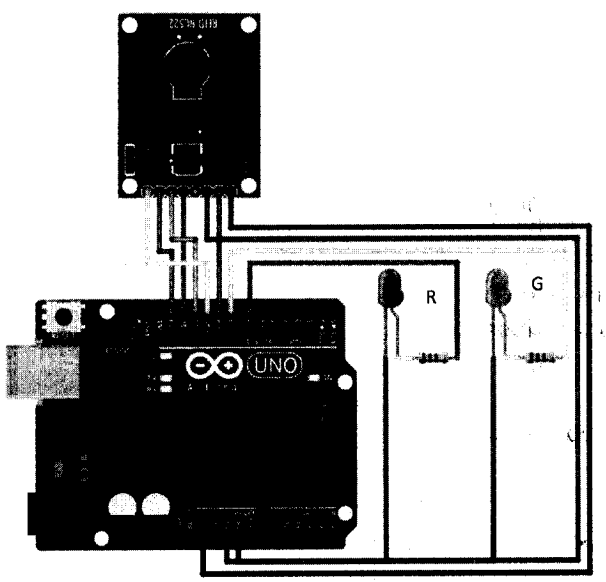
ii. Subtract two numbers, 10001010 from 11010011

b) An instruction is a binary pattern designed inside a microprocessor to perform a specific function. The entire group of instructions, called the instruction set, determines what functions the microprocessor can perform. The intel 8085 Instruction set can be classified into the following five functional categories:

i. data transfer (copy) operations,
ii. arithmetic operations,
iii. logical operations,
iv. branching operations, and
v. machine-control operations

Discuss each of the instruction set with at least one example of the actual instruction performed by the intel 8085 microprocessor [10 Marks].

c) The Department of Computer Science would like to improve on the recording and collection of the students details regarding COVID Contact tracing and attendance register. The diagram below shows the actual connection and the circuit diagram. The two LEDs are connected to pins 7 and 8. If you use the correct Tag/Card, it is recognized and signalized by the green LED. However, if you use the wrong unregistered Tag/Card it is not recognized so the red LED blinks. **Write the Full Code which is well commented for reading the student RFID Cards for the class attendance register based on the circuit diagram below [9 Mark].**

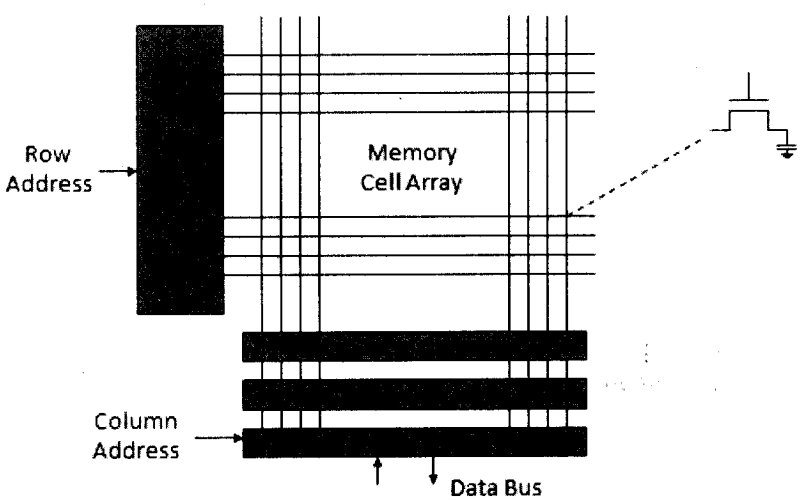


Question III

a) A Piezo is an electronic piece that converts electricity energy to sound. It is a digital output device. You can make white noise or even exact musical notes based on the duration that you iterate between HIGH and LOW signals. Give the full well commented code for the **Arduino Digital Output Sound Piezo** using PIN 13 on Arduino Board for the Sound-Piezo [5 Marks]

b) To implement process control, the computer must collect data from and transmit signals to the production process. Give a brief description for each of the following in relation to computer process interfaces [2 Marks]
   i. Sensors
   ii. Actuators

c) The diagram below shows the basic DRAM Chip Organization. Explain with reference to the diagram below how a computer stores and read data from memory using DRAM as your example. In your discussion make reference to [10 Marks]
   i. Row Decoder
   ii. Sensing Amps
   iii. Row Buffer
   iv. Column Decoder



d) The 8085-programming model includes six registers, one accumulator, and one flag register. In addition, it has two 16-bit registers, the stack pointer and the program counter. Draw a diagram showing each of the following for the 8085-programming model [8 Marks]
   i. Six registers,
   ii. Accumulator,
   iii. flag register
   iv. Stack Pointer
   v. Program Counter
   vi. 8 Data Bus lines bidirectional
   vii. 16 address lines unidirectional

SECTION B

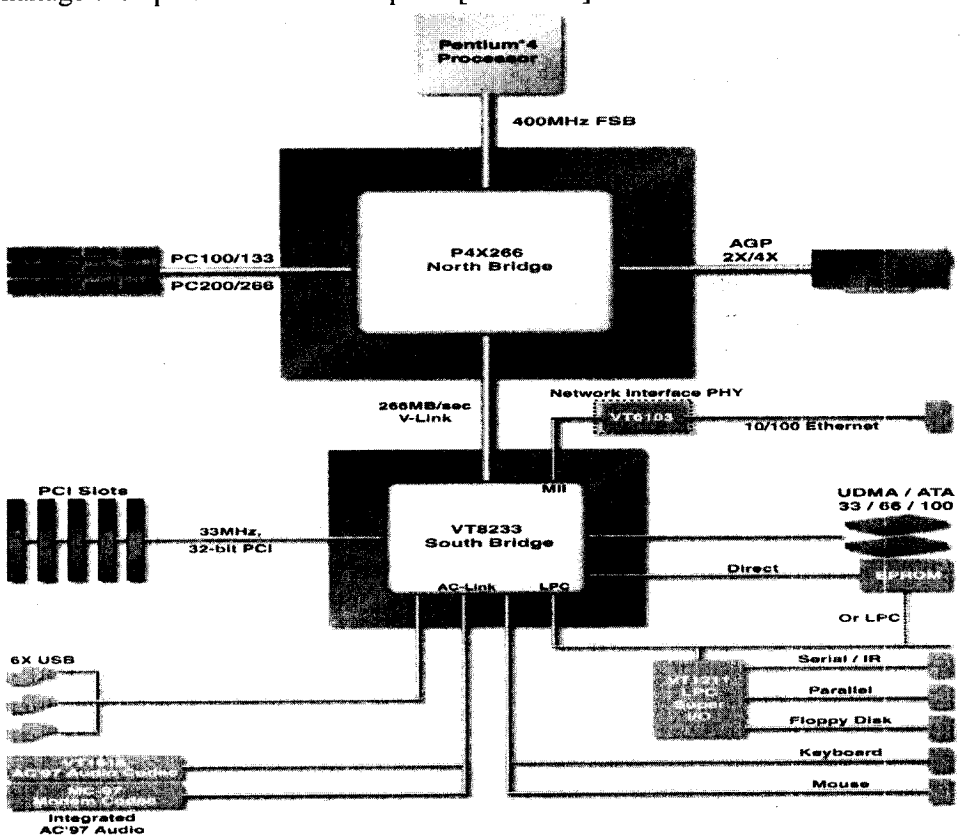
This section has Two Questions. Choose one questions

Question I

a) With the help of the diagram to illustrate the concepts on each case, give a brief description for each of the following [6 Mark].
   i. Flip-Flops
   ii. Counters
   iii. Registers

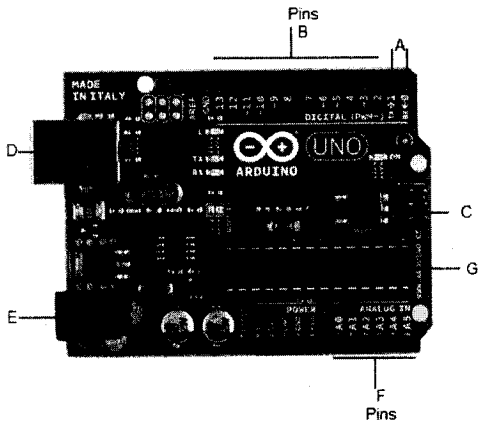
b) An actuator is usually activated by a low-level command signal; hence an amplifier may be required to provide sufficient power to drive the actuator. **Name and discuss** the three main categories of the actuators. Give one example in each case [6 Marks]

c) A chipset is a group of integrated circuits, sold as one unit, designed to perform one or more related functions. The diagram below shows the Apollo Chipset designed for the Pentium (IV) processor. With reference to the diagram below, discuss in details the functions and roles of the chipsets (North Bridge and South Bridge) in relation to the Pentium 4 processor to manage the operation of the computer [13 Marks]



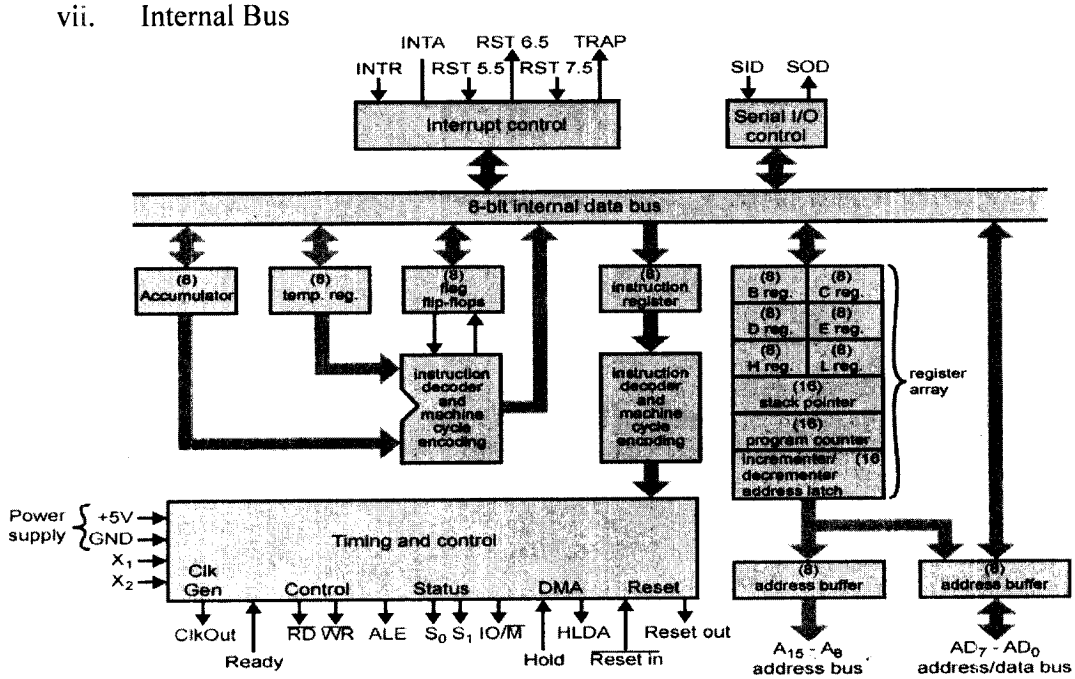
Question II

a) One of the widely used boards in digital electronics is the Arduino board. Arduino UNO supports **ATmega 328 Microcontroller** which is developed by Atmel. Label the PINs, components and features shown on the Arduino board UNO by the letters below [8 Marks].



b) The Figure below shows the Intel 8085 CPU Block Diagram. With reference to the diagram below, give the function of each of the following [17 Marks];

i. Interrupt Control
ii. Serial I/O Control
iii. Registers (A, B, D, E, H, L, Acc. Temp, etc)
iv. Timing and Control
v. Power Supply
vi. Addressing (A_X and AD_X)
vii. Internal Bus



End of the Examination

THE UNIVERSITY OF ZAMBIA

School of Natural Sciences

Department of Computer Science

FINAL EXAMINATION

CSC 4505 GRAPHICS AND VISUAL COMPUTING

Date:	26th NOVEMBER, 2021
Time:	14:00hrs – 17:00hrs
Duration:	3 Hours
Venue:	NSLT

Instructions

1. There are **two (2) Sections** in this exam, **Section A** and **Section B.**
2. In Section A, **Answer all the questions** and in Section B **choose any three (3) questions.**

SECTION A. ANSWER ALL QUESTIONS

1) Give four of the applications of Computer Graphics [4 Marks]
2) Describe what the following are:
   a) Resolution [2 Marks]
   b) Aspect ratio [2 Marks]
3) Describe the two methods of achieving colour in computer graphics [4 Marks]
4) Describe the hardware components of an interactive graphics system. [6 Marks]
5) The conceptual framework of a graphics software system has three components. Describe these components. [6 Marks]
6) Describe the basic attributes of a circle graphics primitive. [4 Marks]
7) Write the pseudocode for the DDA algorithm for drawing lines. [6 Marks]
8) What parameters are required for each of the following transformations
   a) Translation [2 Marks]
   b) Rotation [2 Marks]
   c) Scaling [2 Marks]

SECTION B. ANSWER THREE (3) OF THE FOUR QUESTIONS

1) Consider an RGB display screen with width of $16cm$ and height of $9cm$, aspect ratio of $1:1$, 24bits per pixel and 60Hz refresh rate with 1,024 pixels in horizontally.
   a) What is the resolution of this system? [4 Marks]
   b) How much memory is required for the frame buffer? [6 Marks]
   c) How many colours does this system has? [4 Marks]
   d) Suppose the system has a horizontal retrace of $2.5microseconds$ and $100microseconds$ vertical retrace, how much time is wasted in displaying a single frame? [6 Marks]
2) With the aid of a labelled diagram. Illustrate
   a) the architecture of the interactive Raster graphics system that has a dedicated display processor. [10 Marks]
   b) the Cathode Ray Tube [10 Marks]

3) Suppose $drawTriangle(x_0, y_0, x_1, y_1, x_2, y_2)$ draw a triangle with vertices at (x_0, y_0), (x_1, y_1) and (x_2, y_2) by connecting these points with lines drawn using the DDA algorithm. Show the points that $drawTriangle(3,4,12,11,6,14)$ picks. [20 Marks]
4)
   a) Derive the homogeneous matrix for the following transformations
      i) A translation of point (x, y) by t_x in the x-axis and t_y in the y-axis [8 Marks]
      ii) A rotation of a point (x, y), through an angle θ, about the origin in the anti-clockwise direction. [8 Marks]
   b) Hence, derive the matrix for a rotation of a point (x, y), through an angle θ, about an arbitrary point (x_0, y_0) in the anti-clockwise direction. [Hint: think of translating the point (x_0, y_0) to the origin, do the rotation the get back to (x_0, y_0) by reverse translation]. [4 Marks]

**********END OF EXAMINATION**********

THE UNIVERSITY OF ZAMBIA

School of Natural Sciences

Department of Computer Science

CSC4630 – Advanced Software Engineering

2020/2021 FINAL EXAM

Date:	Tuesday 22nd November 2021
Venue:	NSLT
Time:	14:00 – 17:00 hrs
Duration:	3 Hours

Instructions

1. This exam has two sections A and B.
2. Answer **ALL** questions in **Section A.**
3. Answer **any three (3)** questions in **Section B.**
4. **Total number of questions answered should be 5.**

SECTION A

Answer all questions in this section. Each question carries 20 marks.

QUESTION 1

a) What UML diagram can be used to show how the interface objects are plugged in between the actor and the problem domain classes during a dialog? **[2 Marks]**

b) How do you identify the data fields of a system interface by using UML and the object-oriented approach? **[2 Marks]**

QUESTION 2

a) List five elements included in a sequence diagram. **[5 marks]**

b) What UML diagram is used to model architectural design? **[1 mark]**

c) What are class-level methods and class-level attributes? **[2 marks]**

d) Compare and contrast abstract and concrete classes. Give an example of each **[4 marks]**

e) What are the three types of associations, and which is the most commonly used? **[2 marks]**

QUESTION 3

a) Requirements can be divided into four major types functional, quality, platform and process. Describe quality requirements and give 2 examples of main categories for quality requirements. **[3 marks]**

QUESTION 4

a) What is the purpose of the adapter pattern? **[3 marks]**

b) What common element is found in the singleton pattern and the factory pattern? What is the basic difference between the two patterns? **[4 marks]**

c) How can you most effectively make use of a method that already exists in the other class? Give a sample code for your design. **[4 marks]**

QUESTION 5

a) List six (6) different aspects of software design **[3 marks]**

b) We also used the term "favour object composition over class inheritance". Explain this concept and indicate what possible advantages there may be. In your discussion explain what object composition is, discuss the advantages and disadvantages of class inheritance and the possible advantages of object composition **[5 marks]**

SECTION B

Answer three (3) questions in this section. Each question carries 20 marks.

QUESTION 1 [20 marks]

A professor is trying to open up emailed homework assignments that students have compressed in various formats (zip, tar, jar, arj, sit, rar) in OSX. Unfortunately, OSX has only built-in support for zip and

the professor has to revert to installing various tools to uncompress each file using a command line tool, which is cumbersome.

Design a universal compression tool that can deal with various compression formats.

QUESTION 2 [20 marks]

Lusaka City Council (LCC) have hired your company to build a bus reservation system for all bus trips taken from Intercity Bus Terminal (IBT).

a) Outline in one paragraph the information you would need to gather in order to perform domain analysis for the LCC IBT bus reservation system. **[7 marks]**

b) Requirements can be divided into four major types functional, quality, platform and process. Describe quality requirements and give 2 examples of main categories for quality requirements. **[3 marks]**

c) Classify the following aspects of the LCC IBT bus reservation system into F for functional, Q for quality, PL for platform, PR for process, and X for 'should not be a requirement'. Also indicate the subcategory of requirement. For something that should not be a requirement, explain why not. **[5 marks]**

i. What information appears on tickets and reports.
ii. How fares are calculated.
iii. The system must be available at all times. Only 2 minutes' downtime a week is to be permitted.
iv. The system must run on any Linux system.
v. A merge-sort algorithm must be used to sort the flights by departure time.

d) In describing *simplified use cases* of the LCC IBT bus reservation system, giving the **name** and **steps** of the use cases is enough, however your project manager insists that you describe *complete use cases.* State 5 other components you would add to the description of the use cases of the LCC IBT bus reservation in order to make them complete. Give a short explanation for each component that you state. **[5 marks]**

QUESTION 3 [20 marks]

For this question, read through the MoveYourBooksNow.com case study and answer the questions that follow.

MoveYourBooksNow.com is a book exchange that does business entirely on the Internet. The company acts as a clearinghouse for buyers and sellers of used books.

To offer books for sale, a person must register with MoveYourBooksNow.com. The person must provide a current physical address and telephone number as well as a current e-mail address. The system maintains an open account for this person. Access to the system as a seller is through a secure, authenticated portal.

A seller can list books on the system through a special Internet form. Information required includes all the pertinent information about the book, its category, its general condition, and the asking price. A seller may list as many books as desired. The system maintains an index of all books in the system so buyers can use the search engine to search for books. The search engine allows searches by title, author, category, and keyword.

People who want to buy books come to the site and search for the books they want. When they decide to buy, they must open an account with a credit card to pay for the books. The system maintains all this information on secure servers.

When a request to purchase is made and the payment is sent, MoveYourBooksNow.com sends an e-mail notice to the seller of the book. It also marks the book as sold. The system maintains an open order until it receives notice that the book has been shipped. After the seller receives notice that a listed book has been sold, the seller must notify the buyer via e-mail within 48 hours. Shipment of the order must be made within 24 hours of the seller sending the notification e-mail. The seller sends a notification to the buyer and MoveYourBooksNow.com when the shipment is made.

After receiving notice of shipment, MoveYourBooksNow. com maintains the order in shipped status. At the end of each month, a check is mailed to each seller for the book orders that have been in shipped status for 30 days. The 30-day waiting period allows the buyer to notify MoveYourBooksNow.com if the shipment doesn't arrive for some reason or if the book isn't in the same condition as advertised.

If they want, buyers can enter a service code for the seller. The service code is an indication of how well the seller is servicing book purchases. Some sellers are very active and

use MoveYourBooksNow.com as a major outlet for selling books. Thus, a service code is an important indicator to potential buyers.

For case study above, develop the following diagrams:

a) A domain model class diagram [**5 marks]**

b) A list of uses cases and a use case diagram [**5 marks]**

c) A fully developed description for two use cases: *Add a seller* and *Record a book order* **[5 marks]**

d) An SSD for each of the two use cases in question (c) **[5 marks]**

QUESTION 4 [20 marks]

a) List the elements that make up a transition description. Which elements are optional? **[3 marks]**

b) What is a composite state? What is it used for? **[3 marks]**

c) Assume the diagram below represents the road layout when exiting the UNZA Main Campus along Great East Road with a vehicle. Assume movement in the direction from 2 to 3 represents vehicles moving on Great East Road from Arcades roundabout to Munali roundabout. Traffic lights have been installed at this junction as follows:

i. The traffic light at point 1 has three colors Green, Yellow and Red. When the system starts up the robot is Red.

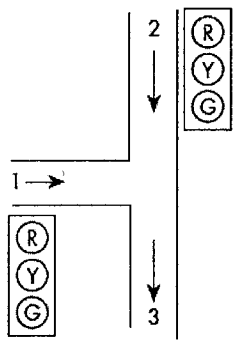
ii. After startup, the system indefinitely rotates among Green, Yellow and Red. The Red light only stays on for 30 seconds, at which time the Green light comes on.

iii. The Green light stays on for 25 seconds, at which time the system changes to Yellow.

iv. After five more seconds the Yellow light gives way to the Red light again.

v. Traffic moving from point 2 to 3 always has a Green light unless a vehicle arrives at point 1 and triggers a sensor.

vi. When the sensor at point 1 is triggered, the robot their changes to Yellow, but only after the traffic coming from point 2 has had at least 25 seconds of Green light. Without this a steady series of vehicles arriving at point 1 would prevent the light at point 2 from staying green long enough for traffic to flow.



Draw a state diagram for the UNZA traffic light system described above, illustrating elapsed-time transitions. **[4 marks]**

d) Discuss the four main reasons why you need to develop an architectural model **[10 marks]**

- END -

THE UNIVERSITY OF ZAMBIA

School of Natural Sciences

Department of Computer Science

CSC4631 – Software Testing & Maintenance

EXAMINATION QUESTION PAPER

Date:	Wednesday 17th November 2021
Venue:	P 207
Time:	14:00 – 17:00 hrs.
Duration:	3 Hours

Instructions

1. This exam has two sections A and B.
2. Answer **ALL** questions in **Section A.**
3. Answer **any four (4)** questions in **Section B.**
4. **Total number of questions answered should be 5.**

SECTION A

QUESTION 1 [20 marks]

1. **[1 mark]** Define software maintenance as described by the IEEE software maintenance standard, IEEE STD 1219-1993.

2. **[6 marks]** The components of the software maintenance framework are *user, environment, maintenance process, software product* and *maintenance personnel.* Discuss in-brief the *user* and *environment* components.

3. **[4 marks]** Under what circumstances might an organization decide to scrap a system when the system assessment suggests that it is of high quality and high business value?

4. **[4 marks]** Give 4 external factors that would motivate or influence change in a software system.

5. **[3 marks]** One of the reasons why software maintenance is needed is *to support mandatory upgrades.* Expound on why this can be said, giving an example of what would be involved.

6. **[2 marks]** Give 2 strategic options for legacy system evolution?

SECTION B

QUESTION 2 [20 marks]

1. **[9 marks]** Describe at least 3 types of change that a software product may undergo in a software maintenance project, giving rationale for each.

2. **[4 marks]** From the period 1974 to 1996, Meir Lehman and Laszlo Belady formulated 8 *laws of software evolution.* The laws describe a balance between forces driving new developments on one hand, and forces that slow down progress on the other hand. Describe the *Law of Conservation of Familiarity* and the *Law of Increasing Complexity.*

3. **[3 marks]** How does *provision of business information* as part of on-going support assist in software maintenance activities?

4. **[4 marks]** As part of the work on a software maintenance project proposal that your team is working on, the team lead asks you to itemize artifacts needed for the design and implementation phases of the project. Give 2 examples of implementation artifacts and design artifacts that you would submit?

QUESTION 3 [20 marks]

1. **[4 marks]** Describe the activities of an individual or team handling configuration management in a software maintenance project?

2. **[3 marks]** Describe briefly the economic implications of modifying software.

3. **[3 marks]** What is a baseline in software configuration management?

4. **[6 marks]** There are several vendors developing and marketing a wide variety of tools that claim to support software maintenance. Bearing this in mind, describe at least 3 factors you should consider before acquiring a tool for software maintenance work?

5. **[4 marks]** The Quick-Fix model of maintaining software in commercial operations is unreliable. Why though is it still used in such settings? And what would be the correct way to use it?

QUESTION 4 [20 marks]

1. **[3 marks]** What is reverse engineering and what is the motivation behind doing it?

2. **[3 marks]** Your co-workers in a software engineering team, Tehila and Isabel are arguing about where it is best to begin reverse engineering. Isabel says the architectural design, Tehila says the source code. Who is right and why?

3. **[6 marks]** Software system abstraction is achieved by highlighting the important features of the subject system and ignoring the irrelevant ones. Briefly describe 3 types of abstractions that can be performed on software systems.

4. **[2 marks]** There are no hard and fast rules as to what criteria a program must fulfil before it may usefully be subject to reverse engineering. There are, however, some indicators which may serve as warning signs. Name at least 2 *product/environment related* indicators that may prove helpful.

5. **[6 marks]** Reverse engineering, in-itself, does not directly lead to modification of a system. The understanding of a system that we obtain through reverse engineering can support the implementation of change. Briefly describe 3 techniques that are used to implement changes after performing reverse engineering.

QUESTION 5 [20 marks]

You are the **maintenance administrator** of a permanent software maintenance team at Zambia Revenue Authority. The revenue authority's taxing software system is large and complex. It is the responsibility of you and your team to ensure that the software system under maintenance is of satisfactory quality. You must also make sure that system changes are effected with minimum possible delay at the least possible cost.

1. **[4 marks]** Briefly describe how you can achieve.

2. **[8 marks]** Describe 4 ways you can motivate personnel on your software maintenance team.

3. **[2 marks]** One of the benefits of exposing your team to education and training is that it enhances recognition. Explain how this is so?

4. **[3 marks]** The rest of your team is made up of a *maintenance leader,* a *user liaison person,* and *maintenance programmers*. What are the typical roles of the these personnel?

5. **[3 marks]** Why do large and complex software systems present challenges for managers of software maintenance projects?

QUESTION 6 [20 marks]

As team lead on the University of Zambia Student Portal System you are putting together a maintenance plan. Part of your plan involves selecting software maintenance measurements.

1. **[2 marks]** Is software measurement different from software metric? Explain.

2. **[4 marks]** In software measurement, there are 2 types of attributes internal attributes and external attributes. Using examples explain how they differ.

3. **[10 marks]** Give 5 main reasons, in brief, of why it is important to carry out software maintenance measurement on the student portal system.

4. **[4 marks]** Some guidelines that can prove helpful in selecting suitable maintenance measures for the student portal system are that the measure should have *well defined objectives*, they should be *fit for purpose,* they should be *easy to use,* they should have *low implementation cost and sensitivity*. Explain how *well defined objectives* and *ease of use* are helpful?

- END OF QUESTION PAPER -

THE UNIVERSITY OF ZAMBIA

School of Natural Sciences

Department of Computer Science

CSC 4642
SOFTWARE QUALITY ASSURANCE

FINAL EXAMINATION

Date:	19th NOVEMBER, 2021
Time:	14:00 – 17:00 HOURS
Duration:	3 Hours
Venue:	NSLT

INSTRUCTIONS

1. This exam paper has **Seven (7)** questions.
2. Answer **ANY FIVE (5)** questions.
3. Clearly identify the problem being solved.
4. Use the marks as a guide to the detail required in your answers while keeping your answers concise and relevant.

QUESTION ONE

1. Consider the following SQA model, where the defect removal activities, effectiveness rates and representative average relative defect-removal costs are illustrated in the following table:

No.	Quality Assurance Activity	Defect Removal Effectiveness Rate	Cost of Removing a Detected defect
1-RSR	Requirements Specification Review	60%	1
2-DI	Design Inspection	50%	5
3-CIUT	Code Inspection	40%	10
4-CUT	Code Unit Test	20%	10
5-IST	Integration	30%	20
6-OPD	Operation Phase Detection	100%	40

Show **the process-oriented illustration** of the comprehensive plan for removing 100 defects that are spread across development phases as follows: **[10 marks]**

- Requirement specification = 15
- Design inspection = 35
- Code inspection = 30
- Integration test = 10
- Operation Phase Detection = 10

2. Define the following metrics of peer review efficiency.
   a. Peer review detection efficiency. [**2 marks**]
   b. Peer review defect detection density. [**2 marks**]
   c. Internal peer review effectiveness. [**2 marks**]

3. Complete the table by putting an "X" in the appropriate columns. [**4 marks**]

Objective of the Review Method	Formal Design Reviews	Inspection	Walkthrough
Error Detection			
Identification of new risks			
Identification of deviation from standards			
Support of corrective actions			
Approval of design documents			
Exchange of professional knowledge between participants			

QUESTION TWO

1. With the aid of a diagram, describe the nine (9) basic phases of the prototyping. [**12 marks**]
2. Comparing the SDLC and prototyping methodologies:
    a. List at least four (4) advantages of prototyping compared to the SDLC methodology for development of small to medium-sized projects. [**4 marks**]
    b. Explain why the advantages of prototyping cannot be realised for large software systems. [**2 marks**]
    c. In what ways can prototyping support the development of large-scale projects? [**2 marks**]

QUESTION THREE

1. One Classification of software quality requirements into software quality factors is the McCall Factor Model.
    a. Name the three (3) factor categories belonging to McCall's factor model. [**1.5 marks**]
    b. List the quality factors under each category from (a). [**5.5 marks**]
    c. Name the other two alternative models for SQ factors. **[3 marks]**
2. Based on items from (b), state the quality factor that best fits each requirement below. [**10 marks**]
    i. Web applications shall be developed to adhere to Hypertext Markup Language (HTML) guidelines and standards.
    ii. The billing system shall be able to process invoices and payments in multiple different currencies. (Currency conversion calculations are to be detailed in business rules and enforced by functional requirements.)
    iii. The data transmission process shall confirm the receiving terminal is in a ready state prior to the start of transmission.
    iv. At least 20 percent of the processor capacity and storage space available to the system shall be unused at peak load seasonal periods.
    v. Accuracy of warehouse temperature readings will be within plus or minus two degrees Celsius.
    vi. The loan origination system shall perform all calculations with rounding to five (5) decimal places before rounding for presentation to two decimal places (dollars and cents).

vii. The firmware of medical laboratory equipment is required to process its results according to a standard data structure that can then serve as input for a number of standard laboratory Information Systems.

viii. The account update process shall roll back all related updates when any update fails to commit.

ix. The baselined version 2 of the spreadsheet must be able to access information from the previous baselined version.

x. A new consumer type code must be able to be added to the product within 12 business hours.

xi. The system shall be developed for Microsoft Vista and Macintosh operating system platforms.

xii. Its heart attack detection function is required to have a failure rate of less than one per million cases.

xiii. A new warehouse clerk shall be able to enter a customer order on the system within a typical 8-hour business day.

xiv. A staff member should be able to handle at least 60 service calls a day.

xv. The size of a SW module will not exceed 30 statements.

xvi. All SmartMeter systems will provide a standard interface that can be used by meter operators for installation and maintenance purposes without disturbing any meter seals and reinstating any tamper detection covers.

xvii. All timestamps recorded by the transaction processing system shall be in UTC (Universal Time Coordinated) when placed into permanent storage.

xviii. Development of functionality to support the Electronic Funds Transfer (EFT) payment option shall be modularized.

QUESTION FOUR

Consider the following system: Module **M12** is integrated with five lower-level **Modules** and only one upper-level **Module**.

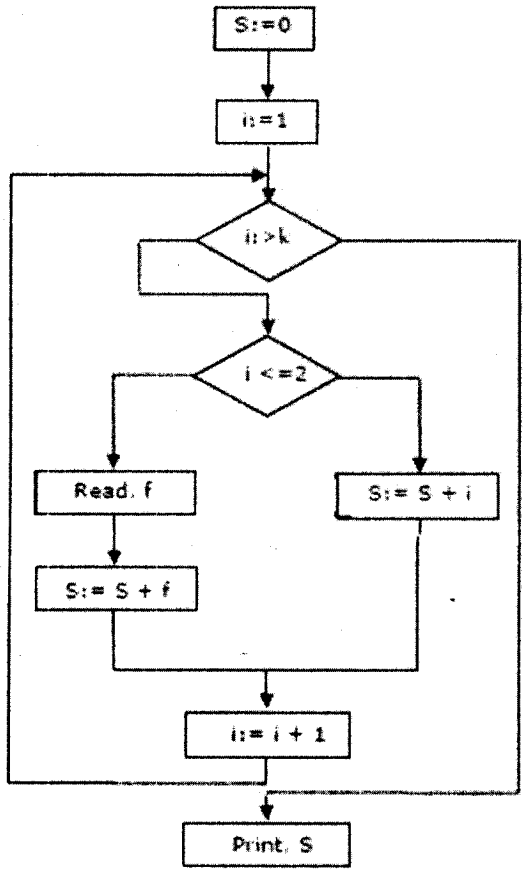
i. Illustrate and describe both top-down and bottom-up testing of the system. [8 marks]

ii. Discuss how stubs and drivers are used in top-down and bottom-up testing of the system. [8 marks]

iii. Based on your discussion in (ii), comment on the resources required to perform each type of testing on the system. [4 marks]

QUESTION FIVE

Consider the following flow chart for a program:



i. Develop the Program Flow Graph for the program. **[5 marks]**

ii. Outline the three (3) methods by which cyclomatic complexity may be computed, and hence compute the Cyclomatic Complexity for each method. **[5 marks]**

iii. Explain what cyclomatic complexity measures. **[3 marks]**

iv. Show the set of paths resulting from your computation of cyclomatic complexity in (ii). **[5 marks]**

v. Comment on the overall complexity of the program based on the Cyclomatic Complexity you computed. **[2 marks]**

QUESTION SIX

1. What is a test case? **[2 marks]**
2. What is Equivalence class partitioning (ECP) and how is it related to test cases? **[3 marks]**

3. One of the fields on a form contains a text box that accepts numeric values in the range of 18 to 25. Identify the Equivalence classes. [**3 marks**]
4. The Switch is switched off once the temperature falls below 18 and then it is turned on when the temperature is more than 21. Identify the Equivalence classes. [**3 marks**]
5. Consider a system designed to work out the taxes to be paid as below and Identify the Equivalence classes: [**4 marks**]
    - An employee has K4000 of salary tax-free.
    - The next K1500 is taxed at 10%.
    - The next K28000 after that is taxed at 22%.
    - Any further amount is taxed at 40%.

6. Consider the following specifications,
    - If you are less than 18, you are too young to be insured.
    - Between 18 and 30 inclusive, you will receive a 20% discount.
    - Anyone over 30 is not eligible for a discount.

    a. Identify the Equivalence classes. [**3 marks**]
    b. Which of the following values for age are in the SAME equivalence partition? [**2 marks**]
        i. 17, 18, 19
        ii. 29, 30, 31
        iii. 18, 29, 30
        iv. 17, 29, 31

QUESTION SEVEN

1. List three categories of individuals who qualify to perform a contract review? [**3 marks**]
2. Outline the characteristics of a 'major proposal'. [**4 marks**]
3. Outline the difficulties of carrying out contract reviews for major proposals [**3 marks**]
4. Outline at least two (2) reasons why it is necessary to develop new project development and quality plans after proposal preparations and review. [**2 marks**]
5. "Preparing full-scale development and quality plans for internal projects, and applying regular full customer–supplier relationships for the implementation of internal projects is highly beneficial to both sides".
    a. Explain four benefits of these procedures to the developer. [**4 marks**]
    b. Explain four benefits to internal customers. [**4 marks**]

The End

THE UNIVERSITY OF ZAMBIA
School of Natural Sciences
Department of Computer Science

FINAL EXAMINATION

CSC 4745 MULTIMEDIA AND HUMAN COMPUTER INTERACTION

Date:	22nd November 2021
Time:	14:00hrs – 17:00hrs
Duration:	3 Hours
Venue:	C126

Instructions

1. There are **two (2) Sections** in this exam, **Section A** and **Section B.**
2. In Section A, **Answer all the questions** and in Section B **choose any three (3) questions.**

SECTION A [40 Marks]

ANSWER ALL QUESTIONS IN THIS SECTION

Question 1 [20 marks]

a) What is the role of Applied Psychology in HCI? **[4 marks]**
b) Explain the top-level concerns of usability goals and user experience goals. **[4 marks]**
c) What are the three reasons for the growth of multimedia from a marketing standpoint? **[4 marks]**
d) Some interactive titles make decision best on user performance. What do we mean by that? **4 marks]**
e) Name the discipline mostly where we get the process by which we build good interfaces. **[4 marks]**

Question 2 [20 marks]

a) In practice, the makeup of a given design team depends on the kind of interactive product being built. Who do you think would need to be involved in developing?
(i) a public kiosk providing information about the exhibits available in a science museum? **[4 marks]**
(ii) an interactive educational website to accompany a TV series? **[4 marks]**

b) Why is it important to under the problem space? **[4 marks]**
c) The more people there are with different backgrounds in a design team, the more difficult it can be to communicate and make progress forward with the designs being generated. Why? **[4 marks]**
d) What are you suppose to take into account when considering the usability of a design. **[4 marks]**

SECTION B [60 MARKS]

ANSWER ANY THREE (3) QUESTIONS IN THIS SECTION.

Question 3 [20 marks]

a) Discuss ten main usability principles, developed by Nielsen and his colleagues. **[5 marks]**

b) Which conceptual model or combination of models do you think is most suited to supporting the following user activities?

i) downloading music off the web **[5 marks]**

ii) programming **[5 marks]**

c) List and explain some considerations and guidelines to keep in mind when working with text. **[5 marks]**

Question 4 [20 marks]

a) What is involved in clarifying your usability and user experience goals is a central part of working out the problem space. **[5 marks]**

b) Explain briefly about multimedia software tools. **[5 marks]**

c) Most of us are familiar with the '404 error' message that pops up now and again when our computer doesn't upload the web page we're trying to view. But what does it mean and why the number 404? How does it make you feel when you see it and what do you do next? Is there a better way of letting users know when they or the computer have made an error? **[5 marks]**

d) Explain briefly on multimedia computer playback systems. **[5 marks]**

Question 5 [20 marks]

a) Explain briefly on what is involved in the process of interaction design? **[5 marks]**

b) Which conceptual model or combination of models do you think is most suited to supporting the following user activities? **[5 marks]**

c) Discuss the tips on designing multimedia for the Web. **[5 marks]**

d) Explain briefly on mental models and external cognition. **[5 marks]**

Question 6 [20 marks]

a) There are times when the multimedia title must include a great deal of text-for example, in reference titles such as encyclopedias. However, there are ways to accommodate large amounts of text without overwhelming and perhaps turning off the user. Explain the ways. **[5 marks]**

b) External cognition is concerned with explaining the cognitive processes involved when we interact with different external representations. A main goal is to explicate the cognitive benefits of using different representations for different cognitive activities and the processes involved. Discuss external cognition. **[5 marks]**

c) Discuss several elements that determine the file size of the video. **[5 marks]**

d) Explain why it is not recommended to first work out how to design the physical interface. **[5 marks]**

THE END

THE UNIVERSITY OF ZAMBIA

School of Natural Sciences

Department of Computer Science

FINAL EXAMINATION

CSC 4792

Data Mining and Warehousing

Date:	15th NOVEMBER 2021
Time:	14:00hrs – 17:00hrs
Duration:	3 Hours
Venue:	NSLT

Instructions

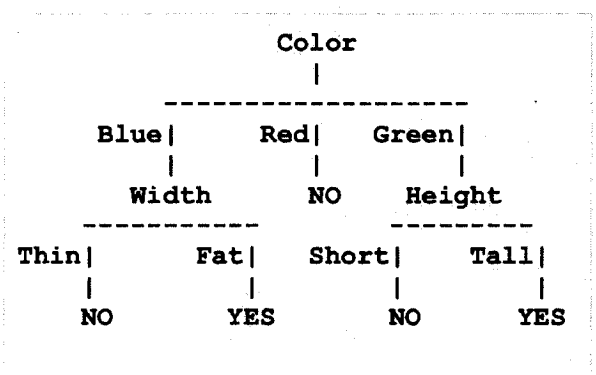
1. There are **two (2) Sections** in this exam, **Section A** and **Section B.**
2. In Section A, **answer all the questions** and in Section B **choose any three (3) questions.**

Section A: Answer **ALL** questions

1. The relationship between hospital patient-to-nurse ratio and various characteristics of job satisfaction and patient care has been a focus of several research studies. Suppose x = patient-to-nurse ratio is the independent variable. For each of the following potential dependent variables, indicate whether you expect the correlation to be positive or negative. **(6 Marks)**
   a. y = a measure of a nurse's job satisfaction
   b. y = a measure of patient satisfaction with hospital care
   c. y = a measure of patient quality of care

2. What is the difference between the Manhattan Distance and Euclidean Distance in Clustering? **(2 Marks)**

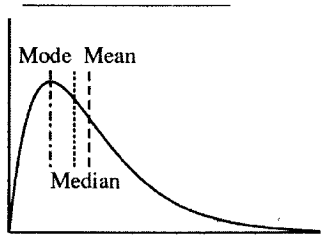
3. Given the following decision tree, show how the new examples in the table would be classified by filling in the last column in the table. If an example cannot be classified, enter UNKNOWN in the last column. **(5 Marks)**



Color	Height	Width	Class
Red	Short	Thin	
Blue	Tall	Fat	
Green	Short	Fat	
Green	Tall	Thin	
Blue	Short	Thin	

4. Given a regression equation $Y = -0.0127 + mX$. It is found that each value of X increases the value of Y by an average amount of 1.8%. Compute the value of m. **(3 Marks)**

5. The figure below represents a distribution of _____ skewed data **(2 Marks)**



6. Given $\dot{O} = \frac{1}{N}\sum_{i=1}^{N}(x_i - \bar{x})^2$, what does $\dot{O}$ compute? **(3 Marks)**

7. The mean of 11 numbers is 7. One of the numbers, 13, is deleted. What is the mean of the remaining 10 numbers? **(2 Marks)**

8. A and B are two events. If P(A, B) decreases while P(A) increases, what happens to P(B|A)? **(3 Marks)**

9. A new test has been devised for detecting a particular type of cancer. If the test is applied to the person who has that type of cancer, the probability that person will have a positive reaction is 0.995. If applied to a person who does not have this type of cancer, the probability that the person will have a (false) positive reaction is 0.012. Suppose that test is given to patients at high risk of having cancer, and that one person, out of 50 in this group has this type of cancer.

    a. What is the probability that the randomly selected person from the group tests positive? **(5 Marks)**

    b. If randomly selected person tests positive, what is the probability that he/she does not have this type of cancer. **5 (Marks)**

10. A regression was done for 20 cities with latitude as the independent variable (x) and average January temperature as the dependent variable (y). The latitude is measured in degrees and average January temperature in degrees Fahrenheit. The latitudes ranged from 26 (Lusaka) to 47 (Ndola). The regression equation is $\hat{y} = 49.4 - 0.313x$. Chipata has latitude 40 degrees with average January temperature of 25 degrees Fahrenheit. **(4 Marks)**
    a. What is the estimated average January temperature for Chipata, based on the regression equation?
    b. What is the residual?

Section B: Answer any **THREE (3)** questions

1. The results for students who sat for the two CSC 4792 tests are shown below: **(20 Marks)**

T1	99	56	78	55.5	32	90	80	81	56	59	45	77	84.5	84	70	72	68	32	79	90	
T2	98	78	68	83	81	89	88	76	65	45	98	90	80	84.5	85	79	78	98	90	79	81	25.5

   a) Find the smallest and largest values, the median, and the first and third quartile for test one (T1)
   b) Find the smallest and largest values, the median, and the first and third quartile test 2 (T2)
   c) Create a box plot for each set of data. Use one number line for both box plots.
   d) Which box plot has the widest spread for the middle 50% of the data (the data between the first and third quartiles)? What does this mean for that set of data in comparison to the other set of data?

2. Given the following 8 coordinates:
   P1(2, 10), P2(2, 5), P3(8, 4), P4(5, 8), P5(7, 5), P6(6, 4), P7(1, 2), P8(4, 9)
   Cluster the following eight points (with (x, y) representing locations) into three clusters: The initial cluster centers are: P1(2, 10), P4(5, 8) and P7(1, 2). The distance function between two points a = (x1, y1) and b = (x2, y2) is defined using the Manhattan distance as: $D(a, b) = |x2 - x1| + |y2 - y1|$. Use K-Means Algorithm to find the three cluster centers after the second iteration. **(20 Marks)**

3. The table below show the data collected for a particular stock. Using the data collected, draw a decision tree by using the GINI Index. Show your calculation for each level. **(20 Marks)**

Past Trend	Open Interest	Trading Volume	Return
Positive	Low	High	Up
Negative	High	Low	Down
Positive	Low	High	Up
Positive	High	High	Up
Negative	Low	High	Down
Positive	Low	Low	Down
Negative	High	High	Down
Negative	Low	High	Down
Positive	Low	Low	Down
Positive	High	High	Up

4. Consider the data set show below:

Instance	A	B	C	Class
1	0	0	1	-
2	1	0	1	+
3	0	1	0	-
4	1	0	0	-
5	1	0	1	+
6	0	0	1	+
7	1	1	0	-
8	0	0	0	-
9	0	1	0	+
10	1	1	1	+

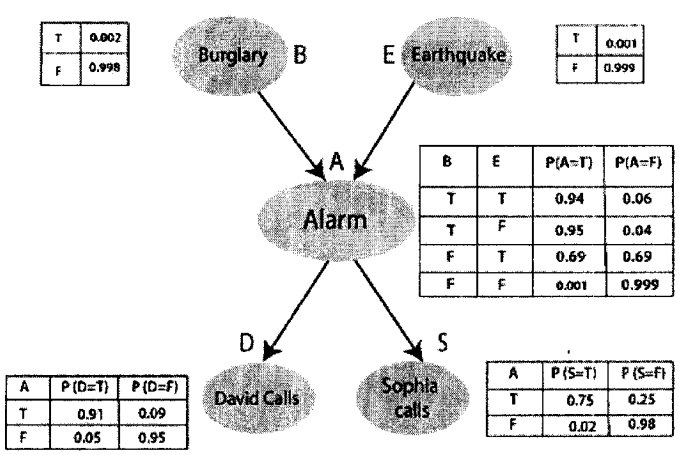
a) Estimate the conditional probabilities for P(A=1|+), P(B=1|+), P(C=1|+), P(A=1|-), P(B=1|-), P(C=1|-). **(12 Marks)**

b) The height (in inches) of 8 high school girls and their scores on an IQ test is given below: **(8 Marks)**

Height, x	62	58	65	67	59	64	65	57
IQ Score, y	109	102	107	114	96	110	116	128

Display the data in a scatter plot, describe the type of correlation, and interpret the correlation in context of the data.

5. Chanda installed a new burglar alarm at his home to detect burglary. The alarm reliably responds at detecting a burglary but also responds for minor earthquakes. Chanda has two neighbors David and Sophia, who have taken a responsibility to inform Chanda at work when they hear the alarm. David always calls Chanda when he hears the alarm, but sometimes he got confused with the phone ringing and calls at that time too. On the other hand, Sophia likes to listen to high music, so sometimes she misses to hear the alarm. The Bayesian belief network structure is given below.



a) Calculate the probability that alarm has sounded, but there is neither a burglary, nor an earthquake occurred, and David and Sophia both called the Harry. **(12 Marks)**

b) Calculate the probability that Sophia calls Chanda, given that the alarm has sounded, there is an earthquake, and no burglary **(8 Marks**

THE UNIVERSITY OF ZAMBIA
School of Natural Science
Department of Computer Science

FINAL EXAMINATION

CSC 4812: CLOUD AND HIGH-PERFORMANCE COMPUTING

Date:	Tuesday, 16th November 2021
Time:	09:00hrs – 12:00hrs
Duration:	3 Hours
Venue:	GLT

Instructions

1. There are **Five (5) questions** and **two (2) sections** in this paper
2. Each question carries **25 marks**
3. *You are required to answer a total of* ***Four (4) Questions***
    a. *Answer* ***all*** *the questions in* ***Section A***
    b. Choose ***one (1)*** *question from* ***Section B***

SECTION A

This Section has Three Questions. Answer all the questions

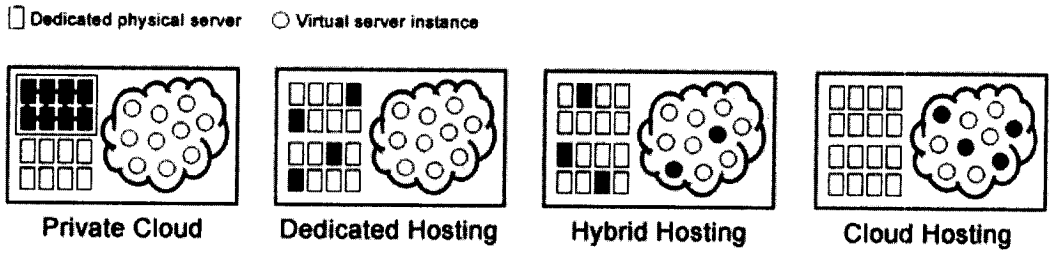
Question I

a) Clouds are a large pool of easily usable and accessible virtualized resources such as hardware, development platforms and/or services. These resources can be dynamically reconfigured to adjust to a variable load, allowing also for optimum resource utilization. The key characteristics of cloud computing include [6 Marks]

i. Pay-per-use
ii. Elastic capacity
iii. Illusion of Infinite Resources
iv. Self-Service interface
v. Resources that are abstracted or virtualized
vi. Provide API and Development tools for developers to build scalable applications on their services.

Briefly discuss each of the characteristics above

b) The diagram below shows the four types of cloud deployment Models. Briefly give a description of each model with at least one example in Zambia [8 Marks]



c) Virtualization is the process of running a virtual instance of a computer system in a layer abstracted from the actual hardware. Most commonly, it refers to running multiple operating systems on a computer system simultaneously. To the applications running on top of the virtualized machine, it can appear as if they are on their own dedicated machine, where the operating system, libraries, and other programs are unique to the guest virtualized system and unconnected to the host operating system which sits below it [11 Marks].

i. What is the Virtual Infrastructure Managers (VIMs)
ii. Discuss each of the following Key Features of the Virtual Infrastructure Managers
    1. Virtualization Support

2. Self-Service, On-Demand Resource Provisioning
3. Multiple Backend Hypervisors
4. Storage Virtualization
5. Interface to Public Clouds
6. Dynamic Resource Allocation
7. Virtual Clusters
8. Reservation and Negotiation Mechanism
9. High Availability and Data Recovery

Question II

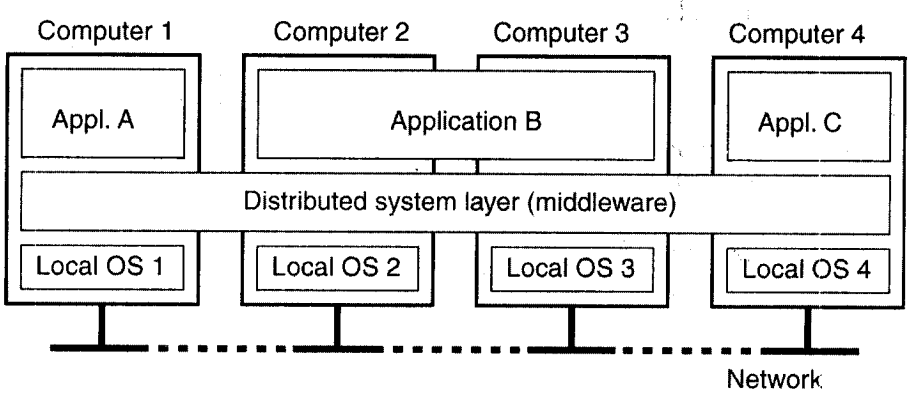
a) The cloud service models can basically be classified as follows [18 Marks]

i. Software as a Service
ii. Platform as a Service
iii. Infrastructure as a Service

Draw a well labelled diagram showing Cloud Service Models and how each of the three services above are related to each other. **For each of the three service models above,**

1. Give a brief description by citing the characteristics of the service model
2. Give the major benefits that comes with the implementation of the service model
3. Give the main disadvantages that comes with the implementation of the service model
4. Give one example implementation in real life

b) The diagram below shows a distributed system organized as middleware. The middleware layer extends over multiple machines, and offers each application the same interface. Discuss the key Middleware Design Goals [7 Marks]

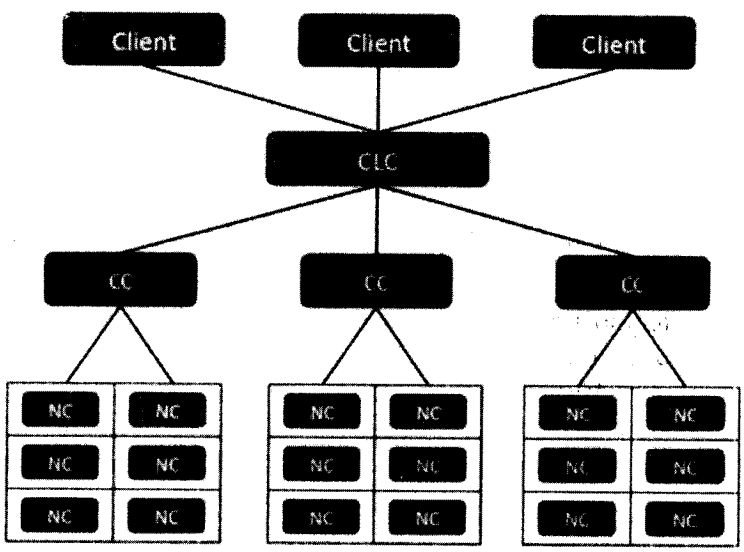


Question III

a) In order to ensure that data is secure, that it cannot be accessed by unauthorized users or simply lost, and that data privacy is maintained, cloud providers attend to the following areas. **Discuss each of the above in relation to cloud computing security** [8 Marks].
   i. Data protection
   ii. Identity management
   iii. Physical and personnel security
   iv. Privacy

b) Scalable Parallel Computer Architectures is based on how processors, memory and interconnect are laid out. Briefly discuss each of the groupings below [6 Marks].
   i. Massively Parallel Processors (MPP)
   ii. Symmetric Multiprocessors (SMP)
   iii. Cache-Coherent Nonuniform Memory Access (CC-NUMA)

c) The diagram below gives the Hierarchical Design of Cloud Computing implementation. with the help of a diagram, give a brief description and function of each of the following component in the implementation. [11 Marks]
   i. Client
   ii. CLC
   iii. CC
   iv. NC



SECTION B

This section has TWO Questions. Choose one question

Question I

a) There are a number of reasons why companies and various organisations are afraid to use cloud services. Briefly discuss each of the following in relation to cloud security and give at least one example in each case. [9 Marks]

i. Cloud Threat Model
ii. Cloud Confidentiality
iii. Cloud Security

b) There are several causes of problems associated with cloud computing. However, most security problems stem from [9 Marks]:

i. Loss of control
ii. Lack of trust (mechanisms)
iii. Multi-tenancy

Discuss each of these challenges and how they are being addressed in cloud implementation

c) Infrastructure as a Service (IaaS) allows existing applications to run on its hardware. IaaS rents out resources dynamically wherever they are needed. Briefly discuss each of the following in relation to IaaS [7 Marks]

i. Services
ii. Geographical Presence
iii. User Interfaces and Access to Servers
iv. Advance Reservation of Capacity
v. Automatic Scaling and Load Balancing
vi. Service-Level Agreement

Question II

a) Discuss each of the following issues in relation to cloud computing [6 Marks]
   i. Security
   ii. Compliance
   iii. Legal

b) Platform as a Service (PaaS) provides all infrastructures needed for a consumer to run applications over the internet. PaaS is a Cloud Computing service that offers a computing platform and solution stack for users [11 Marks].
   i. List four categories of software applications offered as a PaaS
   ii. A PaaS Cloud should be able to support various programming models for different types of programming. List and discuss four examples of PaaS programming Models
   iii. Give two advantages and two disadvantages of PaaS

c) Describe each of the following prominent components of cluster computers [8 Marks]
   i. Cluster Computer Nodes
   ii. State of the art Operating Systems
   iii. Fast Communication Protocols and Services
   iv. Cluster Middleware

End of the Examination

THE UNIVERSITY OF ZAMBIA
School of Natural Sciences
Department of Computer Science

FINAL EXAMINATION

CSC 4822
ROUTING AND SWITCHING TECHNOLOGIES

Date:	17th November 2021
Time:	09:00hrs – 12:00hrs
Duration:	3 Hours
Venue:	NSLT

Instructions

1. There are **two (2) Sections** in this exam, **Section A** and **Section B**.
2. In Section A, **answer all the questions** and in Section B **choose any three (3) questions.**

SECTION A [40 marks]

ANSWER ALL QUESTIONS IN THIS SECTION

Question 1 [20 marks]

a) What advantage does SSH offer over Telnet? **[3 marks]**
b) Name two ways in which a host can be assigned an IP address? **[2 marks]**
c) What is the significant difference between a hub and a Layer 2 LAN switch? **[2 marks]**
d) What is the purpose of frame buffers on a switch? **[2 marks]**
e) Name two console access requirements. **[2 marks]**
f) Which command do you use when you want to name the device? **[2 marks]**
g) What are three advantages of using EtherChannel technology? **[3 marks]**
h) Which command do you use when you want to activate an interface? **[2 marks]**
i) Which command displays the contents of the IPv4 routing table stored in RAM? **[2 marks]**

Question 2 [20 marks]

a) Name two link aggregation protocols. **[2 marks]**
b) Which network device can serve as a boundary to divide a Layer 2 broadcast domain? **[2 marks]**
c) What is the metric of OSPF? **[1 mark]**
d) A router can learn about remote networks in one of two ways. Name the ways. **[2 marks]**
e) When can multiple static routes can be summarized into a single static route? **[1 mark]**
f) Why is a separate VLAN needed to support Voice over IP (VoIP)? **[2 marks]**
g) Which command do you use to disable and eliminate RIP? **[1 mark]**
h) Name two switch forwarding methods? **[2 marks]**
i) Sending out unneeded updates on a LAN impacts the network in three ways in the case of passive interfaces. List the ways. **[3 marks]**
j) What is a disadvantage of using multilayer switches for inter-VLAN routing? **[4 marks]**

SECTION B [60 marks]

ANSWER ANY THREE (3) QUESTIONS IN THIS SECTION

Question 3 [20 marks]

a) A router has the following networks attached to it: network 10.1.1.0/24, network 10.1.2.0/24, and network 192.168.10/30. Configure OSPFv2 on this router. Show all your work. **[5 marks]**
b) OSPF defines five network types. Explain these types of networks. **[5 marks]**
c) Differentiate static from dynamic routing. **[5 marks]**
d) Discuss the purpose of dynamic routing protocols. **[5 marks]**

Question 4 [20 marks]

a) A router has the following networks attached to it: network 10.1.1.0/24, network 10.1.2.0/24, and network 192.168.10/30. Configure EIGRP on this router. Show all your work. **[5 marks]**
b) Discuss the primary uses of static routing. **[5 marks]**
c) Discuss five important characteristics of switches that contribute to alleviating network congestion. **[5 marks]**
d) Discuss the disadvantages of static routing. **[5 marks]**

Question 5 [20 marks]

a) A router has the following networks attached to it: network 10.1.1.0/24, network 10.1.2.0/24, and network 192.168.10/30. Configure EIGRP for IPv6 on this router. Show all your work. **[5 marks]**
b) User productivity and network adaptability are important for business growth and success. VLANs make it easier to design a network to support the goals of an organization. Discuss the primary benefits of using VLANs **[5 marks]**
c) There are various types of switches used in business networks. It is important to deploy the appropriate types of switches based on network requirements. Discuss the types. **[5 marks]**
d) EtherChannels can be formed through negotiation using one of two protocols, PAgP or LACP. Discuss the protocols PAgP and LACP. **[5 marks]**

Question 6 [20 marks]

a) A router has the following networks attached to it: network 10.1.1.0/24, network 10.1.2.0/24, and network 192.168.10/30. Configure OSPFv3 on this router. Show all your work. **[5 marks]**
b) There are guidelines and restrictions that you must use when configuring EtherChannel. Discuss the guidelines and restrictions. **[5 marks]**
c) Explain briefly the difference between IGRP and EIGRP. **[5 marks]**
d) In 1993, RIPv1 was updated to a classless routing protocol known as RIP version 2 (RIPv2). RIPv2 included a number of improvements. Discuss the improvements. **[5 marks]**

THE END

THE UNIVERSITY OF ZAMBIA

School of Natural Sciences

Department of Computer Science

FINAL EXAMINATION

CSC 4845
FUNDAMENTALS OF CLUSTER AND HIGH-PERFORMANCE COMPUTING

Date:	23rd November 2021
Time:	09:00hrs – 12:00hrs
Duration:	3 Hours
Venue:	NSLT

Instructions

1. There are **Five (5) Questions** and **Two (2) Sections** in this paper.
2. Each question carries **25 Marks,** *you are required to answer a total of* ***four (4) Questions***
3. *Answer* ***ALL the questions in Section A*** and choose ***Any One (1)*** *question from* ***Section B***

SECTION A

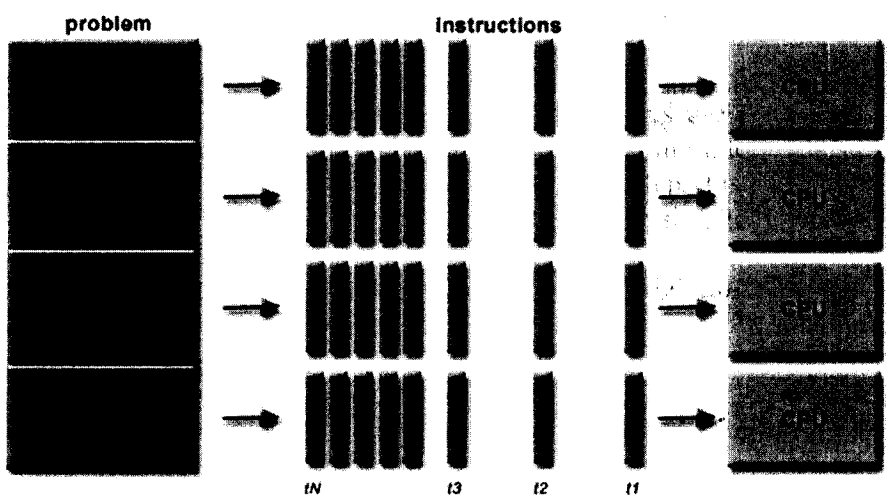
This Section has Three Question. Answer **ALL** the Questions

QUESTION ONE

a) Briefly discuss each of the following terminologies below. Give examples where possible [3 Marks]
   i. Cluster Computing
   ii. High Performance Computing
   iii. Grid Computing

b) Cluster computing is the process of sharing the computation tasks among multiple computers that form the cluster and works on the distributed system with the networks. Describe the major steps required in building a **Virtual Beowulf Cluster** using **VirtualBox** [8 Marks]

c) In the simplest sense, parallel computing is the simultaneous use of multiple compute resources to solve a computational problem. To be run using multiple CPUs, a problem is broken into discrete parts that can be solved concurrently. Each part is further broken down to a series of instructions. Instructions from each part execute simultaneously on different CPUs as shown in the diagram below [14 Marks]
   i. Draw a diagram similar to the diagram below for **Serial Computing** and explain how ***serial computing*** works
   ii. Give **three** reasons why we need Parallel Computing?
   iii. What are some of the Limitations of Serial Computing?
   iv. Traditionally, parallel computing has been considered to be ***"the high end of computing"*** and has been motivated by numerical simulations of complex systems and ***"Grand Challenge Problems"***. Give any four (4) Examples of the grand Challenging Problems



QUESTION TWO

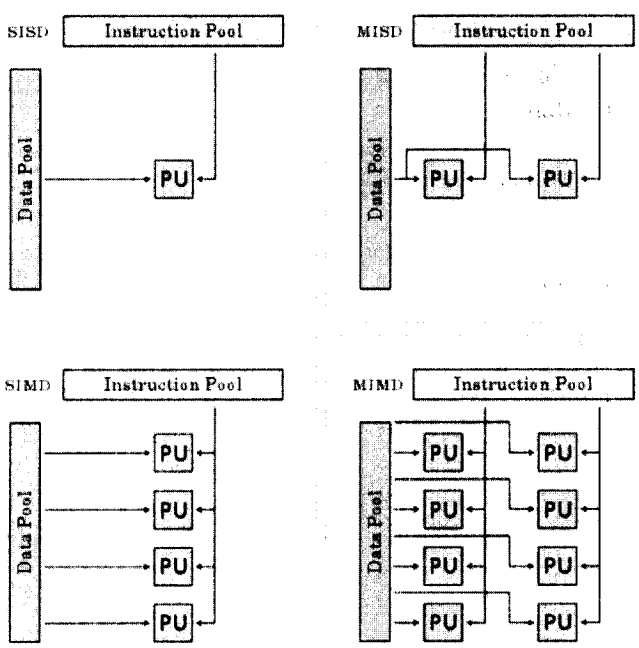
a) Scalable Parallel Computer Architectures is based on how processors, memory and interconnect are laid out. These can be classified in five major groupings. Briefly discuss each of the groupings below [6 Marks].

i. Massively Parallel Processors (MPP)
ii. Symmetric Multiprocessors (SMP)
iii. Cache-Coherent Nonuniform Memory Access (CC-NUMA)

b) Virtualization uses software to create an abstraction layer over computer hardware that allows the hardware elements of a single computer processors, memory and storage to be divided into multiple virtual computers, commonly called virtual machines [9 Marks].

i. Draw a diagram showing the difference between a virtualised and none virtualised implementation
ii. Discuss each of the following with respect to visualization
    1. Host Operating System
    2. Guest Operating System
iii. Name any two open-source virtualisation software for both Windows and LINUX

c) There are different ways to classify parallel computers. One of the more widely used classifications is called Flynn's Taxonomy. Flynn's taxonomy distinguishes multi-processor computer architectures according to how they can be classified along the two independent dimensions of Instruction and Data. Each of these dimensions can have only one of two possible states: Single or Multiple as shown in the diagram below. Discuss each category with the help of a diagram [10 Marks]



QUESTION THREE

a) With reference to single image system, discuss each of the following middleware design goals [6 Marks]
   i. Complete transparency in resource management
   ii. Scalable performance
   iii. Enhanced availability

b) With the help of a diagram, briefly discuss each of the following with respect to **Designing Parallel Programs** [10 Marks]
   i. Automatic vs. Manual Parallelization
   ii. Partitioning
   iii. Communications
   iv. Load Balancing
   v. Granularity

c) There are several parallel programming models in common use today as listed below. Parallel programming models exist as an abstraction above hardware and memory architectures. Although it might not seem apparent, these models are NOT specific to a particular type of machine or memory architecture. Any of these models can be implemented on any underlying hardware. Which model to use is often a combination of what is available and personal choice. There is no best model, although there certainly are better implementations of some models over others. Examples of parallel programming models include [9 Marks]
   i. Threads
   ii. Message Passing
   iii. Data Parallel

   1. **Describe in detail each of the five parallel programming models mentioned above**
   2. **Discuss some of the actual implementations of the five parallel programming models mentioned above**

SECTION B

This Section has Two (2) Questions. Choose **One** (1) question

QUESTION ONE

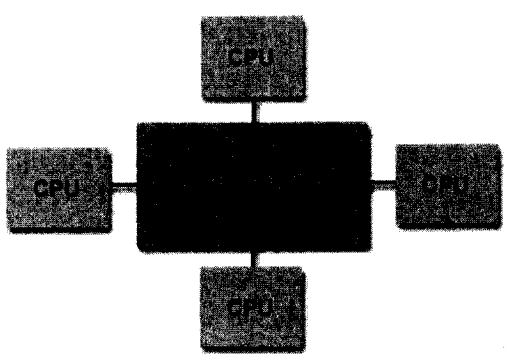
a) A single system image (SSI) is the illusion, created by software or hardware, that presents a collection of resources as one, more powerful resource. SSI makes the cluster appear like a single machine to the user, to applications, and to the network. Name and discuss any five (5) Single System Image Benefits [5 Marks]

b) A cluster is a type of parallel or distributed processing system, which consists of a collection of interconnected stand-alone computers cooperatively working together as a single, integrated computing resource. Briefly discuss each of the following Prominent Components of Cluster Computers [10 Marks]

i. State of the art Operating Systems
ii. High Performance Networks/Switches
iii. Fast Communication Protocols and Services
iv. Cluster Middleware
v. Applications and Subsystems

c) Shared memory parallel computers vary widely, but generally have in common the ability for all processors to access all memory as global address space as shown in the Figure below. Multiple processors can operate independently but share the same memory resources. Changes in a memory location effected by one processor are visible to all other processors. Shared memory machines can be divided into two main classes based upon memory access times namely UMA and NUMA. With the help of a diagram, describe each of the following in details [10 Marks]

i. UMA and NUMA
ii. Distributed Memory
iii. Hybrid Distributed-Shared Memory



QUESTION TWO

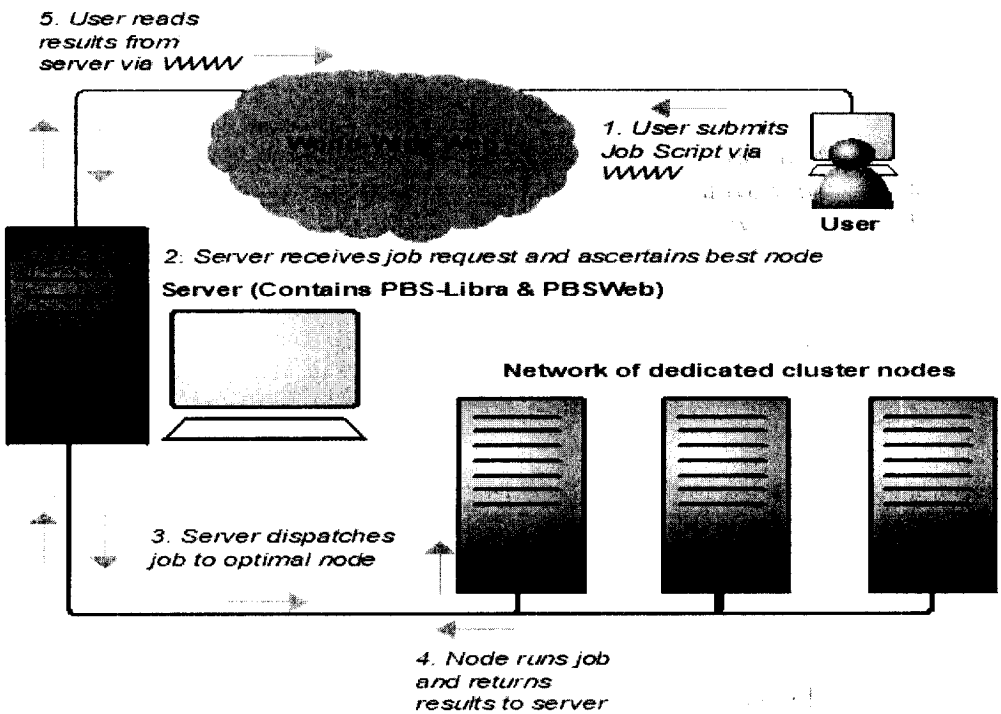
a) Cluster Programming Environments include Shared Memory Based, Threads/OpenMP, Message Passing Based, Parametric Computations, Automatic Parallelising Compilers and Parallel Libraries & Computational Kernels. Briefly discuss each of the following in relation to Cluster Programming Environments and Tools [10 Marks]

i. Threads (PCs, SMPs, NOW.)
ii. Message Passing Systems (MPI and PVM)
iii. Distributed Shared Memory (DSM) Systems
iv. Parallel Debuggers and Profilers
v. Performance Analysis Tools

b) A cluster is a type of parallel or distributed processing system, which consists of a collection of interconnected stand-alone computers cooperatively working together as a single, integrated computing resource called NODES. Give any five major characteristics of a node in the context of cluster computing [5 Marks]

c) Resource Management and Scheduling (RMS) is the act of distributing applications among computers to maximize their throughput and enable the effective and efficient utilization of the resources available.as shown in the diagram below [10 Marks].

i. Draw the diagram showing **cluster scheduler.** *Use **Libra** as an example of the **cluster scheduler** (Show the Server Master Node and Cluster Worker Nodes)*
ii. Explain how RMS enables the effective and efficient utilization of the resources available through the services provided by RMS



END OF EXAMINATION PAPER

THE UNIVERSITY OF ZAMBIA
School of Natural Sciences
Department of Computer Science

FINAL EXAMINATION

CSC 5011 COMPUTER PROGRAMMING

Date:	19th November 2021
Time:	14:00hrs – 17:00hrs
Duration:	3 Hours
Venue:	CL2

Instructions

1. There are **two (2) Sections** in this exam, **Section A** and **Section B.**
2. In Section A, **Answer all the questions** and in Section B **choose any three (3) questions.**

Section A (Compulsory) [40 Marks]

1. What are the values of the following variables? **[5 marks]**
   a) double var1 = 10 / 3;
   b) int var2 = (int) (2.5 * 2.6);
   c) boolean var3 = !(3 > 3);
   d) boolean var4 = (121 % 11 == 0) || (5 == 5);
   e) int var5 = 11 % 3;

2. Assuming that a and b are both int type variables. Describe the difference between "a = b", "a == b" and "a += b". **[3 marks]**

3. Suppose you have the variable str of type String with data "How are you?" Write out the data stored in str and place the index of each character below the string. **[2 marks]**

4. Study a piece of a java code below and answer all the questions below;

```
int i = 30;
while(i >= 0)
{
   if(i % 2 > 0)
   {
     continue;
   }
   System.out.println(i);
   i--;
}
```

   a) What is the output of the above code? **[2 Marks]**
   b) Rewrite the above code using the for loop **[2 Marks]**
   c) Rewrite the above code using the do while loop **[2 Marks]**

5. What is wrong with this piece of code? **[3 marks]**

```
int count = 0;
   while (count < 100)
        if (count % 5 == 0)
          System.out.println(count);
          count++;
```

6. What is wrong with this piece of code? (Circle the error and tell me why it's wrong) **[3 marks]**

```
do {
        System.out.print("The programming language, "Java", ");
   }
while (false);
    System.out.println("is named after the Java coffee");
```

7. What is wrong with this piece of code? (Circle two errors and tell me why they're wrong) **[4 marks]**

```
public int absoluteValue(int num)
    {
      if (num < 0);
            return -num;
      else if (num > 0)
            return num;
     }
```

8. Write the output for the piece of code. **[8 marks]**

```
int a = 2, b = 2, c = 2;
for (int i = 0; i < 3; i++)
{
  a += a;
  b *= b;
  c /= c;
}
System.out.println(a + ", " + b + "," + c + ".");
```

9. Write the output of the method doSomething(). **[6 marks]**

```
public void swap(int a, int b)
 {
   int temp = a;
   a = b;
   b = temp;
}

public void doSomething()
{
    int a = 2, b = 3;
    a = b;
    b = a;
   System.out.println(a + "," + b);
   int c = 2, d = 3;
   int temp = c;
   c = d;
   d = temp;
  System.out.println(c + "," + d);
  int e = 2, f = 3;
  swap(f, e);
  System.out.println(e + "," + f);
}
```

Section B [Answer any three [3] question. Each question is worth 20 Marks]

1. Write a program in Java that displays the grade of a mark. The grade system is as follows;
   90 – 100 A+
   80 – 89 A
   70 – 79 B+
   60 – 69 B
   50 – 59 C+
   45 – 49 C
   0 – 44 D
   Your program must not allow marks below 0 and above 100. Use the command line both for prompting the user for a mark and displaying the grade **[20 Marks]**

2. Create a class that holds 10 grades in an array data structures. **[2 Marks]**
   a) Loop through the data structure and compute the sum of grades **[2 Marks]**
   b) Loop through the data structure and compute the average of grades **[4 Marks]**
   c) Loop through the data structure and print the biggest grade **[4 Marks]**
   d) Loop through the data structure and print the lowest grade **[4 Marks]**
   e) Print the grades in the descending order of indexes **[4 Marks]**

3. Write an instantiable class called Counter that has:
   a) An integer instance variable called *numClicks* **[2 Marks]**
   b) A constructor that sets *numClicks* to 0 **[2 Marks]**
   c) A method called click() that adds 1 to *numClicks* **[4 Marks]**
   d) A method called getClicks() that returns *numClicks* **[4 Marks]**

   Write a driver program called TestCounter that
   e) Creates a counter object **[2 Marks]**
   f) Calls the click method 2 times **[4 Marks]**
   g) Calls the getClicks() method and prints its value **[2 Marks]**

4. Write a main method that
   a) prompts a user to enter an integer **[2 Marks]**
   b) passes that integer to a method called cube **[2 Marks]**
   c) receives the cube of that integer back from the method **[2 Marks]**
   d) displays the return value **[2 Marks]**

   Write a method called cube that
   e) accepts an integer, cubes it and returns the result **[4 Marks]**
   f) Change the preceding code so the main method has a *for* loop **[4 Marks]**
   g) It passes the numbers 0 to 3 to the cube method, one at a time **[2 Marks]**
   h) It receives back the result from the cube method and displays it **[2 Marks]**
   i) The cube method is unchanged

THE UNIVERSITY OF ZAMBIA
School of Natural Sciences
Department of Computer Science

FINAL EXAMINATION

CSC 5021
ALGORITHMS & DATA TRUCTURES

Date	:	25TH NOVEMBER 2021
Time	:	14:00HRS – 17:00HRS
Duration	:	3 HOURS
Venue	:	CL2

Instructions

1. There are **two (2) Sections** in this exam, **Section A** and **Section B**.
2. **Answer ALL the questions** in Section A and **choose any three (3) questions** in Section B

SECTION A. ANSWER ALL QUESTIONS

1)

a) Define what an algorithm is [2 Marks]

b) Explain why algorithm analysis is important [8 Marks]

2)

a) Suppose you are given that $a^x = b^y$, what is x in terms of a, d and y? [2 Marks]

b) Suppose log(x) = 0.2 and log(y) = 0.8, what is

i) $\log(xy)$ [2 Marks]

ii) xy [2 Marks]

3) In terms of n, what is the sum [4 Marks]

$$\sum_{i=1}^{n} a \, , where \; a \; is \; a \; constant$$

4)

a) Define recursion. [2 Marks]

b) Describe the following four rules of recursion. [8 Marks]

i) Base case

ii) Making progress

iii) Compound interest

iv) Assume the recursive calls work.

5) For each of the following data structures

- Describe what it is
- Outline the valid operations on them
- Give two applications

i) A queue [10 Marks]

ii) A Stack [10 Marks]

SECTION B. ANSWER THREE (3) OF THE FOUR QUESTIONS

1)

a) Using the principle of mathematical induction to prove that [8 Marks]

$$\sum_{i=1}^{n} i = \frac{n(n+1)}{2}$$

b) Hence, or otherwise,

i) Evaluate the sum of all even numbers between 1 and 100 [4 Marks]

ii) Derive the formula for the sum of the first n odd numbers [8 Marks]

$$\sum_{i=1}^{n} (2i - 1)$$

2) Consider the code below

$$a \leftarrow 0$$

```
For i ← 1 to n do
        a ← a + i
Next
Print a
```

a) Draw the flowchart for this code.

b) Simulate the execution of the code if n = 5.

c) What is the big-Oh analysis of this algorithm?

3)

a) Design an algorithm which takes as input an array of integers and a value k and returns the index of k in A if it exists or -1 if k is not in A.

b) Give a asymptotic analysis of you algorithm

4)

a) Describe the operations of the Bubble sort algorithm

b) Simulate the sorting of the array below using bubble sort. In each iteration, indicate the number of comparisons and swaps.

23	12	69	5	3

**********************END OF EXAMINATION*******************

Essential Formulas

For constants a and b

$$\sum_{i=1}^{n}(ai+b) = a\sum_{i=1}^{n} i + \sum_{i=1}^{n} b$$

$$\sum_{i=1}^{n} 1 = n$$

THE UNIVERSITY OF ZAMBIA
School of Natural Sciences
Department of Computer Science

FINAL EXAMINATION

CSC 5231
Advanced Web Technologies

Date: 17th NOVEMBER 2021
Time: 14:00hrs – 16:00hrs
Duration: 2 Hours
Venue: CL2

Instructions

1. There are **two (2) Sections** in this exam, **Section A** and **Section B.**
2. In Section A, **answer all the questions** and in Section B **choose any three (3) questions.**

Section A: Answer **ALL** questions

1. In what ways are Web applications are considered revolutionary compared to traditional(desktop) applications. **(4 Marks)**

2. Explain the MVC pattern in Web application development **(4 Marks)**

3. Label each of the tasks below with "Model", "View", or "Controller" to indicate where that task would typically be implemented in a Web application using an MVC architecture. **(8 Marks)**
    a. Validate form data
    b. Make sure a user is logged in
    c. Invoke the link_to method
    d. Return a "redirect" to the browser
    e. Define an event handler for a custom form element
    f. Generate a new session token
    g. Invoke the find_all_by_name method
    h. Create a "salt" for a password

4. How does an HTTP client know that the HTTP server is sending back HTML as opposed to, say, JPEG data? **(4 Marks)**

5. When trying to access a URL, the following message is displayed on the browser: Server; **Error 403** What could be the reason for the message? **(4 Marks)**

6. Describe some of the strategies one can use to optimise and reduce the web page loading time. **(4 Marks)**

7. Describe the key differences between SOAP and REST. **(4 Marks)**

8. What are the advantages of HTTP 2.0 over HTTP 1.1? **(4 Marks)**

9. What are the web relation functionalities that are provided by SOAP protocol? **(4 Marks)**

Section B: Answer any **THREE (3)** questions

Q1. (20 Marks)

a. Explain in details how SOAP web services are used by a number of organizations for their system integration
b. Give some proper example where the developer should need to choose SOAP API. Is there any other better API available for message exchanges rather than SOAP API?
c. Give one example of a major problem normally faced by the developer when using SOAP API for their application?

Q2. (20 Marks)

a. What is the use of Accept and Content-Type Headers in HTTP Request?
b. What is statelessness in RESTful Web services? Explain the advantages of stateless in RESTful
c. Describe some important points that should be kept in mind while designing Resources representation for RESTful web services.

Q3. (20 Marks)

a. What are the core components of the HTTP request and HTTP response?
b. What is Caching? Explain the Cache-control header
c. Describe the main difference between OAuth and OpenID Connect

Q4. (20 Marks)

a. Explain why Web services are important?
b. Describe the primary security issues of Web Services?
c. What is the difference between Web Services and APIs?

Q5. (20 Marks)

JSON Web Tokens (JWTs) are a great authentication mechanism. They give you a structured and stateless way to declare a user and what they can access. They can be cryptographically signed and encrypted to prevent tampering on the client side. JWTs are a great way to declare information about the token and authentication. You have a ton of freedom to decide what makes sense for your application because you are working with JSON. When it comes to authentication using OAuth 2.0, the JWT access token and / or refresh token need to be stored somewhere in the client device, so that once the user authenticates himself by providing login credentials, he doesn't need to provide his credentials again to navigate through the website. There are two options for storing the JWTs on the client side: HTML5 Web Storage (localStorage or sessionStorage) and Cookies. Describe the pros and cons for each storage option and state the use cases in which each option is preferred.

THE UNIVERSITY OF ZAMBIA
School of Natural Science
Department of Computer Science

FINAL EXAMINATION

CSC 5491: SOFT COMPUTING

Date:	Friday, 24th November 2021
Time:	09:00hrs – 12:00hrs
Duration:	3 Hours
Venue:	Computer Science Department – CL 2

Instructions

1. There are **five (5) questions** and **two (2) sections** in this paper.
2. Each question carries **25 marks,**
3. *You are required to answer a total of **Five (4) Questions***
   a. *Answer **all** the questions in **Section A***
   b. Choose ***any one (1)** question from **Section B***

SECTION A

This Section has **Three** questions. Answer all the questions

Question I

a) Artificial intelligence (AI) is a wide-ranging branch of computer science concerned with building smart machines capable of performing tasks that typically require human intelligence. AI is therefore the ability of a digital computer or computer-controlled robot to perform tasks commonly associated with intelligent beings. The term is frequently applied to the project of developing systems endowed with the intellectual processes characteristic of humans, such as the ability to reason, discover meaning, generalize, or learn from past experience. Briefly discuss each of the following with examples in relation to artificial intelligence [10 Marks]

i. Artificial Neural Networks
ii. Evolutionary Computing
iii. Soft Computing
iv. Hard Computing
v. Expert Systems

b) Artificial neural networks is one of the technologies making up Soft Computing [7 Marks]

i. List and discuss any other two technologies that make up soft computing
ii. Discuss the premises and guiding principle of
    1. Soft Computing
    2. Hard Computing

c) Compare and contrast with examples between [4 Marks]

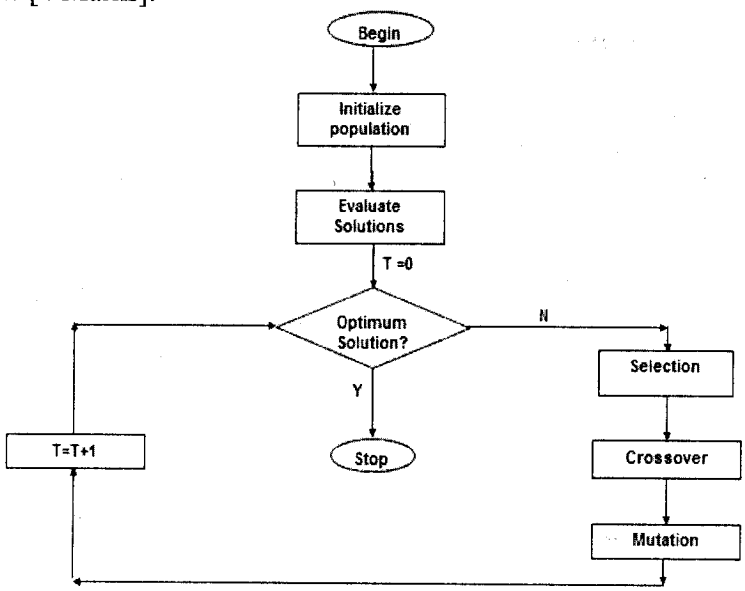
i. Boolean Logic and Fuzzy Logic
ii. Crisp Set and the Fuzzy Set

d) If A, B are fuzzy sets with membership functions μA, μB, respectively, and defined for $x \in U$. Give the fuzzy set for the following [4 Marks];

i. Union $A \cup B$
ii. Intersection $A \cap B$

Question II

a) The diagram below shows the conceptual view of the genetics algorithm. Give a brief description of basic concepts and operation of genetics algorithm with reference to the diagram below [4 Marks].



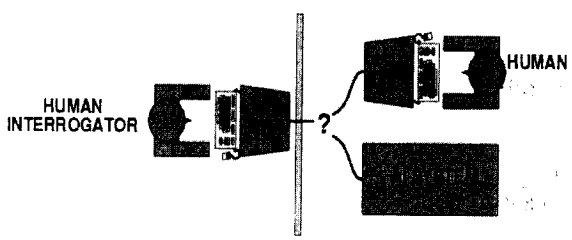
b) The Table below shows the comparison between nature and the computer implementation of genetic algorithm. Complete the Table [5 Marks]

#	Nature	Computer
1	Population	Set of solutions.
2	Individual	
3	Fitness	
4	Chromosome	
5	Gene Reproduction	
6	Reproduction	

c) Briefly discuss each of the following terms in relation to genetics algorithms [6]

i. Recombination
ii. Roulette Wheel Selection
iii. Elitism

d) The diagram below shows a Full Turing Test. Briefly Describe a Turing Test [2 Marks]



e) Artificial intelligence can be defined as creating systems that

i. Think like humans
ii. Think rationally
iii. Act like humans
iv. Act rationally

Discuss the four points above in relation to artificial intelligence systems [8 Marks]

Question III

a) MATLAB/ **Octave** comes with a number of built in Function that can be used to manipulate a matrix. Give the output of the following functions [5 Marks]

i. A = ones(5)
ii. B = random (3,4)
iii. C = [20 : -0.5 : 0]

b) You can create matrices (arrays) of any size using a combination of the methods for creating vectors. One of the methods is by using a comma to separate each column and then a semi colony to define a new row as shown below for the results matrix.

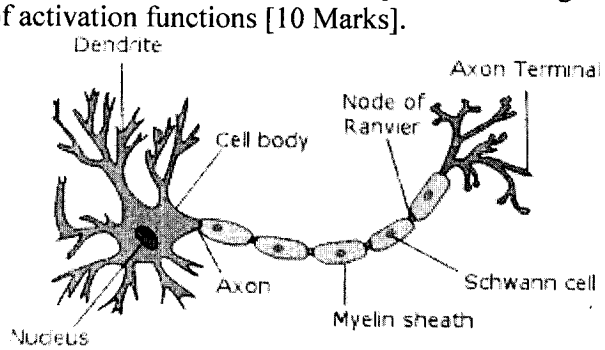
```
>> Results = [1, 0.5, 0.6, 0.3; 2, 0.3, 0.33, 0.75;
              3, 0.54, 0.2, 0.99; 4, 0.7, 0.6, 0.1;
              5, 0.89, 0.73, 0.3; 6, 0.2, 0.9, 0.94;
              7, 1, 0.4, 0.3]

Results =

   1.0000   0.5000   0.6000   0.3000
   2.0000   0.3000   0.3300   0.7500
   3.0000   0.5400   0.2000   0.9900
   4.0000   0.7000   0.6000   0.1000
   5.0000   0.8900   0.7300   0.3000
   6.0000   0.2000   0.9000   0.9400
   7.0000   1.0000   0.4000   0.3000
```

What is the output of the following operations using the matrix above in Octave/MatLab software tool? Please show all your calculations [10 Marks]

i. Results (1:4 , ;)
ii. Results (; , 2)
iii. Results (: , 4) = Results(: , 2) + Results(: , 3)

c) The diagram below shows the biological neuron.

i. Draw a well labelled diagram of the Artificial Neuron and explain how it works in comparison to the biological neuron.
ii. Name and write down at least one example of the integration functions and one example of activation functions [10 Marks].



SECTION B

This section has TWO Questions. Choose one question

Question I

a) Encoding is the process of representing the solution in the form of a string that conveys the necessary information. Just as in a chromosome, each gene controls a particular characteristic of the individual; similarly, each bit in the string represents a characteristic of the solution. With reference to genetic algorithm encoding, give a brief description of the following encoding mechanisms [6 Marks]

i. Binary Encoding
ii. Permutation Encoding
iii. Value Encoding

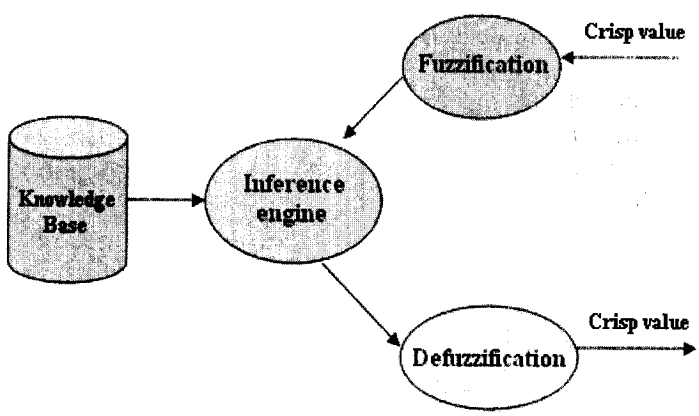
b) Crossover is the process in which two chromosomes (strings) combine their genetic material (bits) to produce a new offspring which possesses both their characteristics. Two strings are picked from the mating pool at random to cross over. The method chosen depends on the Encoding Method. Discuss any three cross-over methods used in genetic algorithm [6 Marks]

c) Give a brief description for each of the following terms [3 Marks]

i. Linguistic variables
ii. Hedges
iii. Knowledge Base

d) The diagram below shows the basic Structure of a Fuzzy Expert System. [10 Marks]

i. With reference to the diagram below, describe how a fuzzy expert system works.
ii. Give any two application areas of fuzzy expert systems



Question II

a) There are many different flavours of Artificial Neural Networks models. The most common ones include the following [6 Marks]

i. Feedforward Neural Networks

ii. Feedback Neural Networks

iii. Competitive Learning Neural Networks

Discuss each of the models below and give an example where possible

b) The three Learning Rules used by artificial neural network include;

i. Supervised learning

ii. Reinforcement learning

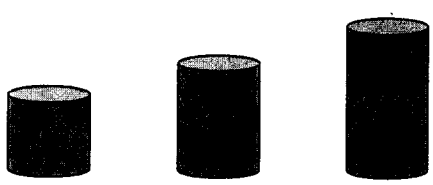
iii. Unsupervised learning

Using a well labelled diagram, discuss each of the three learning rules giving at least one example in real life [9 Marks]

c) The diagram below shows three buckets with capacity of 3 litres, 5 litres and 9 litres. Explain by giving the steps on how you would measure the exactly number of litres of the following using the 3 buckets below [3 Marks]

i. 1 litre

ii. 7 litres

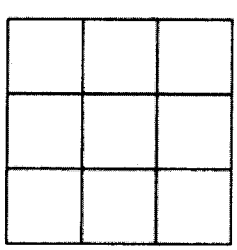


d) The diagram below shows a 3×3 magic square grid where every row, column, and diagonal sum to the same number, which is 15. Using the numbers 1 to 9, place these numbers so that ***each row, column and diagonal add up to number 15***. Use each number exactly once only [7 Marks]

1 2 3

4 5 6

7 8 9



The 3x3 Magic Square

End of the Examination

THE UNIVERSITY OF ZAMBIA

School of Natural Sciences

Department of Computer Science

SOFTWARE ENGINEERING CONCEPTS
CSC 5612

2020-2021 FINAL EXAM

Date: 28th November 2021
Venue: CL2
Time: 14:00hrs – 17:00hrs
Duration: 3 Hours

Instructions

1. *This examination has two sections*
2. *Answer all questions in Section A. Each question carries 20 marks*
3. *Answer any three questions in Section B. Each question carries 20 marks*

Section A – Compulsory

Answer all the questions. Each question carries 20 Marks

Question 1 [20 marks]

1. Explain any 2 software process models? **[8 marks]**
2. What is software prototyping? What are the advantages of using prototypes? **[5 marks]**
3. What are the four important attributes that all professional software should have? **[4 marks]**
4. What is the most difference between generic software product and customer development product? **[3 marks]**

Question 2 [20 marks]

1. What are some roles played by people in the problem domain of a restaurant? **[4 marks]**
2. What are the three types of events? **[3 marks]**
3. What is a use case? **[3 marks]**
4. What are the three key parts of an entity relationship diagram (ERD)? **[3 marks]**
5. What are the two techniques used to identify use cases? **[2 marks]**
6. What are the three types of associations, and which is the most commonly used? **[3 marks]**
7. Sketch a simple ERD that shows a team has zero or more players and each player is on one and only one team. **[2 marks]**

Section B – Optional

Answer any three questions. Each question carries 20 marks.

Question 1 [20 marks]

1. Suggest four reasons why the productivity rate of programmers working as a pair might be more than half that of two programmers working individually.[**4 marks]**
2. Explain the principles of agile method? **[5 marks]**
3. Extreme programming expresses user requirements as stories, with each story written on a card. Discuss the advantages and disadvantages of this approach to requirements description. **[6 marks]**
4. What is pair programming? Give some advantages of pair programming? **[5 marks]**

Question 2 [20 marks]

1. There is a five different ways of writing a system requirements specification. State and explain any two ways of writing requirements specification? **[5 marks]**
2. What checks should be applied during requirements validation? **[5 marks]**
3. What are the stages included in Requirement elicitation and briefly explain each stages? **[4 marks]**
4. Explain any three nonfunctional requirements with example? **[6 marks]**

Question 3 [20 marks]

For this question, read through the MoveYourBooksNow.com case study and answer the questions that follow.

MoveYourBooksNow.com is a book exchange that does business entirely on the Internet. The company acts as a clearinghouse for buyers and sellers of used books.

To offer books for sale, a person must register with MoveYourBooksNow.com. The person must provide a current physical address and telephone number as well as a current e-mail address. The system maintains an open account for this person. Access to the system as a
seller is through a secure, authenticated portal.

A seller can list books on the system through a special Internet form. Information required includes all the pertinent information about the book, its category, its general condition, and the asking price. A seller may list as many books as desired. The system maintains an index of all books in the system so buyers can use the search engine

to search for books. The search engine allows searches by title, author, category, and keyword.

People who want to buy books come to the site and search for the books they want. When they decide to buy, they must open an account with a credit card to pay for the books. The system maintains all this information on secure servers.

When a request to purchase is made and the payment is sent, MoveYourBooksNow.com sends an e-mail notice to the seller of the book. It also marks the book as sold. The system maintains an open order until it receives notice that the book has been shipped. After the seller receives notice that a listed book has been sold, the seller must notify the buyer via e-mail within 48 hours. Shipment of the order must be made within 24 hours of the seller sending the notification e-mail. The seller sends a notification to the buyer and MoveYourBooksNow.com when the shipment is made.

After receiving notice of shipment, MoveYourBooksNow. com maintains the order in shipped status. At the end of each month, a check is mailed to each seller for the book orders that have been in shipped status for 30 days. The 30-day waiting period allows the buyer to notify MoveYourBooksNow.com if the shipment doesn't arrive for some reason or if the book isn't in the same condition as advertised.

If they want, buyers can enter a service code for the seller. The service code is an indication of how well the seller is servicing book purchases. Some sellers are very active and use MoveYourBooksNow.com as a major outlet for selling books. Thus, a service code is an important indicator to potential buyers.

For case study above, develop the following diagrams:

1. A domain model class diagram **[5 marks]**
2. A list of uses cases and a use case diagram **[5 marks]**
3. A fully developed description for two use cases: *Add a seller* and *Record a book order* **[5 marks]**
4. An SSD for each of the two use cases in question (c) **[5 marks]**

Question 4 [20 marks]

1. What are the fundamental activities that are common to all software processes? **[4 marks]**
2. What are the development stages in reuse-based development? **[4 marks]**
3. What are user requirements and system requirements? **[4 marks]**
4. Compare/contrast precondition and postcondition. **[4 marks]**
5. What does a domain model class diagram show about system requirements, and how is it different from an ERD? **[4 marks]**

THE UNIVERSITY OF ZAMBIA
School of Natural Sciences
Department of Computer Science

FINAL EXAMINATION

DATABASES AND INFORMATIONS MANAGEMENT SYSTEMS
CSC 5711

Date: 23RD NOVEMBER 2021
Time: 14:00hrs – 17:00hrs
Duration: 3 Hours
Venue: CL2

Instructions

1. *Answer **all** the questions in Section A.*
2. Choose ***any THREE** (3) questions in Section B.*

SECTION A

Answer ALL Questions in this section. Both questions carry an equal weight of **20 Marks**.

Question 1 [20 Marks]

i. Define the following terms briefly in not more than 3 lines: [**5 Marks**]
   a. *Database*
   b. *Database program*
   c. *Database System*
   d. *Record*
   e. *Attribute*

ii. What is a DBMS, and what are its functions? (list at least 3 functions) [**5 Marks**]

iii. Describe the main components you are likely to find in a DBMS environment? **[5 Marks]**

iv. Give at least 5 reasons why the file based system approach is desirable over the database approach. **[5 Marks]**

Question 2 [20 Marks]

i. Explain what it means to say a database displays both *entity integrity* and *referential integrity*? [**4 Marks**]

ii. Define the following terms in relation to the database: [**4 Marks**]
   a. Intentions
   b. Extension

iii. Draw a well labelled diagram of the ANSI-SPARC DBMS architecture and describe the different aspect of it. [**6 Marks**]

iv. In relation to databases, explain what a data model is. Also state three components that describe a data model? [**3 Marks**]

v. State three categories in which you can classify data models? [**3 Marks**]

SECTION B

There are FOUR questions in this section. All questions carry an equal weight of **20 Marks**. Choose only **three (3)** question!

Question 3

i. In relation to Relational Database Model, list at least five (5) attributes that differentiate relations from tables. [**5 Marks**]

ii. Suppose you wanted to apply for a Job in a database computing environment, what are the five (5) different roles you may likely find? [**5 Marks**]

iii. What do you mean when you say "cardinality of the relation" and "degree of the relation" when you are talking about relational databases? [**4 Marks**]

iv. What two conditions must be met before an entity can be classified as a weak entity? Give an example of a weak [**2 Marks**]

v. Discuss the difference between a composite key and a composite attribute. How would each be indicated in an Entity Relationship Diagram? [**4 Marks**]

Question 4

i. Define the following terms: [**5 Marks**]

   a. *Composite key*
   b. *Super key*
   c. *Candidate key*
   d. *Foreign key*
   e. *Primary key*

ii. Briefly describe the four (4) integrity constraints that are associated with relational database model? [**4 Marks**]

iii. What is the difference between a "view" and "base relation"? [**2 Marks**]

iv. Give at least 3 reasons why the file based system approach is undesirable over manual filing system? [**3 Marks**]

v. What three data anomalies are likely to be the result of data redundancy? [**6 Marks**]

Question 5

i. What is a partial dependency? With what normal form is it associated? [**4 Marks**]

ii. Explain the difference between "Functional Dependency" and "Transitive Dependency". [**4 Marks**]

iii. When is a relationship in ER modelling said to be "recursive"? [**2 Marks**]

iv. Define the following attributes and give example of each: [**6 Marks**]

   a. Derived
   b. Simple
   c. Composite
   d. Multi-valued

v. Briefly, but precisely, explain the difference between single-valued attributes and simple attributes. Give an example of each. [**4 Marks**]

Question 6

i. In database development process, what does the term "fact-finding" mean? [**2 Marks**]

ii. State when "fact-finding" in Q6 (i) is particularly important during database development life cycle? [**2 Marks**]

iii. Explain why "fact-finding" is crucial to the database development process? Especially to phase you have stated in Q6 (ii). [**4 Marks**]

iv. State and briefly explain the five (5) most used fact-finding techniques you may adopt for your database design.[**10 Marks**]

v. Why is a table whose primary key consists of a single attribute automatically in 2NF when it is in 1NF? [**2 Marks**]

---- End of Exam ----

THE UNIVERSITY OF ZAMBIA
School of Natural Sciences
Department of Computer Science

FINAL EXAMINATION

CSC 5771
Advanced Distributed Systems

Date:	18th NOVEMBER 2020
Time:	09:00hrs – 12:00hrs
Duration:	3 Hours
Venue:	CSC CL2

Instructions

1. There are **two (2) sections** in this exam paper. *Answer all the questions in **Section A*** and choose *any three (3) questions from **Section B***

Section A

1.

a. One technique that is used to achieve scalability is replication. What problems does replication introduce in a distributed system implementation? **[4 marks]**

b. Many distributed systems are needlessly complex caused by mistakes that required patching later on. Many false assumptions are often made. Explain three such false assumptions. **[6 marks]**

c. One type of distributed system is a high performance distributed system which can come in the form of grid computing and cluster computing. Briefly discuss the two types of type of high performance computing environments. **[4 marks]**

d. Cloud computing has increasingly become an important part of the distributed systems world. Briefly discuss the four layers of a cloud computing architecture. **[6 marks]**

2. Deciding on whether to use processes or threads often makes a big difference in application performance

a. What is a process and a thread? **[2 marks]**

b. What would be the reason behind the difference in performance between processes and threads? **[4 marks]**

c. Consider a distributed web application.

i. How would threads be used to improve performance on the client side? **[3 marks]**

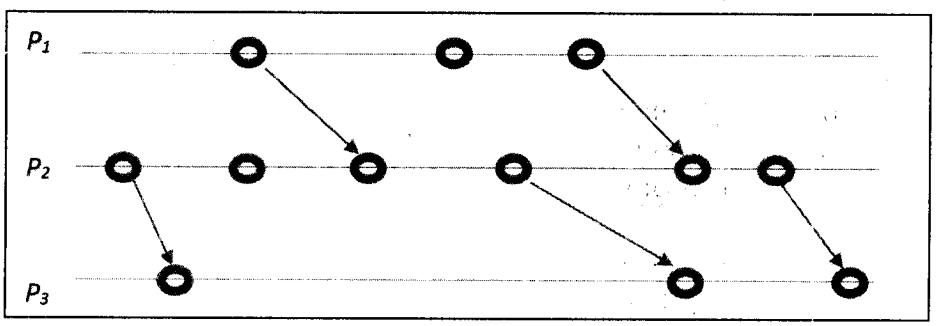
ii. How would threads be used to improve performance on the server side? **[3 marks]**

d. What is virtualization and why has it become increasingly important in distributed systems. **[4 marks]**

e. Briefly explain how a 3-tier client server architecture works. **[4 marks]**

SECTION B

1. Clock synchronization is an important concept in distributed systems. The classical problem of compilation using a make file utility being a typical example illustrating the difference between clock synchronization in a uniprocessor system and synchronization in a distributed system.
    a. Why is compilation using a make file challenging in a distributed system when compared to a uniprocessor system? **[3 marks]**
    b. Explain the principle difference that one should take into account when working with Christian's clock synchronization algorithm as opposed to Berkeley's clock synchronization algorithm? **[3 marks]**
    c. Two approaches are often considered when looking at logical clocks. These are Lamport's timestamps and Vector timestamps. Given the following processes and their related events,



i.
    1. generate and illustrate Lamport's time stamps for the events. **[5 marks]**
    2. Which events occur in parallel? **[2 marks]**

ii.
    1. Why would one consider Vector timestamps up and above Lamport's timestamps? **[2 marks]**
    2. generate and illustrate Vector time stamps for the events **[5 marks]**

2. Control of access to critical sections in distributed computing is important when serializing parallel processes.
    a. What is mutual exclusion? **[2 marks]**
    b. What is the main difference between centralized and decentralized mutual exclusion algorithms? **[4 marks]**

c. There are four processes in a distributed system, P1, P2, P3 and P4. P1 requests to enter the critical region at time 1 with a job that will last 5 time units. P3 then requests to enter the critical region at a time 4 with a job that will take 3 time units. Meanwhile at time 3 P4 had also requested to enter the critical region with a process that will take 4 time units.
    i. Assuming that a centralized algorithm is used and that P2 is chosen as the coordinator for mutual exclusion using an illustration explain how and in what order the processes will enter the critical region. **[5 marks]**
    ii. Assuming that a decentralized algorithm like Ricart and Agrawala's algorithm is used instead and also that the process ids are used for selecting the processes to enter the critical region, illustrate how and in what order the processes will enter the critical region. **[5 marks]**
    iii. Using you answers in the previous section, how do the algorithms compare when it comes to first come first served fairness policy? **[4 marks]**

3. Consider a group of processes in a distributed system, P1, P2, P3, P4 and P5, P6 and P7 (P5 is currently the coordinator) because P6 and P7 had earlier on failed. P7 recovers from failure and restarts. At the same time P2 notices the failure of P5. Illustrate the election processes initiated by P2 and P7
    a. If the Bully algorithm is used for election of a new coordinator and the election attribute is the (Max of) processor numbers, show the set of all messages communicated through each communication channel Pij i,j = 1..7 for this election. Show the type of each message as "election", "response", "coordinator". **[8 marks]**
    b. Illustrate the election processes that would result if the ring election algorithm was used in place of the bully election algorithm. **[8 marks]**
    c. Compare the number of messages needed to finish the election for each algorithm and discuss which algorithm is message efficient. **[4 marks]**

4. Architecture of distributed systems is significant to their operation.
    a. Briefly explain the mechanisms of a client-server model. **[4 marks]**
    b. Client server applications can be organized using three-tier approach or alternatively using vertical or horizontal distribution. What is vertical and horizontal distribution? **[4 marks]**
    c. What are super peer networks and why are they important in peer-to-peer architecture like the one supposedly implemented by Skype? **[6 marks]**

d. BitTorent implements a collaboration mechanism that prevents peers from selfishly consuming without participating in the file sharing. Discuss the mechanism used by BitTorent to exchange file blocks and how it helps achieve unselfish collaboration. **[6 marks]**

5.

a. Architectural styles are important when designing distributed systems. What are the basic issues one needs to consider when formulating an architectural style? **[4 marks]**
b. What are the basic operations in a restful architecture? **[4 marks]**
c. One of the key aspects of publish and subscribe architectures is coordination. With the aid of diagrams explain how event-based and shared data spaces are used in coordination. **[6 marks]**
d. At times organisations fail to discard of legacy software and are left with no choice but to build middleware using the legacy software. To achieve this, adapters are often used. What is an adapter? Using illustrations, explain two basic ways of organizing adapters. **[6 marks]**

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
2019/2020 ACADEMIC YEAR FINAL EXAMINATIONS

CSC 5781: SPATIAL DATABASES AND WEB MAPPING

TIME: Three hours

INSTRUCTIONS: Answer question one and any other three
Candidates are encouraged to make use of illustrations wherever appropriate

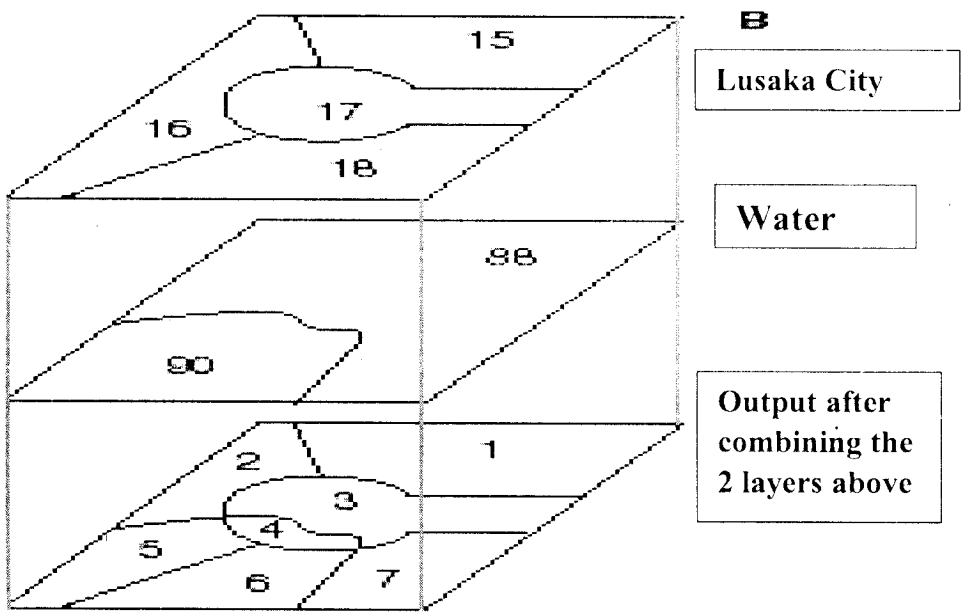
---

QUESTION ONE

a) Define each of the following
   i. Internet Protocols
   ii. Search Engines
   iii. Web Server
   iv. Intranet **[4 marks]**

b) Data on different themes are stored in separate layers. Layers geo-referenced from different sources can easily be integrated using location. This can be used to build up complex models of the real world from widely disparate sources. Figure 1 shows the two layers combined into one. Answer the questions that follow.

Figure 1: A model of spatial data



OUTPUT

Lusaka-ID	Name
15	Kabulonga
16	Longacres
17	Munali
18	Mutendela

Water-ID	Water
88	Water
90	Land

i. Draw and complete the Table using the information above and answer the following questions
ii. Name the regions that are part of the water body
iii. Give the name of the regions that is not touched by the water body **[10 marks]**

Output-ID	Lusaka-ID	Name	Water-ID	Water
1				
2				
3				
4				
5				
6				
7				

c) In Central Province of Zambia, three investors own a huge piece of land which is used as a forest reserve. This forest is monitored by a fire station. There is a river that passes through their forest which supplies the water for the fire station. The three investors also have built a facility in the forest used for logging and wood processing.

i. Draw the Entity Relation Diagram for the scenario above
ii. Draw the equivalent enhanced Spatial Entity Relation Diagram
iii. Come up with the tables by showing both the primary and secondary keys **[10 marks]**

Question Two

a) Describe the following function of the spatial operations with respect to SQL/OGIS.

i. Intersection
ii. Cross
iii. Contains
iv. Overlap **[4 marks]**

b) With the help of a diagram, describe each of the following in relation to geospatial data modelling.

i. Conceptual Modelling
ii. Theme
iii. Geographic Objects **[9 marks]**

c) Figure 2 shows the ERD for all the countries in the world. More information is provided in Tables 1, 2 and 3.

Figure 2: ERD for all the countries in the world

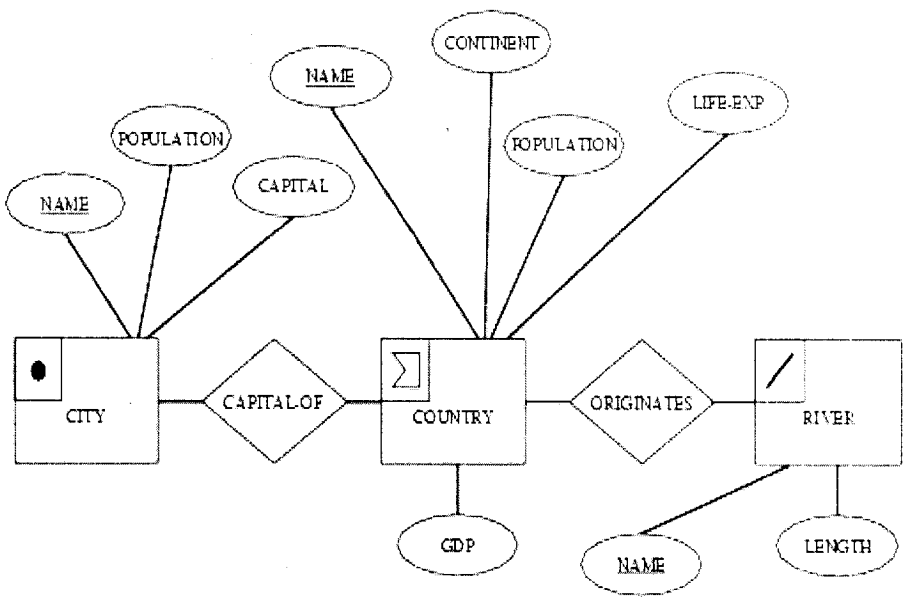


Table 1: Selected countries

Name	Continent	Population	Life Expectance	Shape
Namibia	Africa	3,300,000	65	Ploygonid-1
Germany	Europe	80,000,000	88	Ploygonid-2
China	Asia	1,400,000,000	80	Ploygonid-3
USA	North America	320,000,000	85	Ploygonid-4

Table 2: Selected cities

Name	Country	Pop.	City	Shape
Windhoek	Namibia	330,000	Y	Pointid-1
Katima Mulilo	Namibia	28,000	N	Pointid-2
Washington DC	USA	4,000,000	Y	Pointid-3
Beijing	China	11,500,000	Y	Pointid-4
Hong Kong	China	7,100,000	N	Pointid-5
Berlin	German	3,500,000	Y	Pointid-6
Frankfurt	German	690,000	N	Pointid-7

Table 3: Selected rivers

Name	Country of Origin	Length (km)	Shape
Zambezi	Namibia	2,500	LineStringid-1
St. Lawrence	USA	1,200	LineStringid-2
Yongding	China	1,800	LineStringid-3
Spree	German	400	LineStringid-4

Answer the following questions using the information above. Write the SQL queries for the following.

i. List all the cities and the country they belong to
ii. List the names of the capital cities in the CITY table
iii. List the population and the distance of a country's capital city to the equator for all countries
iv. The Zambezi River can supply water to cities that are within 200 km. List the cities that can use water from the Zambezi River **[12 marks]**

Question Three

a) Give a brief description for each of the following
   i. GIS
   ii. Spatial Databases and Web Mapping
   iii. Database Normalization **[3 marks]**

b) Geographical Information is different from other kinds of information and therefore requires special methods to be analyzed. Give any three characteristics that make geographical information special **[3 marks]**

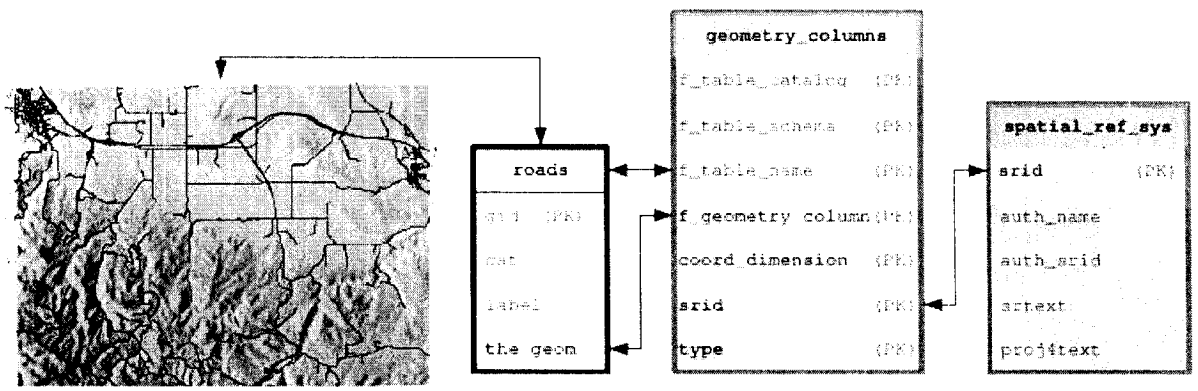
c) There are a number of Geographical Information Systems available today ranging from high-powered analytical software to visual web applications each used for a different purpose. Give a description with examples for each of the following categories.
   i. Web-based GIS
   ii. Geobrowser
   iii. Desktop GIS **[3 marks]**

d) Give any three reasons why it is important for you to study Spatial Databases and Web Mapping. What are some of your job prospects? **[3 Marks]**

e) With the aid of the diagram, discuss each of the following presentation modes
   i. Spaghetti Model
   ii. Network Model **[7 marks]**

f) Figure 3 shows a spatial enabled database. Give the three basic steps required to create a new spatially enabled table when using PostgreSQL database **[6 Marks]**

Figure 3: Spatially enabled database

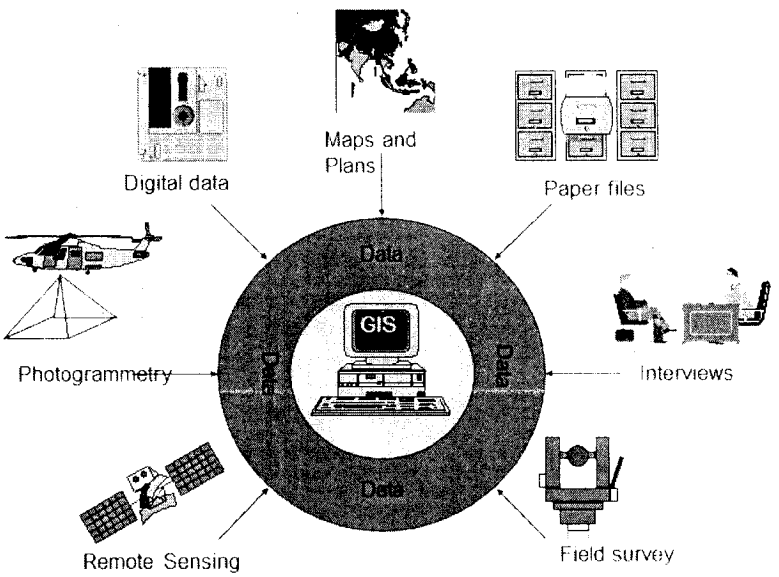


Question Four

a) The OpenGIS Spatial Data Model consists of the base-class Geometry and four sub-classes which include the Point, Curve, Surface and GeometryCollection. Draw the OpenGIS Simple Feature Specification for SQL diagram by showing all the relationships that include aggregation and heritance **[8 Marks]**

b) Figure 4 shows the major sources of the GIS Data. Briefly discuss each of the sources **[7 Marks]**.

Figure 4: GIS data sources



GIS Data Sources

c) To create a spatial database system, you need to follow the five major steps. Briefly discuss each of the steps.

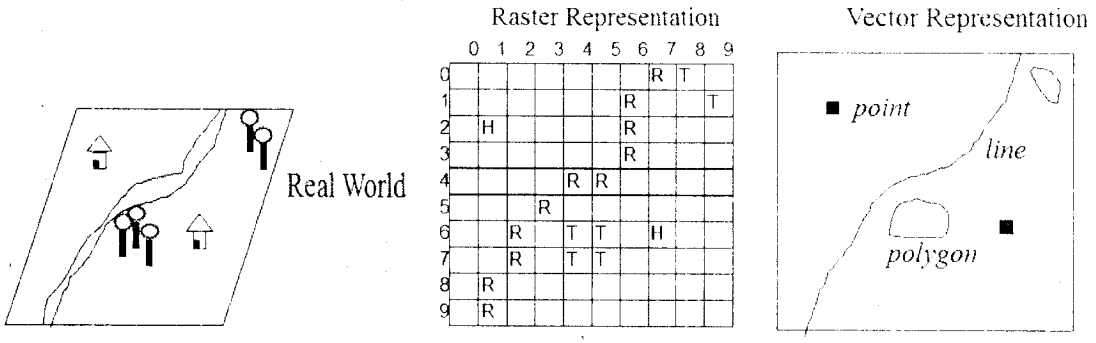
i. Step 1: Creating a Data Model
ii. Step 2: Defining an Attribute Model
iii. Step 3: Identify and Capture Business Rules
iv. Step 4: Define Physical Model
v. Step 5: Review Final Design **[10 marks]**

Question Five

a) What is SQL? Discuss the following three major components of SQL.
   i. DDL
   ii. DML
   iii. DCL **[5 marks]**

b) Figure 5 shows the two data representation models namely Raster Data Model and Vector Data Model. Describe each of the two GIS Data Models **[8 Marks]**

Figure 5: GIS data models



c) Give any two examples of each of the following spatial data types.
   i. Continuous
   ii. Networks
   iii. Fixed **[6 marks]**

d) Draw the following lines and polygons
   i. Simple closed polyline
   ii. Non-simple polyline
   iii. Monotone polyline
   iv. Non-monotone polyline
   v. Simple polygon
   vi. Non-simple polygon **[6 marks]**

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
School of Natural Sciences
Department of Computer Science

FINAL EXAMINATION

CSC 5812
COMPUTER NETWORK AND DATA COMMUNICATION

Date:	1st December 2021
Time:	09:00hrs – 12:00hrs
Duration:	3 Hours
Venue:	CL2

Instructions

1. There are **two (2) Sections** in this exam, **Section A** and **Section B**.
2. In Section A, **answer all the questions** and in Section B **choose any three (3) questions**.

SECTION A [40 MARKS]

ANSWER ALL THE QUESTIONS IN THIS SECTION

Question 1 [20 marks]

a) Name the three key features of a protocol. **[3 marks]**

b) What is the major function of the network access layer? **[2 marks]**

c) List any four protocols in the application layer. **[4 marks]**

d) Why would you expect a CRC to detect more errors than a parity bit? **[2 marks]**

e) What tasks are performed by the transport layer? **[3 marks]**

f) What is the relationship between the wavelength and frequency of a sine wave? **[2 marks]**

g) What is the primary cause of signal loss in satellite communications? **[2 marks]**

h) What are important characteristics of a periodic signal? **[2 marks]**

Question 2 [20 marks]

a) Differentiate half duplex from full duplex. **[2 marks]**

b) What two functions are performed by an antenna? **[2 marks]**

c) What is the difference between QPSK and offset QPSK? **[2 marks]**

d) What are some advantages to layering as seen in the TCP/IP architecture? **[3 marks]**

e) Why must a satellite have distinct uplink and downlink frequencies? **[3 marks]**

f) Why is the twisted pair cable twisted? **[2 marks]**

g) What are some major limitations of twisted-pair wire? **[4 marks]**

h) What is a protocol architecture? **[2 marks]**

SECTION B [60 MARKS]

ANSWER ANY THREE (3) QUESTIONS FROM FOUR (4) IN THIS SECTION

Question 3 [20 marks]

a) Illustrate the TCP/IP Model. **[5 marks]**

b) The three guided media commonly used for data transmission are twisted pair, coaxial cable, and optical fiber. Discuss these media. **[5 marks]**

c) Trends in technology enable the provision of increasing traffic capacity and the support of a wide range of services. Four technology trends are particularly notable. Discuss the trends. **[5 marks]**

d) In the last 20 years, two significant trends altered the role of the personal computer and therefore the requirements on the LAN. Discuss the two significant trends. **[5 marks]**

Question 4 [20 marks]

a) Explain in detail about the satellite microwave. **[5 marks]**

b) Discuss the characteristics distinguishing optical fiber from twisted pair. **[5 marks]**

c) Discuss the factors that determine how successful the receiver will be in interpreting the incoming signal. **[5 marks]**

d) Illustrate the OSI Model. **[5 marks]**

Question 5 [20 marks]

a) Explain in detail about the infrared communications. **[5 marks]**

b) With any communications system, the signal that is received may differ from the signal that is transmitted, due to various transmission impairments. Discuss the most significant impairments. **[5 marks]**

c) A number of design factors relating to the transmission medium and the signal determine the data rate and distance. Discuss these design factors. **[5 marks]**

d) Explain the functions and services provided by the data link layer. **[5 marks]**

Question 6 [20 marks]

a) Explain in detail about broadcast radio. **[5 marks]**

b) Discuss the comparison of wireless to fiber optics. **[5 marks]**

c) The Internet today is made up of thousands of overlapping hierarchical networks. Discuss the six internet terminologies. **[5 marks]**

d) The question naturally arises as to which is the preferred method of transmission. The answer being supplied by the telecommunications industry and its customers is digital. Both long-haul telecommunications facilities and intrabuilding services have moved to digital transmission and, where possible, digital signaling techniques. Discuss the most important reasons for moving into digital transmission **[5 marks]**

THE END

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

2020/2021 ACADEMIC YEAR FINAL EXAMINATIONS

GES 2130: THE GEOGRAPHY OF AFRICA WITH SPECIAL REFERENCE TO ZAMBIA.

TIME: Three Hours

INSTRUCTIONS: Answer question 1, and any other two. All questions carry equal marks. Candidates are advised to make use of illustrations wherever appropriate.

---

1. Write short explanatory notes on ALL of the following:

   (a) Formation of the Great East African Rift Valley.

   (b) Early Man in Africa according to Pritchard (1979).

   (c) The role of tourism in the economy of Kenya.

   (d) How to mitigate against regional disparity in African countries like Ghana.

   (e) The significance of the Economic Reforms in Zambia since 1991.

2. 'Miombo woodland needs to be conserved through sustainable land use practices in order to mitigate the impacts of climate change in Zambia'. Discuss.

3. How can the 'One Zambia, One Nation' Concept be kept alive as a basis for promoting national unity in the country despite ethnic and linguistic diversity?

4. Evaluate the statement by Mbiti (2011), that 'Colonial interface in Africa had deep and profound social-cultural impacts, for better or for worse'.

5. In what ways has Tanzania experienced a paradigm shift in her economic policy after the retirement of President Julius Nyerere?

END OF EXAMINATION.

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2020/2021 ACADEMIC YEAR FINAL EXAMINATIONS

GES 2210: FUNDAMENTALS OF PHYSICAL GEOGRAPHY

Time: Three hours

Instructions: Answer only one (1) question from each of the three (3) sections. All questions carry equal marks. Candidates are encouraged to make use of illustrations wherever appropriate.

SECTION A

1. Describe the energy balance of the atmosphere by identifying the types and sources of energy that it receives and loses.
2. With reference to cloud formation.
   (a) Describe the classification of clouds.
   (b) Outline four cloud families,
   (c) Name two broad types of cloud forms, and
   (d) Name three specific cloud types

SECTION B

3. Explain the earth's inner structure, the types of crust present and how they are different from each other.
4. Trace the fluvial processes and landforms you might expect to find on a journey along the river from its headwaters to the ocean.

SECTION C

5. Elucidate the following for the savannah environment:
   (a) Causes of the seasonal rainfall variations,
   (b) Vegetation types,
   (c) Food and woodland resources, and
   (d) Human impacts.
6. Describe the role of clay particles and clay mineral colloids as they influence horizon development, soil chemical fertility, and water holding capacity in a soil.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2020/2021 ACADEMIC YEAR FINAL EXAMINATIONS

GES 2322: FUNDAMENTALS OF NATURAL RESOURCES ECONOMICS

TIME: Three (3) Hours

INSTRUCTIONS: Answer at least one question from each section and another from any section. Graph paper is provided.

Section A: Micro-economics

1. Write brief explanatory notes on each of the following:
   a) Normative statements
   b) Complementary goods
   c) Unitary Elasticity
   d) Law of diminishing marginal utility
   e) Shift in the supply of goods

2. Using the supply and demand diagrams for milk illustrate:
   a) An increase in demand
   b) An increase in supply
   c) A decrease in demand
   d) A decrease in supply
   e) On each of the graphs, show what happens to equilibrium price and equilibrium quantity in each case (each graph should show an original demand and supply curve, the original equilibrium price and quantity, the shifted demand or supply curve, and the resulting equilibrium price and quantity)
   f) Offer possible reasons for each of the shifts you illustrated in each of the graphs from (a) to (d).

Section B: Macro- Economics

3. Discuss the use of trade liberalization policies in promoting economic development in natural resource rich developing countries.

4. Explain how the following factors can determine a country's economic growth:
   (a) Natural resources
   (b) Technology
   (c) Human resources
   (d) Geography
   (e) Socio-cultural-political factors.

5. Elucidate the use of monetary and fiscal policies in directing a country's economic growth.

END OF EXAMINATION

CANDIDATE'S COMPUTER NUMBER: .....

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
2021 FINAL EXAMINATIONS

GES 2411: MAPPING AND FIELD TECHNIQUES IN GEOGRAPHY

PAPER I: THEORY

TIME: Three Hours

INSTRUCTIONS: Answer **ALL** questions in Sections A and B and **ONE** from Section C. Candidates are encouraged to use illustrations wherever appropriate.

MATERIALS PROVIDED: Examination Answer Book

FOR USE BY EXAMINER

Section/Question	Examiner's Mark	Moderator's Mark
A. 1 - 20		
B. 21 - 30		
C. 32 - 34		
Total		

IMPORTANT

Please read the instructions before attempting any question on this examination paper
Failure to follow instructions will lead to automatic loss of marks

SECTION A: MULTIPLE CHOICE [20 Marks]

(Circle the letter of the correct response on this question paper)

1. A photographic contact print scanned at high resolution and saved in raster format is known as:

   (a) a digital imagery
   (b) a mosaic
   (c) an enlargement
   (d) a film.

2. What are fiducial marks?

   (a) Symbols that show relief, drainage, spot heights, latitude and longitude.
   (b) Small registration marks exposed on the edges of an aerial photograph.
   (c) Symbols that show features that are not real and do not exist in reality.
   (d) Registration marks exposed on the edges of a map.

3. When are aerial photographs categorised as high oblique?

   (a) When they show fine spatial detail of objects.
   (b) When they show shadows of objects.
   (c) When they show the horizon.
   (d) When they show sensitivity in all parts of the electromagnetic spectrum.

4. The distance from the middle of the camera lens to the focal plane is known as:

   (a) the Scale
   (b) the focal length
   (c) the ratio
   (d) the altitude

5. Which one of the following statements about large-scale maps is true?

   (a) They cover small areas in greater detail.
   (b) They cover large areas in less detail.
   (c) They are generally large in size.
   (d) They cover several regions.

6. What are the three types of map symbols?

   (a) Circle, point and line symbols
   (b) Small, Big and medium symbols
   (c) Point, line and area symbols
   (d) Area, circle and point symbols

7. What is the importance of an altimeter on a vertical aerial photograph?

   (a) To indicate the focal length of the camera.
   (b) To indicate the height at which the photograph was taken.
   (c) To indicate the time of exposure.
   (d) To indicate that the flight path was horizontal with no tilt of aircraft.

8. The photo survey is designed to acquire a forward overlap (between photos along the same flight line) and lateral overlap (between photos on adjacent flight lines). What are the percentages of these overlaps?

   (a) 60% forward overlap and 30% lateral overlap
   (b) 40% forward overlap and 10% lateral overlap
   (c) 80% forward overlap and 20% lateral overlap
   (d) 60% forward overlap and 40% lateral overlap

9. Which elements of a good map do not normally apply to sketch maps?

   (a) Date and direction
   (b) Map scale and date
   (c) Map title and map legend
   (d) Direction and legend.

10. Which one of the following statements about maps is false?

   (a) They are a representation of the spatial distribution of selected phenomena.
   (b) They show spatial relationships.
   (c) Only man-made features are shown on maps.
   (d) They can be used for planning.

11. What is an insert map?

(a) A political map of a country.
(b) A two-dimensional small-scale map.
(c) A smaller map that shows physical features.
(d) A smaller map that shows a larger area of land around a map.

12. Lines of latitude and longitude form a grid system called:

(a) Polar Systems
(b) Universal Transverse System
(c) Coordinate System
(d) The Geometric Lines.

13. With reference to a fractional scale, which one of the following statements is false?

(a) A fractional scale is expressed as a fraction or as a ratio.
(b) A fractional scale compares map and ground distances proportionally.
(c) Fractional scale only refers to the scale of 1: 50 000.
(d) The same unit of measurement is used in both the numerator and the denominator.

14. The practice of determining the geometric properties of objects from aerial photographs is called:

(a) cadastral survey.
(b) map projection.
(c) photogrammetry.
(d) geodetic survey.

15. A navigation system using satellites, a receiver and algorithms to synchronize location, velocity and time data for air, sea and land travel is known as:

(a) Synchronised Satellite System.
(b) Geographical Coordinate System.
(c) Geographical Information System.
(d) Global Position System.

16. Which one of the following statements about aerial photography is false?

(a) The optical axis is the line through the projection centre perpendicular to the film plane.

(b) The principal point is found where the optical axis hits the film plane.

(c) The distance between the principal point and the projection centre is the focal length of the camera.

(d) The focal length of the camera used on most metric cameras is fixed.

17. Which one of the following statements is NOT an advantage of aerial photographs over maps?

(a) Aerial photographs show all land surface details that are large enough to be recorded on film.

(b) Aerial photographs show the actual earth's surface.

(c) Aerial photographs can be taken even of impenetrable or remote areas which cannot be visited by ground surveys

(d) Human error cannot be eliminated because aerial photographs are captured by cameras operated by humans.

18. Which one of the following air photo interpretation clues takes into account the relationship between other recognizable objects or features in proximity to the target of interest?

(a) Tone

(b) Pattern

(c) Association

(d) Shape.

19. What instrument can be used to measure the height of objects or gradients?

(a) GPS

(b) Ranging pole

(c) Clinometer

(d) Campus

20. When maps are classified according to function, which one of the following maps does NOT fall in that classification?

(a) Topographic maps
(b) Thematic maps
(c) Site plans
(d) Charts.

SECTION B: SHORT ANSWER [10 Marks]

(Write your responses in the spaces provided on this examination question paper)

21. What is the basic difference between thematic and topographic maps? [2 Marks]

.....
.....
.....
.....
.....
.....
.....
.....
.....
.....
.....

22. What is the difference between a map and an aerial photograph? [2 Marks]

.....
.....
.....
.....
.....
.....

23. What is gradient? [1 Mark]

.....

.....

.....

.....

.....

24. How could one distinguish between large- and small-scale maps? [2 Marks]

.....

.....

.....

.....

.....

.....

.....

.....

25. Explain the difference between aerial surveys and hydrographic surveys? [2 Marks]

.....

.....

.....

.....

.....

.....

26. What is the importance of contour interval (CI) on a topographic map? [1 Mark]

.....

.....

.....

.....

.....

.....

SECTION C: SHORT ESSAY QUESTIONS (20 marks)

(Answer one question only from this Section in the examination answer book provided)

27. Forest field surveys are an important research agenda in vegetation science and natural resources management. Explain the different methods and tools used for forest field surveys.

28. Explain the main characteristics of aerial photographs.

29. Maps in Zambia have been critical to both natural resources management and social development. Discuss the practical uses of maps in Zambia.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2020/2021 ACADEMIC YEAR DEFERRED FINAL EXAMINATIONS
GES 2420: RESEARCH AND STATISTICAL METHODS IN GEOGRAPHY

TIME: Three hours

INSTRUCTIONS: Answer any FOUR questions
All questions carry equal marks
Use of certified calculator is allowed

---

1. A researcher was interested in finding out which one of the two farm blocks, Mkushi and Nkehema produced more maize in 2020 farming season. In order to do this, she sampled a number of farms and recorded the number of 90kg bags of maize each one of them harvested, as shown in Table 1. Assuming she used the 0.05 level of significance, and that the data from both samples were normally distributed, what was her conclusion?

Table 1: Maize production in two farm blocks

Mkushi farm block (x)	40	17	60	40	99	15	29	45	28	14	98	88	43	55
Nkehema farm block (y)	20	55	11	11	16	15	61	89	40	16	10	78	88	15

Source: *Hypothetical*

2. Write short explanatory notes on ALL of the following:
   (a) Basic research
   (b) Weakness of case studies
   (c) Unit of analysis in research
   (d) Inferential statistics
   (e) Stratified sampling

3. For a topic of your choice:
   a) Formulate a statement of the problem
   b) Formulate the aim and three (3) objectives of the study
   c) Construct a questionnaire for collecting such data.

4. A sample of 650 members of political parties in four provinces was taken as shown in Table 2. At $\alpha = 0.05$, is there an association between political party affiliation and province of residence?

Table 2: Political party affiliation and province of residence

Political affiliation	Province of Residence			
	Lusaka	Southern	Northern	Eastern
UPND	90	60	104	95
PF	30	50	51	20
Socialist	30	40	45	30

Source: *Hypothetical*

- 645

5. Write short explanatory notes on ALL of the following.

   a) Parametric and non-parametric tests
   b) One tailed and two tailed tests
   c) Three levels of measuring geographical data
   d) Statistics and parameters
   e) Normal and skewed distributions
   f) Three ways to state the alternative hypothesis
   g) Rejection region of the null hypothesis
   h) Three reasons why statistics is important

6. Ice cream hawkers push their tricycles from street to street, door to door and sometimes even ringing a bell to attract the attention of the would be buyers who are in their homes. This is common during the hot season. But do people really buy a lot of ice cream during the hot season? What conclusion can you make from the data presented in Table 3 at $\alpha = 0.05$ and assuming that the data is normally distributed? Temperature (Temp) data is in degrees Celsius (^{o} C) and sales in Zambian Kwacha (ZMW).

Table 3: Temperature and sales data for ice cream hawkers

Temp	14.2	16.4	11.9	15.2	18.5	22.1	19.4	25.1	23.4	18.1	22.6	17.2
Sales	215	325	185	332	406	522	412	614	544	421	445	408

Source: *Hypothetical*

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

2020/2021 ACADEMIC YEAR FINAL EXAMINATIONS

GES 3151: REGIONAL PLANNING AND DEVELOPMENT

TIME: Three hours

INSTRUCTIONS: Answer any three questions. All questions carry equal marks. Candidates are encouraged to use illustrations wherever appropriate.

---

1. 'The Growth Pole Theory asserts that public investment programmes will have maximum effects on a region's growth if concentrated in a number of favourable locations'. Elaborate.

2. 'The Central Place Theory is a spatial theory that attempts to rationalise the existence of hierarchies of settlements in a given region based on the concept of market places'. Explain.

3. Describe the three tier and alternative approaches to classification of regional economies.

4. 'Economic growth and development are not synonymous'. Discuss.

5. Write short explanatory notes on ALL of the following:

    a) Energy consumption as a measure of economic development status
    b) Leakage in a regional economy
    c) Advanced endowments as part of the global competitive advantage
    d) Globalization
    e) Economic base multiplier

END OF EXAMINATION

L.b Cop

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

2020/21 ACADEMIC YEAR FINAL EXAMINATIONS

GES 3321: ENVIRONMENT AND NATURAL RESOURCES ECONOMICS

Time:	Three hours
Instructions:	Answer question 1 and any three questions. All questions carry equal marks. Use of an approved calculator is allowed. Discounting tables are provided. Use of appropriate examples will be credited.

---

1. Kantwa Village currently depends on communal fishing from Lake Kantwa. It costs the village K1000 per year to maintain the boats and fishing nets. The village earns a gross income of K6000 per year from this activity. The nets will need to be replaced in year 10 at a cost of K5000. The village development committee has proposed the setting up of a community ecotourism enterprise composed of a hotel to be built on the banks of the river. The village will need K8000 to set up the enterprise and K3000 per year to operate it. It is expected to generate tourism revenues of K 10 000 per year. The village development committee argues that the current fishing activities are unsustainable due to severely depleted fisheries resources. Fishing will only be possible for 15 years due to depletion of fish stocks. The ecotourism project will have a life span of 30 years.

   (a) Conduct a cost-benefit analysis to determine which option would be most beneficial to the community. Use a discount rate of 10%.

   (b) Explain how rent dissipation happens in open access or poorly managed communal fisheries.

2. Explain the advantages and disadvantages of hedonic pricing method in environmental valuation.

3. "Human beings are the ultimate resource" (Julian Simon, 1981:380). Discuss.

4. The government of Zambia wants to introduce a charge on plastic bottles used for popular soft drinks such as Coca cola and Fanta. You have been hired by the Zambia Environmental Management Agency (ZEMA) to get views from consumers of various socio-economic status on their willingness to pay for the plastic bottles of soft drinks.

   (a)Use Contingent Valuation Method (CVM) to explain how you would conduct the task.

   (b) Identify three biases associated with CVM.

   (c) How would you mitigate each of the biases identified in (b)?

5. Discuss the potential use of ecolabels as an economic instrument for sustainable natural resources management in developing countries.

6. Explain the use of taxes and standards in pollution control.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2020/21 ACADEMIC YEAR FINAL EXAMINATIONS

GES 3330: ENVIRONMENT AND DEVELOPMENT

TIME: Three Hours

INSTRUCTIONS: **Answer any three questions.** All questions carry equal marks. Candidates are encouraged to use illustrations wherever appropriate.

---

1. 'Human development embodies a history of continuous redefinition to the human-environment relationship'. Elucidate.

2. What are the challenges of sustainable development goals and why Zambia might not realize the 2030 agenda of 'Our Common Future and Leave No One Behind'?

3. Outline the Green Revolution technologies and their socio-environmental effects on the Zambian agricultural landscape.

4. 'Ozone layer depletion is the major cause of global climate change.' Discuss.

5. What can we realistically do to fight off climate change in view of the fact that renewable sources provide only a small percentage of our energy and nuclear power is very expensive?

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

2020/2021 ACADEMIC YEAR FINAL EXAMINATIONS

GES 3342: ENVIRONMENTAL PLANNING AND MANAGEMENT

TIME: Three Hours

INSTRUCTIONS: Answer any three questions. All questions carry equal marks.

---

1. Use the example of communal grazing of cattle in rural Zambia to discuss the concept of 'tragedy of the commons'.

2. Explain the challenges and opportunities of decentralised natural resources management, using the fisheries sector for illustration.

3. Elucidate the Malthusian and Neo- Malthusian schools of thought on natural resource scarcity.

4. Explain the major stages of a life cycle analysis.

5. With an example, explain the fundamental cause of the environmental problems taking place in Zambia.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2020/21 ACADEMIC YEAR FINAL EXAMINATIONS

GES 3361: POPULATION, CULTURE AND ENVIRONMENT

TIME: Three Hours

INSTRUCTIONS: **Answer questions 1 and any other two.** Use of an approved calculator is allowed. Candidates are encouraged to use illustrations wherever appropriate.

---

1. According to CSO projections, by 2020 Lusaka will have a population of 265, 588 and has an area of 360 km^2. On average, hypothetically, a Lusaka resident requires about 1.5 hectares (ha) of crop and grazing land under current land management practices to produce his/her high meat protein diet consumed at 200kg/capita/year and about 1 ha of wood for energy use consumed at 500kg/capita/year. Further, each resident occupies about 0.5ha of ecologically degraded and built-over land.

   Calculate:

   a. The average annual productivity or yield (p_i) for each consumption item
   b. The *per capita* land area appropriated (aa) for the production of each major consumption item 'i'.
   c. The total *per capita* ecological footprint ('ef')
   d. Ecological footprint (EF) of a study population. Interpret the meaning of the Ecological footprint (EF) value obtained.

2. 'Despite technological, economic and cultural achievements humans have made, achieving sustainability requires that we understand human beings as ecological entities' (Rees 1996). Elucidate.

3. Using examples from one clean energy technology, show how Zambia can upscale its uptake and highlight the key environmental problems that could be resolved.

4. Outline the demographic transition theory and explain why most sub-Saharan countries are still in stage 2.

5. Write short explanatory notes on all of the following:

   a. Any five of Hoffman and Hoffman (1973) values of children,
   b. Famine as a contributing factor to high mortality before 1850,
   c. Three main schools of thought concerning the influence of infant and child mortality on fertility,
   d. Any five characteristics of a census,
   e. Anti-natalist population policy,
   f. Marx's forms of relative surplus population.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

2020/21 ACADEMIC YEAR FINAL EXAMINATION

GES 4165: MIGRATION, REFUGEES AND THE ENVIRONMENT

TIME: Three Hours

INSTRUCTIONS: **Answer questions 1 and any other two.** Candidates are encouraged to use illustrations wherever appropriate.

---

1. Write short explanatory notes on ALL of the following:
   a) Net migration and Gross migration
   b) Migration cycle and migration
   c) Asylum seeker and Asylum
   d) Emigrant and Immigrant
   e) Environmental refugees due to expropriation of the environment
   f) Humanitarian factors influencing the International Refugee Policy
   g) The United Nations High Commissioner for Refugees (UNHCR's) mandate
   h) Spontaneous and organised settlements for refugees (40 Marks)

2. Discuss Todaro's (1969) model of migration and its relevance to contemporary migration. (30 Marks)

3. Outline the durable solutions for refugees and explain why voluntary repatriation is the most desirable of all. (30 Marks)

4. With special reference to sub-Saharan Africa

   a. Explain any five reasons for rural – urban migration (15 Marks)
   b. Suggest possible solutions to mitigate rural – urban migration. (15 Marks)

5. Refugees have a positive impact on the host country. Discuss. (30 Marks)

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

SHOOL OF NATURAL SCIENCES

GES 4172: RURAL LAND USE AND LANDSCAPES

2020/2021 ACADEMIC YEAR FINAL EXAMINATIONS

TIME: Three Hours

INSTRUCTIONS: Answer question 1 and any other two questions.

---

1. Write short explanatory notes on ALL of the following:
   (a) Rural poverty
   (b) Rural landscapes
   (c) Food security
   (d) Concept of gender
   (e) Concept of livelihood.

2. Explain four factors that influence sustainability of Rural Landscapes in Zambia.

3 'Rural Landscapes in Africa are dynamic and not static'. Discuss.

4 What is the role of transport and mobile technologies in the transformation of rural economies in Africa?

5 'Women are not only producers and reproducers, but are also environmental mangers in rural Africa'. Discuss.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2020/2021 ACADEMIC YEAR FINAL EXAMINATIONS

GES 4181: URBAN GEOGRAPHY AND PLANNING

TIME: Three hours

INSTRUCTIONS: Answer Question 1 and any other two. All questions carry equal marks.

---

1. Write short explanatory notes on ALL of the following:
   a) Pre-Industrial urbanization
   b) Rapid Urban Environmental Assessment
   c) City marketing and branding
   d) Urban competitiveness and industrialization
   e) Location theory in determining housing location.
2. Describe the stages of urban development (Urban Life Cycle).
3. 'A settlement conventionally includes the totality of the human community, that is, all the social, material, organizational, spirit and cultural elements that sustain it'. Elaborate.
4. 'An urban environmental problem is a problem referring to the damage to the physical environment mostly caused by people, which have harmful consequences for human welfare, either now or in the future'. Explain.
5. With reference to the rational comprehensive planning process, justify the statement that 'urban planning can be said to be an art and science of anticipating change'.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2020/21 ACADEMIC YEAR FINAL EXAMINATIONS

GES 4285: GEOGRAPHICAL HYDROLOGY

TIME: Three Hours

INSTRUCTIONS: **Answer questions 1 and any other two.** Candidates are encouraged to use illustrations wherever appropriate.

---

1. With specific examples, discuss the factors that may influence surface runoff into the Goma Lakes at the University of Zambia. **(40 Marks)**

2. Discuss the historical development of hydrology. **(30 Marks)**

3. Explain how the developments in the Forest 27 may affect groundwater availability in the Chalimbana Catchment. **(30 Marks)**

4. Examine the relationship between precipitation and energy balance. **(30 Marks)**

5. Write short explanatory notes on all of the following
   a) Hydrological cycle **(6 Marks)**
   b) Interception and infiltration **(6 Marks)**
   c) Evapotranspiration **(6 Marks)**
   d) Forms of precipitation **(6 Marks)**
   e) Types of Aquifers **(6 Marks)**

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2020/2021 ACADEMIC YEAR FINAL EXAMINATIONS

GES 4372: TOURISM, ENVIRONMENT AND DEVELOPMENT

TIME: Three Hours

INSTRUCTIONS: Answer question 1 and any other two questions. All questions carry equal marks.

---

1. Write short explanatory notes on ALL of the following:
   (a) Distinction between travel and tourism
   (b) The basic forms of tourism
   (c) Cohen's familiarity-strangerhood continuum
   (d) Influences of Plog's psychographics
   (e) Allocentrics and psycho-centrics

2. Examine the main reasons why tourism has expanded since the 1950s.

3. Demand for tourism is primarily associated with the natural resources of a tourism destination. Discuss.

4. Using relevant examples, discuss the impacts of tourism on the environment.

5. The tourism industry has played a vital role in the development of social, cultural, and economic sectors of many countries. With specific reference to Zambia, explain how the tourism industry has contributed to the development of these sectors.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2020/2021 ACADEMIC YEAR FINAL EXAMINATIONS

GES 4385: ENVIRONMENTAL HAZARDS AND DISASTERS

TIME: Three Hours

INSTRUCTIONS: Answer Questions **One** and **any other two**.

---

1. Explain how each of the following can increase disaster risk:
   a) Exposure and vulnerability (4 Marks)
   b) Risk and disaster risk (4 Marks)
   c) Political factors (4 Marks)
   d) Temporal characteristics of hazards (4 Marks)
   e) Slow on-set hazards. (4 Marks)

2. 'Hazards always arise from the interplay of social and biological and physical systems.' Using specific examples, explain any four types of natural hazards commonly affecting humanity. (20 Marks).

3. With special reference to any flood prone area of your choice:
   a) Mention the area and describe its geographical characteristics. (4 Marks).
   b) Explain how the geographical characteristics described in (a) make it susceptible to floods. (8 Marks)
   c) Outline and explain structural and non-structural flood mitigation measures that should be put in place to lessen impact of floods in the named area in (a). (8 Marks).

4. Write an essay titled, 'Household coping strategies for unreliable water supplies in my home town'. (20 Marks)

5. (a) Outline and explain the basic elements of Community Based Approach to Disaster Management.
   (b) What are the components of Community Based Approach to Disaster Plan?

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
2020/2021 ACADEMIC YEAR FINAL EXAMINATIONS

GES 4472: FUNDAMENTALS OF GEOGRAPHIC INFORMATION SYSTEM

TIME: Three hours

INSTRUCTIONS: Answer question 1 and any other two questions.
Candidates are encouraged to make us of illustrations wherever appropriate.

---

1. Write short explanatory notes on ALL of the following

    a) Two advantages and two disadvantages of tablet digitizing
    b) Four components of a GIS system
    c) Georeferencing
    d) Overlay analysis
    e) Geoid, ellipsoid, topographic surface, datum
    f) Proximity analysis
    g) GIS 'themes', 'layers' or 'coverages
    h) Network analysis

2. Describe four types of map projections.

3. Describe the relational database management system (RDBMS) and five keys that are used in managing it.

4. Explain the types of vector and raster analyses that are done in GIS.

5. With the aid of examples, explain how GIS can be applied in urban planning.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

2019/2020 ACADEMIC YEAR FINAL EXAMINATION

GES 5131: GEOGRAPHY OF RURAL DEVELOPMENT

TIME: Three Hours.

INSTRUCTIONS: Answer any **Four** questions. All questions carry equal marks. Use of illustrations and examples is encouraged.

---

1. 'While more attention is paid to the role of the state as the driver of rural development in Africa, little attention is paid to the contributions that each individual should make'. Discuss.

2. 'Value addition is the ultimate exit option for the majority of the rural subsistence cultivators in Africa'. Explain

3. Comment on the assertion that 'women have played the crucial roles of frontline rural food producers and environmental managers in Africa for many decades'.

4. In what ways are the policies to promote crop diversification in Africa an attempt to reverse crop succession that has taken root since the imposition of colonial rule?

5. Explain the gender dimension of energy poverty in rural Zambia.

6. Discuss how political factors shape the nature and extent of rural development in Zambia.

END OF EXAMINATION.

UNIVERSITY OF ZAMBIA

2020/2021 ACADEMIC YEAR FINAL EXAMINATION

GES 5161: EVOLUTION AND PHILOSOPHY OF GEOGRAPHY.

TIME: Three Hours.

INSTRUCTIONS: Answer any **four** questions. All questions carry equal marks. Candidates are advised to make use of illustrations and examples wherever appropriate.

---

1. During the evolution of geography around the 19th century, the discipline developed into what was termed as 'new geography'. Explain what was 'new' about this new geography.

2. Discuss the role of explorations and mapping in the development of the discipline of geography.

3. According to Karl Popper, 'the conduct of research is about conjectures and refutations' Discuss.

4. Suggest ways in which African geographers can contribute to research on the impacts of climate change in Africa as part of a research frontier.

5. How can philosophy of geography be used to build essential unity and a theoretical bridge between what might appear to be polarities in geographic thought: Idealism and Faith on the one side, versus materialism and pragmatism on the other?

6. According to Lisimba (1999), 'the Bakongo people believe that life is a journey and a continuing struggle for prosperity'. Evaluate this statement with the lens of an African Bantu Philosopher.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

2019/2020 ACADEMIC YEAR FINAL EXAMINATIONS

GES 5325: ENVIRONMENTAL AND NATURAL RESOURCE ECONOMICS

TIME: Three Hours

INSTRUCTIONS: Answer Question 1 and any other three. Candidates are encouraged to use illustrations wherever appropriate. Use of an approved calculator is allowed. Discounting tables are provided.

---

1. An international mining firm commissioned a study to determine the profitability of mining nickel in Ikelenge District. The consultant reports back with the summary of costs and revenues shown in Table 1. The proposed mine will have a lifespan of 40 years.

   Table 1. Costs and revenues for proposed mine in Ikelenge District.

Parameter	Amount (in 000' USD)
1. Average annual maintenance and operational costs	40
2. Payments at start of mining activities for licences, purchase of capital equipment	400
3. Annual payments to state regulatory agencies (ZEMA, district council)	20
4. Payment for land rehabilitation after close of mine (when mining operations cease)	40
5. Gross annual income from gold sales	300
6. Yearly government corporate tax	20% of annual gross income
7. Income from sale of equipment when mine operations cease.	180

   (Source: hypothetical)

   a) Calculate the Net Present Value of the project, assuming a discount rate of 10%.

   b) If you were the consultant, would you advise the mining firm to go ahead with the project, based on the cost benefit analysis results in (a)? Give a reason for your answer.

c) A 'green' non-governmental organization analyses the report and laments that the discount rate used discriminates against future generations, and advises the consultant to change it. If the consultant is to act on this advice, how would he change the discount rate? Give a brief reason for your answer.

d) How is Cost Benefit Analysis different from financial analysis?

e) Explain two situations in which shadow prices are preferred.

2. Discuss how quotas could be used as an economic instrument to lower fish harvest levels in publicly managed fisheries.

3. Show how a contingent valuation exercise can be conducted to valuate a recreational park.

4. Explain the advantages and disadvantages of the hedonic pricing method for determining environmental quality.

5. Discuss the potential use of eco-labeling schemes as economic instruments for sustainable utilization of natural resources by producers in developing countries.

6. 'The polluter pay principle has been effectively used to formulate economic instruments for pollution control in Zambia'. Discuss using the ban on single- use plastics as an example.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

2019/2020 ACADEMIC YEAR FINAL EXAMINATIONS
GES 5332: ENVIRONMENTAL PLANNING AND MANAGEMENT

TIME: Three hours

INSTRUCTIONS: Answer any **FOUR** questions

All questions carry equal marks

---

1. To what extent is Environmental Impact Assessment (EIA) seen as a tool for sustainable development?

2. How is the global economy affecting land-use change at regional and local scales, and how does this land-use change impact natural systems?

3. Explain how the present dominant global paradigm of resource use could lead to peak resources.

4. Analyse the assertion that 'spatial planning is a useful tool for promoting synergies between climate change response and other development priorities at city-region level'.

5. Discuss factors influencing the quality of environmental performance in Zambia.

6. Explain the importance of Strategic Environmental Assessment (SEA) in integrated development Planning.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

2019/2020 ACADEMIC YEAR FINAL YEAR EXAMINATIONS

GES 5410: RESEARCH METHODOLOGY

TIME: Three Hours

INSTRUCTIONS: Answer any two questions from section A and any two questions from section B. Candidates are encouraged to use illustrations wherever possible. Use of an approved calculator is allowed.

Section A

1. Analyse the considerations that you should take into account when searching for literature.
2. (a) Explain two qualitative and two quantitative data collection methods
   (b) Elaborate how you would analyse the data collected using the methods in (a).
3. 'Ontology and epistemology inform the process of knowledge generation'. Elucidate.

Section B

4. With an example explain how you would apply the two or more sample Chi-Square test to solve a research problem. Clearly state the hypotheses and the expected results.

5. With an example, demonstrate how you would apply multiple regression analysis to solve a research problem. Clearly define the variables and the expected results.

6. Explain how you would apply the Analysis of Variance (ANOVA) test with two factors to solve a research problem. Clearly state the hypotheses and the expected results.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2019/20 ACADEMIC YEAR FINAL EXAMINATIONS

GES 5712: GIS FOR HYDROLOGY AND WATER RESOURCES

TIME: Three Hours

INSTRUCTIONS: Answer any four (4) questions. All questions carry equal marks. Candidates are advised to make use of illustrations and examples wherever appropriate.

---

1. 'In the water management resilience discourse, several governance attributes have been identified as the contributing factors for enhancing resilience'. Discuss this statement in the context of Zambia's water policy.

2. With an example, explain how the Integrated Water Resources Management (IWRM) approach can be applied in any Zambian river basin.

3. Using remote sensing to extract quantitative information on soil moisture is a relatively complex process that takes into account a number of factors and tradeoffs. Discuss.

4. As a spatial hydrologist working for a consultancy firm, you are asked to develop a water balance analysis of an area in Zambia using remote sensing datasets due to lack of adequate insitu input data.
   a) Indicate the components of your conceptual water balance model (equation), clearly showing your model inputs and outputs.
   b) For each of the water balance input and output identified in (a), mention one remote sensing product you would use, and justify your selection of this product based on spatial and temporal resolution and or coverage.
   c) During the implementation process, the major problem you are likely to encounter is the failure to close the water budget. Explain any two ways you would consider to reduce uncertainties and close the water budget.

5. The Soil Conservation Service Curve Number (SCS-CN) is an example of a typical GIS based hydrological model.
   a) Using an illustration, show the major components of the model and how it can be coupled with a hydraulic model.
   b) From the hydrological and hydraulic model component in your illustration, identify at least four (4) remote sensing based input data.

6. You have been asked to provide technical assistance to a project team evaluating the amount of water used by commercial irrigation in the dry season in Chongwe Catchment, Zambia. Explain the major data and GIS based software you would need, and highlight the major processing steps in chronological order.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
2019/2020 ACADEMIC YEAR FINAL EXAMINATIONS

GES 5731 : ADVANCED IMAGE PROCESSING AND IMAGE INTERPRETATION

TIME: Three hours

INSTRUCTIONS: Answer any **four** questions
Candidates are encouraged to make use of illustrations wherever appropriate

---

1. With reference to image processing and interpretation:
   a. What are the major distinguishing attributes between Image Processing and Image Interpretation?
   b. Image interpretation is primarily concerned with extracting information from images. Provide at least four examples of interpretation keys in visual interpretation.

2. With reference to earth observation satellites:
   a. Give five examples of earth observation satellites
   b. Discuss either the LandSat or Spot Image systems and its characteristics and programmes.

3. With reference to the following:
   a. Discuss the NDVI index and how it can be used in vegetation analysis
   b. Using sketches, illustrate how electromagnetic energy is propagated through the atmosphere to the earth onto the imaging device. Include in your discussion, the role atmospheric windows play in letting through certain energy of particular wavelengths.

4. Briefly discuss the following:
   a. Land use and Land cover
   b. Supervised and Unsupervised classification
   c. Radiometric correction
   d. Geometric correction.

5. With reference to image processing:
    a. What does the term Image pre-processing mean?
    b. Discuss the different levels of processing a Spot or LandSat image may undergo and what each of the resulting image products may be used for.

6. With reference to the following:
    a) Discuss the following resampling techniques, giving the advantages and disadvantages of each method: nearest neighbour; bilinear interpolation; and cubic convolution
    b) Discuss the notions "Geo-stationary" and "Sun-synchronous" satellites.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
2019/2020 ACADEMIC YEAR FINAL EXAMINATIONS

GES 5861: ENVIRONMENTAL REMOTE SENSING

TIME: Three hours

INSTRUCTIONS: Answer any four questions
Candidates are encouraged to make use of illustrations wherever appropriate

---

1. With reference to the electromagnetic radiation:

   a) Explain how the electromagnetic radiation interacts with the atmosphere and geographic phenomena on the surface of the earth.
   b) Explain how these interactions are useful for the purposes of environmental remote sensing.

2. Describe the information we can get from digital satellite imagery and the related importance to both image interpretation and semi-automatic image classification.

3. Explain key considerations that are needed when:

   a. Determining location for training points or polygon for image classification to enable accurate image classification results
   b. Determining sample points for accuracy assessment
   c. Addressing possible errors in the image classification results

4. Suppose you have been hired to provide remote sensing expert advice to the Kuomboka Ceremony Committee on how best to host the 2021 ceremony. Demonstrate how you would apply remote sensing to provide information about the extent (area) of the flood over the last 10 years to enable the Kuomboka Ceremony Committee to plan for the next (2021) Kuomboka Ceremony on the Zambezi Flood Plains.

5. With reference to SDG 1 (End poverty in all form and everywhere), explain how satellite imagery and remote sensing techniques can be used to monitor progress made to poverty reduction in Africa since 2015. Include imagery used, possible preprocessing, image classification and change detection.

6. Table 1 presents the results of the error matrix for Zambia 2010 land cover assessment.

a) Explain the implication to the producer and the users of the classification results.
b) Provide examples to explain your case, include the sample size.
c) If the result is meant to be used for investigating cropland expansion, is the obtained result good enough to explain cropland expansion?

Table 1: Zambia Land Cover 2010

		Reference Data						
		Forestland	Grassland	Cropland	Wetland	Settlement	Otherland	*User Accuracy*
Classified Data	Forestland	1099	72	52	13	0	0	*88.92%*
	Grassland	63	480	34	20	0	0	*80.40%*
	Cropland	67	45	337	0	5	1	*74.07%*
	Wetland	6	4	2	327	0	0	*96.46%*
	Settlement	0	0	1	1	56	0	*96.55%*
	Otherland	0	2	0	0	0	13	*86.57%*
	Producer Accuracy	*88.92%*	*79.34%*	*79.11%*	*90.58%*	*91.8%*	*92.86%*	***Overall Accuracy = 85.53%***

Source: Hypothetical

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

Department of Mathematics & Statistics

2020/2021 ACADEMIC YEAR FINAL EXAMINATION

15th December, 2021.

M1100—FOUNDATION MATHEMATICS

Time allowed : THREE(3) HOURS

Instructions :

- There are seven(7) questions. Answer **ANY FIVE (5)** questions
- All questions carry equal marks. Marks to parts have been indicated at the end of each question.
- Show all your working to earn full marks.
- Write your Computer Number (Student ID) on each answer booklet submitted.
- **CALCULATORS ARE NOT ALLOWED**

---

1. (a) Consider the subsets $A = [-10, 2]$, $B = (-3, 3]$, and $C = (0, 10]$ of the universal set $U = [-11, 12)$. Find each of the following sets and display them on the number line:

   (i) $(A \cup C)'$ (ii) $A \cap B \cap C$ (iii) $A \cup (B \cap C)'$.

(b) Let X and Y be subsets of the universal set Z. Given that $X \subseteq Y$, simplify the following in parts (i) and (ii):

(i) $(X \cup Y)' \cap Y$.

(ii) $X \cap Z'$.

(iii) Simplify the following into its simplest form: $[(A \cap B)' \cup (A - B)]'$.

(c) An operation $*$ on the set $\mathbb{R}$ of real numbers is defined by $a * b = (a - b)^3$.

(i) Is $*$ a binary operation on $\mathbb{R}$? (Justify your answer)

(ii) Is $*$ commutative? (Justify your answer)

(iii) Compute $(-1 * 0) * 1$ and $-1 * (0 * 1)$ and hence deduce whether or not $*$ is associative. **[7;7;6]**

2. (a) (i) Express the rational number $1.03\overline{5}$ in the form $\frac{p}{q}$ where p and q are nonzero integers with no common factor.

(ii) Given that $\sqrt{5}$ is irrational, prove that $\frac{\sqrt{125}}{\sqrt{625}}$ is irrational.

(iii) Find the imaginary part of the complex number $z = \frac{1}{1+i} + \frac{1}{2-i} + i$.

(b) (i) Express $-1 + \sqrt{125} + \frac{1}{1-\sqrt{5}}$ in the form $a + b\sqrt{c}$ where a and b are rational and c is a positive integer.

(ii) Solve the equation $|iy|^2 = 4$ for real values of y.

(iii) Express $(1+i)^{10} - (1-i)^{12}$ in the form $x + iy$, $x, y \in \mathbb{R}$.

(c) (i) Find the domain of the function $g(x) = \frac{\sqrt{x+1}}{\sqrt{x-2}}$

(ii) Find the domain of the function $h(x) = \sqrt{\frac{x+1}{x-2}}$.

(iii) Given that $f(x) = \frac{2x}{4-x}$ and $g(x) = \frac{1}{x^2}$, find $(f \circ g)(x)$ and state its domain.

[7;7;6]

3. (a) Find the exact values of the following:

(i) $\tan(-720°)$.

(ii) $\frac{\sin\frac{\pi}{4}+\cos\frac{\pi}{4}}{\cos(-\frac{\pi}{4})}$.

(iii) $\text{cosec}^2\frac{\pi}{2} - \sin^2\frac{\pi}{6}$.

(b) (i) Solve the trigonometric equation $\tan^2 x + 2\sec x + 1 = 0$ for x in the interval $0 \leq x \leq 2\pi$:

(ii) Given that $\sin\alpha = \frac{4}{5}$ and α is in the first quadrant, and $\sin\beta = \frac{5}{13}$, where β is in the second quadrant, find $\frac{\cos\alpha-\cos\beta}{\tan\beta}$.

(iii) Prove the identity $\frac{1+\tan x}{1-\tan x} = \frac{\cos x+\sin x}{\cos x-\sin x}$.

(c) Solve the differential equation

$$\frac{dy}{dx} = \frac{x\sqrt{1-y^2}}{\sqrt{1-x^2}}; \quad y(0) = 0. \qquad \textbf{[7;7;6]}$$

4. (a) (i) Find the values of x at which the function $y = f(x) = x^3 - 4x^2 + x + 6$ has a local maximum or local minimum.

Hence skecth the graph of the function, indicating all the intercepts and turning points.

(ii) Find the quotient and remainder when $x^5 + x^4 - 8x^3 + x + 2$ is divided by $x^2 + x - 7$.

(iii) Given that $x - 1$ and $x + 1$ are factors of $f(x) = px^3 + qx^2 - 3x - 7$, find the values of p and q.

(b) (i) Let α and β be the roots of the equation $1 - 3x - 2x^2 = 0$. Find the value of $\frac{\alpha}{\alpha+1} + \frac{\beta}{\beta+1}$.

(ii) Solve the inequality $\sqrt{3x+1} > \sqrt{x-3}$ for real values of x.

(iii) Solve the inequality $\frac{x+6}{x+1} \geq 2$ for real values of x.

(c) Find the equation of the tangent to the curve given by the equation $x^2 + 2x + y^2 - 4y - 24 = 0$ at the point $(4, 0)$.

[8;7;5]

5. (a) (i) The coefficient of x^3 in the expansion of $(3+bx)^5$ is -720. Find the value of the constant b.

(ii) Expand $\sqrt{1-2x}$ in ascending powers of x upto, and including the term in x^3, indicating the set of values of x for which the expansion is valid.

(iii) Find the term independent of x in the expansion of $(x^2 - \frac{3}{x})^{12}$, without evaluating the binomial coefficient.

(b) (i) Solve the equation $\log_4(x+3) + \log_4(x-3) = 2$ for real values of x.

(ii) Solve the equation $4^x - 2^{x+1} - 48 = 0$ for real values of x.

(iii) Evaluate the following limit: $\lim_{x\to 2} \sqrt{\frac{x^2-4}{x^2-3x+2}}$.

(c) A rectangular dog pen is constructed using a barn wall as one side and 60cm of fencing for the other three sides. Find the dimensions of the pen that give the greatest area. **[8;7;5]**

6. (a) (i) Find the derivative of $y = f(x) = \sqrt{x+1}$ from first principles.

(ii) Find $\frac{dy}{dx}$ given that $y = x^3\sqrt{x^2-3}$.

(iii) Evaluate the following integral: $\int_0^{\frac{\pi}{2}} \cos^3 x \sin^4 x dx$.

(b) (i) Sketch the graph of the function $f(x) = \frac{1}{x^2+x-6}$, indicating all intercepts, maximum or minimum, and any asymptotes.

(ii) Express

$$\frac{x^2}{(x-1)(x-2)(x-3)}$$ into partial fractions.

(iii) Hence evaluate

$$\int_4^5 \frac{x^2}{(x-1)(x-2)(x-3)} dx.$$

(c) Find the set of values of k such that the graph of the function $f(x) = \frac{-1}{3}x^2 + kx - 3$ does not cross the x-axis.

[8;8;4]

7. (a) (i) Let $A = \begin{pmatrix} 1 \\ -1 \\ 2 \end{pmatrix}$ and $B = \begin{pmatrix} 3 & -2 & -3 \end{pmatrix}$. Find AB, and determine its order.

(ii) Let $A = \begin{pmatrix} 1 & 0 \\ 0 & 3 \end{pmatrix}$. Find A^2, A^3, A^4, and hence write a general formula for A^n, for any positive integer n.

(iii) Find the exact value of $\sec[\cos^{-1}(\frac{1}{3})]$.

(b) (i) Find the determinant of the matrix

$$A = \begin{pmatrix} 2 & 1 & -1 \\ 1 & 0 & 1 \\ 0 & -1 & 5 \end{pmatrix}.$$

(ii) Find the cofactors C_{31} and C_{23} of the matrix A in part (i).

(iii) Using the fact that

$$A^{-1} = \begin{pmatrix} -\frac{1}{2} & 2 & -\frac{1}{2} \\ \frac{5}{2} & -5 & -\frac{3}{2} \\ -\frac{1}{2} & -1 & \frac{1}{2} \end{pmatrix},$$

or otherwise, solve the following system of equations

$$2x + y - z = 4 \ ; x + z = 2 \ ; -y + 5z = 11.$$

(c) On the same axes, sketch the graphs of $f(x) = x^2$ and $g(x) = |x|$. Hence, find the area of the finite region enclosed by the two curves.

[7;7;6]

END.

The University of Zambia

Department of Mathematics & Statistics

2020/2021 Academic Year, Final Examinations

MAT1110: Foundation Mathematics & Statistics For Social Sciences

Monday 13^{th} December 2021 – 14 : 00hrs

Time Allowed: **3 hours**

Instructions:

1. There are **Seven** (7) questions in this examination paper. Attempt **any five (5)** questions.
2. Indicate your **computer number** on all your answer booklets.
3. **Full credit** will only be given when **all necessary working** is shown.
4. **Calculators** are **not** allowed.

---

1. (a) A fast food restaurant conducted a survey on its 185 customers. The results came out as follows; 70 liked pizza, 60 liked fries, and 50 liked shawarma. In addition, 30 liked pizza and fries, 20 liked pizza and shawarma, 35 liked fries and shawarma. 17 liked all the three meals.
   i. Illustrate this information on a Venn diagram.
   ii. Find the number of customers who did not like any of these available meals?
   iii. Find the number of customers who liked exactly one meal?

   (b) Simplify each of the following leaving your answer in the form $a\sqrt{b}$, where a and b are natural numbers.
   i. $\sqrt{48} + \sqrt{108}$
   ii. $(\frac{\sqrt{3}}{21})^{-1} + \sqrt{27}$.

   (c) i. Let $\mathbb{R}$ be the universal set, $A = [-2, 3)$ and $B = (-3, 3]$. Find the set
   $$B \cap A^c,$$
   and display your answer on the number line.
   ii. Let X and Y be any non-empty sets. Express the following in its simplest form:
   $$[(X \cap Y^c) \cup (X \cap Y)^c]^c.$$

[8, 7, 10]

2. (a) i. Express

$$\frac{-1+i}{3-2i}$$

in the form $a+bi$, where a and b are real numbers.

ii. By completing the square method, express $f(x) = 2x^2 - 6x + 4$ in the form $f(x) = a(x-h)^2 + k$, where (h,k) is the turning point.

(b) Let

$$f(x) = \frac{4x+1}{2x+1}.$$

i. Find f^{-1}.

ii. Find the domain, and range of f.

iii. Sketch the graph of f.

(c) Let P be the polynomial given by $P(x) = x^4 + 6x^3 + 2x^2 + 3x + 1$.

i. Find the remainder when P is divided by $2x+1$.

ii. Express P in the form

$$P(x) = (x^2+1)Q(x) + R(x),$$

where Q is the quotient and R the remainder when P is divided by x^2+1.

[7, 1(

3. (a) Solve each of the following equations.

i.

$$\left(\frac{1}{32}\right)^{-2x} = 4^{4x+2}$$

ii.

$$\log_3(3x+9) = 4$$

(b) Prove each of the following identities:

i.

$$\frac{\cos^2 x + 4\cos x + 3}{\sin^2 x} \equiv \frac{3+\cos x}{1-\cos x}.$$

ii.

$$\tan^2 x + 1 + \tan x \sec x \equiv \frac{1}{1-\sin x}.$$

(c) Let

$$f(x) = -\sin(x+30°) \quad \text{for } 0° \leq x \leq 360°,$$

i. Solve the equation $f(x) = 0$.

ii. Hence, or otherwise, sketch the graph of $f(x) = -\sin(x+30^c)$.

[8, 8,

4. (a) Evaluate each of the following:

i.
$$\lim_{x\to 3} \frac{27-x^3}{x-3}.$$

ii.
$$\lim_{x\to 0} \frac{\sqrt{3}-\sqrt{x+3}}{x}.$$

(b) Let f be a polynomial given by
$$f(x) = x^3 + 2x^2 - 3x.$$

i. Sketch the graph of f.

ii. Hence, or otherwise, find the area of the region bounded by the graph of f and the x-axis.

(c) The amount of money in a certain bank account is increasing exponentially. If K100,000 is present initially and K400,000 after 1 hour, how much money will be present after 210 minutes?

[9, 10, 6]

5. (a) i. Use the **first principle** to differentiate
$$f(x) = \frac{1}{1-x}.$$

ii. Let $y = (x^2+1)^{\frac{1}{4}}$. Show that
$$\frac{d^2y}{dx^2} = \frac{a-x^2}{b(x^2+1)^c},$$
where a, b and c are real numbers.

(b) Let $f(x) = x^4 - x^2$.

i. Determine the intervals where f is increasing or decreasing.

ii. Hence, or otherwise, sketch the graph of f.

(c) Evaluate

i.
$$\int_1^4 \left(\frac{2}{x^3} - 3\sqrt{x}\right)\, dx.$$

ii.
$$\int_0^{\frac{\pi}{2}} \sin x\, e^{(1+\cos x)}\, dx.$$

[8, 9, 8]

6. (a) Let
$$f(x) = \frac{1}{x^3+5x}.$$

i. Find the partial fraction decomposition of f.

ii. Hence integrate
$$\int \frac{1}{x^3+5x}\, dx.$$

(b) i. In a group of 40 college students, 16 are on self sponsorship. Find the probability that a student chosen at random is not on self sponsorship?

ii. Two dice are thrown.Find the probability of scoring either the same number on both dice or scoring a sum greater than 8.

(c) The table below shows the scores observed for 50 tosses of a die.

score(x)	1	2	3	4	5	6
frequency (f)	7	15	10	3	9	6

i. Find the mean, $\overline{x}$.

ii. Find the median.

iii. Find the mode.

[8, 10

7. (a) Events A and B are independent such that $P(A) = y$, $P(B) = y + \frac{1}{5}$, and $P(A \cap B) = \frac{3}{20}$. Find

i. the value of y.

ii. $P(A \cup B)$.

(b) Integrate

i. $$\int \frac{x}{6} e^{3x^2} \, dx.$$

ii. $$\int x \cos x \, dx.$$

(c) The grouped frequency distribution below shows the weights, to the nearest gram, of 84 letters.

Mass(g)	$1-20$	$21-40$	$41-60$	$61-80$	$81-100$
Number of letters	10	18	24	14	18

i. Complete the frequency distribution table below.

Mass(g)	Interval width	Frequency	Frequency density
$0.5 \leq x < 20.5$	20	10	0.5

ii. Find the interval representing the median class.

iii. Draw a histogram.

[7, 9, 9]

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
DEPARTMENT OF MATHEMATICS AND STATISTICS

2020/2021 ACADEMIC YEAR
FINAL EXAMINATIONS
DECEMBER 2021

MAT 1120 : INTRODUCTORY MATHEMATICS, STATISTICS, AND PROBABILITY

Time Allowed: Three (3) Hours

Instructions:

1. You must write your **Computer Number,**
2. You must write your **TG Number** on each answer booklet used.
3. There are **Six (6)** questions in this paper.
4. Candidates must answer any **Five (5)** questions only.
5. All questions carry equal marks.
6. Calculators may be used.
7. Show necessary working to earn full marks.

---

1. (a) (i) Write $2.5\overline{17}$ in the form $\frac{a}{b}$, where $b \neq 0$ and $a, b \in Z$.

(ii) Given that $z = \frac{3+i}{1-i}$, find $z - \frac{1}{z}$ giving the answer in the form $a + ib$, where a and b are real numbers.

(iii) Let A = (-2,2), B = (0,8] and C = (-5, 1] be subsets of the universal set of real numbers R. Find the set $(A \cap B) - C$, expressing your answer in interval notation.

(b) Let $f(x) = x^2 - 4x - 5$.

(i) Sketch the graph of $f(x)$, indicating all intercepts and turning points.

(ii) Is the function $f(x)$, even or odd or neither? Justify your answer.

(iii) Find the values of x for which $f(x) > 0$.

(c) (i) Solve the equation $2\sin^3 x - \sin x = 0$, for $0 \leq x < 2\pi$.

(ii) Find $\frac{dy}{dx}$, given that $y = \sqrt{x^2 - 1}\, sinx$.

2. (a) Let $f(x) = \cos(2x - \pi)$, $0 \leq x \leq 2\pi$.

(i) Find the amplitude, phase shift and period of the function f(x).

(ii) Sketch the graph of f(x).

(iii) Find the values of x for which $f(x) = \frac{\sqrt{3}}{2}$.

(b) Simplify the following as much as possible where A and B are any sets

(i) $(A \cup B) \cap (A \cup B')$

(ii) $[A' \cup (A \cap B)']'$

(c) The observations below show the number of patients at a particular health centre in a given month.

26	47	30	8	3	20	36	44	18	7	33	22	9	5	48
20	12	5	36	40	2	26	35	33	46	14	10	19	22	30

(i) Construct a frequency table with classes $1-5, 6-10, \ldots$

(ii) Construct a cumulative frequency curve.

(iii) Use (ii) above to estimate the interquartile range of the distribution.

(iv) Construct a bar chart of this distribution.

(v) Using the frequency distribution in (i), calculate the average number of patients at the health centre.

3. (a) The table below shows the distribution of the prevalence of a particular disease according to age.

Age	1 - 5	6 - 10	11 - 15	16 - 20	21 - 25	26 - 30	31 - 35	36 - 40	41 and abo
Frequency	1	3	7	9	15	6	4	2	1

(i) Calculate the mean age of the disease prevalence.

(ii) Calculate the standard deviation of the distribution of the disease.

(iii) Construct a frequency polygon of the distribution.

(b) Let $f(x) = \begin{cases} 2x+1, & if\ x \le -1 \\ x^2 - 2 & if\ x > -1 \end{cases}$

(i) Sketch the graph of $f(x)$.

(ii) Find $\lim_{x \to -1} f(x)$.

(iv) Is the function $f(x)$ continuous at $x = -1$? Justify your answer.

(c) (i) Evaluate $\int_0^{\frac{\pi}{4}} x \cos x dx$.

(ii) Find $\int \frac{3x}{(x-2)(x-1)} dx$.

(iii) Find $\frac{dy}{dx}$ given that $x^2 + y^3 = 12$.

4. (a) Let $f(x) = (2x-1)^2(x+1)$.

(i) Find the critical points of f(x).

(ii) Determine the nature of the critical points.

(iii) Sketch the graph of $f(x)$.

(v) Determine the intervals on which $f(x)$ is increasing or decreasing.

(b) (i) Let $A = \begin{pmatrix} 1 & 0 & 2 \\ 3 & 1 & 0 \\ 1 & -1 & -2 \end{pmatrix}$, find A^{-1}.

(ii) Hence or otherwise, solve the system of equations

$x + 2z = 1$

$3x + y = -2$

$x - y - 2z = 1$

(c) (i) Expand $\sqrt{4-x}$ in ascending powers of x, up to and including the term in x^3, and state the range values of x for which the expansion is valid.

(ii) Evaluate $\int \frac{1}{x \ln x} dx$.

(iii) Express $\log_p 12 - \left(\frac{1}{2}\log_p 9 + \frac{1}{3}\log_p 8\right)$ as a single logarithm.

5. (a) (i) Given that $\sqrt{2}$ is an irrational number, prove that $\frac{1}{\sqrt{2}+1}$ is an irrational number.

(ii) Let $U = [-5, 5]$ be the universal set, $A = (-2,1]$, B = [0 , 5] and C = (-3, 2). Find $A \cup (B' \cap C)$ and illustrate your answer on the number line.

(iii) On the same axis sketch the graphs of $f(x) = |3x + 1|$ and $h(x) = |2 - x| - 1$.

(iv) Prove that $\frac{\cos^2 x}{\sin x + \sin^2 x} = \frac{1 - \sin x}{\sin x}$.

(b) Let $f(x) = \frac{25}{3x - 2}$ and $g(x) = x + 1$.

(i) Find the domain and range of f.

(ii) Find the inverse function of f.

(iii) Solve the equation $(fog)(x) = \frac{2}{x-1}$.

(c) The probability distribution of blood type is given as:

Blood Type	O	A	B	AB
Probability	0.44	0.42	0.10	0.04

Here is some additional information

- A person with type **A** can donate blood to a person with type **A** or **AB**.
- A person with type **B** can donate blood to a person with type **B** or **AB**.
- A person with type **AB** can donate blood to a person with type **AB**

(i) A person with type O blood can donate to anyone. What is the probability that a randomly chosen person is a potential donor for a person with blood type A?

(ii) If two people are selected simultaneously and at random from all people in the Zambia, what is the probability that both have blood type O?

(iii) If three people are chosen simultaneously and at random, what is the probability that all three have blood type B?

6. (a) (i) A curve has equation $yx^2 - 3x = \ln y$. Find the equation of the normal to the curve at the point (3,1).

(ii) Find the derivative of $f(x) = \dfrac{1}{x-1}$ from first principles.

(iii) If α and β are roots to the equation $2x^2 - 3x + 2 = 0$, find the quadratic equation whose roots are $\dfrac{1}{\alpha\beta}$ and $\dfrac{1}{\alpha+\beta}$.

(b) In a certain region, one in every thousand people (0.001) is infected by the HIV virus that causes AIDS. Tests for presence of the virus are fairly accurate but not perfect. If someone actually has HIV, the probability of testing positive is 0.95. Let **H** denote the event of having HIV, and **T** the event of testing positive.

(i) Express the information that is given in the problem in terms of the events H and T.

(ii) If an individual has HIV, what is the probability of testing positive?

(iii) If someone has HIV, what is the probability of testing negative?

(c) (i) Given that $y = \sec x + \tan x$, prove the identity $\dfrac{dy}{dx} - y\tan x = 1$.

(ii) Given that $x - k$ is a factor of $p(x) = kx^3 - 3x^2 - 5kx - 9$, and $k \in R$, find the possible values of k.

(iii) Show that $\dfrac{1+2i}{3-i} + \dfrac{1-2i}{3+i}$ is real.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

DEPARTMENT OF MATHEMATICS & STATISTICS

2020/2021 Academic Year
End of Year Final Examinations

25 November 2021 (am)

MAT2001 – Principles of Financial Mathematics

Time allowed : **Three (3) hours** Full marks : **100**

Instructions:
- There are **six (6)** questions in this paper. Attempt any **five (5)** questions.
- **All** questions carry **equal** marks. Mark allocations are shown in brackets.
- **Full credit** will only be given when **necessary work** is shown.
- Indicate your **computer number** on all answer booklets used.

---

1. (a) Explain why the nominal rate of interest per annum convertible every 5 days would be much less than the equivalent annual effective rate of interest. **(2)**

   (b) The nominal rate of interest is 3.4% per annum convertible quarterly.

   (i) Calculate the annual effective rate of discount. **(1)**

   (ii) Calculate the nominal rate of discount per annum convertible monthly. **(1)**

   (iii) Calculate the nominal rate of interest per annum convertible half-yearly. **(1)**

   (iv) Calculate the annual force of interest. **(1)**

   (v) Calculate the effective rate of interest over a six year period. **(1)**

   (vi) Explain why your answer to (i) is lower than your answer to (ii). **(2)**

(c) The force of interest, $\delta(t)$, is a function of time and at any time t, measured in years, is given by the formula

$$\delta(t) = \begin{cases} 0.03, & 0 \leq t \leq 7, \\ 0.004t^2, & t > 7. \end{cases}$$

(i) Calculate the present value of a unit sum of money due at time $t = 12$. **(4)**

(ii) Hence determine from $t = 0$ to $t = 12$ the equivalent constant force of interest. **(2)**

(iii) A continuous payment stream is received at a rate of $320e^{0.025t}$ kwacha per annum between time 6 and time 9. Calculate the value at time 4 of this payment stream. **(5)**

2. (a) A borrower repays a loan effected on 1 January 2018 by making 36 equal monthly payments starting on 31 July 2018. The flat rate of interest is 11% *pa*.

Explain why the APR for this arrangement would be quite a lot less than 22% (twice the flat rate), which should be the usual first guess. **(2)**

(b) Dr Musonda is struggling to repay his loan of K300,000 with payments of K6,400 made monthly in arrears for 5 years.

(i) Calculate the flat rate of interest per annum. **(2)**

(ii) Hence, or otherwise, calculate the APR of Dr Musonda's loan. **(3)**

After exactly one year, a loan company offers to "help" Dr Musonda by restructuring his loan with new monthly payments of K3,500 made in arrears.

(iii) Assuming the company charges the same APR as Dr Musonda's original loan, calculate the term of the new loan. **(3)**

(iv) Calculate how much more interest in total Dr Musonda will pay on his restructured loan than on his original loan. **(2)**

(c) A loan is repaid by an immediate annuity. The annuity starts at a rate of K3,600 per annum and increases by K420 per annum. The annuity is paid for 9 years. Repayments are calculated using a rate of interest of 30% per annum effective.

(i) Calculate the amount of the loan. **(2)**

(ii) Construct a loan schedule showing the capital and interest elements in and the amount of loan outstanding after the 6th and 7th payments. **(4)**

(iii) Find the capital and interest element of the last instalment. **(2)**

3. (a) State two reasons why both the discounted payback period and the payback period are inferior measures compared with the net present value for determining whether to proceed with an investment project. **(2)**

(b) An insurance company borrows K38 million at an effective interest rate of 13% per annum. The insurance company uses the money to invest in a capital project that pays 6 million per annum payable half-yearly in arrear for 22 years. The income from the project is used to repay the loan. Once the loan has been repaid, the insurance company can earn interest at an effective interest rate of 4% per annum.

(i) Calculate the discounted payback period for this investment. **(4)**

(ii) Calculate the accumulated profit the insurance company will have made at the end of the term of the capital project. **(5)**

(c) A fund had a value of K6.5 million on 1 January 2019. On 1 May 2019, K7.6 million was invested. Immediately before this investment, the value was K7.2 million. At the close of business on 31 December 2019, the value of the fund was K11 million.

(i) Calculate the annual effective time-weighted rate of return for 2019. **(3)**

(ii) Calculate the annual effective money-weighted rate of return for 2019. **(4)**

(iii) Comment on your answers to parts (i) and (ii). **(2)**

4. (a) A investor, who is taxed at 30% on income, has just purchased 700 shares in a small education company ex-dividend. Dividends are paid annually and the next dividend is due in two month's time. The last dividend was K95 per share and dividends are expected to rise by 2% pa.

(i) Explain what is meant for a share to be offered for sale "ex-dividend". **(1)**

(ii) Calculate the price paid by the investor if the expected yield is 10% pa effective. **(4)**

(b) A loan of nominal amount K2.21 million is to be issued bearing coupons payable quarterly in arrear at a rate of 6% per annum. Capital is to be redeemed at K102 per K100 nominal on a coupon date between 12 and 18 years inclusive after the date of issue. The date of redemption is at the option of the borrower.

An investor who is liable to income tax at 20% and capital gains tax at 30% wishes to purchase the entire loan at the date of issue.

(i) Carry out the capital gains test to determine if there is a gain on redemption if the investor requires a net effective yield of 3% per annum. **(1)**

(ii) Explain the significance of the redemption date being at the option of the borrower in relation to your calculation in part (i). **(2)**

(iii) Determine the price which the investor should pay to ensure a net effective yield of at least 3% per annum. **(4)**

(c) In January 2017, the government of a country issued an index-linked bond with a term of two years. Coupons were payable half-yearly in arrears, and the annual nominal coupon rate was 6%. The redemption value, before indexing, was K100 per K100 nominal. Interest and capital payments were indexed by reference to the value of an inflation index with a time lag of six months.

A tax-exempt investor purchased K100,000 nominal at issue and held it to redemption. The issue price was K97 per K100 nominal.

The inflation index was as follows:

Date	Inflation Index
July 2016	120.0
January 2017	122.3
July 2017	124.9
January 2018	127.2
July 2018	129.1
January 2019	131.8

(i) Set out a schedule of the cashflows for the investor, showing the amount and month of each cashflow. **(3)**

(ii) Determine the annual effective real yield obtained by the investor to the nearest 0.01% per annum. **(5)**

5. (a) A one-year forward contract is issued on 1 April 2007 on a share with a price of K900 at that date. Dividends of K50 per share are expected on 30 September 2007 and 31 March 2008. The 6-month and 12-month spot, risk-free rates of interest are 5% and 6% per annum effective respectively on 1 April 2007. Calculate the forward price at issue, stating any assumptions. **(4)**

(b) The annual effective forward rate applicable over the period t to $t + r$ is defined as $f_{t,r}$ where t and r are measured in years.

$$f_{0,1} = 4\%, \quad f_{1,1} = 4.25\%, \quad f_{2,1} = 4.5\%, \quad f_{2,2} = 5\%.$$

(i) Calculate $f_{3,1}$ **(1)**

(ii) Calculate all possible zero coupon (spot) yields that the above information allows you to calculate. **(4)**

(iii) Calculate the gross redemption yield of a four-year bond, redeemable at par, with a 3% coupon payable annually in arrears.

(iv) Explain why the gross redemption yield from the four-year bond is lower than the one-year forward rate up to time 4, $f_{3,1}$.

(c) Explain what is meant by the market segmentation theory. **(3)**

6. (a) The expected effective annual rate of return from a bank's investment portfolio is 6% and the standard deviation of annual effective returns is 8%. The annual effective returns are independent and $(1 + i_t)$ is lognormally distributed. where i_t is the return in year t.

Deriving any necessary formulae:

(i) calculate the expected value of an investment of K2 million after ten years, **(6)**

(ii) calculate the probability that the accumulation of the investment will be less than 80% of the expected value. **(3)**

(b) (i) Explain what is meant by a "forward contract". Your answer should include reference to the terms short forward position and long forward position. **(2)**

(ii) An investor entered into a long forward contract for K100 nominal of a security seven years ago and the contract is due to mature in three years' time. The price per K100 nominal of the security was K96 seven years ago and is now K148. The risk-free rate of interest can be assumed to be 4% per annum effective during the contract.

Calculate the value of the contract now if the security will pay a single coupon of K7 in two years time and this was known from the outset. You should assume no arbitrage. **(4)**

(c) A pension fund has liabilities to pay pensions each year for the next 60 years. The pensions paid will be K100m at the end of the first year, K105m at the end of the second year, K110.25m at the end of the third year and so on, increasing by 5% each year. The fund holds government bonds to meet its pension liabilities. The bonds mature in 20 years' time and pay an annual coupon of 4% in arrears.

(i) Calculate the present value of the pension fund's liabilities at a rate of interest of 3% per annum effective. **(4)**

(ii) Calculate the nominal amount of the bond that the fund needs to hold so that the present value of the assets is equal to the present value of the liabilities. **(3)**

END OF PAPER

STANDARD NORMAL DISTRIBUTION: Table Values Represent AREA to the LEFT of the Z score.

Z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
-3.9	.00005	.00005	.00004	.00004	.00004	.00004	.00004	.00004	.00003	.00003
-3.8	.00007	.00007	.00007	.00006	.00006	.00006	.00006	.00005	.00005	.00005
-3.7	.00011	.00010	.00010	.00010	.00009	.00009	.00008	.00008	.00008	.00008
-3.6	.00016	.00015	.00015	.00014	.00014	.00013	.00013	.00012	.00012	.00011
-3.5	.00023	.00022	.00022	.00021	.00020	.00019	.00019	.00018	.00017	.00017
-3.4	.00034	.00032	.00031	.00030	.00029	.00028	.00027	.00026	.00025	.00024
-3.3	.00048	.00047	.00045	.00043	.00042	.00040	.00039	.00038	.00036	.00035
-3.2	.00069	.00066	.00064	.00062	.00060	.00058	.00056	.00054	.00052	.00050
-3.1	.00097	.00094	.00090	.00087	.00084	.00082	.00079	.00076	.00074	.00071
-3.0	.00135	.00131	.00126	.00122	.00118	.00114	.00111	.00107	.00104	.00100
-2.9	.00187	.00181	.00175	.00169	.00164	.00159	.00154	.00149	.00144	.00139
-2.8	.00256	.00248	.00240	.00233	.00226	.00219	.00212	.00205	.00199	.00193
-2.7	.00347	.00336	.00326	.00317	.00307	.00298	.00289	.00280	.00272	.00264
-2.6	.00466	.00453	.00440	.00427	.00415	.00402	.00391	.00379	.00368	.00357
-2.5	.00621	.00604	.00587	.00570	.00554	.00539	.00523	.00508	.00494	.00480
-2.4	.00820	.00798	.00776	.00755	.00734	.00714	.00695	.00676	.00657	.00639
-2.3	.01072	.01044	.01017	.00990	.00964	.00939	.00914	.00889	.00866	.00842
-2.2	.01390	.01355	.01321	.01287	.01255	.01222	.01191	.01160	.01130	.01101
-2.1	.01786	.01743	.01700	.01659	.01618	.01578	.01539	.01500	.01463	.01426
-2.0	.02275	.02222	.02169	.02118	.02068	.02018	.01970	.01923	.01876	.01831
-1.9	.02872	.02807	.02743	.02680	.02619	.02559	.02500	.02442	.02385	.02330
-1.8	.03593	.03515	.03438	.03362	.03288	.03216	.03144	.03074	.03005	.02938
-1.7	.04457	.04363	.04272	.04182	.04093	.04006	.03920	.03836	.03754	.03673
-1.6	.05480	.05370	.05262	.05155	.05050	.04947	.04846	.04746	.04648	.04551
-1.5	.06681	.06552	.06426	.06301	.06178	.06057	.05938	.05821	.05705	.05592
-1.4	.08076	.07927	.07780	.07636	.07493	.07353	.07215	.07078	.06944	.06811
-1.3	.09680	.09510	.09342	.09176	.09012	.08851	.08691	.08534	.08379	.08226
-1.2	.11507	.11314	.11123	.10935	.10749	.10565	.10383	.10204	.10027	.09853
-1.1	.13567	.13350	.13136	.12924	.12714	.12507	.12302	.12100	.11900	.11702
-1.0	.15866	.15625	.15386	.15151	.14917	.14686	.14457	.14231	.14007	.13786
-0.9	.18406	.18141	.17879	.17619	.17361	.17106	.16853	.16602	.16354	.16109
-0.8	.21186	.20897	.20611	.20327	.20045	.19766	.19489	.19215	.18943	.18673
-0.7	.24196	.23885	.23576	.23270	.22965	.22663	.22363	.22065	.21770	.21476
-0.6	.27425	.27093	.26763	.26435	.26109	.25785	.25463	.25143	.24825	.24510
-0.5	.30854	.30503	.30153	.29806	.29460	.29116	.28774	.28434	.28096	.27760
-0.4	.34458	.34090	.33724	.33360	.32997	.32636	.32276	.31918	.31561	.31207
-0.3	.38209	.37828	.37448	.37070	.36693	.36317	.35942	.35569	.35197	.34827
-0.2	.42074	.41683	.41294	.40905	.40517	.40129	.39743	.39358	.38974	.38591
-0.1	.46017	.45620	.45224	.44828	.44433	.44038	.43644	.43251	.42858	.42465
-0.0	.50000	.49601	.49202	.48803	.48405	.48006	.47608	.47210	.46812	.46414

STANDARD NORMAL DISTRIBUTION: Table Values Represent AREA to the LEFT of the Z score.

Z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0.0	.50000	.50399	.50798	.51197	.51595	.51994	.52392	.52790	.53188	.53586
0.1	.53983	.54380	.54776	.55172	.55567	.55962	.56356	.56749	.57142	.57535
0.2	.57926	.58317	.58706	.59095	.59483	.59871	.60257	.60642	.61026	.61409
0.3	.61791	.62172	.62552	.62930	.63307	.63683	.64058	.64431	.64803	.65173
0.4	.65542	.65910	.66276	.66640	.67003	.67364	.67724	.68082	.68439	.68793
0.5	.69146	.69497	.69847	.70194	.70540	.70884	.71226	.71566	.71904	.72240
0.6	.72575	.72907	.73237	.73565	.73891	.74215	.74537	.74857	.75175	.75490
0.7	.75804	.76115	.76424	.76730	.77035	.77337	.77637	.77935	.78230	.78524
0.8	.78814	.79103	.79389	.79673	.79955	.80234	.80511	.80785	.81057	.81327
0.9	.81594	.81859	.82121	.82381	.82639	.82894	.83147	.83398	.83646	.83891
1.0	.84134	.84375	.84614	.84849	.85083	.85314	.85543	.85769	.85993	.86214
1.1	.86433	.86650	.86864	.87076	.87286	.87493	.87698	.87900	.88100	.88298
1.2	.88493	.88686	.88877	.89065	.89251	.89435	.89617	.89796	.89973	.90147
1.3	.90320	.90490	.90658	.90824	.90988	.91149	.91309	.91466	.91621	.91774
1.4	.91924	.92073	.92220	.92364	.92507	.92647	.92785	.92922	.93056	.93189
1.5	.93319	.93448	.93574	.93699	.93822	.93943	.94062	.94179	.94295	.94408
1.6	.94520	.94630	.94738	.94845	.94950	.95053	.95154	.95254	.95352	.95449
1.7	.95543	.95637	.95728	.95818	.95907	.95994	.96080	.96164	.96246	.96327
1.8	.96407	.96485	.96562	.96638	.96712	.96784	.96856	.96926	.96995	.97062
1.9	.97128	.97193	.97257	.97320	.97381	.97441	.97500	.97558	.97615	.97670
2.0	.97725	.97778	.97831	.97882	.97932	.97982	.98030	.98077	.98124	.98169
2.1	.98214	.98257	.98300	.98341	.98382	.98422	.98461	.98500	.98537	.98574
2.2	.98610	.98645	.98679	.98713	.98745	.98778	.98809	.98840	.98870	.98899
2.3	.98928	.98956	.98983	.99010	.99036	.99061	.99086	.99111	.99134	.99158
2.4	.99180	.99202	.99224	.99245	.99266	.99286	.99305	.99324	.99343	.99361
2.5	.99379	.99396	.99413	.99430	.99446	.99461	.99477	.99492	.99506	.99520
2.6	.99534	.99547	.99560	.99573	.99585	.99598	.99609	.99621	.99632	.99643
2.7	.99653	.99664	.99674	.99683	.99693	.99702	.99711	.99720	.99728	.99736
2.8	.99744	.99752	.99760	.99767	.99774	.99781	.99788	.99795	.99801	.99807
2.9	.99813	.99819	.99825	.99831	.99836	.99841	.99846	.99851	.99856	.99861
3.0	.99865	.99869	.99874	.99878	.99882	.99886	.99889	.99893	.99896	.99900
3.1	.99903	.99906	.99910	.99913	.99916	.99918	.99921	.99924	.99926	.99929
3.2	.99931	.99934	.99936	.99938	.99940	.99942	.99944	.99946	.99948	.99950
3.3	.99952	.99953	.99955	.99957	.99958	.99960	.99961	.99962	.99964	.99965
3.4	.99966	.99968	.99969	.99970	.99971	.99972	.99973	.99974	.99975	.99976
3.5	.99977	.99978	.99978	.99979	.99980	.99981	.99981	.99982	.99983	.99983
3.6	.99984	.99985	.99985	.99986	.99986	.99987	.99987	.99988	.99988	.99989
3.7	.99989	.99990	.99990	.99990	.99991	.99991	.99992	.99992	.99992	.99992
3.8	.99993	.99993	.99993	.99994	.99994	.99994	.99994	.99995	.99995	.99995
3.9	.99995	.99995	.99996	.99996	.99996	.99996	.99996	.99996	.99997	.99997

The University of Zambia

School of Natural Sciences

Department of Mathematics & Statistics

2020/2021 Academic Year Final Examinations

MAT 2100 - Analytic Geometry and Calculus

Time allowed : Three **(3)** hrs | Full marks : 100

Instructions:

- Indicate your **computer number** on all answer booklets.
- There are seven (7) questions in this examination. Attempt **any five (5)** questions. All questions carry equal marks.
- **Full credit** will only be given when **necessary work** is shown.

This paper consists of 4 pages of questions.

---

1. **(a)** Given the conic section

$$x^2 + 4x + 5y^2 - 10y + 9 = 45,$$

find the centre and foci. **[9]**

(b) A conic section is rotated through an angle $\alpha = 45^o$. If the centre in the $x'y'-$coordinate system is $(1, -1)$, find the coordinates of this centre in the original $xy-$coordinate system. **[6]**

(c) Given that the centre of curvature of the curve $y = f(x)$ at the point $(-1, 0)$ is $(1, \sqrt{5})$, find the curvature at the same point. **[5]**

2. **(a)** The function

$$f(x) = \frac{4}{7}x^{\frac{7}{4}} - \frac{a}{2}x^2$$

satisfies the hypotheses of the Rolle's theorem in the interval $\left[0, \frac{4096}{2401}\right]$.

(i) Find the value of a. **[4]**

(ii) Find the number $c \in \left(0, \frac{4096}{2401}\right)$ that satisfies the conclusion of the theorem. **[4]**

Turn Over/...

(b) Evaluate the following limits:

(i) $\lim\limits_{x\to 8}\left(\dfrac{x^{\frac{1}{3}}-x+6}{\sin\left(\frac{\pi x}{8}\right)}\right)$ **(ii)** $\lim\limits_{x\to\frac{\pi}{2}^-}(\tan x)^{\cos x}$ **[3, 4]**

(c) Determine whether or not the pair of planes

$$5x+6y-9z=5 \quad \text{and} \quad -10x-12y+18z=-3$$

intersect. **[5]**

3. **(a)** Evaluate the following indefinite integrals:

(i) $\displaystyle\int \sin^2\theta\cos(2\theta)\,d\theta$ **(ii)** $\displaystyle\int \frac{\sqrt[3]{x}}{\sqrt{x^{\frac{4}{3}}+5}}\,dx$ **[4, 3]**

(b) **(i)** Find the reduction formula for

$$\int x^m(\ln x)^n\,dx,$$

for $m, n \in \mathbb{Z}$, $n \geq 1$. **[5]**

(ii) Hence, or otherwise, evaluate $\displaystyle\int x^3(\ln x)^2\,dx$ **[3]**

(c) With one focus at the origin, the conic section is given by

$$r=\frac{30}{3-7\sin\theta}.$$

(i) Identify the conic section. **[2]**

(ii) Find the coordinates of the vertex or vertices of the conic section. **[3]**

4. **(a)** The line with parametric equations

$$x=2t-1,\ y=t+1,\ z=-3,\quad t\in\mathbb{R},$$

intersects the plane $2x-y+2z=-3$ at the point A.

(i) Find the coordinates of A. **[3]**

(ii) Find the volume of the parallelepiped with $\overrightarrow{OA}$, $\overrightarrow{OB}$ and $\overrightarrow{OC}$ as adjacent edges, where $B(1,0,1)$, $C(0,1,0)$ and O is the origin. **[3]**

(b) Find the length of the space curve

$$R(t)=\frac{4}{3}t^{\frac{3}{2}}i-\cos t\,j+\sin t\,k$$

over the interval $[0, \frac{3\pi}{2}]$. **[8]**

(c) Find the moment of inertia about the $y-$axis, (I_y), for the region under the curve

$$y=\sqrt{x},\ x=1,\ x=4 \text{ and } y=0$$ **[6]**

Turn Over/...

5. **(a)** Determine the nature of the critical points of the function

$$f(x, y) = -x^3 + 4xy - 2y^2 + 1.$$ [8]

(b) The radius and height of a cylindrical tank is 2 metres and 7 metres respectively. There is a maximum error of ± 0.02 metres in the measurement of the radius and ± 0.001 metres in the measurement of the height. Use total differentials to find the maximum error in the calculation of the volume of the tank. [5]

(c) The finite region bounded by the curves

$$y = 2x^2, \quad y = x^2 \quad \text{and} \quad x = 1,$$

is revolved about the line $y = -1$. Find the volume of the resulting solid. [7]

6. **(a)** Solve the following ordinary differential equations:

(i) $x^5 \dfrac{dy}{dx} + x^4 y = x^3$ [4]

(ii) $y'' - 5y' - 14y = 0$ [3]

(b) The first-order ordinary differential equation of first degree is given by

$$(x^2 + 2y)\, dx - x\, dy = 0$$

(i) Show that the differential equation is not exact. [2]

(ii) Find the general solution to the differential equation. [7]

(c) Given that $f(x, y, z) = xyz + y$, where

$$x(t, s) = \frac{s}{t} + 1, \quad y(t, s) = t + 1 \quad \text{and} \quad z(t, s) = s + e^t,$$

find, in terms of t and s, $\dfrac{\partial f}{\partial s}$. [4]

7. **(a)** Given the ordinary differential equation

$$(\sin^2 x)y'' - (2 \sin x \cos x)y' + (1 + \cos^2 x)y = \sin^3 x$$

and that $y_1 = \sin x$ and $y_2 = x \sin x$ are linearly independent solutions of the corresponding homogeneous equation,

(i) find the Wronskian $W(y_1, y_2)$, of y_1 and y_2. [2]

(ii) Hence, or otherwise, solve the differential equation. [6]

Turn Over/...

(b) The velocity v, of an object of mass m, dropped from a hovering helicopter, satisfies the differential equation

$$\frac{dv}{dt} + \frac{k}{m}v = g, \quad v(0) = 0,$$

where t is time, g is gravitational constant and k is a constant of proportionality. Given that air resistance is proportional to the velocity of the body, find v as a function of t in terms of m and k. **[7]**

(c) A particular curve $y = f(x)$, $x \geq 0$, has the derivative given by

$$\frac{dy}{dx} = \sqrt{e^x - 1}.$$

Find an intrinsic equation in the form $s = g(\psi)$, where s is measured from the point $(0, 0)$ and ψ is the angle the tangent to the curve makes with the positive $x-$axis. **[5]**

END OF EXAMINATION!

THE UNIVERSITY OF ZAMBIA
DEPARTMENT OF MATHEMATICS AND STATISTICS
2020/2021 SESSIONAL EXAMINATIONS
MAT2300 INTRODUCTION TO REAL ANALYSIS

DURATION: THREE (3) HOURS
INSTRUCTIONS:

- **There are seven (7) questions in this paper**
- **Answer any five (5) questions**
- **All questions carry equal marks**
- **Marks for each question are indicated in brackets**
- **Show all necessary work to earn full marks**

---

1. (a) Define the following terms:
   i. The supremum of a set $A \subset \mathbb{R}$. [2]
   ii. The infimum of a set $A \subset \mathbb{R}$. [2]

   (b) i. Prove the nested interval property. [6]
   ii. If A and B are subsets of $\mathbb{R}$ that are bounded above, prove that $C = \{a + b : a \in A, b \in B\}$ is bounded above and $\sup C = \sup A + \sup B$. [6]

   (c) Consider the set $S = \{\frac{2n-3}{3n+1} : n \in \mathbb{N}\}$.
   i. Show that S is bounded. [2]
   ii. Find $\sup S$ and $\inf S$. [2]

2. (a) Define the following terms:
   i. An equivalence relation on a set X. [2]
   ii. A partial order relation on a set X. [2]

   (b) Prove the following:
   i. The equivalence classes of an equivalence relation R on set X form a partition of X. [6]
   ii. Set inclusion $\subset$ is a partial order relation on the power set $\mathcal{P}(X)$ of a non-empty set X. [4]

   (c) Consider the relation $R = \{(a, b) : a - b \in 2\mathbb{Z}\}$ on the set $\mathbb{Z}$ of integers.

i. Show that R is an equivalence relation. [3]

ii. Find the equivalence classes. [3]

3. (a) Define the following terms:

i. The direct image of a set under a function. [2]

ii. The inverse image of a set under a function. [2]

(b) Let $f : A \to B$ be a function, $A_1, A_2 \subset A$ and $B_1, B_2 \subset B$. Prove the following:

i. $f(A_1 \cup A_2) = f(A_1) \cup f(A_2)$. [4]

ii. $f^{-1}(B_1 \cap B_2) = f^{-1}(B_1) \cap f^{-1}(B_2)$. [4]

(c) Consider the function defined by $f(x) = x^2 - 1$ and let $A = (-1, 1), B = [3, 8]$.

i. State the domain and range of f. [2]

ii. Find $f(A)$. [3]

iii. Find $f^{-1}(B)$. [3]

4. (a) Define the following terms:

i. A countable set of real numbers. [2]

ii. An infinite set of real numbers. [2]

(b) Prove the following:

i. The set $\mathbb{R}$ of all real numbers is uncountable. [6]

ii. The set $\mathbb{Q}$ of all rational numbers is countable. [4]

(c) i. Show that the set $2\mathbb{Z}$ of all even integers is countable. [3]

ii. Show that the sets $\mathbb{Z}$ and $2\mathbb{Z}$ are equinumerous. [3]

5. (a) Define the following terms:

i. A convergent sequence of real numbers. [2]

ii. A Cauchy sequence of real numbers. [2]

(b) i. Prove that a sequence of real numbers is convergent if and only if it is Cauchy. [6]

ii. State and prove the Bolzano-Wierestrass theorem. [6]

(c) i. Show that the sequence $x_n = \dfrac{1}{n+1}$ is Cauchy. [2]

ii. Show that the sequence $x_n = \dfrac{1}{n!}$ is convergent. [2]

6. (a) Define the following terms:

i. A convergent series of real numbers $\displaystyle\sum_{n=1}^{\infty} a_n$. [2]

ii. A conditionally convergent series of real numbers $\displaystyle\sum_{n=1}^{\infty} a_n$. [2]

(b) Prove the following:

i. The limit form of the comparison test. [5]

ii. The ratio test. [5]

(c) Discuss convergencce of the following series:

i. $\sum_{n=1}^{\infty} \frac{2n-1}{3n^3+2}$. [3]

ii. $\sum_{n=1}^{\infty} (-1)^n \frac{2n}{n!}$. [3]

7. (a) Define the following terms:

i. An upper section of rational numbers. [2]

ii. A rational section. [2]

(b) i. If α and β are upper sections of rational numbers, prove that $\alpha + \beta = \{a + b : a \in \alpha, b \in \beta\}$ is an upper section of rational numbers. [6]

ii. If r^* and s^* are rational sections, prove that r^*s^* is a rational section and $r^*s^* = (rs)^*$. [5]

(c) Show that the set $\alpha = \{p \in \mathbb{Q} : p < 0\} \cup \{p \in \mathbb{Q} : p > 0, p < \sqrt{3}\}$ is an upper section of rational numbers. [5]

END OF EXAMINATION

The University of Zambia

School of Natural Sciences

Department of Mathematics and Statistics

2021/21 Academic year Final examination

MAT 2602 Introduction to statistics

Time allowed **Three (3) Hours**

Instructions: **(1) Answer any FIVE (5) Questions**

(2) Show all essential workings

---

1. (a) A random sample of 600 was chosen from the adults living in Lusaka in order to investigate the number x of days of work lost through illness. Before taking the sample it was decided that certain category of people would be excluded from the analysis of the number of working days lost although they would not be excluded from the sample. In the sample 180 were found to be from these categories. For the remaining 420 members of the sample $\sum x = 1260$ and $\sum x^2 = 46000$.

   (i) Estimate the mean number of days lost through illness, for the restricted population and give a 95% confidence interval for the mean number of days lost.

   (ii) Estimate the percentage of people in the town who fall into the excluded categories, and find a 99% confidence interval for this percentage

   (iii)Give two examples, with reasons of people who might fall into the excluded categories.

   (b) A survey takes a simple random sample of 500 people from a town of 55,000. On the average, it finds 2.30 health problems per person (standard deviation = 1.65). Find a 99% confidence interval of health problems

2. (a) The diameters of the heads of 100 rivets from a factory production line were measured correctly to the nearest 0.1 mm and the results were as given below:

Diameter(mm)	11.1	11.2	11.3	11.4	11.5	11.6	11.7
f	1	6	24	33	22	12	2

(ii) Using the assumed mean of 11.4 calculate the sample mean and standard deviation of the diameters

(ii) Determine the 99% confidence limits for the population mean diameter.

(b) (i) Find the 95% confidence Interval for the ratio of variances with $n_1 = 21$, sample variance =121, $n_2 = 16$ and sample variance 64, and alpha = 5%.

(ii) show that the sample mean $\overline{X}$ is an unbiased estimator of the population mean

3. (a) The table below shows the scores of students in statistics test.

26	47	30	8	3
20	36	44	18	7
33	22	9	5	48
20	12	5	36	40
2	26	35	33	46
14	10	19	22	30
27	42	17	19	22
35	9	17	23	20
35	21	5	14	27
28	15	9	40	27

(i) Construct a frequency table of width length 4

(ii) Construct a cumulative curve

(iii) Use (ii) above estimate the inter quartile range of the scores

(iv) Illustrate this distribution using a box and whisker plot

(b) (i) Outline the steps of conducting an Analysis of Variance in statistics. Justifying each step clearly why it has to be done.

(iii) In the event that you reject the null hypothesis. What would be your next action of plan? Justify your reasoning

4 (a) An experiment was conducted to investigate the difference in mean time to assemble four different electronic devices, 1, 2, 3, and 4. Two sources of unwanted variation affect the response – the variation between people and the effect of fatigue if a person assembles a series of the devices over time. Consequently, four assemblers were selected and each assembled all four of the devices in the Latin-square design of Table below (The observed responses, in minutes, are shown in the cells. Circled numbers in the design above indicates the treatments employed.) Do the data provide sufficient evidence to indicate a difference in mean time to assemble the four devices? A difference in the meantime to assemble for people? Is there evidence of a fatigue factor (a difference in mean response for positions in the assembly sequence) at 1% level of significance.

Latin Square Design Table

Rows (Position in Assembly sequence	Columns (Assemblers) 1	2	3	4	Total
1	③ 44	① 41	② 30	④ 40	155
2	② 41	③ 42	④ 49	① 49	181
3	① 59	④ 41	③ 59	② 34	193
4	④ 58	② 37	① 53	③ 59	207
Total	202	161	191	182	736

(b) (i) A random sample of n observations from a population distribution had values $x_1,...,x_n$ whose mean is $\bar{x}$. Show that $\sum(x-c)^2 = \sum(x-\bar{x})^2 + n(c-\bar{x})^2$.

(ii) Fifty boxes of matches were selected at random from a large carton box. The number of matches in each of the 50 boxes were counted and the mean and standard deviation of these numbers were found to be 48 and 0.5 respectively. Between what limits would you expect the mean for all of the boxes in the carton to be with 0.95 probability?

5. (a) The Figure below illustrates the apparatus used in a simple experiment which many people can have performed for themselves. When weights are added to the scale pan, the spring stretches. The Table below shows the result obtained when different loads were applied in a random order.

x_i, load (in newtons)	y_i, length of spring (cm)
0.1	10.7
0.2	11.3
0.3	12.0
0.4	12.4
0.5	13.0
0.6	13.7
0.7	14.5
0.8	15.1
0.9	15.6
1.0	16.0

(i) Construct a scatter diagram and interpret the results

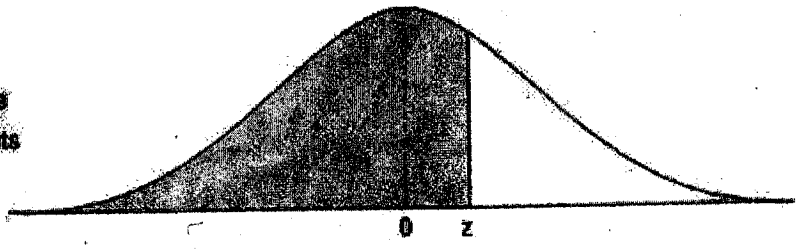
(ii)Calculate the regression line of Y on X for the data given above

(iii) Predict the length for a load of 0.65 N.

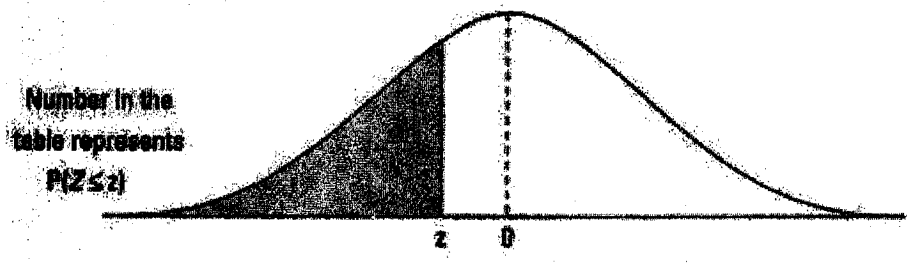
(b) A manufacturer claims that his light bulbs have an average lifetime of 1500 hours. A purchaser decides to check this claim and finds that for six bulbs the lifetimes are 1472, 1486, 1401, 1350, 1610, 1590 hours. Does this evidence support the manufacturer's claim?

You have to assume the lifetimes of the light of the light bulbs are normally distributed

umber in the
able represents
P(Z ≤ z)



z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	.5000	.5040	.5080	.5120	.5160	.5199	.5239	.5279	.5319	.5359
0.1	.5398	.5438	.5478	.5517	.5557	.5596	.5636	.5675	.5714	.5753
0.2	.5793	.5832	.5871	.5910	.5948	.5987	.6026	.6064	.6103	.6141
0.3	.6179	.6217	.6255	.6293	.6331	.6368	.6406	.6443	.6480	.6517
0.4	.6554	.6591	.6628	.6664	.6700	.6736	.6772	.6808	.6844	.6879
0.5	.6915	.6950	.6985	.7019	.7054	.7088	.7123	.7157	.7190	.7224
0.6	.7257	.7291	.7324	.7357	.7389	.7422	.7454	.7486	.7517	.7549
0.7	.7580	.7611	.7642	.7673	.7704	.7734	.7764	.7794	.7823	.7852
0.8	.7881	.7910	.7939	.7967	.7995	.8023	.8051	.8078	.8106	.8133
0.9	.8159	.8186	.8212	.8238	.8264	.8289	.8315	.8340	.8365	.8389
1.0	.8413	.8438	.8461	.8485	.8508	.8531	.8554	.8577	.8599	.8621
1.1	.8643	.8665	.8686	.8708	.8729	.8749	.8770	.8790	.8810	.8830
1.2	.8849	.8869	.8888	.8907	.8925	.8944	.8962	.8980	.8997	.9015
1.3	.9032	.9049	.9066	.9082	.9099	.9115	.9131	.9147	.9162	.9177
1.4	.9192	.9207	.9222	.9236	.9251	.9265	.9279	.9292	.9306	.9319
1.5	.9332	.9345	.9357	.9370	.9382	.9394	.9406	.9418	.9429	.9441
1.6	.9452	.9463	.9474	.9484	.9495	.9505	.9515	.9525	.9535	.9545
1.7	.9554	.9564	.9573	.9582	.9591	.9599	.9608	.9616	.9625	.9633
1.8	.9641	.9649	.9656	.9664	.9671	.9678	.9686	.9693	.9699	.9706
1.9	.9713	.9719	.9726	.9732	.9738	.9744	.9750	.9756	.9761	.9767
2.0	.9772	.9778	.9783	.9788	.9793	.9798	.9803	.9808	.9812	.9817
2.1	.9821	.9826	.9830	.9834	.9838	.9842	.9846	.9850	.9854	.9857
2.2	.9861	.9864	.9868	.9871	.9875	.9878	.9881	.9884	.9887	.9890
2.3	.9893	.9896	.9898	.9901	.9904	.9906	.9909	.9911	.9913	.9916
2.4	.9918	.9920	.9922	.9925	.9927	.9929	.9931	.9932	.9934	.9936
2.5	.9938	.9940	.9941	.9943	.9945	.9946	.9948	.9949	.9951	.9952
2.6	.9953	.9955	.9956	.9957	.9959	.9960	.9961	.9962	.9963	.9964
2.7	.9965	.9966	.9967	.9968	.9969	.9970	.9971	.9972	.9973	.9974
2.8	.9974	.9975	.9976	.9977	.9977	.9978	.9979	.9979	.9980	.9981
2.9	.9981	.9982	.9982	.9983	.9984	.9984	.9985	.9985	.9986	.9986
3.0	.9987	.9987	.9987	.9988	.9988	.9989	.9989	.9989	.9990	.9990
3.1	.9990	.9991	.9991	.9991	.9992	.9992	.9992	.9992	.9993	.9993
3.2	.9993	.9993	.9994	.9994	.9994	.9994	.9994	.9995	.9995	.9995
3.3	.9995	.9995	.9995	.9996	.9996	.9996	.9996	.9996	.9996	.9997
3.4	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9998
3.5	.9998	.9998	.9998	.9998	.9998	.9998	.9998	.9998	.9998	.9998
3.6	.9998	.9998	.9999	.9999	.9999	.9999	.9999	.9999	.9999	.9999



z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
-3.9	.0002	.0002	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001
-3.8	.0002	.0002	.0002	.0002	.0002	.0002	.0002	.0002	.0002	.0002
-3.7	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0002
-3.6	.0005	.0005	.0005	.0004	.0004	.0004	.0004	.0004	.0004	.0003
-3.5	.0007	.0007	.0006	.0006	.0006	.0006	.0006	.0005	.0005	.0005
-3.4	.0010	.0009	.0009	.0009	.0008	.0008	.0008	.0008	.0007	.0007
-3.3	.0013	.0013	.0013	.0012	.0012	.0011	.0011	.0011	.0010	.0010
-3.2	.0019	.0018	.0018	.0017	.0016	.0016	.0015	.0015	.0014	.0014
-3.1	.0026	.0025	.0024	.0023	.0023	.0022	.0021	.0021	.0020	.0019
-3.0	.0035	.0034	.0033	.0032	.0031	.0030	.0029	.0028	.0027	.0026
-2.9	.0047	.0045	.0044	.0043	.0041	.0040	.0039	.0038	.0037	.0036
-2.8	.0062	.0060	.0059	.0057	.0055	.0054	.0052	.0051	.0049	.0048
-2.7	.0082	.0080	.0078	.0075	.0073	.0071	.0069	.0068	.0066	.0064
-2.6	.0107	.0104	.0102	.0099	.0096	.0094	.0091	.0089	.0087	.0084
-2.5	.0139	.0136	.0132	.0129	.0125	.0122	.0119	.0116	.0113	.0110
-2.4	.0179	.0174	.0170	.0166	.0162	.0158	.0154	.0150	.0146	.0143
-2.3	.0228	.0222	.0217	.0212	.0207	.0202	.0197	.0192	.0188	.0183
-2.2	.0287	.0281	.0274	.0268	.0262	.0256	.0250	.0244	.0239	.0233
-2.1	.0359	.0351	.0344	.0336	.0329	.0322	.0314	.0307	.0301	.0294
-2.0	.0446	.0436	.0427	.0418	.0409	.0401	.0392	.0384	.0375	.0367
-1.9	.0548	.0537	.0526	.0516	.0505	.0495	.0485	.0475	.0465	.0455
-1.8	.0668	.0655	.0643	.0630	.0618	.0606	.0594	.0582	.0571	.0559
-1.7	.0808	.0793	.0778	.0764	.0749	.0735	.0721	.0708	.0694	.0681
-1.6	.0968	.0951	.0934	.0918	.0901	.0885	.0869	.0853	.0838	.0823
-1.5	.1151	.1131	.1112	.1093	.1075	.1056	.1038	.1020	.1003	.0985
-1.4	.1357	.1335	.1314	.1292	.1271	.1251	.1230	.1210	.1190	.1170
-1.3	.1587	.1562	.1539	.1515	.1492	.1469	.1446	.1423	.1401	.1379
-1.2	.1841	.1814	.1788	.1762	.1736	.1711	.1685	.1660	.1635	.1611
-1.1	.2119	.2090	.2061	.2033	.2005	.1977	.1949	.1922	.1894	.1867
-1.0	.2420	.2389	.2358	.2327	.2296	.2266	.2236	.2206	.2177	.2148
-0.9	.2743	.2709	.2676	.2643	.2611	.2578	.2546	.2514	.2483	.2451
-0.8	.3085	.3050	.3015	.2981	.2946	.2912	.2877	.2843	.2810	.2776
-0.7	.3446	.3409	.3372	.3336	.3300	.3264	.3228	.3192	.3156	.3121
-0.6	.3821	.3783	.3745	.3707	.3669	.3632	.3594	.3557	.3520	.3483
-0.5	.4207	.4168	.4129	.4090	.4052	.4013	.3974	.3936	.3897	.3859
-0.4	.4602	.4562	.4522	.4483	.4443	.4404	.4364	.4325	.4286	.4247
-0.3	.5000	.4960	.4920	.4880	.4840	.4801	.4761	.4721	.4681	.4641

TABLE A.2

t Distribution: Critical Values of *t*

Degrees of freedom	*Two-tailed test:* / *One-tailed test:*	*Significance level* 10% / 5%	5% / 2.5%	2% / 1%	1% / 0.5%	0.2% / 0.1%	0.1% / 0.05%
1		6.314	12.706	31.821	63.657	318.309	636.619
2		2.920	4.303	6.965	9.925	22.327	31.599
3		2.353	3.182	4.541	5.841	10.215	12.924
4		2.132	2.776	3.747	4.604	7.173	8.610
5		2.015	2.571	3.365	4.032	5.893	6.869
6		1.943	2.447	3.143	3.707	5.208	5.959
7		1.894	2.365	2.998	3.499	4.785	5.408
8		1.860	2.306	2.896	3.355	4.501	5.041
9		1.833	2.262	2.821	3.250	4.297	4.781
10		1.812	2.228	2.764	3.169	4.144	4.587
11		1.796	2.201	2.718	3.106	4.025	4.437
12		1.782	2.179	2.681	3.055	3.930	4.318
13		1.771	2.160	2.650	3.012	3.852	4.221
14		1.761	2.145	2.624	2.977	3.787	4.140
15		1.753	2.131	2.602	2.947	3.733	4.073
16		1.746	2.120	2.583	2.921	3.686	4.015
17		1.740	2.110	2.567	2.898	3.646	3.965
18		1.734	2.101	2.552	2.878	3.610	3.922
19		1.729	2.093	2.539	2.861	3.579	3.883
20		1.725	2.086	2.528	2.845	3.552	3.850
21		1.721	2.080	2.518	2.831	3.527	3.819
22		1.717	2.074	2.508	2.819	3.505	3.792
23		1.714	2.069	2.500	2.807	3.485	3.768
24		1.711	2.064	2.492	2.797	3.467	3.745
25		1.708	2.060	2.485	2.787	3.450	3.725
26		1.706	2.056	2.479	2.779	3.435	3.707
27		1.703	2.052	2.473	2.771	3.421	3.690
28		1.701	2.048	2.467	2.763	3.408	3.674
29		1.699	2.045	2.462	2.756	3.396	3.659
30		1.697	2.042	2.457	2.750	3.385	3.646
32		1.694	2.037	2.449	2.738	3.365	3.622
34		1.691	2.032	2.441	2.728	3.348	3.601
36		1.688	2.028	2.434	2.719	3.333	3.582
38		1.686	2.024	2.429	2.712	3.319	3.566
40		1.684	2.021	2.423	2.704	3.307	3.551
42		1.682	2.018	2.418	2.698	3.296	3.538
44		1.680	2.015	2.414	2.692	3.286	3.526
46		1.679	2.013	2.410	2.687	3.277	3.515
48		1.677	2.011	2.407	2.682	3.269	3.505
50		1.676	2.009	2.403	2.678	3.261	3.496
60		1.671	2.000	2.390	2.660	3.232	3.460
70		1.667	1.994	2.381	2.648	3.211	3.435
80		1.664	1.990	2.374	2.639	3.195	3.416
90		1.662	1.987	2.368	2.632	3.183	3.402
100		1.660	1.984	2.364	2.626	3.174	3.390
120		1.658	1.980	2.358	2.617	3.160	3.373
150		1.655	1.976	2.351	2.609	3.145	3.357
200		1.653	1.972	2.345	2.601	3.131	3.340
300		1.650	1.968	2.339	2.592	3.118	3.323
400		1.649	1.966	2.336	2.588	3.111	3.315
500		1.648	1.965	2.334	2.586	3.107	3.310
600		1.647	1.964	2.333	2.584	3.104	3.307
∞		1.645	1.960	2.326	2.576	3.090	3.291

TABLE A.3

F Distribution: Critical Values of *F* (5% significance level)

ν_2 \ ν_1	1	2	3	4	5	6	7	8	9	10	12	14	16	18	20
1	161.45	199.50	215.71	224.58	230.16	233.99	236.77	238.88	240.54	241.88	243.91	245.36	246.46	247.32	248.01
2	18.51	19.00	19.16	19.25	19.30	19.33	19.35	19.37	19.38	19.40	19.41	19.42	19.43	19.44	19.45
3	10.13	9.55	9.28	9.12	9.01	8.94	8.89	8.85	8.81	8.79	8.74	8.71	8.69	8.67	8.66
4	7.71	6.94	6.59	6.39	6.26	6.16	6.09	6.04	6.00	5.96	5.91	5.87	5.84	5.82	5.80
5	6.61	5.79	5.41	5.19	5.05	4.95	4.88	4.82	4.77	4.74	4.68	4.64	4.60	4.58	4.56
6	5.99	5.14	4.76	4.53	4.39	4.28	4.21	4.15	4.10	4.06	4.00	3.96	3.92	3.90	3.87
7	5.59	4.74	4.35	4.12	3.97	3.87	3.79	3.73	3.68	3.64	3.57	3.53	3.49	3.47	3.44
8	5.32	4.46	4.07	3.84	3.69	3.58	3.50	3.44	3.39	3.35	3.28	3.24	3.20	3.17	3.15
9	5.12	4.26	3.86	3.63	3.48	3.37	3.29	3.23	3.18	3.14	3.07	3.03	2.99	2.96	2.94
10	4.96	4.10	3.71	3.48	3.33	3.22	3.14	3.07	3.02	2.98	2.91	2.86	2.83	2.80	2.77
11	4.84	3.98	3.59	3.36	3.20	3.09	3.01	2.95	2.90	2.85	2.79	2.74	2.70	2.67	2.65
12	4.75	3.89	3.49	3.26	3.11	3.00	2.91	2.85	2.80	2.75	2.69	2.64	2.60	2.57	2.54
13	4.67	3.81	3.41	3.18	3.03	2.92	2.83	2.77	2.71	2.67	2.60	2.55	2.51	2.48	2.46
14	4.60	3.74	3.34	3.11	2.96	2.85	2.76	2.70	2.65	2.60	2.53	2.48	2.44	2.41	2.39
15	4.54	3.68	3.29	3.06	2.90	2.79	2.71	2.64	2.59	2.54	2.48	2.42	2.38	2.35	2.33
16	4.49	3.63	3.24	3.01	2.85	2.74	2.66	2.59	2.54	2.49	2.42	2.37	2.33	2.30	2.28
17	4.45	3.59	3.20	2.96	2.81	2.70	2.61	2.55	2.49	2.45	2.38	2.33	2.29	2.26	2.23
18	4.41	3.55	3.16	2.93	2.77	2.66	2.58	2.51	2.46	2.41	2.34	2.29	2.25	2.22	2.19
19	4.38	3.52	3.13	2.90	2.74	2.63	2.54	2.48	2.42	2.38	2.31	2.26	2.21	2.18	2.16
20	4.35	3.49	3.10	2.87	2.71	2.60	2.51	2.45	2.39	2.35	2.28	2.22	2.18	2.15	2.12
21	4.32	3.47	3.07	2.84	2.68	2.57	2.49	2.42	2.37	2.32	2.25	2.20	2.16	2.12	2.10
22	4.30	3.44	3.05	2.82	2.66	2.55	2.46	2.40	2.34	2.30	2.23	2.17	2.13	2.10	2.07
23	4.28	3.42	3.03	2.80	2.64	2.53	2.44	2.37	2.32	2.27	2.20	2.15	2.11	2.08	2.05
24	4.26	3.40	3.01	2.78	2.62	2.51	2.42	2.36	2.30	2.25	2.18	2.13	2.09	2.05	2.03
25	4.24	3.39	2.99	2.76	2.60	2.49	2.40	2.34	2.28	2.24	2.16	2.11	2.07	2.04	2.01
26	4.22	3.37	2.98	2.74	2.59	2.47	2.39	2.32	2.27	2.22	2.15	2.09	2.05	2.02	1.99
27	4.21	3.35	2.96	2.73	2.57	2.46	2.37	2.31	2.25	2.20	2.13	2.08	2.04	2.00	1.97
28	4.20	3.34	2.95	2.71	2.56	2.45	2.36	2.29	2.24	2.19	2.12	2.06	2.02	1.99	1.96
29	4.18	3.33	2.93	2.70	2.55	2.43	2.35	2.28	2.22	2.18	2.10	2.05	2.01	1.97	1.94
30	4.17	3.32	2.92	2.69	2.53	2.42	2.33	2.27	2.21	2.16	2.09	2.04	1.99	1.96	1.93
35	4.12	3.27	2.87	2.64	2.49	2.37	2.29	2.22	2.16	2.11	2.04	1.99	1.94	1.91	1.88
40	4.08	3.23	2.84	2.61	2.45	2.34	2.25	2.18	2.12	2.08	2.00	1.95	1.90	1.87	1.84
50	4.03	3.18	2.79	2.56	2.40	2.29	2.20	2.13	2.07	2.03	1.95	1.89	1.85	1.81	1.78
60	4.00	3.15	2.76	2.53	2.37	2.25	2.17	2.10	2.04	1.99	1.92	1.86	1.82	1.78	1.75
70	3.98	3.13	2.74	2.50	2.35	2.23	2.14	2.07	2.02	1.97	1.89	1.84	1.79	1.75	1.72
80	3.96	3.11	2.72	2.49	2.33	2.21	2.13	2.06	2.00	1.95	1.88	1.82	1.77	1.73	1.70
90	3.95	3.10	2.71	2.47	2.32	2.20	2.11	2.04	1.99	1.94	1.86	1.80	1.76	1.72	1.69
100	3.94	3.09	2.70	2.46	2.31	2.19	2.10	2.03	1.97	1.93	1.85	1.79	1.75	1.71	1.68
120	3.92	3.07	2.68	2.45	2.29	2.18	2.09	2.02	1.96	1.91	1.83	1.78	1.73	1.69	1.66
150	3.90	3.06	2.66	2.43	2.27	2.16	2.07	2.00	1.94	1.89	1.82	1.76	1.71	1.67	1.64
200	3.89	3.04	2.65	2.42	2.26	2.14	2.06	1.98	1.93	1.88	1.80	1.74	1.69	1.66	1.62
250	3.88	3.03	2.64	2.41	2.25	2.13	2.05	1.98	1.92	1.87	1.79	1.73	1.68	1.65	1.61
300	3.87	3.03	2.63	2.40	2.24	2.13	2.04	1.97	1.91	1.86	1.78	1.72	1.68	1.64	1.61
400	3.86	3.02	2.63	2.39	2.24	2.12	2.03	1.96	1.90	1.85	1.78	1.72	1.67	1.63	1.60
500	3.86	3.01	2.62	2.39	2.23	2.12	2.03	1.96	1.90	1.85	1.77	1.71	1.66	1.62	1.59
600	3.86	3.01	2.62	2.39	2.23	2.11	2.02	1.95	1.90	1.85	1.77	1.71	1.66	1.62	1.59
750	3.85	3.01	2.62	2.38	2.23	2.11	2.02	1.95	1.89	1.84	1.77	1.70	1.66	1.62	1.58
1000	3.85	3.00	2.61	2.38	2.22	2.11	2.02	1.95	1.89	1.84	1.76	1.70	1.65	1.61	1.58

Chi-square Distribution Table

d.f.	.995	.99	.975	.95	.9	.1	.05	.025	.01
1	0.00	0.00	0.00	0.00	0.02	2.71	3.84	5.02	6.63
2	0.01	0.02	0.05	0.10	0.21	4.61	5.99	7.38	9.21
3	0.07	0.11	0.22	0.35	0.58	6.25	7.81	9.35	11.34
4	0.21	0.30	0.48	0.71	1.06	7.78	9.49	11.14	13.28
5	0.41	0.55	0.83	1.15	1.61	9.24	11.07	12.83	15.09
6	0.68	0.87	1.24	1.64	2.20	10.64	12.59	14.45	16.81
7	0.99	1.24	1.69	2.17	2.83	12.02	14.07	16.01	18.48
8	1.34	1.65	2.18	2.73	3.49	13.36	15.51	17.53	20.09
9	1.73	2.09	2.70	3.33	4.17	14.68	16.92	19.02	21.67
10	2.16	2.56	3.25	3.94	4.87	15.99	18.31	20.48	23.21
11	2.60	3.05	3.82	4.57	5.58	17.28	19.68	21.92	24.72
12	3.07	3.57	4.40	5.23	6.30	18.55	21.03	23.34	26.22
13	3.57	4.11	5.01	5.89	7.04	19.81	22.36	24.74	27.69
14	4.07	4.66	5.63	6.57	7.79	21.06	23.68	26.12	29.14
15	4.60	5.23	6.26	7.26	8.55	22.31	25.00	27.49	30.58
16	5.14	5.81	6.91	7.96	9.31	23.54	26.30	28.85	32.00
17	5.70	6.41	7.56	8.67	10.09	24.77	27.59	30.19	33.41
18	6.26	7.01	8.23	9.39	10.86	25.99	28.87	31.53	34.81
19	6.84	7.63	8.91	10.12	11.65	27.20	30.14	32.85	36.19
20	7.43	8.26	9.59	10.85	12.44	28.41	31.41	34.17	37.57
22	8.64	9.54	10.98	12.34	14.04	30.81	33.92	36.78	40.29
24	9.89	10.86	12.40	13.85	15.66	33.20	36.42	39.36	42.98
26	11.16	12.20	13.84	15.38	17.29	35.56	38.89	41.92	45.64
28	12.46	13.56	15.31	16.93	18.94	37.92	41.34	44.46	48.28
30	13.79	14.95	16.79	18.49	20.60	40.26	43.77	46.98	50.89
32	15.13	16.36	18.29	20.07	22.27	42.58	46.19	49.48	53.49
34	16.50	17.79	19.81	21.66	23.95	44.90	48.60	51.97	56.06
38	19.29	20.69	22.88	24.88	27.34	49.51	53.38	56.90	61.16
42	22.14	23.65	26.00	28.14	30.77	54.09	58.12	61.78	66.21
46	25.04	26.66	29.16	31.44	34.22	58.64	62.83	66.62	71.20
50	27.99	29.71	32.36	34.76	37.69	63.17	67.50	71.42	76.15
55	31.73	33.57	36.40	38.96	42.06	68.80	73.31	77.38	82.29
60	35.53	37.48	40.48	43.19	46.46	74.40	79.08	83.30	88.38
65	39.38	41.44	44.60	47.45	50.88	79.97	84.82	89.18	94.42
70	43.28	45.44	48.76	51.74	55.33	85.53	90.53	95.02	100.43
75	47.21	49.48	52.94	56.05	59.79	91.06	96.22	100.84	106.39
80	51.17	53.54	57.15	60.39	64.28	96.58	101.88	106.63	112.33
85	55.17	57.63	61.39	64.75	68.78	102.08	107.52	112.39	118.24
90	59.20	61.75	65.65	69.13	73.29	107.57	113.15	118.14	124.12
95	63.25	65.90	69.92	73.52	77.82	113.04	118.75	123.86	129.97
100	67.33	70.06	74.22	77.93	82.36	118.50	124.34	129.56	135.81

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2020 ACADEMIC YEAR
FINAL EXAMINATIONS

MAT2901: INTRODUCTION TO PROBABILITY

Time Allowed: Three (3) Hours

Instructions:
1. Answer any **Five (5)** Questions
2. Show All Essential Working
3. Calculators are Allowed
4. Express all fractions in lowest terms and decimals correct to 4 decimal places.

---

1. (a) Define the following:
   (i) mutually exclusive events A and B.
   (ii) a permutation.

   (b) Events A and B are such that $P(A) = \frac{1}{4}$, $P(B|A) = \frac{2}{5}$ and $P(A \cup B) = \frac{3}{4}$.
   (i) Find $P(A \cap B)$.
   (ii) Find $P(B)$.
   (iii) Find $P(A'|B)$.
   (iv) Determine whether A and B are independent.

   (c) A random variable Y has probability function

x	-1	0	1	2	3
$P(X = x)$	0.10	0.30	0.20	0.35	0.05

   (i) Find the cumulative distribution function of X.
   (ii) Sketch the cumulative distribution function in (i).
   (iii) Find $P(0 < X < 3)$.
   (iv) Find $Var\left(\frac{X-5}{2}\right)$.

2. (a) (i) State Boole's inequality.

(ii) If $M_X(t)$ is the moment generating function of a random variable X, prove that the moment generating function of a random variable $Y = aX + b$ is given by $M_Y(t) = e^{tb} M_X(at)$ where a and b are constants.

(b) If all the letters of the word KASAMA are arranged in a line, find the

(i) number of distinct letter arrangements possible.

(ii) probability that an arrangement starts with the letter K and ends with the letter S.

(iii) probability that the letters S and M are next to each other.

(c) Suppose that X and Y are discrete random variables with joint probability function

$$f(x, y) = c(x + y) \quad , \quad x = 0, 1, 2 \quad ; \quad y = 0, 1, 2$$

(i) Show that $c = \frac{1}{18}$.

(ii) Find the marginal probability functions $f_X(x)$ and $f_Y(y)$.

(iii) Find $Cov(X, Y)$.

3. (a) We are interested in the sequence of male and female births in families that consist of three children.

(i) List all the elements of the sample space.

(ii) Find the probability that the first child and the third child are male.

(iii) Given that a family has at least two female children, find the probability that the firstborn is male.

(b) A continuous random variable X has probability function

$$f(x) = \begin{cases} kx & , \quad 0 < x < 1 \\ \frac{k}{x^4} & , \quad x > 1 \\ 0 & , \quad otherwise \end{cases}$$

(i) Show that $k = \frac{6}{5}$.

(ii) Find E(X).

(iii) Find Var(X).

(iv) Find the cumulative distribution function of X.

(c) The joint moment generating function of two random variables X and Y is given by

$$M_{X,Y}(t_1, t_2) = e^{3 - 2e^{t_1} - e^{t_2}}$$

(i) Find the marginal moment generating functions of X and Y.

(ii) Are X and Y independent? Explain.

4. (a) Prove each of the following:

(i) $E[E(Y|X)] = E(Y)$ for jointly distributed random variables X and Y.

(ii) $Cov(aX, bX - Y) = abVar(X) - aCov(X, Y)$ for any two random variables X and Y, and constants a and b.

(b) Let X be a gamma random variable with probability density function

$$f(x) = \frac{\lambda}{\Gamma(r)} (\lambda x)^{r-1} e^{-\lambda x} \quad , \quad x > 0 \quad ; \quad \lambda > 0 \quad , \quad r > 0$$

(i) Show that the moment generating function of X is given by

$$M_X(t) = \left(\frac{\lambda}{\lambda - t}\right)^r \quad , \quad t < \lambda$$

(ii) Use the moment generating function in (i) to find Var(X).

(c) A biased coin that shows heads with probability 0.15 is tossed repeatedly. Find the probability that

(i) 4 heads are obtained in 15 tosses.

(ii) the third head is obtained on the 8^{th} toss.

(iii) at least 25 tosses are required to obtain the first head.

5. (a) Suppose X and Y are independent random variables with E(X) = 2, E(Y) = 3, Var(X) = 4 and Var(Y) = 16. Find

(i) $E(2X - Y)$

(ii) $Var(X - 3Y)$

(b) A soldier who hits a target with probability $\frac{2}{3}$ fires shots until he hits the target or 5 shots have been fired. Let X denote the number of shots fired. Find the

(i) probability distribution of X.

(ii) mean of X.

(c) The length of phone calls at a public telephone booth follows an exponential distribution with a mean of 10 minutes. If someone arrives immediately ahead of you at a public telephone booth, find the probability that you will wait

(i) more than 10 minutes.

(ii) between 10 and 20 minutes.

(iii) an additional 15 minutes or more if the person is still on the phone 5 after you arrive minutes.

6. (a) (i) Define the joint moment generating function of random variables $X_1, X_2, \ldots, X_n$.

(ii) For jointly distributed random variables X and Y, prove that $Var(X) = E[Var(X \mid Y)] + Var[E(X \mid Y)]$

(b) Molecules of a rare gas occur at an average rate of 3 per cubic metre of air and follow a Poisson distribution.

(i) Find the probability that a cubic metre of air contains none of the molecules.

(ii) Find the probability that 3 cubic metre of air contain exactly 4 of the molecules.

(iii) The probability that at least one molecule is found in 0.99. Find how much air is taken as sample.

(c) The joint probability density function of random variables X and Y is given by

$$f(x,y) = e^{-(x+y)} \quad , \quad x > 0 \quad , \quad y > 0$$

(i) Find the marginal probability density functions $f_X(x)$ and $f_Y(y)$.

(ii) Are X and Y independent? Why or why not?

(iii) Find $P(Y < 5)$.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
DEPARTMENT OF MATHEMATICS AND STATISTICS
2020/2021 ACADEMIC YEAR FINAL EXAMINATION
MAT3001 – INSURANCE AND ALTERNATIVE RISK TRANSFER

16TH NOVEMBER 2021

Time Allowed: THREE (3) hours

INSTRUCTIONS

1. Answer ALL Questions
2. Show all your workings to earn full credit
3. Indicate your computer number on ALL answer booklets

Question One **[Total 25 Marks]**

(a) Outline any three characteristics of insurable risks. [3 marks]

(b)
(i) Define the term risk management. [2 marks]
(ii) Outline any four COSO principles of risk management. [4 marks]

(c) Outline the importance of the following principles/terms in ensuring the smooth and credible operation of the insurance mechanisms.

(i) Insurable interest [3 marks]
(ii) Utmost good faith [3 marks]
(iii) Conditions and warranties in insurance [3 marks]
(iv) Subrogation [2 marks]

(d) Discuss whether each of the benefits of insurance to the society could be more or less through a Takaful arrangement than the conventional forms. [5 marks]

Question Two **[Total 25 Marks]**

(a) Outline the characteristics of the various stages of the insurance cycle [6 marks]

(b) Outline scope of cover, possible exclusions and other factors that might affect premium rate changes for the following types of insurance products:

(i) Household All risk policy in Lusaka. [4 marks]
(ii) Employers' liability for a Copper mining company in Zambia [2 marks]
(iii) Satellite launch insurance [2 marks]

(c) Explain how the following strategies of implementing partial insurance leads to lower insurance premiums.

(i) Increase deductible [3 marks]
(ii) Reduce Cap [2 marks]

(d) Describe practical scenarios for each of the following.

(i) Multiple peril in agriculture insurance [3 marks]
(ii) Multiple trigger in power outage insurance [3 marks]

Question Three **[Total 25 Marks]**

(a) Outline the roles and processes associated with the following insurance operations.

(i) Strategy [2 marks]
(ii) Production/marketing [3 marks]

(b) CorpSure is a large insurance company specialising in providing general insurance solutions to businesses through a large network of brokers. They are aiming to be the first local insurer to launch a "Cyber" insurance product. The product would provide cover for losses as a result of unauthorised access or "hacking" of an insured's computer systems.

Describe how the actuarial control cycle may be used in the design, pricing, and ongoing risk management of the product. [8 marks]

(c) Describe the insurance business transaction process at the Lloyd's of London. [4 marks]

(d) Explain in detail how any two alternative risk transfer solutions have been used to compliment or substitute to conventional reinsurance for the total exposure named catastrophic risks or pandemics. You write up should include actual global examples. [8 marks]

Question Four **[Total 25 Marks]**

(a) Describe how the reasons for taking our reinsurance determine the preferred type of reinsurance. [5 marks]

(b) C&C Insurance Company has an option of arranging either a Quota share treaty or a Risk Excess of loss on its fire portfolio. The information available is as follows;

Quota share
80% quota share treaty with a ceding commission to the cedant of 40%. The treaty is subject to a maximum gross acceptance of K 500,000

Risk XOL
Per risk protection for K 400,000 excess of K 100,000. Premium adjustable at 20% of the Original Gross Premium (OGP).
The Company's OGP is expected to be K 10,000,000. Commission and expenses (net of commission) ratios will be 15% and 20%respectively.

Total claims in the first year total K 5,000,000. Only ten claims are given under the Risk XOL (from ground up) and these are as follows:

150,000	295,000
280,000	220,000
175,000	310,000
80,000	265,000
200,000	325,000

(i) Which treaty is C&C going to choose based on the information above? Show all workings. [12 marks]

Suppose the following additional information is given in respect of C&C Insurance Company:

5 line 1st surplus treaty
5 line 2nd Surplus treaty

(ii) Show how a risk with a Sum Insured of K 6,000,000 will be allocated to the reinsurance facilities. Allocation to retention should be based on treaty chosen in part (i) of the question. [3 marks]

(iii) Show how a loss of K 325,000 (arising from the risk in (ii) above) will be recovered from the different facilities. [2 marks]

(iv) Assuming it has been established that the Estimated Maximum loss (EML) for the risk in (ii) is 50%, show how the risk will be ceded to the different facilities and also how a loss of K 325,000 will be recovered. [3 marks]

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
DEPARTMENT OF MATHEMATICS AND STATISTICS
2020/2021 ACADEMIC YEAR EXAMINATION
MAT3011 – PRINCIPLES OF FINANCE AND FINANCIAL REPORTING
23rd NOVEMBER 2021

Time Allowed: THREE (3) hours

INSTRUCTIONS

1. Answer **Question One** and **ANY** other **FOUR** Questions
2. Show all your workings to earn full credit
3. Indicate your computer number on ALL answer booklets

Question One **[20 Marks] – MULTIPLE CHOICE – [2 marks each]**

1. Why are quoted companies required to have non-executive directors on their boards?

A Executive directors are corrupt and incompetent.
B Executive directors are often inexperienced.
C Non-executive directors can fulfil a supervisory role.
D Non-executive directors require lower salaries than executives.

2 Which of the following is an agency cost?

A Board meetings
B Directors' salaries
C External audit of a company's financial statements
D Interest on corporate debt.

3 A parent company has a foreign subsidiary located in a host country that does not have a double tax arrangement with the parent's home country. The foreign subsidiary pays regular dividends to the parent company. Which of the following will apply?

A The subsidiary will not be taxed on profits earned in its host country and the parent will pay tax on dividends in its home country.
B The subsidiary will pay tax on profits earned in its host country and the parent will not be required to declare the dividends as taxable income in its home country.
C The subsidiary will pay tax on profits earned in its host country and the parent will pay tax on dividends received in its home country.
D The subsidiary will pay tax on profits earned in its host country and the parent will pay tax on dividends received in the subsidiary's host country.

4 A company has issued subordinated debt securities. Which of the following reflects the priority that would apply in the event of default?

A Mortgage loans first, followed by preference shares, then equity shares, then subordinated debt.

B Mortgage loans first, followed by preference shares, then subordinated debt, then equity shares.
C Mortgage loans first, followed by subordinated debt, then preference shares, then equity shares.
D Subordinated debt first, followed by mortgage loans, then preference shares, then equity shares.

5 A company with floating rate debt has entered into a swap arrangement with a counterparty that has fixed rate debt.
What are the implications to the company of a default by the counterparty?

A Nothing will change.
B The company will be forced to pay interest on both loans.
C The company will be left with floating rate debt.
D The company's loan will be written off.

6 A holiday company takes bookings for holidays up to a year before customers travel. The company recognises revenue from those bookings in the same accounting period as the costs associated with providing the holidays is incurred.
Which accounting concept is the holiday company applying?

A Accruals
B Dual aspect
C Matching
D Prudence.

7 Why do analysts disregard intangible assets when calculating net asset value per share?
A Intangible assets have no value to the shareholders.
B Intangible assets may prove difficult to sell if the company fails.
C It is unrealistic to expect company directors to use intangible assets to create value.
D Only tangible assets can be controlled.

8 Which of the following is a valid formula for Return on Capital Employed (ROCE)?

A (Profit before tax)/(share capital + reserves + long term debt)
B (Profit before tax and interest)/(share capital + reserves)
C (Profit before tax and interest)/(share capital + reserves + long term debt)
B (Profit before tax and interest)/(share capital + long term debt)

9 A company's factory cost K50 million. Depreciation to date on the building is K12 million. The factory was recently valued at K55 million. What amount will appear in the company's revaluation reserve in respect of this revaluation?
A K5 million
B K17 million
C K38 million
D K55 million.

10 T is a quoted company that owns 5% of Z, an unquoted company. T has contracts in place that gives it the right to be involved in any decisions made by Z's directors. T also has the right to replace Z's directors at any time. How should Z be accounted for in the TGroup's consolidated financial statements?

A As an associate
B As an investment
C As a non-controlling interest
D As a subsidiary.

Question Two **[Total 20 Marks]**

(a) Directors are duty-bound to maximise shareholder wealth.
Discuss the impact on this duty if they must also consider the needs of a wider range of stakeholders. [5 marks]

(b) Describe the difficulties in deciding whether a particular quoted company is a suitable acquisition target for a larger quoted company. [5 marks]

(c) A change in safety regulations will require a train company to fit new equipment to all trains. The company does not believe that the equipment will reduce the risk of accidents and it will be expensive.

Explain the usefulness of the Net Present Value (NPV) criterion in planning the company's response to this change. [5 marks]

(d) A quoted company has a policy of seeking an internal rate of return of at least 14% p.a. on all investments of more than K5 million. This rate was set 5 years ago. Describe the company's approach to capital project appraisal. [5 marks]

Question Three **[Total 20 Marks]**

(a) Discuss the proposition that businesses should take account of social responsibility when conducting their operations. [5 marks]

(b) Describe whether preference shares should be treated as debt rather than equity when evaluating a company's gearing. [5 marks]

(c) Explain the implications of credit risk for entities which are considering entering into interest rate swaps. [5 marks]

(d) Using your own hypothetical figures, present an outline of the structure of a company's cashflow statements. [5 marks]

Question Four **[Total 20 Marks]**

(a) For a well-known company in Zambia of your choice.

(i)Discuss the implications of the company retaining the surplus cash in order to take advantage of any new opportunity which might arise. [4 marks]

(ii) Discuss the potential advantages and disadvantages of using the surplus funds in order to diversify. [6 marks]

(iii) Discuss the suitability of a share buyback assuming that the company is listed on the Lusaka Securities Exchange (LuSE). [5 marks]

(b) Protégé is an unquoted company which was founded 12 years ago and which has grown steadily since. Its directors are considering an investment opportunity that will increase the productive capacity of the business by 30%.

Protégé was established using the savings of its three founders, who now comprise the company's board of directors. Each of the three founders owns one third of the company's equity. Protégé's growth has been funded using retained earnings and the proposed expansion will be funded in the same way. The company has no debt. None of the founders has any other significant personal assets apart from their shares in Protégé and their family homes.

The founders are considering more sophisticated approaches to the evaluation of capital investment projects. They have asked you to determine Protégé's cost of equity.

They have established the following facts:
- The risk free rate is 4% per annum.
- The equity risk premium is 10% per annum.
- The beta coefficient of a quoted company which is in the same industry as Protégé is 1.4.
- The above quoted company has a debt:equity ratio of 0.6:1.
- The corporation tax rate is 20%.

Calculate Protégé's cost of equity. [5 marks]

Question Five **[Total 20 Marks]**

(a) Outline the roles of accounting information to the various users. [5 marks]

(b) Ndiyepano is a quoted company that manufactures bicycles and was established many years ago. It has been making losses for the past 5 years because its products have not kept up with consumer tastes and sales have been declining.

Despite the losses, Ndiyepano has continued to pay a steady dividend each year. Ndiyepano's Board is considering a proposal to sell a range of battery-powered electric bicycles, which is a major growth area in the bicycle market. Ndiyepano's current range of bicycles is suitable for modification to carry an electric motor. This would require a significant investment in order to acquire the rights to use patented manufacturing processes and also to acquire the specialised machinery that would have to be built to Ndiyepano's specifications. The

investment required is equivalent to approximately 25% of the company's market capitalisation.

Ndiyepano's beta is currently 1.8. The Board believes that the beta will fall to 1.6 if the company proceeds with the electric bicycle project.

(i) Evaluate the relevance of the decline in Ndiyepano's beta for the decision to invest in electric bicycles. [7 marks]

(ii) Discuss Ndiyepano's policy of maintaining its dividend payments despite losses. [8 marks]

Question Six **[Total 20 Marks]**

The information provided below was obtained from Emmanuel plc's bookkeeping records on 31 March 2020.

(a) Prepare Emmanuel plc's financial statements in a form suitable for publication:

(i) statement of profit or loss [9 marks]
(ii) statement of changes in equity [2 marks]
(iii) statement of financial position. [4 marks]

(b) Discuss the implications of the loss on revaluation of property for Emmanuel's shareholders. [5 marks]

Emmanuel plc - List of balances as at 31 March 2020

	K000
Administrative expenses	939
Cash at bank	155
Borrowings (long term)	361
Directors' remuneration	1,366
Dividends paid	101
Interest on borrowings	44
Manufacturing costs	1,734
Manufacturing materials – inventory at start of year	614
Manufacturing purchases	4,003
Manufacturing wages	1,120
Plant and equipment – accumulated depreciation	939
Plant and equipment – cost	7,081
Property – accumulated depreciation	1,543
Property – cost	3,251
Retained earnings	1,610
Revenue	16,927
Sales salaries	890
Selling expenses	888
Share capital	1,626
Share premium	434
Trade payables	184
Trade receivables	1,438

Further information:

(1) Inventory was counted at 31 March 2020 and was valued at K740,000.

(2) Manufacturing costs exclude K50,000 of compensation that will be paid in June 2020 to employees who were injured in an industrial accident.

(3) Property was valued at K1,500,000 on 31 March 2020. That valuation is to be incorporated into the financial statements.

(4) Corporation tax of K1,337,000 is to be provided for the year.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
DEPARTMENT OF MATHEMATICS & STATISTICS

2020/2021 Academic Year Final Examinations
26^{TH} NOVEMBER, 2021
MAT 3100 ADVANCED CALCULUS

Total time allowed: Three (3) hours
Instructions:

- This question paper comprises seven (7) questions. All questions carry equal marks. Marks to parts of each question are indicated at the end of the question. **Answer any five (5) questions.**
- Show detailed working to earn full marks.

---

1. (*a*) (*i*) Sketch the surface $f(x, y) = \sin x$.

   (*ii*) Find $\dfrac{\partial w}{\partial x}$ at the point $(0, 1, \pi)$ given that

   $$w = x^2 + y^2 + z^2, \ ysinz + z\sin x = 1.$$

   (*b*) (*i*) Solve the shifted data Initial Value Problem by the Laplace transform:

   $$y' - 6y = 0, \ y(-1) = 4.$$

   (*ii*) Prove that if $\boldsymbol{r}(s)$ is the arc length parametrization of the continously differentiable curve $\boldsymbol{r}$, then $\boldsymbol{u}(s) = \dfrac{d\boldsymbol{r}(s)}{ds}$ is a unit vector tangent to the curve.

   (*c*) (*i*) Show that the two functions:

   $$u(x, y) = \cos(x^2 + y^2 - t) \ \text{ and } v(x, y) = \sin(x^2 + y^2 - t)$$

   where t is some constant, are functionally dependent in their domain of definition.

   (*ii*) Find a functional relation for the functions in part $c(i)$.

   [3; 4; 4; 4; 3; 2]

2. (*a*) (i) Find the gradient of the function $f(x, y, z) = e^{x+y} \cos z$ at the point $(0, 0, \frac{\pi}{6})$.

(*ii*) In which two directions is the derivative of $f(x, y) = xy + y^2$ at the point $(2, 5)$ equal to zero?

(*b*) (i) Solve the following integral equation using the Laplace transform method and the idea of convolution

$$y(t) - \int_0^t y(\tau)(t - \tau)d\tau = 2 - \frac{t^2}{2}.$$

(*ii*) State, without proof, the inverse function theorem.

(*c*) (i) Show that the following vector field is conservative, hence find all functions f such that $\nabla f = \boldsymbol{F}$:

$$\boldsymbol{F}(x, y, z) = e^y \boldsymbol{i} + xe^y \boldsymbol{j} + (z + 1)e^z \boldsymbol{k}.$$

(*ii*) Evaluate the line integral $\int_C \boldsymbol{F} \cdot d\boldsymbol{r}$ where C is the curve $\boldsymbol{r}(t) = t\boldsymbol{i} + t^2\boldsymbol{j} + t^3\boldsymbol{k}$, $0 \leq t \leq 1$, where $\boldsymbol{F}(x, y, z)$ is given in part $c(i)$.

[3; 3; 5; 3; 4; 2]

3. (*a*) (i) Evaluate the integral

$$\int_0^2 \int_{\frac{y}{2}}^1 e^{x^2} dxdy.$$

(*ii*) Consider the ellipsoid $x^2 + 2y^2 + 3z^2 - 72 = 0$, find all points on this surface where the tangent plane to the surface is parallel to the plane $x + y + 3z = \frac{3}{4}$.

(*b*) (i) Sketch the region whose area is given by the integral and evaluate the integral

$$\int_\pi^{2\pi} \int_4^6 r \, drd\theta.$$

(*ii*) Find the area of the region bounded by the curves $r = 2\cos\theta$ and $r = 2\sin\theta$.

(*c*) (i) Evaluate the line integral $\int_C y \, dx + x \, dy$ given that C is the straight line segment joining $(1, 2)$ to $(3, 10)$.

(*ii*) Use differentials to estimate the amount of metal in a closed cylindrical can that is 15 cm high and 6 cm in diameter if the metal in the top and bottom is 0.2 cm thick and the metal in the sides is 0.07 cm thick.

[4; 4; 3; 3; 3; 3]

4. (*a*) (i) Find the shortest distance from the point $(2, 1, -1)$ to the plane $x + y - z = 1$.

(*ii*) Use Jacobians to find the parametric equations of the tangent line to the two surfaces at the point indicated:

$$x^2 + y^2 + z^2 = 9, \ x^2 + y^2 - 8z^2 = 0, \ \ (2, 2, 1).$$

(*b*) (i) Prove that if $\boldsymbol{F}$ is a conservative vector field, then $\text{Curl}(\boldsymbol{F}) = \boldsymbol{0}$.

(*ii*) Find the inverse Laplace transform, $f(t)$ given that $F(s) = \dfrac{s + 14}{2s^2 - s + 3}$.

(*c*) Given that

$$\boldsymbol{F}(x, y, z) = 2xy\boldsymbol{i} + (x^2 + 2yz)\boldsymbol{j} + y^2\boldsymbol{k}.$$

Find

(i) $\text{div}(\boldsymbol{F})$,

(*ii*) $\text{Curl}(\boldsymbol{F})$.

[4; 4; 4; 4; 1; 2]

5. (*a*) (i) State, without proof, Stoke's theorem.

(*ii*) Find the circulation of the field $\boldsymbol{F}$ across the surface S given that

$$\boldsymbol{F}(x, y, z) = x^2\boldsymbol{i} + 2x\boldsymbol{j} + z^2\boldsymbol{k}$$

and S is the surface bounded by the ellipse $4x^2 + y^2 = 4$, counterclockwise as viewed from above.

(*b*) (i) Find the Laplacian ∇^2 of the function $f(x, y, z) = \sin x^2y^2z^2$.

(*ii*) Find the Laplace transform, $F(s)$ given that $f(t) = te^{-t}\cos t$.

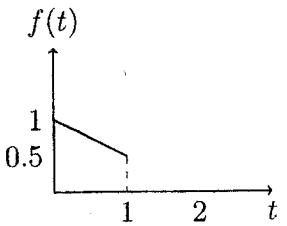
(*c*) (i) Obtain the even periodic extension of the given function:

$$f(x) = \sin x, \ 0 \leq x \leq \pi$$

(*ii*) and sketch, in the interval $-3\pi \leq x \leq 3\pi$, the corresponding even periodic extension for the function.

[3; 4; 3; 4; 4; 2]

6. (*a*) (i) Find the Laplace transform of the following function $f(t)$ defined for $0 < t < 1$ and zero everywhere else.



(*ii*) State, without proof, Green's theorem.

(*b*) (i) Use Lagrange multipliers to find the maximum and minimum values of the function f subject to the given constraint: $f(x, y, z) = x + 2y$, $x + y + z = 1$, $y^2 + z^2 = 4$.

(*ii*) Find the arc length of a complete arc of the cycloid

$$\boldsymbol{r}(t) = a(t - \sin t)\boldsymbol{i} + a(1 - \cos t)\boldsymbol{j} + 0\boldsymbol{k}, \ 0 \leq t \leq 2\pi.$$

(*c*) (i) Obtain the Fourier series of the function

$$f(x) = \frac{x^2}{4}$$

assumed to be periodic of period 2π, $-\pi \leq x \leq \pi$.

(*ii*) Hence or otherwise prove that $1 + \dfrac{1}{2^2} + \dfrac{1}{3^2} + \dfrac{1}{4^2} + \cdots = \dfrac{\pi^2}{6}$.

[3; 3; 4; 4; 4; 2]

7. (*a*) (*i*) Find the Fourier cosine transform of the function

$$f(x) = \begin{cases} c & \text{if } 0 < x < a, \\ 0 & \text{if } x > a. \end{cases}$$

for some constants a nd c.

(*ii*) Obtain the first partial derivatives of the function

$$f(x, y) = \int_{2xy+1}^{x^3} e^{s^2+1} ds.$$

(*b*) (i) Sketch the solid whose volume is given by the iterated integral:

$$\int_0^2 \int_0^{2-y} \int_0^{4-y^2} dx dz dy.$$

(*ii*) Evaluate the integral in part $b(i)$.

(*c*) (i) Evaluate $\int\int\int_E z dV$ where E lies between the spheres $x^2 + y^2 + z^2 = 1$ and $x^2 + y^2 + z^2 = 4$.

(*ii*) Use Green's theorem to find the area enclosed by the ellipse

$$\frac{(x-1)^2}{a^2} + \frac{(y+2)^2}{b^2} = 1.$$

[3; 4; 3; 2; 4; 4]

END OF EXAM!

The University of Zambia
School of Natural Sciences
Department of Mathematics and Statistics

2020/21 Academic Year Examinations

MAT 3110 Engineering Mathematics II

November 16, 2021.

Duration: THREE Hours

Instructions:

- Do not open this booklet until you are told to do so.
- This paper consists of seven questions, each carry 20 marks. Attempt any FIVE questions. Total marks is 100.
- Show all the essential working to earn full marks.
- Non programmable calculators are allowed.

---

1. (a) Find a power series solution in powers of x of the following ordinary differential equations.

   i. $(x-2)y' = xy$ (6)

   ii. $y'' - 4xy' + (4x^2 - 2)y = 0$ (9)

   (b) Find the eigenvalues and corresponding eigenvectors of the matrix below. (5)

$$\begin{pmatrix} -4 & -17 \\ 2 & 2 \end{pmatrix}$$

2. (a) Find the general solution to the following differential equations.

   i. $x^2y'' + 3xy' + 4y = 0$ (5)

   ii. $x^2y'' - 7xy' + 16y = 0$ (5)

   (b) Solve the following system of first order linear differential equation with the given initial conditions. (10)

$$\begin{aligned} x' &= 3x - 13y, & x(0) &= 3, \\ y' &= 5x + y, & y(0) &= -10. \end{aligned}$$

3. (a) Use Laplace transforms to solve the following initial value problem. (10)

$$y'' + y = \begin{cases} t, & 0 \le t < 1 \\ 0, & t \ge 1 \end{cases}, \quad y(0) = 0, y'(0) = 0.$$

   (b) i. Find the Laplace transform of the function (5)

$$f(t) = \begin{cases} t, & 0 \le t < 1 \\ e^t, & t \ge 1. \end{cases}$$

   ii. Find the inverse Laplace transform of the function (5)

$$F(s) = \frac{2s+3}{s^2 + 4s + 13}.$$

4. (a) Evaluate the following double integrals.

   i. (8)

$$\int\int_R x^2y^3e^{x^3-y^4}\mathrm{d}A$$

   where $R = \{(x, y) : 0 \le x \le 1, -1 \le y \le 0\}$.

ii. (6)

$$\int\int_D 4x - 2y \mathrm{d}A,$$

where D is the top half of region between $x^2 + y^2 = 4$ and $x^2 + y^2 = 25$.

(b) Use a double integral to determine the volume of the solid bounded by the plane $z = 4 - 2x - 2y$, $y = 2x$, $y = 0$ and $z = 0$. (6)

5. (a) Evaluate the following triple integrals.

i. (7)

$$\int\int\int_E 5y^2 \mathrm{d}V,$$

where E is the portion of $x^2 + y^2 + z^2 = 4$ with $x \geq 0$.

ii. (7)

$$\int\int\int_E 9yz^3 \ \mathrm{d}V,$$

where E is the region between $x = -\sqrt{9y^2 + 9z^2}$ and $x = \sqrt{y^2 + z^2}$ inside the cylinder $y^2 + z^2 = 1$.

(b) Use a triple integral to determine the volume of the solid bounded by the planes $z = 0$ and $z = 2y$, and the surface $y = 4 - x^2$. (6)

6. (a) i. Evaluate (7)

$$\int_C \mathbf{F} \cdot \mathrm{d}r$$

where

$$\mathbf{F}(x, y) = 2x^2 \ \mathbf{i} + (y^2 - 1) \ \mathbf{j}$$

and C is the portion of $\frac{x^2}{25} + \frac{y^2}{9} = 1$ that is in the is in 1st, 4th and 3rd quadrant with the clockwise orientation.

ii. Use Green's Theorem to evaluate (6)

$$\int_C \mathbf{F} \cdot \mathrm{d}r$$

where

$$\mathbf{F}(x, y) = (y^3 - xy^2) \ \mathbf{i} + (2 - x^3) \ \mathbf{j}$$

and C consists of the line segment from $(0, 0)$ to $(0, -4)$, the path along $x^2 + y^2 = 16$ from $(0, -4)$ to $(4, 0)$ and the line segment from $(4, 0)$ to $(0, 0)$.

(b) Show that the vector field given below is conservative and find is potential function. (7)

$$\mathbf{F}(x, y, z) = \left(\frac{x}{\sqrt{x^2 + z^2}}\right) \ \mathbf{i} + (2yz - 6y) \ \mathbf{j} + \left(y^2 + \frac{z}{\sqrt{x^2 + z^2}}\right) \ \mathbf{k}$$

7. (a) i. Evaluate (6)

$$\int\int_S \mathbf{F} \cdot d\mathbf{S},$$

where $\mathbf{F}(x, y, z) = y\ \mathbf{j} - z\ \mathbf{k}$ and S is the surface given by the paraboloid $y = x^2 + z^2$, $0 \leq y \leq 1$.

ii. Use the Divergence theorem to evaluate (7)

$$\int\int_S \mathbf{F} \cdot d\mathbf{S},$$

where $\mathbf{F}(x, y, z) = xy\ \mathbf{i} - \frac{1}{2}y^2\ \mathbf{j} + z\ \mathbf{k}$ and S is the surface that consists of three surfaces, $z = 4 - 3x^2 - 3y^2$, $1 \leq z \leq 4$ on the top, $x^2 + y^2 = 1$, $0 \leq z \leq 1$ on the sides and $z = 0$ on the bottom.

(b) Use Stoke's theorem to evaluate (7)

$$\int\int_S \text{curl } \mathbf{F} \cdot d\mathbf{S},$$

where $\mathbf{F}(x, y, z) = z^2\ \mathbf{i} - 3cy\mathbf{j} + x^3y^3\mathbf{k}$ and S is the part of $z = 5 - x^2 - y^2$ above the plane $z = 1$.

End of Examination

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
DEPARTMENT OF MATHEMATICS & STATISTICS

2020 Academic Year Final Examinations — 18^{th} November, 2021
MAT 3200 Abstract Algebra

Total time allowed: Three (3) hours
Instructions:

- There are seven questions in this paper; answer any five (5).
- All questions carry equal marks.
- Show detailed working to earn full marks.

---

1. (a) (i) Define the order of an element in a group. [3]
   (ii) State the Finite Subgroup Test. [3]

   (b) Consider the permutation $\beta = (1\ 2\ 3\ 5\ 6\ 7)(1\ 4\ 5)(2\ 4\ 5\ 6\ 7)$ in the Symmetric group S_7. Write β as a single cycle or as a product of disjoint cycles. Hence, find the inverse of β in cycle notation and find the order of β. [5]

   (c) Given that $M = \begin{pmatrix} 2 & 5 \\ 3 & 5 \end{pmatrix}$ is an element of the general linear group $\mathrm{GL}(2,\ \mathbb{Z}_7)$, find the multiplicative inverse of M. [5]

   (d) Let a and b be elements of an Abelian group and let n be any positive integer. Show that $(ab)^n = a^n b^n$. [4]

2. (a) Define a symmetric group on a non-empty set A. [2]

   (b) (i) Find all the distinct left cosets of the subgroup $H = \{1,\ 10,\ 19\}$ in the group of units modulo 27, $U(27)$. [4]
   (ii) Construct the Cayley table for the quotient group $U(27)/H$. Hence, find the inverse of every element in the quotient group $U(27)/H$. [4]

   (c) The function $f : \mathbb{C}^* \to \mathbb{C}^*$ defined by $f(x) = x^2$ is a group homomorphism from the group $\mathbb{C}^*$ to itself. Find the pre-images of the element $z = -7-24i$. [5]

(d) State and prove Lagrange's Theorem. [5]

3. (a) (i) Define a cyclic group. [2]

(ii) State the Fundamental Theorem of Group Homomorphisms. [2]

(b) Consider the dihedral group
$D_6 = \{1,\ r,\ r^2,\ r^3,\ r^4,\ r^5,\ s,\ sr,\ sr^2,\ sr^3,\ sr^4,\ sr^5\}$.
Find all the non-cyclic subgroups in this group. [5]

(c) Consider the group $U(30) \oplus D_6$, the external direct product of $U(30)$ with D_6. Find the order of the element $(7,\ r)$ and the inverse of the element $(14,\ r^3)$. [4]

(d) Consider the group homomorphism $\phi : \mathbb{Z}_{12} \to \mathbb{Z}_9$ defined by $\phi(x) = 3x$.

(i) Find $\text{Ker}\phi$ and $\phi^{-1}(6)$. [3]

(ii) Use this homomorphism to verify the Fundamental Theorem of Group Homomorphisms. [4]

4. (a) (i) Define a normal subgroup. [3]

(ii) Define a Sylow $p-$subgroup. [3]

(b) Consider the group of integers modulo 24, $\mathbb{Z}_{24}$. Find the Sylow $2-$subgroup and the Sylow $3-$subgroup in this group. [4]

(c) Find $\gcd(273, 213)$ and then find integers m and n such that the equation $273m+213n = \gcd(273, 213)$ is satisfied. [5]

(d) Consider the dihedral group

$$D_6 = \{1,\ r,\ r^2,\ r^3,\ r^4,\ r^5,\ s,\ sr,\ sr^2,\ sr^3,\ sr^4,\ sr^5\}.$$

Write all the distinct conjugacy classes for this group. [5]

5. (a) (i) Define an integral domain. [3]

(ii) State the Subring Test. [3]

(b) Find the greatest common divisor of the Gaussian integers $1 - 5i$ and $1-3i$. [4]

(c) Consider the ring of the Gaussian integers modulo 7,
$\mathbb{Z}_7[i] = \{a+bi \mid a, b \in \mathbb{Z}_7\}$. Find the multiplicative inverse of $3+5i$ in this ring. [5]

(d) State and prove Bezout's Identity. [5]

6. (a) (i) Define a zero-divisor. [2]

(ii) State the Division Algorithm. [3]

(b) Let $S = \left\{ \begin{pmatrix} a & b \\ -a & -b \end{pmatrix} \mid a, b \in \mathbb{Z} \right\}$. Prove or disprove that S is a subring of $M_2(\mathbb{Z})$. [5]

(c) Show that the matrix $A = \begin{pmatrix} 1 & 2 \\ 3 & 6 \end{pmatrix}$ is a zero-divisor in the ring, $M_2(\mathbb{Z})$, of 2×2 matrices with integer entries. [5]

(d) Prove that if v is an eigenvector of a linear operator T corresponding to the eigenvalue λ, then $\text{span}\{v\}$ is invariant under the linear operator T. [5]

7. (a) Define the following terms:

(i) An eigenvector of a linear operator T. [2]

(ii) A Jordan block. [3]

(b) Find the matrix representation with respect to the basis $B = \{(1,-1,1),\ (2,1,4), (1,3,0)\}$ in $\mathbb{R}^3$ for the linear operator T : $\mathbb{R}^3 \to \mathbb{R}^3$ defined by $T \begin{pmatrix} a \\ b \\ c \end{pmatrix} = \begin{pmatrix} 3a - b \\ 2b + c \\ a + b - c \end{pmatrix}$. [5]

(c) Determine whether or not the matrix $A = \begin{pmatrix} 0 & 1 & 2 \\ 0 & -2 & 0 \\ 2 & 1 & 0 \end{pmatrix}$ is diagonalizable. [5]

(d) Find the Jordan canonical form of the matrix $B = \begin{pmatrix} 6 & 2 \\ -2 & 2 \end{pmatrix}$ [5]

END OF EXAM

The University of Zambia
School of Natural Sciences
Department of Mathematics & Statistics
2020/2021 Final Examination - 26th November, 2021
MAT 3300 - Real Analysis

Time allowed : Three (3) hrs | Full marks : 100

Instructions:

- Indicate your **computer number** on all answer booklets.
- Attempt **any (5) five** questions. All questions carry equal marks.
- **Full credit** will only be given when **necessary work** is shown.

This paper consists of 5 pages of questions.

---

1. **(a)** let $X \subset \mathbb{R}$.

   (i) When is X said to be open? [1]

   (ii) Show that a finite intersection of open sets is open. [4]

   (b) Let $F \subset \mathbb{R}$.

   (i) When is F said to be closed? [1]

   (ii) Show that the intersection of an arbitrary collection of closed sets is closed. [4]

(c) (i) Show that $\mathbb{R}$ and $\emptyset$ are both open and closed. [2]

(ii) Discuss whether the set $\bigcap_{n=1}^{\infty} \left[-2, \frac{1}{n}\right)$ is open or closed. [5]

(iii) Determine the interior, closure and boundary of the set

$$\bigcap_{n=1}^{\infty} \left[-2, \frac{1}{n}\right).$$

[3]

2. **(a)** (i) Give the $\epsilon - \delta$ definition of a continuous function at a point $x_0 \in A$.

[1]

(ii) Use the $\epsilon - \delta$ definition of continuity at a point to prove that

$$f(x) = x^2$$

is continuous at $x = 3$. [5]

(iii) Let $f : [a, b] \to \mathbb{R}$ be continuous. Prove that $|f|$ is also continuous on $[a, b]$. [4]

(b) Let $f : A \to \mathbb{R}$ be a function and let c be a cluster point of A. Prove that $\lim_{x \to c} f(x) = L$ if and only if all sequences (a_n) from the domain A where $a_n \neq c$ and $\lim_{n \to \infty} a_n = c$, then

$$\lim_{n \to \infty} f(a_n) = L.$$

[7]

(c) Use the limit divergence criteria to show that the limit of the function $f : \mathbb{R} \to \mathbb{R}$ defined by $f(x) = \dfrac{1}{x - 1}$ as $x \to 1$ does not exist.

[3]

3. **(a)** (i) Define a Lipschitz function [1]

(ii) Give two examples of Lipschitz functions [2]

(iii) Prove that every Lipschitz function is continuous. [3]

(b) (i) Define a uniformly continuous function. [1]

(ii) Prove that if a function $f : A \to \mathbb{R}$ is uniformly continuous on A, then f is also continuous on A. [5]

(iii) Prove that $f(x) = \sqrt{x}$ is uniformly continuous on $[0, \infty)$. [3]

(c) Let I be a closed and bounded interval in $\mathbb{R}$. Suppose $f : I \to \mathbb{R}$ is continuous. Show that $f(I)$ is a closed and bounded interval in $\mathbb{R}$. [5]

4. **(a)** (i) Define a partition of a closed interval $[a, b]$. [1]

(ii) Define a function of bounded variation f on the closed interval $[a, b]$. [2]

(iii) Prove that if f is a function of bounded variation on the interval $[a, b]$, then f is bounded on $[a, b]$. [5]

(b) Prove that if f and g are of bounded variation on $[a, b]$, then $f + g$ is of bounded variation. [7]

(c) Prove that if f is of bounded variation on $[a, b]$ and $t \in \mathbb{R}$, then tf is of bounded variation on $[a, b]$. [5]

5. **(a)** (i) Let f be a function defined on the interval (a, b) and let $c \in (a, b)$. When is f said to be differentiable at c? [1]

(ii) Discuss the differentiability of $f(x) = |x^2 - 4|$ at $x = 2$. [4]

(b) (i) Let f and g be functions defined on the open interval (a, b) and let $c \in (a, b)$. Prove that if f and g are differentiable at c, then $f \cdot g$ is differentiable at c and

$$(f \cdot g)' = f(c)g'(c) + f'(c)g(c)$$

[5]

(ii) Show that the function

$$f(x) = \begin{cases} x^2 \sin\left(\frac{1}{x}\right) & \text{if } x \neq 0 \\ 0 & \text{if } x = 0 \end{cases}$$

is differentiable at $x = 0$. [5]

(c) Let $f(x)$ be differentiable at a. Find

$$\lim_{n \to \infty} \frac{a^n f(x) - x^n f(a)}{x - a}$$

where $n \in \mathbb{N}$. [4]

6. **(a)** (i) When is a function f said to be Riemann integrable on $[a, b]$? [1]

(ii) Prove that every constant function on $[a, b]$ is Riemann integrable on $[a, b]$. [4]

(b) (i) When is $f : [a, b] \to \mathbb{R}$ said to be Darboux integrable on $[a, b]$?

[2]

(ii) Show that the following function is Darboux integrable on $[0, 2]$:

$$f(x) = \begin{cases} 1 & \text{if } x \neq 1 \\ 0 & \text{if } x = 1 \end{cases}$$

[7]

(c) Use Riemann sums to find the following limit:

$$\lim_{n\to\infty} \sum_{k=1}^{k=n} \frac{n}{4n^2 + k^2}$$

[6]

END!

The University of Zambia
School of Natural Sciences
Department of Mathematics and Statistics

2020/21 Academic Year Examinations

MAT 3401 Topology

November 19, 2021.

Duration: Three Hours

Instructions:

- Do not open this booklet until you are told to do so.
- This paper consists of six questions, each carry 20 marks. Attempt any FIVE questions. Total marks is 100.
- Show all the essential working to earn full marks.

---

1. (a) i. Let $f : X \to Y$ be a function of X into Y and let B be a subset of Y. Define the inverse image of B. (3)

ii. Given that (8)

$$f(x) = \frac{1}{x^2 - 9},$$

find $f([-1, 2])$, $f([5, 6])$, $f^{-1}((-\infty, -1])$ and $f^{-1}\left((-\frac{1}{9}, 0)\right)$.

(b) Let $f : X \to Y$ be a function of X into Y and let $\{X_i\}_{i \in I}$ be a collection of subsets of X. Prove that

i. (5)

$$f^{-1}\left(\bigcup_{i \in I} X_i\right) = \bigcup_{i \in I} f^{-1}(X_i).$$

ii. (4)

$$f^{-1}\left(\bigcap_{i \in I} X_i\right) = \bigcap_{i \in I} f^{-1}(X_i).$$

2. (a) i. Define a metric on a non-empty set X. (3)

ii. Show that (6)

$$d(x, y) = \max\{|x_1 - x_2|, |y_1 - y_2|\},$$

where $x = (x_1, y_1)$ and $y = (x_2, y_2)$, is a metric on $\mathbb{R}^2$.

iii. Show that (6)

$$d(x, y) = |x_1 - x_2| + |y_1 - y_2|,$$

where $x = (x_1, y_1)$ and $y = (x_2, y_2)$, is a metric on $\mathbb{R}^2$.

(b) Let d be a metric on a non-empty set X.

i. For what values of k is the function $d_1(x, y) = kd(x, y)$ a metric on X. (2)

ii. For what values of k is the function $d_2(x, y) = k + d(x, y)$ a metric on X. (3)

3. (a) i. Define an open set in a metric space. (3)

ii. Prove that in any metric space X, each open sphere is an open set. (4)

iii. Let X be a metric space. If $\{x\}$ is a subset of X consisting of a single point, show that its complement $\{x\}'$ is open. (5)

(b) i. In the metric space $(\mathbb{R}^2, d)$ where (4)

$$d(x, y) = |x_1 - x_2| + |y_1 - y_2|,$$

$x = (x_1, y_1)$ and $y = (x_2, y_2)$, describe the open sphere $S_1((0, 0))$.

ii. In the metric space $(\mathbb{R}^2, d)$ where (4)

$$d(x, y) = \max\{|x_1 - x_2|, |y_1 - y_2|\},$$

$x = (x_1, y_1)$ and $y = (x_2, y_2)$, describe the open sphere $S_1((0, 0))$.

4. (a) i. Define a closed set in a metric space. (3)

ii. Let X be a metric space. Define a limit point a subset A of X. (3)

iii. Let X be a metric space. Prove that a subset F of X is a closed set if and only if F it contains each of its limit points. (7)

(b) Determine if the following subsets of $\mathbb{R}^2$ with the usual metric are either open sets, closed sets or neither open nor closed sets. (7)

$$A = \{(x, y) \mid x = y\}$$

$$B = \{(x, y) \mid x^2 + y^2 = 1\}$$

$$C = \{(x, y) \mid x^2 + y^2 < 1\}$$

5. (a) i. Define a convergent sequence in a metric space X. (2)

ii. Prove that every convergent sequence in a metric space is a Cauchy sequence. (3)

iii. Let X and Y be metric spaces and f be a function of X into Y. Prove that f is continuous at a point $x_0 \in X$ if and only if for any sequence $\{a_n\}_{n\in\mathbb{N}}$ in X converging to x_0, we have that the sequence $\{f(x_n)\}$ converges to $f(x_0)$. (7)

(b) i. Define a continuous function from metric space X to metric space Y. (2)

ii. Let X and Y be metric spaces and f be a mapping of X into Y. Prove that f is continuous if and only if $f^{-1}(G)$ is open in X whenever G is open in Y. (6)

6. (a) i. Define a topology on a non-empty set X. (3)

ii. Let $X = \{a, b, c\}$. Show that (3)

$$\mathbf{T} = \{\emptyset, \{a\}, \{a, b\}, \{a, c\}, X\}$$

forms a topolgy on X.

(b) i. Define a neighbourhood of a point in a topological space X. (2)

ii. Let X be a topological space and A be an arbitrary subset of X. Prove that (8)

$$\overline{A} = \{x : \text{ each neighbourhood of } x \text{ intersects } A\}$$

iii. Let X be a topological space and let A and B be arbitrary subsets of X. Prove that (4)

$$\overline{A \cup B} = \overline{A} \cup \overline{B}.$$

End of Examination

The University of Zambia

School of Natural science

Department of Mathematics and Statistics

2021/21 Academic year Final examination

MAT 3601 Mathematical statistics

Time allowed Three (3) Hours

Instructions: (1) Answer any FIVE (5) Questions

(2) Show all essential workings

---

1. (a) An opinion poll is taken as to how an electorate will vote in a forthcoming referendum. Out of a random sample of 100, 40 say 'yes' and 60 say 'no'.

(i) What is the 95% confidence interval for the proportion of the population who will vote yes?

(ii) How large should the sample have been in (i) to reduce the error to less than 0.005.

(b) Let $X_1,\ldots,X_n$ be a random sample from a normal distribution with mean μ and variance 1. Find a sufficient statistic for the parameter μ.

2. (a) Suppose that $X_1, X_2,..,X_n$ are iid uniform $(0,\vartheta)$, where $\vartheta > 0$ is unknown. Suppose that we are interested in the following hypotheses:

$$H_o : 3 \le \vartheta \le 4$$

$$H_1 : \vartheta < 3 \text{ or } \vartheta > 4$$

(i) State the maximum likelihood estimate of ϑ

(ii) Find the power function $\pi(\vartheta|\delta)$

(b) Let X denote the IQ of a randomly selected adult Zambians. Assume, a bit unrealistically, that is normally distributed with unknown mean and standard deviation 16. Take a random sample of n = 16 students, so that, after setting the probability of committing a Type I error at $\alpha = 0.05$, we can test the null hypothesis $H_0 : \mu = 100$ against the alternative hypothesis that $H_1 : \mu > 100$.

What is the power of the hypothesis test if the true population mean were $\mu = 108$?

3. **(a)** The Brinell hardness scale is one of several definitions used in the field of materials science to quantify the hardness of a piece of metal. The Brinell hardness measurement of a certain type of rebar used for reinforcing concrete and masonry structures was assumed to be normally distributed with a standard deviation of 10 kilograms of force per square millimetre. Using a random sample of n = 25 bars, an engineer is interested in performing the following hypothesis test:

- $H_0 : \mu = 170$ versus
- $H_1 : \mu > 170$

If the engineer decides to reject the null hypothesis if the sample mean is 172 or greater, that is, if $\overline{X} \geq 172$.

(i) What is the probability that the engineer commits a Type I error?

(ii) If, unknown to engineer, the true population mean were $\mu = 173$, what is the probability that the engineer commits a Type II error?

(b) Suppose that a coin with unknown probability θ of landing heads is flipped n times, yielding results $X_1, ..., X_n$ (where we interpret heads as 1 and tails as 0).

Let $\hat{\theta} = \frac{1}{n}(x_1 + ... + x_n)$.

(i) Show that $\hat{\theta}$ is an unbiased estimator of θ.

(ii) Find the variance of $\hat{\theta}$.

(iii) Show that $\hat{\theta}$ has the minimum variance of all possible unbiased estimators of θ.

4. (a) (i) Suppose $Y \sim Bin(n,\theta)$ where θ the probability of success is. Show that $\hat{\theta} = \frac{Y}{n}$ is a consistent estimator of the population parameter θ.

(ii) The data are the same as in (a) but now σ^2 is no longer known. Thus, the parameter of unknowns' $\theta = (\mu, \sigma^2)$.Derive a Confidence Interval for $g(\theta) = \mu$.

(b) (i) Let a pdf be given as $f(x|x_o, \vartheta) = \vartheta x^{\vartheta}{}_o x^{-n-1}$, $x \geq x_o$, $x > 1$ assume that $x_o > 0$ is an iid sample. Find the Maximum Likelihood estimator of ϑ.

(ii) Consider a power function defined as $\pi(\mu, \sigma^2/\delta) = 1 - T_{n-1}(c|\Psi)$, where $c = T_{n-1}^{-1}(1-\alpha_0)$, (the $(1-\alpha_0)$-quantile) of the t-distribution with n-1 degrees of freedom. Write the properties of the power function $\pi(\mu, \sigma^2/\delta)$

5. (a) Outline the steps of conducting a hypotheses testing in research. Justify why each stage is important in solving a problem (s)?

(b) A food processing company packages honey in small glass jars. Each jar is supposed to contain 10 fluid grams of the sweet and gooey good stuff. Previous experience suggests that the volume *X*, the volume in fluid grams of a randomly selected jar of the company's honey is normally distributed with a known variance of 2. Derive the likelihood ratio test for testing, at a significance level of α=0.05, the null hypothesis $H_o : \mu = 10$ against the alternative Thus, you have: hypothesis $H_1 : \mu \neq 10$.

6. (a) Consider a radar system that uses radio waves to detect aircraft. The system receives a signal and, based on the received signal, it needs to decide whether an aircraft is present or not. Let X be the received signal. Suppose that we know

$X = W$, if no aircraft is present.

$X = 1 + W$, if an aircraft is present.

Where $W \sim N(0, \sigma^2 = \frac{1}{9})$. Thus, we can write $X = \theta + W$, where $\theta = 0$ if there is no aircraft, and $\theta = 1$ if there is an aircraft.

(i) Write the null hypothesis, H_0 , and the alternative hypothesis, H_1, in terms of possible values of θ

(ii) Design a level 0.05 test (α=0.05) to decide between H_0 and H_1

(iii) Find the probability of type II error, β, for the above test. Note that this is the probability of missing a present aircraft.

(iv) If we observe X=0.6, is there enough evidence to reject H_0 at significance level $\alpha = 0.01$?

(v) If we would like the probability of missing a present aircraft to be less than 5%, what is the smallest significance level that we can achieve?

(b) Let X_1, X_2, X_3, ..., X_n be a random sample of size n Zambian population from a pdf defined as:

$$f_X(x) = \begin{cases} 1 \text{ if male} \\ 0 \text{ if female} \end{cases}$$

Find the maximum likelihood estimators for P.

END of EXAMINATION

The University of Zambia

School of Natural Sciences

Department of Mathematics and Statistics

2020/21 Academic Year Final Examinations

MAT3622 - Linear Regression

Time allowed : 3 Hours

Instructions:

- There are **five (5)** questions in this examination paper. Attempt **any four (4)** questions. **All** questions carry **equal** marks.
- Indicate your **Computer Number** on all your answer booklets.
- You are required to show all **necessary** steps in your solutions.

*This paper consists of **4** pages of questions.*

---

1. (a) The table below presents data on compressive strength (x) and intrinsic permeability (y) of various concrete mixes and cures.

Strength	Permeability	Strength	Permeability
3.1	33.0	2.4	35.7
4.5	31.0	3.5	31.9
3.4	34.9	1.3	37.3
2.5	35.6	3.0	33.8
2.2	36.1	3.3	32.8
1.2	39.0	3.2	31.6
5.3	30.1	1.8	37.7
4.8	31.2		

(i) Plot the scatter diagram and the regression line. Does the regression function appear to have a good fit here?

(ii) Fit the regression model.

(iii) Interpret the meaning of the values of $\hat{\beta}_0$ and $\hat{\beta}_1$ calculated in part (ii).

(iv) Obtain an estimate of σ^2 and find the estimated standard errors of $\hat{\beta}_0$ and $\hat{\beta}_1$.

(v) Construct 95% confidence intervals for β_1 and β_0.

(vi) Use a t-test to test for significance of the intercept at $\alpha = 0.05$.

(vii) Construct the ANOVA table and test for significance of regression at $\alpha = 0.05$.

(b) (i) What is multicollinearity?

(ii) Give any five sources of multicollinearity.

2. (a) Suppose the experimenter postulates a model:

$$y_i = \beta_0 + \beta_1 x_i + \varepsilon_i; \quad (i = 1, 2, \ldots, n),$$

where $E(\varepsilon_i) = 0, \text{Var}(\varepsilon_i) = \sigma^2$, and ε_i's uncorrelated.

(i) Find the least squares estimators of the model parameters.

(ii) Prove that $Var(\varepsilon_1 - \bar{\varepsilon}) = \left(1 - \frac{1}{n}\right)\sigma^2$.

(iii) Show that $\sum_{i=1}^{n} \hat{y}_i e_i = 0$, where $\hat{y}_i$ is the fitted value of y_i from the model and e_i is the residual.

(iv) Find the variance of the slope $(\hat{\beta}_1)$ for the least-squares estimator found in part (i).

(v) Show that $Cov(\bar{y}, \hat{\beta}_1) = 0$.

(vi) Find the variance of $\hat{\beta}_0$ in the simplest form.

(vii) Prove that $E\left[\sum_{i=1}^{n}(y_i - \hat{y}_i)^2\right] = (n-2)\sigma^2$.

(b) Consider the multiple linear regression model $Y = X\beta + \varepsilon$, $\varepsilon \sim N(0, \sigma^2 I)$.

(i) Show that the residuals from a linear regression model can be expressed as $e = (I - H)\varepsilon$, where $H = X(X'X)^{-1}X'$ is the "hat" matrix.

(ii) Find $Var(e)$.

(iii) Show that $\text{COV}(\hat{\beta}, \hat{y}) = \sigma^2 X(X'X)^{-1}$.

(iv) Find $Var(\hat{y})$.

3. (a) The vapor pressure of water at various temperatures follows:

Observation #, i	1	2	3	4	5	6	7	8	9	10	11
Temperature (°K)	273	283	293	303	313	323	333	343	353	363	373
Vapour Pressure	4.6	9.2	17.5	31.8	55.3	92.5	149.4	233.7	355.1	525.8	760

(i) Draw a scatter diagram of these data. What type of relationship seems appropriate in relating y to x?

(ii) Fit a simple linear regression model to these data.

(iii) Test for significance of regression using $\alpha = 0.05$. What conclusions can you draw?

(iv) Plot the residuals from the simple linear regression model versus y_i. What do you conclude about model adequacy?

(v) The Clausis-Clapeyron relationship states that $\ln(Pv) \propto -\frac{1}{T}$, where Pv is the vapor pressure of water. Repeat parts (ii) and (iv), using an appropriate transformation.

(b) Consider the simple linear regression model $y = \beta_0 + \beta_1 x_i + \varepsilon_i$, with $E(\varepsilon_i) = 0, \text{Var}(\varepsilon_i) = \sigma^2$, and ε_i's uncorrelated.

(i) Calculate the variance of the mean response, $E(y|x_0) = \mu_{y|x_0} = \hat{\beta}_0 + \hat{\beta}_1 x_0$.

(ii) Calculate the variance of the predictor $\hat{y}_0$, where $\hat{y}_0 = \hat{\beta}_0 + \hat{\beta}_1 x_0$.

(iii) Show that $SS_{Res} = S_{yy} - \hat{\beta}_1 S_{xy}$

4. (a) Suppose that we want to fit the no-intercept model $y_i = \beta(x_i - \bar{x}) + \varepsilon_i$ using weighted least squares. Assume the errors are uncorrelated but have unequal variances.

(i) Find a general formula for the weighted least-squares estimator of β.

(ii) Find the variance of the weighted least-squares estimator in (i)?

(iii) Suppose that $Var(y_i) = k\sqrt{(x_i - \bar{x})}$ that is, the variance of y_i is proportional to the corresponding square root of centred x_i. Using the results of parts (i) and (ii), find the weighted least-squares estimator of β and the variance of this estimator.

(iv) Suppose that $Var(y_i) = k(x_i - \bar{x})^2$ that is, the variance of y_i is proportional to the square of the corresponding centred x_i. Using the results of parts (i) and (ii), find the weighted least-squares estimator of β and the variance of this estimator.

(b) The data in the table below give the percentage share of market of a particular brand of canned peaches (y_t) for the past 15 months and the relative selling price (x_t).

t	x_t	y_t	t	x_t	y_t
1	100	15.93	9	85	16.60
2	98	16.26	10	83	17.16
3	100	15.94	11	81	17.77
4	89	16.81	12	79	18.05
5	95	15.67	13	90	16.78
6	87	16.47	14	77	18.17
7	93	15.66	15	78	17.25
8	82	16.94			

(i) Fit a simple linear regression model to these data.

(ii) Plot the residuals versus time. Is there any indication of autocorrelation?

(iii) Use the Durbin-Watson test (at 0.05 level of significane) to determine if there is positive autocorrelation in the errors. What are your conclusions? Clearly stating the alternatives, decision rule, and conclusion.

(iv) Give four sources of autocorrelation.

5. (a) Consider a simple linear regression model with first-order autoregressive errors $y_t = \beta_0 + \beta_1 x_t + \varepsilon_t$ where $\varepsilon_t = \rho\varepsilon_{t-1} + a_t$.

(i) Define autocorrelation.

(ii) Show that $\varepsilon_t = \sum_{j=0}^{\infty} \rho^j a_{t-j}$.

(iii) Find $Var(\varepsilon_t)$.

(iv) Show that $Cov(\varepsilon_t, \varepsilon_{t+k}) = \frac{\rho^k \sigma_a^2}{1-\rho^2}$.

(v) Find the least squares estimate of ρ.

(b) An article in Biotechnology Progress (Vol. 17, 2001, pp. 366-368) reported an experiment to investigate and optimize nisin extraction in aqueous two-phase systems (ATPS). The nisin recovery was the dependent variable (y). The two regressor variables were concentration (%) of PEG 4000 (denoted as x_1) and concentration (%) of Na_2SO_4 (denoted as x_2).

x_1	x_2	y
13	11	62.8739
15	11	76.1328
13	13	87.4667
15	13	102.3236
14	12	76.1872
14	12	77.5287
14	12	76.7824
14	12	77.4381
14	12	78.7417

(i) Compute $\mathbf{X}'\mathbf{X}$ and $\mathbf{X}'\mathbf{Y}$.

(ii) $(\mathbf{X}'\mathbf{X})^{-1}$ for this problem is

$$(\mathbf{X}'\mathbf{X})^{-1} = \begin{bmatrix} \frac{766}{9} & -\frac{7}{2} & -3 \\ -\frac{7}{2} & \frac{1}{4} & 0 \\ -3 & 0 & \frac{1}{4} \end{bmatrix}.$$

Fit a multiple linear regression model to these data.

(iii) Test for the significance of β_1 and β_2 at 5% level.

(iv) Estimate σ^2 and the standard errors of the regression coefficients.

(v) Use the model to predict the nisin recovery when $x_1 = 14.5$ and $x_2 = 12.5$. Construct a 95% Prediction Interval.

(vi) Compute the mean responseof the nisin recovery when $x_1 = 14.5$ and $x_2 = 12.5$. Construct a 95% Confidence Interval.

END OF EXAM

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

DEPARTMENT OF MATHEMATICS AND STATISTICS

2021 ACADEMIC YEAR

Tuesday, November 22, 2021 (09:00-12:00)

MAT 3632-FUNDAMENTALS OF SURVIVAL ANALYSIS

FINAL EXAMINATION

TIME ALLOWED: Three (3) hours

INSTRUCTIONS TO THE CANDIDATE

1. **Attempt any four (4) questions**, beginning your answer to each question on a fresh page.
2. Full credit will only be given when necessary working is shown.
3. **Graph paper is NOT required for this paper**
4. In addition to the paper you should have available Actuarial Tables and your own electronic calculator

This examination paper consists of 8 printed pages, each printed on one side only.

The front cover is page 1.

Question 1 starts on page 2

QUESTION 1

(a) You are given that $\mu_{35+t} = (100 + t)^{-1}$. Calculate

(i) ${}_{10}p_{35}$. [2]

(ii) ${}_{20}q_{45}$. [2]

(iii) ${}_{10|20}q_{40}$. [2]

(b) (i) Mortality follows Makeham's law. You are given that $q_{55} = 0.01$, $q_{65} = 0.02$, and $q_{75} = 0.05$. Determine μ_{65}. [4]

(ii) You are given:

$$d_{48} = 80 \qquad l_{50} = 450 \qquad {}_{3|2}q_{45} = \frac{1}{6} \qquad {}_{3}p_{45} = \frac{2}{3}$$

Determine d_{49}. [6]

(c) Explain the difference between informative and non-informative censoring with suitable examples. [2]

(d) A group of 10 patients (K-T) suffering from cancer are being investigated for the effects of a new medicine. A group of another 10 patients (A-J) who have been administered an earlier medicine are also being observed. The details of these patients are given below.

New Medicine		
	Week of exit	Reason for exit
K	11	Death due to cancer
L	10	Went to village to spend rest of lifetime there
M	3	Committed suicide
N	8	Death due to heart attack
O	9	Discharged on family insistence
P	-	-
Q	7	Death due to heart attack
R	10	Death due to cancer
S	-	-
T	-	-

Old Medicine		
	Week of exit	Reason for exit
A	8	Death due to cancer
B	6	Death due to heart attack
C	5	Death due to cancer
D	-	-
E	6	Death due to cancer
F	9	Went abroad for further treatment
G	3	Death due to cancer
H	-	-
I	5	Death due to cancer
J	10	Was discharged for marriage of son and returned in 12th week.

(i) Calculate the Kaplan-Meier estimate of survival function for each of the above 2 treatments and comment on your results. [6]

(ii) A patient who was on the old medicine was administered the new medicine after 8 weeks on the old medicine. Find the probability of surviving for another 9 weeks on the new medicine. [1]

[Total: 25 marks]

QUESTION 2

(a) The mortality of a certain population is governed by the survival function

$$ {}_tp_0 = \left(\frac{w}{w-t}\right)^{-0.25}, 0 \le x \le \omega $$

where ω is the limiting age. Given that $\mu_{65} = \frac{1}{180}$, Calculate the value of e_{106}. [4 marks]

(b) Mortality of a group of lives is assumed to follow Gompertz' law with $\mu_{45} = 0.1968$ and $\mu_{55} = 0.5015$. Calculate $f_{50}(10)$. [4]

(c) The table below gives the data for a small sample of individuals with a heart condition in a hospital. It shows the time in months until death. Observations marked $*$ show that the said individuals either left the hospital or died due to a cause not related to the heart condition.

Males	5*	10	12*	14	15*	18*	19	
Females	1*	3	6	7*	9*	11*	16	20 *

The Cox proportional hazards model is to be used to model the rate at which these individuals die from the heart condition.

(i) Defining clearly all the terms you use, write down an expression for the hazard function in this model. [2]

(ii) Write down the general expression for the partial likelihood for such investigation. [1]

(iii) Derive an expression for the partial likelihood for the above data [4]

(iv) Calculate the maximum partial likelihood estimate of the parameter(s) involved. [4]

(v) We are subsequently able to generate the following additional data

Male 19, *Female* 8*

(vi) Write down the partial likelihood after including the additional data provided. [2]

(d) (i) State three different methods of graduating crude mortality data. [1]

(ii) Give, for each method, advantage(s) and disadvantage(s). [3]

[Total: 25 marks]

QUESTION 3

(a) (i) Explain precisely what is meant by ${}_{3|5}q_{50}$ [1]

(ii) Write down an integral expression for ${}_{3|5}q_{50}$ in terms of the hazard rates over the appropriate age range only. [2]

(i) Evaluate ${}_{3|5}q_{50}$ using the AM92 Ultimate mortality table. [1]

(b) You are given that $q_{75} = 0.06229$.

(ii) Calculate ${}_{0.25}p_{75}$ and ${}_{0.25}p_{75.75}$, assuming a uniform distribution of deaths between integer ages. [4]

(iii) Repeat part (iv), using the alternative assumption that a constant hazard rate applies between integer ages. [2]

(c) You are given the following survival function of a newborn:

$$ {}_tp_0 = \begin{cases} \dfrac{250 - t}{250}, & 0 \le t < 40 \\ \dfrac{10000 - t^2}{10000}, & 40 \le t \le 100 \end{cases} $$

(i) Calculate the probability that a person age 30 dies within the next 20 years. [3]

(ii) Calculate the probability that a person age 40 dies between ages 60 and 65. [2]

(d) An electronics company developed a revolutionary new battery which it believed would make it enormous profits. It commissioned a sub-contractor to estimate the survival function of battery life for the first 12 prototypes. The sub-contractor inserted each prototype battery into an identical electrical device at the same time and measured the duration elapsing between the time each device was switched on and the time its battery ran out. The sub-contractor was instructed to terminate the test immediately after the failure of the 8th battery, and to return all 12 batteries to the company.

When the test was complete, the sub-contractor reported that he had terminated the test after 150 days. He further reported that:

- two batteries had failed after 97 days
- three further batteries had failed after 120 days

- two further batteries had failed after 141 days
- one further battery had failed after 150 days

However, he reported that he was only able to return 11 batteries, as one had exploded after 110 days, and he had treated this battery as censored at that duration when working out the Kaplan-Meier estimate of the survival function.

(i) State, with reasons, the forms of censoring present in this study. [3]

(ii) Calculate the Kaplan-Meier estimate of the survival function based on the information supplied by the sub-contractor. [5]

In his report, the sub-contractor claimed that the Kaplan-Meier estimate of the survival function at the duration when the investigation was terminated was 0.2727.

(iii) Explain why the sub-contractor's Kaplan-Meier estimate would be consistent with him having stolen the battery he claimed had exploded. [2]

[Total: 25 marks]

QUESTION 4

(a) (i) List five key preparatory steps in a data analysis process prior to performing an exploratory analysis of the data. [2.5]

(ii) Describe the properties that can lead to data being classified as "big data". [4]

(iii) Describe four limitations of using models in actuarial work. [4]

(b) A mortality investigation was held between 1 January 2016 and 1 January 2018. The following information was collected. The figures in the table below are the numbers of lives on each census date with the specified age labels.

	Date		
Age last birthday	1/01/2016	1/01/2017	1/01/2018
48	3,684	3,354	3,204
49	3,450	3,705	3,435
50	3,610	3,595	3,740

During the investigation there were 45 deaths at age 49 nearest birthday. Estimate μ_{49} stating any assumptions that you make. [5]

(c) (i) State the principle of correspondence as it applies to the estimation of mortality rates. [1]

(ii) Explain why it might be difficult to ensure the principle of correspondence is adhered to, and give a specific example of an investigation where this may be the case. [1]

(d) As part of a medical experiment you observe a total of 1,000 mice, infected with a virus, for 1 month. Your hypothesis is that the hazard rate is 0.4. Calculate the following:

(i) The expected total waiting time. [3]

(ii) The expected number of deaths. [2]

You actually observe 32 deaths and a total waiting time of 78 hours.

(iii) Discuss whether or not your initial hypothesis appears valid. [2.5]

[Total: 25 marks]

QUESTION 5

(a) Describe three shortcomings of the Chi-square test for comparing crude estimates of mortality with a standard table and why they may occur. [3]

The following table gives an extract of data from a mortality investigation conducted in the rural highlands of a developed country. The raw data have been graduated by reference to a standard mortality table of assured lives.

Age x	*Expected deaths*	*Observed deaths*	z_x
60	36.15	35	−1.191
61	28.92	24	−0.915
62	31.34	27	−0.775
63	38.01	35	−0.488
64	26.88	32	0.988
65	37.59	36	−0.259
66	33.85	34	0.026
67	26.66	32	1.034
68	22.37	26	0.767
69	18.69	33	3.310
70	18.24	22	0.880

(b) For each of the three shortcomings you described in (a):

(i) name a test that would detect that shortcoming. [3]

(ii) carry out the test on the data above. Clearly state your conclusions. [12]

(c) Explain the importance of dividing the data for a mortality investigation into homogeneous classes. [2]

(d) You want to use a Cox regression model to estimate the force of mortality for a group of endowment assurance policyholders. You propose using a model that takes account of duration (*ie* the time that has elapsed since the policy was issued) and the age and sex of the policyholder. You start by investigating the model:

$$\lambda(x, Z_1, Z_2) = \lambda_0(x)e^{\beta Z_1 + \beta Z_2}$$

where:

x denotes the age of the policyholder

$$Z_1 = \begin{cases} 0, & if\ the\ duration\ is\ less\ than\ 1\ year \\ 1, & if\ the\ duration\ is\ at\ least\ 1\ year \end{cases}$$

$$Z_2 = \begin{cases} 0, & for\ males \\ 1, & for\ females \end{cases}$$

You have estimated the values of the parameters β_1 and β_2 , and have obtained the following results:

Covariate	*Parameter value*	*Standard error*
Duration	0.416	0.067
Sex	−0.030	0.017

(i) State the class of policyholders to which the baseline hazard refers. [1]

(ii) Explain whether the duration covariate is significant in determining mortality. [2]

(iii) Compare the force of mortality for a new female policyholder to that of a male policyholder of the same age, who took out a policy 2 years ago. [2]

[Total: 25 marks]

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

DEPARTMENT OF MATHEMATICS & STATISTICS

2020/2021 Academic Year
End of Year Final Examinations

23 November 2021 (am)

MAT3902 – Probability Theory

Time allowed : **Three (3) hours** Full marks : **100**

Instructions:
- There are **six (6)** questions in this paper. Attempt any **five (5)** questions.
- **All** questions carry **equal** marks. Mark allocations are shown in brackets.
- **Full credit** will only be given when **necessary work** is shown.
- Indicate your **computer number** on all answer booklets used.

Relevant statistical distributions and tables are attached.

---

1. (a) Suppose that X and Y are two independent, Exp(1)-distributed random variables.

Use the CDF technique to derive the probability density function of $Z = X + Y$. **(5)**

(b) Let X_1 and X_2 have joint probability density function

$$f(x_1, x_2) = \begin{cases} 4e^{-2(x_1+x_2)} & \text{for } 0 < x_1, x_2 < \infty, \\ 0 & \text{otherwise.} \end{cases}$$

(i) Use transformation methods to derive the joint pdf of $X = X_1/X_2$ and $Y = X_1$. **(4)**

(ii) Hence, or otherwise, find the marginal pdf of X. **(5)**

(c) Two actuaries are interested in combining Poisson distributions.

John states that the difference between two independent Poisson distributions has a Poisson distribution, i.e., if $X_1 \sim \text{Poi}(\lambda)$ and $X_2 \sim \text{Poi}(\mu)$ then $X_1 - X_2 \sim \text{Poi}(\lambda - \mu)$.

Mary states that the sum of two independent Poisson distributions has a Poisson distribution, i.e., if $X_1 \sim \text{Poi}(\lambda)$ and $X_2 \sim \text{Poi}(\mu)$ then $X_1 + X_2 \sim \text{Poi}(\lambda + \mu)$.

Use the method of moment generating functions to examine John and Mary's claims **(6)**

2. (a) Prove from first principles that

$$E(Y) = E\big[E(Y|X)\big]$$

given that X and Y are continuous random variables. **(3)**

(b) The random variable X has a gamma distribution with parameters $\alpha = 3$ and $\lambda = 2$ A related variable Y has conditional mean and variance of

$$E(Y|X = x) = 3x + 1 \quad \text{and} \quad \text{var}(Y|X = x) = 2x^2 + 5$$

(i) Calculate the unconditional mean of Y. **(2)**

(ii) Calculate the unconditional standard deviation of Y. **(4)**

(c) The joint density function of X and Y is given by

$$f_{X,Y}(x, y) = \begin{cases} cx & \text{for } x, y \geq 0, \quad x + y \leq 1, \\ 0 & \text{otherwise.} \end{cases}$$

(i) Compute the value of the constant c. **(3)**

(ii) Compute the conditional expectations $E(Y|X = x)$ and $E(X|Y = y)$. **(8)**

3. (a) Let $X_2, X_3, \ldots$ be independent random variables with common density

$$f(x) = \begin{cases} -n\left(1 - \frac{1}{n}\right)^{nx-1} & \text{if } x > 0,\ n \geq 2, \\ 0 & \text{otherwise.} \end{cases}$$

Show that X_n converges in distribution as $n \to \infty$, and find the limiting distribution. **(6)**

(b) The weak law of large numbers states that if $X_1, X_2, \ldots$ are independent, identically distributed random variables with finite mean $E(X_i) = \mu$, then

$$\frac{X_1 + \cdots + X_n}{n} \xrightarrow{p} \mu \quad \text{as } n \to \infty.$$

Use generating functions to prove this law. (Hint: $\left[M_X(t/n)\right]^n \to e^{tE(X)}$ as $n \to \infty$.) **(6)**

(c) Let $X_2, X_3, \ldots$ be independent random variables such that

$$P(X_n = 1) = 1 - \frac{1}{n} \quad \text{and} \quad P(X_n = n) = \frac{1}{n}, \quad n \geq 2$$

and, furthermore, independent of $X \sim N(0,1)$. Set $Y_n = XX_n$ for $n \geq 2$.

(i) Show that $X_n \xrightarrow{p} 1$ as $n \to \infty$. **(2)**

(ii) Show that $Y_n \xrightarrow{d} N(0,1)$ as $n \to \infty$. **(2)**

(iii) Show that $E(Y_n) = 0$ and $\text{var}(Y_n) = \infty$ as $n \to \infty$. **(4)**

4. (a) Let X be a Poisson random variable with mean λ so that its moment generating function is $M_X(t) = e^{\lambda(e^t - 1)}$. Use Chernoff bounds to show that for any $a > \lambda$,

$$P(X \geq a) \leq \frac{e^{-\lambda}(e\lambda)^a}{a^a} \qquad \textbf{(6)}$$

(b) Let X be a Poisson random variable with mean 20. Suppose that $p = P(X \geq 26)$.

(i) Use the Markov inequality to obtain an upper bound on p. **(2)**

(ii) Use the one-sided Chebyshev inequality to obtain an upper bound on p. **(2)**

(iii) Use the Chernoff bound to obtain an upper bound on p. (*Hint:* Use part (a).) **(2)**

(iv) Approximate p by making use of the central limit theorem. **(3)**

(c) Four out of every five trucks on the road are followed by a car, while one out of every six cars is followed by a truck.

Use Markov chains to find the proportion of vehicles on the road that are trucks? **(5)**

5. (a) In the following you may assume that the third and fourth moments of a random variable with distribution $N(0, \sigma^2)$ are 0 and $3\sigma^4$ respectively.

(i) Derive a formula for $E\left(X^2 e^{aX^2}\right)$ where $X \sim N(0, b)$, and a and b are constants. **(4)**

(ii) Let $F_t = \sigma(B_s, 0 \leq s \leq t)$ be a natural filtration of a random variable B_t such that $B_t - B_s \sim N(0, t-s)$ are independent increments. Derive the conditional expectations $E(B_t^2|F_s)$ and $E(B_t^4|F_s)$ for any $s \leq t$. (*Hint*: $B_t = B_s + B_t - B_s$) **(5)**

(b) Let B_t be a random variable such that $B_t - B_s \sim N(0, t-s)$ are independent increments, where $0 \leq s \leq t$. Show that for any arbitrary constant a,

$$X_t = (B_t - at)e^{aB_t - \frac{1}{2}a^2 t}$$

is a continuous-time martingale. You may assume that $E(|X_t|) < \infty$. **(6)**

(c) Let $S_n = X_1 + \cdots + X_n$, where the X_i are independent random variables such that

$$P(X_i = 1) = P(X_i = -1) = \frac{1}{2}$$

Show that $S_n^2 - n$ is a discrete-time martingale. **(5)**

6. (a) The random variable X has probability density function

$$f(x) = Ce^x, \quad 0 < x < 1.$$

(i) Find the value of the constant C. **(2)**

(ii) Use the inverse transformation method to present an approach for simulating such a random variable. **(6)**

(b) Give an algorithm to simulate a random variable having probability density function

$$f(x) = 30(x^2 - 2x^3 + x^4), \quad 0 < x < 1.$$

Hint: Use the acceptance–rejection method with $g(x) = 1, \quad 0 < x < 1$. **(6)**

(c) Let X and Y be independent exponential random variables with mean 1.

(i) Explain how we could use simulation to estimate $E(e^{XY})$. **(3)**

(ii) Show how to improve the estimation approach in (i) by using a control variate. **(3)**

END OF PAPER

SOME STATISTICAL DISTRIBUTIONS

Gamma distribution

Parameters: $\alpha > 0,\ \lambda > 0$

Probability density function: $f(x) = \dfrac{\lambda^\alpha}{\Gamma(\alpha)} x^{\alpha-1} e^{-\lambda x}, \qquad x > 0$

Moment generating function: $M_X(t) = E\left(e^{tX}\right) = \left(1 - \dfrac{t}{\lambda}\right)^{-\alpha}, \qquad t < \lambda$

Moments: $E(X) = \dfrac{\alpha}{\lambda}, \qquad \text{var}(X) = \dfrac{\alpha}{\lambda^2}$

Exponential distribution

Parameters: $\lambda > 0$

Probability density function: $f(x) = \lambda e^{-\lambda x}, \qquad x > 0$

Moment generating function: $M_X(t) = E\left(e^{tX}\right) = \left(1 - \dfrac{t}{\lambda}\right)^{-1}, \qquad t < \lambda$

Moments: $E(X) = \dfrac{1}{\lambda}, \qquad \text{var}(X) = \dfrac{1}{\lambda^2}$

Poisson distribution

Parameters: $\lambda > 0$

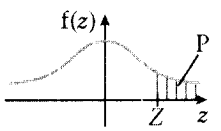
Probability mass function: $p(x) = \dfrac{e^{-\lambda}\lambda^x}{x!}, \qquad x = 0, 1, 2, \ldots$

Moment generating function: $M_X(t) = E\left(e^{tX}\right) = e^{\lambda(e^t - 1)}$

Moments: $E(X) = \lambda, \qquad \text{var}(X) = \lambda$

Percentage points of the normal distribution

The values z in the table are those which a random variable $Z \sim \text{N}(0,1)$ exceeds with probability p; that is, $\text{P}(Z > z) = p$.



p	z	p	z
0.5000	0.0000	0.0500	1.6449
0.4000	0.2533	0.0250	1.9600
0.3000	0.5244	0.0100	2.3263
0.2000	0.8416	0.0050	2.5758
0.1500	1.0364	0.0010	3.0902
0.1000	1.2816	0.0005	3.2905

STANDARD NORMAL DISTRIBUTION: Table Values Represent AREA to the LEFT of the Z score.

Z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
-3.9	.00005	.00005	.00004	.00004	.00004	.00004	.00004	.00004	.00003	.00003
-3.8	.00007	.00007	.00007	.00006	.00006	.00006	.00006	.00005	.00005	.00005
-3.7	.00011	.00010	.00010	.00010	.00009	.00009	.00008	.00008	.00008	.00008
-3.6	.00016	.00015	.00015	.00014	.00014	.00013	.00013	.00012	.00012	.00011
-3.5	.00023	.00022	.00022	.00021	.00020	.00019	.00019	.00018	.00017	.00017
-3.4	.00034	.00032	.00031	.00030	.00029	.00028	.00027	.00026	.00025	.00024
-3.3	.00048	.00047	.00045	.00043	.00042	.00040	.00039	.00038	.00036	.00035
-3.2	.00069	.00066	.00064	.00062	.00060	.00058	.00056	.00054	.00052	.00050
-3.1	.00097	.00094	.00090	.00087	.00084	.00082	.00079	.00076	.00074	.00071
-3.0	.00135	.00131	.00126	.00122	.00118	.00114	.00111	.00107	.00104	.00100
-2.9	.00187	.00181	.00175	.00169	.00164	.00159	.00154	.00149	.00144	.00139
-2.8	.00256	.00248	.00240	.00233	.00226	.00219	.00212	.00205	.00199	.00193
-2.7	.00347	.00336	.00326	.00317	.00307	.00298	.00289	.00280	.00272	.00264
-2.6	.00466	.00453	.00440	.00427	.00415	.00402	.00391	.00379	.00368	.00357
-2.5	.00621	.00604	.00587	.00570	.00554	.00539	.00523	.00508	.00494	.00480
-2.4	.00820	.00798	.00776	.00755	.00734	.00714	.00695	.00676	.00657	.00639
-2.3	.01072	.01044	.01017	.00990	.00964	.00939	.00914	.00889	.00866	.00842
-2.2	.01390	.01355	.01321	.01287	.01255	.01222	.01191	.01160	.01130	.01101
-2.1	.01786	.01743	.01700	.01659	.01618	.01578	.01539	.01500	.01463	.01426
-2.0	.02275	.02222	.02169	.02118	.02068	.02018	.01970	.01923	.01876	.01831
-1.9	.02872	.02807	.02743	.02680	.02619	.02559	.02500	.02442	.02385	.02330
-1.8	.03593	.03515	.03438	.03362	.03288	.03216	.03144	.03074	.03005	.02938
-1.7	.04457	.04363	.04272	.04182	.04093	.04006	.03920	.03836	.03754	.03673
-1.6	.05480	.05370	.05262	.05155	.05050	.04947	.04846	.04746	.04648	.04551
-1.5	.06681	.06552	.06426	.06301	.06178	.06057	.05938	.05821	.05705	.05592
-1.4	.08076	.07927	.07780	.07636	.07493	.07353	.07215	.07078	.06944	.06811
-1.3	.09680	.09510	.09342	.09176	.09012	.08851	.08691	.08534	.08379	.08226
-1.2	.11507	.11314	.11123	.10935	.10749	.10565	.10383	.10204	.10027	.09853
-1.1	.13567	.13350	.13136	.12924	.12714	.12507	.12302	.12100	.11900	.11702
-1.0	.15866	.15625	.15386	.15151	.14917	.14686	.14457	.14231	.14007	.13786
-0.9	.18406	.18141	.17879	.17619	.17361	.17106	.16853	.16602	.16354	.16109
-0.8	.21186	.20897	.20611	.20327	.20045	.19766	.19489	.19215	.18943	.18673
-0.7	.24196	.23885	.23576	.23270	.22965	.22663	.22363	.22065	.21770	.21476
-0.6	.27425	.27093	.26763	.26435	.26109	.25785	.25463	.25143	.24825	.24510
-0.5	.30854	.30503	.30153	.29806	.29460	.29116	.28774	.28434	.28096	.27760
-0.4	.34458	.34090	.33724	.33360	.32997	.32636	.32276	.31918	.31561	.31207
-0.3	.38209	.37828	.37448	.37070	.36693	.36317	.35942	.35569	.35197	.34827
-0.2	.42074	.41683	.41294	.40905	.40517	.40129	.39743	.39358	.38974	.38591
-0.1	.46017	.45620	.45224	.44828	.44433	.44038	.43644	.43251	.42858	.42465
-0.0	.50000	.49601	.49202	.48803	.48405	.48006	.47608	.47210	.46812	.46414

THE UNIVERSITY OF ZAMBIA

DEPARTMENT OF MATHEMATICS AND STATISTICS

2020/2021 ACADEMIC YEAR EXAMINATION

MAT4011 – OPERATIONAL RISK MANAGEMENT

19TH NOVEMBER 2021

Time Allowed: Three (3) hours

INSTRUCTIONS TO CANDIDATES

1. Answer ANY FOUR (4) Questions
2. Start the answer to each full question on a fresh page of the answer booklet.
3. Write neatly and legibly, showing ALL numbering and workings were necessary

REQUIREMENTS: NONE

Question One **[Total 25 Marks]**

(a) Give an acceptable definition of operational risk. [2 marks]

(b) Outline how operational risk may interact with any four other banking risks that may be made worse by OR. [4 marks]

(c) The failure of a large company in a neighbouring country has caused the regulator in Zambia to investigate potential sources of contagion.

(i) Explain why the regulator is concerned with contagion. [2 marks]

(ii) Describe two possible sources of systemic risk to the local banking sector. [2 marks]

(d) Using data in the next Table, determine the required operational risk capital charge for DTC bank under the following approaches.

(i) Basic indicator approach [3 marks]

(ii) Standardised approach [4 marks]

Business line	Beta (%)	Gross Income (in millions)		
		Year 1	Year 2	Year 3
Corporate Finance	18	255	300	200
Trading and Sales	18	100	-70	-80
Retail Banking	12	500	200	-300
Commercial Banking	15	400	300	420
Payments and Settlement	18	300	350	370
Agency Services	15	-75	-50	-40
Asset management	12	50	-100	-20
Retail Brokerage	12	150	100	200

(iii) Outline the requirements and detailed procedures in using advanced models such as the loss distribution (LDA) by DTC bank. [7 marks]

Question Two **[Total 25 Marks]**

(a) Outline Solvency II's mandatory 3 pillar framework. [11 marks]

(b) Describe the own risk solvency assessment process under Solvency II. [6 marks]

(c) Explain any four challenges of quantitative risk management [8 marks]

Question Three **[Total 25 Marks]**

(a) COSO (2017) defines ERM as the culture, capabilities, and practices, integrated with strategy-setting and its execution, that organizations rely on to manage risk in creating, preserving, and realizing value.'

Identify any six key words from this definition and outline how they aid to effective risk management. [9 marks]

(b) Describe the nature and elements of the bottom–up models approach in assessing operational risks. [7 marks]

(c) You are given information on a medium-sized general insurance company in the table below.

Year	Insurer C
2017	-
2018	900,000
2019	850,000
2020	1,200,000

You are given that:

Alpha = 15%

NL = 87,000 and

$ORCI = 2\%*\{\max(GP_1,NL) + \max(0, \left| GP_1 - GP_0 \right| - 0.2 * GP_0)\}$

Calculate the operational risk capital charge under the solvency II. Comment on your results. Define all notation used. [4 marks]

(d) Describe the types and roles of capital for a typical insurance company. [5 marks]

Question Four **[Total 25 Marks]**

(a) Give a summary outline of the reasons for the developments in bank regulation from Basel I to Basel III [9 marks]

(b) Discuss which of the three versions you adjudge to be the best for Zambia. [6 marks]

(c) Given the wide scope of operational risk, a company should employ a range of qualitative and Quantitative tools to assess, measure and manage operational risks.

(d) For a named non-financial company of your choice, present the key processes and requirements under the following specific ORM tools.

(i) Loss incidence database

(ii) Control self-assessment

(iii) Risk mapping

(iv) Key risk indicators [10 marks]

Question Five **[Total 25 Marks]**

(a) Describe the meaning and applications of each of the following terms for a credit portfolio of a typical banking institution in Zambia.

(i) Extreme value theory [3 marks]

(ii) credit default swap (CDS) [4 marks]

(iii) Scenario analysis [3 marks]

(b) The IFoA agrees with the Committee's view that the variability of modelling approaches adopted for AMA could exacerbate the variability of Risk-Weighted Asset (RWA) figures for operational risk. We believe, due to the idiosyncratic nature of operational risk, there will always be variability in the underlying operational risk exposures. These will vary in accordance with different business models and control frameworks. The operational risk exposure of a global private bank catering to high net worth clients will be different from a retail bank operating within one particular country. Naturally both of these different banking models will differ significantly from an investment bank.

(i) Prescribe a model risk management framework for the above case [5 marks]

(ii) Explain any two benefits of adopting a model risk management framework addressing the above concerns. [3 marks]

(c) The fixed price for bridge construction has not been reviewed in 5 years. It had been set using the average cost of previous bridge construction projects with a margin for profit and overhead expenses.

The CRO believes that some high costs may be caused by extreme events previously discussed with the CEO and suggests the fixed pricing for bridge construction be revised to include an allowance.

The table below shows the actual costs per km of the last 50 bridge construction projects:

Bridge	*Cost (A$)*	*Bridge*	*Cost (A$)*	*Bridge*	*Cost (A$)*	*Bridge*	*Cost (A$)*	*Bridge*	*Cost (A$)*
1	7,640	11	6,154	21	5,152	31	6,881	41	5,195
2	7,950	12	5,749	22	5,675	32	8,118	42	5,976
3	4,717	13	8,765	23	6,409	33	10,824	43	5,376
4	3,175	14	3,256	24	2,654	34	9,040	44	5,414
5	9,503	15	6,978	25	4,404	35	9,125	45	6,531
6	3,001	16	5,809	26	6,616	36	6,517	46	6,565
7	2,946	17	6,867	27	5,617	37	2,617	47	1,626
8	7,059	18	7,964	28	2,554	38	2,424	48	8,882
9	3,239	19	3,851	29	5,678	39	4,450	49	8,321
10	3,057	20	2,288	30	2,298	40	6,034	50	8,777

(i) Describe two possible approaches to fitting a distribution to the extreme values, using a different probability distribution for each. [4 marks]

(ii) Recommend, with reasons, which approach RBC should use to fit the distribution to the extreme values, including suggested values for the block size or hurdle. [3 marks]

******END OF EXAMINATION*****

The University of Zambia

School of Natural Sciences

Department of Mathematics and Statistics

2020-21 Academic Year

End of Year University Examinations

MAT4022: Pension Design and Valuation

Time: Three hours. [Maximum Marks : 100]

1. Attempt All questions. All questions carry equal marks.
2. Write clearly your computer number on each answer booklet.
3. Show all essential working

Some Useful Formulas:

Probabilities : Joint life and Last survivor

$$ {}_tp_{x:y} = {}_tp_x {}_tp_y \quad , \quad {}_tq_{x:y} = {}_tq_x + {}_tq_y - {}_tq_{\overline{x:y}} $$
$$ {}_tq_{\overline{x:y}} = {}_tq_x {}_tq_y \quad , \quad {}_tp_{\overline{x:y}} = {}_tp_x + {}_tp_y - {}_tp_{x:y} $$

Joint Assurances and annuities

$$ A_{\overline{x:y}} = A_x + A_y - A_{x:y} \quad , \quad \ddot{a}_{\overline{x:y}} = \ddot{a}_x + \ddot{a}_y - \ddot{a}_{x:y} $$

Contingent Assurances and Reversionary annuities

$$ A^1_{x:y} + A_{x:y}{}^1 = A_{x:y} \quad , \quad \ddot{a}_{x|y} = \ddot{a}_y - \ddot{a}_{x:y} \cong a_y - a_{x:y} = a_{x|y} $$

Independent and Dependent joint life functions

$$ (aq)^k_x = \frac{(ad)^k_x}{(al)_x} \quad , \quad (al)_{x+1} = (al)_x - (ad)^k_x - (ad)^{-k}_x $$
$$ (aq)^k_x = \frac{\mu^k_x}{\sum_j \mu^j_x}\left(1 - e^{\sum_j \mu^j_x}\right) = \int_0^1 {}_t(ap)_x (a\mu)^k_{x+t} dt $$
$$ q^k_x = \frac{(aq)^k_x}{1 - \frac{1}{2}(aq)^{-k}_x} \qquad \text{where } -k \text{ indicates the state not } k $$
$$ (aq)^k_x = q^k_x \left[1 - \frac{1}{2}\sum_{i\neq k} q^i_x + \frac{1}{3}\sum_{i\neq k}\sum_{i\neq j\neq k} q^i_x q^j_x + \cdots\cdots\right] $$

Funding methods

$$ \text{PUSCR} = \frac{\sum_j \frac{1}{A} \times S_j \times \left(\frac{1+e}{1+i}\right)^{R-x_j} \times a'_R}{\sum_j S_j \times a_{\overline{1}|@i'}} \quad , \quad \text{PUAL} = \sum_j \frac{P_j}{A} \times S_j \times \left(\frac{1+e}{1+i}\right)^{R-x_j} \times $$

$$ \text{CUSCR} = \frac{\sum_j \frac{1}{A} S_j (1+e) \times \left(\frac{1}{1+i}\right)^{R-x_j} \times a'_R + (\text{CUAL}_j \times e)}{\sum_j S_j \times a_{\overline{1}|@i'}} $$

$$ \text{CUAL} = \sum_j \frac{P_j}{A} \times S_j \times \left(\frac{1}{1+i}\right)^{R-x_j} \times a'_R $$

QUESTION ONE

(a) Stae the pros and cons of offering a lump sum on retirement. [3]

(b) You are an actuary advising the senior management of an investment bank in setting up a new DC scheme for new employees instead of the current DB pension scheme. Set out the various design issues you will discuss with your client before preparing the report. [7]

(c) A company wants to set up a defined benefits pension scheme for its works employees. Members will be expected to contribute 5% of their pensionable earnings. Employees' earnings fluctuate significantly from year to year. There are 3 ways in which the scheme would structure the defined benefits to to accommodate the fluctuating earnings.These are: revalued career average, pensionable earnings and defined benefit + money purchase.

(i) Describe how they three different ways operate and how they accommodate the fluctuating earnings. [5]

(ii) List the advantages and disadvantages of each of the three ways. [5]

[Total 20 marks]

QUESTION TWO

(a) Write down an alternative expression for each of the following statements using Actuarial notation.

(i) Probability[maximum $\{ T_x , T_y \} \leq n$] [1]

(ii) $E[g(K_x)]$ where $g(K_x) = v^{K_x+1}$ for $K_x < n$ and 0 for $K_x \geq n$ [1]

(iii) Probability $\{ n < T_x \leq m \}$ [1]

(iv) $lim_{dt \to 0} \frac{1}{dt}$Probability[minimum $\{T_x , T_y\} \leq t + dt | T_x > t, T_y > t$] [1]

(v) $E[a_{\overline{\text{minimum}(n1,K_x)}|} + 1]$ [1]

[Total 5]

(b) Use the Pension Scheme tables to calculate probability of staying in active service from age 35 to 53, [3]

(c) A certain population is subject to three modes of decrement: α, β and γ.

(i) Write down an expression for $(aq)_x^{\alpha}$ in terms of the single decrement table probabilities q_x^{α}, q_x^{γ} and q_x^{β}, assuming each of the three modes of decrement is uniformly distributed over the year of age x to $x+1$ in the corresponding single decrement table. [2]

(ii) Suppose now that in the single decrement table α, ${}_tp_x^{\alpha} = 1 - t^2 q_x^{\alpha}$t $(0 \leq t \leq 1)$, while decrements β and γ remain uniformly distributed. Derive a revised expression for $(aq)_x^{\alpha}$ in terms of the single decrement table probabilities q_x^{α}, q_x^{γ} and q_x^{β} [5]

(d) Active members of a pension scheme are subject to three decrements; withdrawal, ill-health retirement and death. Calculate the probability of an active member currently aged 35 remaining an active member of the pension scheme for the next two years. State any assumptions you make into addition to the following single decrement rates:

- mortality rates in line with AM92 Ultimate,
- ill-health retirement rates are 0.001 pa,
- withdrawal rates are 0.05 pa.

[5 marks]

[Total 20 marks]

QUESTION THREE

(a) A special policy on two lives aged x and y respectively provides cash sums of K10,000 and K20,000 immediately on the death of the first and second lives respectively. In addition, an annuity at the rate of K1,000 per annum will be paid continuously, commencing immediately on the first death and ceasing on the second death. Show that the mean present value of the benefit in terms of single and joint life functions and the force of interest is

$$20,000\left(\bar{A}_x + \bar{A}_y\right) - 10,000\bar{A}_{x:y} + 1000\left(\bar{a}_x + \bar{a}_y - 2\bar{a}_{x:y}\right)$$

[5]

(b) In order to value the benefits in a final salary pension scheme as at 1 January 2020, a salary scale, s_x, has been defined so that $\frac{s_{x+t}}{s_x}$ is the ratio of a member's total earnings between ages $x+t$ and $x+t+1$ to the member's total earnings between ages x and $x+1$. Salary increases take place on 1 July every year. One member, whose date of birth is 1 April 1973, has an annual salary rate of K75,000 on the valuation date.

Write an expression for the member's expected earnings during 2020. [3]

(c) The table extract below shows the death statistics in a population due to cancer and other causes.

Age (x)	Population $(al)_x$	Cancer $(ad)^c_x$	Others $(ad)^o_x$
61	10,000	55	248
62	9,697	175	533
63	8,989		

Recent changes have resulted in an estimate that the annual independent cancer death rate is reduced by 20% than that previously used.
Calculate a revised table assuming no changes to the other independent death rates.

(i) Calculate dependent rates $\left[(aq)^k_x\right]$ from the information given. [2]

(ii) Calculate approximate independent rates $\left[q^k_x\right]$ [3]

(iii) Make the necessary adjustment given and calculate approximate dependent rates $\left[(aq)^k_x\right]$ from the adjusted indepndent rates. [4]

(iv) Reconstruct the Revised Table. [3]

[Total 20 Marks]

QUESTION FOUR

(a) Assuming that the AM92 life table is appropriate for both lives and that the survival of each is independent. Calculate

(i) ${}_3p_{62:65}$, [2]

(ii) ${}_2p_{\overline{45:47}}$ [3]

(b) Consider a 10-year unit linked endowment assurance, which provides a minimum guaranteed sum assured, K100,000, on death during the 10-year term. Imagine the policyholder pays at the start of each year a premium of K9,000, of which K120 p.a. is charged for the guaranteed life cover and an additional 2% is used to meet expenses relating to the policy.

Imagine the unit price on a bid basis is K1.56, and there is a fixed 3% bid/offer spread.

At the end of the year, a 0.5% management fee is charged. The unit price on a bid basis is K1.75.

Calculate the bid value of the unit account just prior to the second year's premium payment.

(c) An amount of K300,000 is to be divided between the surviors of the three males aged 30, 35 and 40 in 20 years time. Find the expected values of the amount recieved by (40). Use AM92 Ultimate and 4% interest. [10]

QUESTION FIVE

(a) State the standard contribution rate for the four funding methods. [6]

(b) Using the following assumptions and data:

* the discount rate ($i = 13\%$pa);
* the rate at which earnings grow ($e = 10\%$pa);
* the age at which members retire from the scheme ($R = 55$);
* the age at which members enter the scheme (entry age $E = 25$); and
* the accrual rate is 75ths, and
* the value of annuity payable from age R (allowing for any contigent, spouse's pension or pension increases) is $a'_R = 15$
* Assume that salaries are payable at the end of each month in each year.

(ignore all pre-retirement decrements).

(i) Calculate the Standared contribution rate and the Actuarial Liability for a scheme that contains only these three members under the Projected Unit method and Current Unit method and comment on your results.

- 20 year old, no past service, salary K120,000pa
- 40 year old, 15 years past service, salary K100,000
- 50 year old, 25 years past service, salary K300,000

(Note: the formulea are provide on page 2) [14]

[Total 20 marks]

======END OF MAT4022 EXAMINATION ======

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

DEPARTMENT OF MATHEMATICS & STATISTICS

2020/2021 Academic Year
End of Year Final Examinations

18 November 2021 (am)

MAT4032 – Financial Engineering

Time allowed : **Three (3) hours** Full marks : **100**

Instructions:
- There are **six (6)** questions in this paper. Attempt **any five (5)** questions
- **All** questions carry **equal** marks. Mark allocations are shown in brackets.
- **Full credit** will only be given when **necessary work** is shown.
- Indicate your **computer number** on all answer booklets used.

This paper consists of 5 pages of questions..

---

1. (a) In the following you may assume that the third and fourth moments of a random variable with distribution $N(0, \sigma^2)$ are 0 and $3\sigma^4$ respectively.

   (i) Derive a formula for $E\left(X^2 e^{aX^2}\right)$ where $X \sim N(0, b)$, and a and b are constants. **(3)**

   (ii) Let $F_t = \sigma(B_s, 0 \leq s \leq t)$ be a natural filtration of a random variable B_t such that $B_t - B_s \sim N(0, t-s)$ are independent increments. Derive the conditional expectations $E(B_t^2|F_s)$ and $E(B_t^4|F_s)$ for any $s \leq t$. (*Hint*: $B_t = B_s + B_t - B_s$) **(5)**

   (b) Let B_t be a standard Brownian motion, and let $F_t = \sigma(B_s, 0 \leq s \leq t)$ be its natural filtration. Show that for any arbitrary constant a, the process

$$X_t = (B_t - at)e^{aB_t - \frac{1}{2}a^2 t}$$

   is a martingale with respect to F_t. You may assume that $E(|X_t|) < \infty$. **(6)**

(c) The price S_t of non-dividend paying shares is governed by the differential equation

$$\mathrm{d}S_t = S_t(\mu\,\mathrm{d}t + \sigma\,\mathrm{d}B_t)$$

where $\mu = 10\%$, $\sigma = 20\%$ and $S_0 = 1$. Derive the distribution of S_t, and hence calculate the amount that should be invested in the shares to give a 40% probability of having savings of at least K650,000 in 5 years' time. **(6)**

2. (a) Consider a trading position which involves

- A short position in a call option with a strike price $K = 85$ and price $c = 12$.
- A short position in a put option with a strike price $K = 85$ and price $p = 12$.

Both options have the same underlying stock and the same expiration date. Find and draw the payoff diagram for this position as a function of S_T. **(4)**

(b) A stock market includes four options set out below. All the options are for a term of 7 years and relate to a single non-dividend paying stock, currently priced at K60.

	Type	*Strike price*	*Option price*
Option A	European Call	K90	K5
Option B	European Put	K90	?
Option C	European Put	K100	?
Option D	American Put	K100	?

The continuously compounded risk-free rate is 4% per annum.

(i) Calculate the price of Option B. **(2)**

(ii) Determine lower and upper bounds for the price of option C. **(3)**

(iii) Determine lower and upper bounds for the price of option D. **(3)**

(c) Consider a 30-day, at-the-money call option on a non-dividend-paying share currently valued at K100 pa. The volatility of the share is 24% and the continuously compounded risk-free rate of interest is 4% pa.

The outputs of a computer model used to value the option are:

Option value	K7.12	Theta	−K0.0514/day
Delta	0.1202	Vega	K0.182/%
Gamma	K0.001032	Rho	K0.049/%

(i) After one day the share price increases by K9, volatility becomes 27% pa and the risk-free rate moves to 3.5% pa. Estimate the new price of the option. **(5)**

(ii) Explain why a low value of gamma is desirable when using options in a delta-hedged portfolio. **(3)**

3. (a) The process S_t is defined by

$$S_t = S_0 \exp\left\{(\alpha - \frac{1}{2}\sigma^2)t + \sigma Z_t\right\},$$

where $Z_t \sim N(0,t)$ under a probability measure P, and α and σ are constants.

(i) State how the Cameron–Martin–Girsanov theorem could be applied here if we wished to work with a process of the form

$$S_t = S_0 \exp\left\{(r - \frac{1}{2}\sigma^2)t + \sigma \tilde{Z}_t\right\},$$

where $\tilde{Z}_t \sim N(0,t)$ under a probability measure Q and r is the risk-free rate. **(4)**

(ii) Determine the stochastic differential equation for S_t in terms of $\mathrm{d}t$ and $\mathrm{d}\tilde{Z}_t$. **(6)**

(iii) State the drift of the process in part (ii) and comment on your answer. **(2)**

(b) A company has decided to provide managers with a performance bonus scheme. The scheme entitles the managers to a cash payment of K165,000 should the company share price have increased by more than 15% at the end of the next 9 months. In addition, the managers will be entitled to 300 free shares each, should the share price have increased by more than 12% at the end of the next 9 months.

You are given the following data:

Current share price	K83.70
Continuously-compounded risk-free rate	8% pa
Share price volatility	19% pa
No dividends to be paid over the next 9 months.	

By considering the terms of the Black-Scholes call option pricing formula, calculate the value of the bonus scheme to one manager. **(6)**

(c) Describe two limitations of the Black-Scholes model of option prices. **(2)**

4. (a) Explain what is meant by a "risk-neutral probability measure" and state mathematically what it implies about the pricing of derivatives relative to the price of the underlying asset. **(2)**

(b) Show that in a one-step binomial tree model of the price of a non-dividend-paying share, the risk-neutral probability q of an up movement is given by

$$q = \frac{e^{r\delta t} - d}{u - d}$$

where d , u , r and δt are quantities you should define. **(5)**

(c) A company share price is to be modelled using a 6-step recombining binomial tree, with each step representing one day. Each day, it is assumed that the share price

- increases by 3%, or
- decreases by 5%

You may assume that the force of interest is $\delta = 4\%$ pa and that there are 365 days in a year. No dividends are to be paid over the next six days.

(i) Calculate the risk-neutral probability of an up-step on any given day. **(2)**

(ii) Calculate the fair price of a 6-day at-the-money call option on K450,000 worth of shares in this company. **(5)**

(iii) A special option is available where the payoff after 6 days is given by

$$\max\left\{S_6^* - K, 0\right\},$$

where S_6^* is the arithmetic average share price recorded at the end of each of the 6 days and K is the strike price. Calculate the fair price of a 6-day special option (strike price $K = 1.1S_0$) on K450,000 worth of shares in this company. **(4)**

(iv) Explain whether the at-the-money option in part (ii) is likely to have a higher value of vega than the special option in part (iii). **(2)**

5. (a) Describe the two-state model for credit defaults. **(3)**

(b) Company A's bond is modelled according to a two-state model. Company A has zero-coupon bond in issue, with a recovery rate of $\delta = 60\%$. The bond matures in one year's time. The bond has a continuously compounded credit spread of 4%. The continuously compounded risk-free rate is 1.5% p.a.

(i) Calculate the price per K100 nominal of the bond in one year. **(2)**

(ii) Deduce the implied risk-neutral probabilities of no default in one year and in two years' time. **(3)**

(iii) Determine the implied value of the default intensity, assuming that it is constant for one year. **(2)**

(c) If $A(t)$ is a strictly positive supermartingale, then zero-coupon bond prices can be modelled using the formula $B(t,T) = \dfrac{E_P\left[A(T)|F_t\right]}{A(t)}$, where P is a suitably-chosen probability measure

(i) Express mathematically the fact that $A(t)$ is a strictly positive supermartingale. **(2)**

(ii) Verify that the function $A(t) = e^{-0.05t+0.02W_t}$, where W_t denotes standard Brownian motion, satisfies the properties in part (i). **(2)**

(iii) State why the supermartingale property is required. **(1)**

(iv) Write down the name given to this type of process. **(1)**

(v) By writing $A(t)$ in the form $A(t) = e^{X(t)}$, or otherwise, show that $A(t)$ satisfies a stochastic differential equation of the form

$$\mathrm{d}A(t) = A(t)\big[\mu_A(t)\,\mathrm{d}t + \sigma_A(t)\,\mathrm{d}W(t)\big]$$

State the forms of the functions $\mu_A(t)$ and $\sigma_A(t)$. **(4)**

6. (a) Consider the following model for the short-rate r:

$$\mathrm{d}r_t = \mu r_t\,\mathrm{d}t + \sigma\,\mathrm{d}Z_t$$

where μ and σ are fixed parameters and Z is a standard Brownian motion.

Comment on the suitability of this model for the short-rate. **(4)**

(b) An alternative model for the short-rate is the Vasicek model

$$\mathrm{d}r_t = \alpha(\mu - r_t)\,\mathrm{d}t + \sigma\,\mathrm{d}Z_t$$

(i) Derive an expression for r_t. **(6)**

(ii) State the distribution of r_t. **(1)**

(c) An analyst is using a two-state continuous-time model to study the credit risk of zero coupon bonds issued by different companies. The risk-neutral transition intensity function is

- $\lambda_A(s) = 0.0148$ for Company A, and
- $\lambda_B(s) = 0.01s^2$ for Company B where s measures time in years from now.

It was observed that the credit spread on a 3-year zero-coupon bond just issued by Company B is twice that on a 3-year zero-coupon bond just issued by Company A.

(i) Given that the risk-free force of interest is 5% pa, and that the average recovery rate in the event of default, δ, where $0 < \delta < 1$, is the same for both companies, calculate δ. **(7)**

(ii) Explain how the two-state model for credit risk can be generalised to give the Jarrow- Lando-Turnbull model. **(2)**

End of Paper

STANDARD NORMAL DISTRIBUTION: Table Values Represent AREA to the LEFT of the Z score.

Z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
-3.9	.00005	.00005	.00004	.00004	.00004	.00004	.00004	.00004	.00003	.00003
-3.8	.00007	.00007	.00007	.00006	.00006	.00006	.00006	.00005	.00005	.00005
-3.7	.00011	.00010	.00010	.00010	.00009	.00009	.00008	.00008	.00008	.00008
-3.6	.00016	.00015	.00015	.00014	.00014	.00013	.00013	.00012	.00012	.00011
-3.5	.00023	.00022	.00022	.00021	.00020	.00019	.00019	.00018	.00017	.00017
-3.4	.00034	.00032	.00031	.00030	.00029	.00028	.00027	.00026	.00025	.00024
-3.3	.00048	.00047	.00045	.00043	.00042	.00040	.00039	.00038	.00036	.00035
-3.2	.00069	.00066	.00064	.00062	.00060	.00058	.00056	.00054	.00052	.00050
-3.1	.00097	.00094	.00090	.00087	.00084	.00082	.00079	.00076	.00074	.00071
-3.0	.00135	.00131	.00126	.00122	.00118	.00114	.00111	.00107	.00104	.00100
-2.9	.00187	.00181	.00175	.00169	.00164	.00159	.00154	.00149	.00144	.00139
-2.8	.00256	.00248	.00240	.00233	.00226	.00219	.00212	.00205	.00199	.00193
-2.7	.00347	.00336	.00326	.00317	.00307	.00298	.00289	.00280	.00272	.00264
-2.6	.00466	.00453	.00440	.00427	.00415	.00402	.00391	.00379	.00368	.00357
-2.5	.00621	.00604	.00587	.00570	.00554	.00539	.00523	.00508	.00494	.00480
-2.4	.00820	.00798	.00776	.00755	.00734	.00714	.00695	.00676	.00657	.00639
-2.3	.01072	.01044	.01017	.00990	.00964	.00939	.00914	.00889	.00866	.00842
-2.2	.01390	.01355	.01321	.01287	.01255	.01222	.01191	.01160	.01130	.01101
-2.1	.01786	.01743	.01700	.01659	.01618	.01578	.01539	.01500	.01463	.01426
-2.0	.02275	.02222	.02169	.02118	.02068	.02018	.01970	.01923	.01876	.01831
-1.9	.02872	.02807	.02743	.02680	.02619	.02559	.02500	.02442	.02385	.02330
-1.8	.03593	.03515	.03438	.03362	.03288	.03216	.03144	.03074	.03005	.02938
-1.7	.04457	.04363	.04272	.04182	.04093	.04006	.03920	.03836	.03754	.03673
-1.6	.05480	.05370	.05262	.05155	.05050	.04947	.04846	.04746	.04648	.04551
-1.5	.06681	.06552	.06426	.06301	.06178	.06057	.05938	.05821	.05705	.05592
-1.4	.08076	.07927	.07780	.07636	.07493	.07353	.07215	.07078	.06944	.06811
-1.3	.09680	.09510	.09342	.09176	.09012	.08851	.08691	.08534	.08379	.08226
-1.2	.11507	.11314	.11123	.10935	.10749	.10565	.10383	.10204	.10027	.09853
-1.1	.13567	.13350	.13136	.12924	.12714	.12507	.12302	.12100	.11900	.11702
-1.0	.15866	.15625	.15386	.15151	.14917	.14686	.14457	.14231	.14007	.13786
-0.9	.18406	.18141	.17879	.17619	.17361	.17106	.16853	.16602	.16354	.16109
-0.8	.21186	.20897	.20611	.20327	.20045	.19766	.19489	.19215	.18943	.18673
-0.7	.24196	.23885	.23576	.23270	.22965	.22663	.22363	.22065	.21770	.21476
-0.6	.27425	.27093	.26763	.26435	.26109	.25785	.25463	.25143	.24825	.24510
-0.5	.30854	.30503	.30153	.29806	.29460	.29116	.28774	.28434	.28096	.27760
-0.4	.34458	.34090	.33724	.33360	.32997	.32636	.32276	.31918	.31561	.31207
-0.3	.38209	.37828	.37448	.37070	.36693	.36317	.35942	.35569	.35197	.34827
-0.2	.42074	.41683	.41294	.40905	.40517	.40129	.39743	.39358	.38974	.38591
-0.1	.46017	.45620	.45224	.44828	.44433	.44038	.43644	.43251	.42858	.42465
-0.0	.50000	.49601	.49202	.48803	.48405	.48006	.47608	.47210	.46812	.46414

STANDARD NORMAL DISTRIBUTION: Table Values Represent AREA to the LEFT of the Z score.

Z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0.0	.50000	.50399	.50798	.51197	.51595	.51994	.52392	.52790	.53188	.53586
0.1	.53983	.54380	.54776	.55172	.55567	.55962	.56356	.56749	.57142	.57535
0.2	.57926	.58317	.58706	.59095	.59483	.59871	.60257	.60642	.61026	.61409
0.3	.61791	.62172	.62552	.62930	.63307	.63683	.64058	.64431	.64803	.65173
0.4	.65542	.65910	.66276	.66640	.67003	.67364	.67724	.68082	.68439	.68793
0.5	.69146	.69497	.69847	.70194	.70540	.70884	.71226	.71566	.71904	.72240
0.6	.72575	.72907	.73237	.73565	.73891	.74215	.74537	.74857	.75175	.75490
0.7	.75804	.76115	.76424	.76730	.77035	.77337	.77637	.77935	.78230	.78524
0.8	.78814	.79103	.79389	.79673	.79955	.80234	.80511	.80785	.81057	.81327
0.9	.81594	.81859	.82121	.82381	.82639	.82894	.83147	.83398	.83646	.83891
1.0	.84134	.84375	.84614	.84849	.85083	.85314	.85543	.85769	.85993	.86214
1.1	.86433	.86650	.86864	.87076	.87286	.87493	.87698	.87900	.88100	.88298
1.2	.88493	.88686	.88877	.89065	.89251	.89435	.89617	.89796	.89973	.90147
1.3	.90320	.90490	.90658	.90824	.90988	.91149	.91309	.91466	.91621	.91774
1.4	.91924	.92073	.92220	.92364	.92507	.92647	.92785	.92922	.93056	.93189
1.5	.93319	.93448	.93574	.93699	.93822	.93943	.94062	.94179	.94295	.94408
1.6	.94520	.94630	.94738	.94845	.94950	.95053	.95154	.95254	.95352	.95449
1.7	.95543	.95637	.95728	.95818	.95907	.95994	.96080	.96164	.96246	.96327
1.8	.96407	.96485	.96562	.96638	.96712	.96784	.96856	.96926	.96995	.97062
1.9	.97128	.97193	.97257	.97320	.97381	.97441	.97500	.97558	.97615	.97670
2.0	.97725	.97778	.97831	.97882	.97932	.97982	.98030	.98077	.98124	.98169
2.1	.98214	.98257	.98300	.98341	.98382	.98422	.98461	.98500	.98537	.98574
2.2	.98610	.98645	.98679	.98713	.98745	.98778	.98809	.98840	.98870	.98899
2.3	.98928	.98956	.98983	.99010	.99036	.99061	.99086	.99111	.99134	.99158
2.4	.99180	.99202	.99224	.99245	.99266	.99286	.99305	.99324	.99343	.99361
2.5	.99379	.99396	.99413	.99430	.99446	.99461	.99477	.99492	.99506	.99520
2.6	.99534	.99547	.99560	.99573	.99585	.99598	.99609	.99621	.99632	.99643
2.7	.99653	.99664	.99674	.99683	.99693	.99702	.99711	.99720	.99728	.99736
2.8	.99744	.99752	.99760	.99767	.99774	.99781	.99788	.99795	.99801	.99807
2.9	.99813	.99819	.99825	.99831	.99836	.99841	.99846	.99851	.99856	.99861
3.0	.99865	.99869	.99874	.99878	.99882	.99886	.99889	.99893	.99896	.99900
3.1	.99903	.99906	.99910	.99913	.99916	.99918	.99921	.99924	.99926	.99929
3.2	.99931	.99934	.99936	.99938	.99940	.99942	.99944	.99946	.99948	.99950
3.3	.99952	.99953	.99955	.99957	.99958	.99960	.99961	.99962	.99964	.99965
3.4	.99966	.99968	.99969	.99970	.99971	.99972	.99973	.99974	.99975	.99976
3.5	.99977	.99978	.99978	.99979	.99980	.99981	.99981	.99982	.99983	.99983
3.6	.99984	.99985	.99985	.99986	.99986	.99987	.99987	.99988	.99988	.99989
3.7	.99989	.99990	.99990	.99990	.99991	.99991	.99992	.99992	.99992	.99992
3.8	.99993	.99993	.99993	.99994	.99994	.99994	.99994	.99995	.99995	.99995
3.9	.99995	.99995	.99996	.99996	.99996	.99996	.99996	.99996	.99997	.99997

The University of Zambia
School of Natural Sciences
Department of Mathematics & Statistics
2020/2021 Final Examination - 22nd November, 2021
MAT 4100 - Complex Variables

Time allowed : Three (3) hrs | Full marks : 100

Instructions:

- Indicate your **computer number** on all answer booklets.
- Attempt **any (5) five** questions. All questions carry equal marks.
- **Full credit** will only be given when **necessary work** is shown.

This paper consists of 4 pages of questions.

---

1. **(a)** Reduce the quantity

$$\frac{5i}{(1-i)(2-i)(3-i)}$$

to a real number. [4]

(b) Sketch the curve in the complex plane given by

$$|z-1| = |z+i|,$$

where $z = x + iy$. [5]

Turn Over/...

(c) (i) Use the exponential form of a complex number to compute

$$(1+\sqrt{3}i)^{2011}.$$

[5]

(ii) Find the four roots of the polynomial z^4+16. [2]

(iii) Use the roots you found in part (ii) above to factor z^4+16 into two quadratic polynomials with real coefficients. [4]

2. **(a)** (i) Show that

$$|\sin z|^2 = (\sin x)^2 + (\sinh y)^2$$

for any complex number $z = x+iy$. [5]

(ii) Show that

$$\tan(z_1+z_2) = \frac{\tan z_1 + \tan z_2}{1-(\tan z_1)(\tan z_2)}$$

for all complex numbers z_1 and z_2 satisfying $z_1, z_2, z_1+z_2 = n\pi + \frac{\pi}{2}$ for any integer n. [6]

(b) Find all the complex roots of the equation $\cos z = 3$. [4]

(c) Compute $\cos\left(\frac{\pi}{3}+i\right)$. [5]

3. **(a)** (i) Show that $\lim_{z\to 0}\frac{z}{\bar{z}}$ does not exist. [4]

(ii) Compute the following limit if it exits

$$\lim_{z\to\infty}\frac{4+z^2}{(z-1)^2}.$$

[4]

(b) Let

$$f(z) = \begin{cases} \frac{\bar{z}^3}{z^2} & \text{if } z \neq 0 \\ 0 & \text{if } z = 0. \end{cases}$$

Show that

(i) $f(z)$ is continuous everywhere on $\mathbb{C}$. [4]

(ii) the complex derivative $f'(0)$ does not exist. [4]

(c) Suppose $w^3 + 3z^2w + 4\ln z$, find $\dfrac{dw}{dz}$. [4]

4. **(a)** Let

$$T(z) = \frac{z}{z+1}.$$

Find the inverse image of the disk $|z| < \dfrac{1}{2}$ under T and sketch it. [6]

(b) (i) Show that the transformation $w = iz + i$ maps the right half plane $\mathrm{Re}(z) \geq 1$ onto the upper half plane $\mathrm{Im}(w) \geq 2$. [4]

(ii) Find the bilinear transformation that maps $z = 0, -i, -1$ onto $w = i, 1, 0$, respectively. [5]

(c) Find the region of convergence of the following series:

$$\sum_{n=1}^{\infty} \frac{(-1)^{n-1} z^{2n-1}}{(2n-1)!}.$$

[5]

5. **(a)** (i) State the Residue Theorem. [1]

(ii) Find the residues of the following function:

$$f(z) = \frac{8-z}{z(4-z)}$$

at $z = 0$ and $z = 4$. [5]

(iii) Evaluate the following integral:

$$\int_C \frac{8-z}{z(4-z)}dz,$$

where C is the circle of radius 7, centre 0 and negatively oriented.

[2]

(b) Compute the following integral:

$$\int_0^{\pi} \frac{d\theta}{2-\cos\theta}.$$

[7]

(c) (i) State the maximum modulus principal. [1]

(ii) Find the maximum modulus of $f(z) = 2z+5i$ on the closed circular region defined $|z| \leq 2$. [6]

6. **(a)** Evaluate the Cauchy Principal Value of $\int_0^{\infty} \frac{x \sin x}{x^2+9}$ [8]

(b) (i) State, without proof, Rouche's Theorem. [1]

(ii) Show that all the four zeros of the polynomial $g(z) = z^4-7z-1$ has one zero in the disc $|z| < 2$. [5]

(c) Expand $f(z) = \frac{1}{(z+1)(z+3)}$ in Laurent series valid for $1 < |z| < 3$.

[6]

END!

The University of Zambia

School of Natural Sciences

Department of Mathematics & Statistics

2020/2021 Academic Year

End of Year Final Examinations

MAT 4119 - Engineering Mathematics III

Time allowed : **Three (3)** hours **Full marks : 100**

Instructions:

- Indicate your **computer number** on all answer booklets.
- There are seven (7) questions in this examination. Attempt **any five (5)** questions. All questions carry equal marks.
- **Full credit** will only be given when **all necessary work** is shown.

This question paper consists of 6 pages.

---

1. **(a)** The Taylor polynomial of order one for the function

$$f(x) = \frac{1}{3+3^x}$$

about $x = 1$ is

$$P_1(x) = \frac{1}{6} - \frac{\ln 3}{12}(x-1).$$

Use $P_1(x)$ to approximate $f(\log_3 2)$. [4]

(b) **(i)** Find the actual error involved in using $P_1(x)$ to approximate $f(\log_3 2)$. [2]

(ii) Find an upper bound of the error in part (a). [7]

(c) Let $f(x) = x^4 + x - 2$. Determine the number of iterations necessary to solve $f(x) = 0$ by bisection method with accuracy within 10^{-3} in the interval $[0.5, 1.5]$. [7]

Turn Over/...

2. **(a)** **(i)** By sketching the graphs of

$$y = \arcsin(x-1) \text{ and } y = e^{-x}$$

on the same coordinate system, show that there is a root of the equation

$$\arcsin(x-1) - e^{-x} = 0 \qquad [3]$$

(ii) Starting with $P_0 = 1$, use the Newton-Raphson method to solve the equation in part (i) to 1 significant figure. [5]

(b) The function

$$f(x) = \tan^{-1}(x-1) + x - x^2$$

has a zero at $x = 1$.

(i) Determine the multiplicity of the zero $x = 1$. [3]

(ii) Use the modified Newton-Raphson method to perform one iteration to solve the equation $f(x) = 0$ starting with $P_0 = 0.5$. [4]

(c) The following is a quadratic spline interpolating $(-1, 0)$, $(0, 1)$ and $(1, 3)$:

$$S(x) = \begin{cases} ax^2 + x + b, & x \in [-1, 0] \\ cx^2 + x + 1, & x \in [0, 1]. \end{cases}$$

Find the values of the real constants a, b and c. [5]

3. **(a)** Solve the following system of linear equations using Gauss elimination method:

$$\begin{aligned} x_1 + x_2 - x_3 &= 3 \\ 2x_1 - x_2 + 3x_3 &= 0 \\ -x_1 - 2x_2 + x_3 &= -5. \end{aligned}$$

[8]

Turn Over/...

(b) The system of non-linear equations

$$e^{x_1} + x_2 = 1 \quad \text{and} \quad x_1^2 + x_2^2 = 4$$

can be written as a fixed-point problem on

$$D = \left\{ X = (x_1, x_2)^t : -2 \leq x_1 \leq 2,\ -2 \leq x_2 < 1 \right\}.$$

One pair of equations is

$$x_1 = \ln(1 - x_2), \qquad x_2 = -\sqrt{4 - x_1^2}$$

and another pair is

$$x_1 = \ln(1 - x_2), \qquad x_2 = \frac{4 - x_1^2}{x_2}.$$

Given that the system has a solution near $(1, -1.7)^t$, determine which pair will converge to a solution and perform one iteration. [8]

(c) Suppose we wish to evaluate

$$\int_{0.25}^{1} x \sin\left(\frac{1}{x^2}\right) dx$$

using Trapezoidal rule. Find an upper bound of the error given that $\max_{\xi \in [0.25, 1.00]} |f''(\xi(x))| \approx 1662.4$. [4]

NOTE: Error function: $E(f) = -\frac{h^3}{12} f''(\xi(x))$

4. (a) The mesh analysis formulation of equations for a particular circuit of five resistors, driven by a 6 Volt battery gives the following equations:

$$10\,000 I_1 - 6\,000 I_3 = -6$$

$$12\,000 I_2 - 3\,000 I_3 = 6$$

$$-6\,000 I_1 - 3\,000 I_2 + 21\,000 I_3 = 0,$$

where I_i, $i = 1, 2, 3$ is current. Starting with $I^{(0)} = (0, 0, 0)^t$, use Gauss-Seidel iterative method with five-decimal places rounding to approximate I_i until

$$\frac{||I^{(k)} - I^{(k-1)}||_\infty}{||I^{(k)}||_\infty} < 10^{-1}$$

[8]

Turn Over/...

(b) Laboratory tests on a flocculant suspension in a settling column give the following values of the percentage of solids removed (S) as a function of the sampling time (t):

t(min)	5	23	33	49
S(%)	9	57	64	68

Find the percent removal for detention time of 660 seconds using a Lagrange interpolating polynomial. [7]

(c) A number P^* approximates the number P to 3 significant figures and is such that the absolute error is 0.001. Find the range of values of P. [5]

5. (a) A structural engineer is designing a temporary structure that will be in place for one year. To account for wind load in the design, the engineer uses the 34−year past record of annual maximum wind speed with the mean value ($\bar{Y}$) of 85 km/hr and standard deviation (S_Y) of 20. The engineer decides to use a wind speed of 116 km/hr for the design wind loading. The 34−year record suggests that the annual maximum wind speed is normally distributed, so the z−value is 1.55. The engineer wishes to estimate the probability that the design loading will exceed 116 km/hr and the normal probabilities he has available for z values from 1.5 to 2.0 are shown in the table below:

z	1.5	1.6	1.7	1.8
$f(z)$	0.0668	0.0548	0.0446	0.0359

Use the appropriate Newton difference formula to estimate the probability for $z = 1.55$. [8]

(b) The table below shows some values of $f(x) = x \sin(\frac{1}{x^2})$:

x	0.25	0.5	0.75	1.00
$f(x)$	-0.0728	-0.378	0.734	0.841

Approximate the value of $f''(0.75)$. [5]

Turn Over/...

(c) The system reliability function $R(t)$, is given by $R(t) = 1 - F(t)$, where

$$F(t) = \int f(t)\,dt$$

is the probability that the component will fail in the interval from 0 to t, and $f(t)$ is the probability density of the time to failure of the system. Estimates of $f(t)$ are given below:

t(days)	0	1	2	3	4	5	6	7	8	9
$f(t)$	0.33	0.24	0.17	0.12	0.09	0.06	0.04	0.03	0.02	0.01

Find the reliability function at $t = 6$ days. [7]

6. (a) Show that the Initial-Value Problem (IVP)

$$\frac{dy}{dt} = t^2 y + 1, \quad 0 \le t \le 1, \; y(0) = 1$$

is well-posed on $D = \{(t, y) : 0 \le t \le 1, \; -\infty < y < \infty\}$.

[4]

(b) Use the Runge-Kutta method of order four to solve the IVP in part (a) at $y(0.2)$ using 5 subintervals of $[0, 1$. [8]

(c) Use Euler's method to solve the IVP in part (a) at $y(0.8)$ using 5 subintervals of $[0, 1$. [8]

7. (a) Evaluate each of the following, giving your answer in the form $a + ib$, $a, b \in \mathbb{R}$:

(i) $Log(-i)^i$ (ii) $\sin\left(\frac{\pi}{3} + i\sqrt{3}\right)$ (iii) $\tanh(-i)$ [2, 2, 2]

(b) (i) Evaluate the following limit:

$$\lim_{z \to -\pi i} e^{\frac{z^2+\pi^2}{z+\pi i}}$$ [3]

(ii) Determine the set where the function

$$f(x + iy) = (x^3 - 3xy^2 - x + 1) + i(3x^2 y - y^3 - y)$$

is analytic and find the derivative. [4]

Turn Over/...

(c) Evaluate each of the following:

(i) $\int_C (\overline{z}+1)\,dz,$

where C is a smooth arc $y = x^3$ from $z = 0$ to $z = \sqrt[3]{\pi}+i\pi$ **[4]**

(ii) $\oint_C \frac{e^{z^2}}{z^3}\,dz,$

around a positively oriented contour C, given by $\{z \in \mathbb{C} : |z| = 5\}$ **[3]**

END OF EXAMINATION!

The University of Zambia
School of Natural Sciences
Department of Mathematics & Statistics
2020/2021 Final Examination - 19th November, 2021
MAT 4300 - Elements of Functional Analysis

Time allowed : Three (3) hrs | Full marks : 100

Instructions:

- Indicate your **computer number** on all answer booklets.
- Attempt **any (5) five** questions. All questions carry equal marks.
- **Full credit** will only be given when **necessary work** is shown.

This paper consists of 6 pages of questions.

---

1. **(a)** (i) Define a metric on a non-empty set X. [3]

(ii) Let X be the set of continuous functions from $[a, b]$ to $\mathbb{R}$. For all $x, y \in X$, define $d(x, y)$ by

$$d(x, y) = \max\{|x(t) - y(t)| : t \in [a, b]\}.$$

Show that (X, d) is a metric space. [7]

(b) Let $C[0, 1]$ be the space of continuous functions on $[0, 1]$. For $f, g \in C[0, 1]$, consider the following metrics on $C[0, 1]$:

$$d_1(f, g) = \int_0^1 |f(x) - g(x)|dx$$

and

$$d_\infty(f, g) = \max_{0 \le x \le 1} |f(x) - g(x)|.$$

Compute the following distances, where $f(x) = x$ and $g(x) = x^3$.

(i) $d_1(f, g)$ [2]

(ii) $d_\infty(f, g)$ [4]

(c) Let (X, d) be a metric space and $A \subseteq X$.

(i) When is A said to be open? [1]

(ii) Show that the set

$$A = \{(x, y) \in \mathbb{R}^2 : x^2 + y^2 < 2y\}$$

is open in $\mathbb{R}^2$. [3]

2. **(a)** Let (X, d) be a metric space.

(i) Define a Cauchy sequence in X. [1]

(ii) When is a metric space (X, d) said to be complete? [1]

(iii) Show that (X, d) is complete, if d is a discrete metric. [3]

(iv) Show that the set

$$A = \{(x, y) \in \mathbb{R} : y > 0\}$$

is not complete. [2]

(b) Let (X, d) be a metric space and let $f : (X, d) \to (X, d)$ be a mapping.

(i) Define a fixed point of f. [1]

(ii) When is f said to be a contraction mapping? [1]

(iii) Let $X = (0, \frac{1}{4})$ be a metric space with the metric d defined by $d(x, y) = |x-y|$ for any $x, y \in X$. Show that $f(x) = x^2$ is a contraction mapping. [3]

(c) (i) State, without proof, the Banach contraction principal. [1]

(ii) Show that $f(x) = \ln(x + 2)$ has a unique fixed point in $[0, 2]$.

[4]

(iii) Show that $f(x) = x^3$ is a contraction on $X = (0, \frac{1}{2})$ but has no fixed point in X. [3]

3. **(a)** Let l^∞ be the sequence space defined by

$$l^\infty = \left\{ \{x\}_{i=1}^\infty : \{x\}_{i=1}^\infty \text{ is bounded} \right\}$$

(i) Show that l^∞ is a vector space. [6]

(ii) Show that $||\cdot|| : l^\infty \to [0, \infty)$ defined by

$$||\{x_i\}_{i=1}^\infty||_\infty = \sup_{i \geq 1}\{|x_i|\}$$

for all $\{x_i\}_{i=1}^\infty \in l^\infty$, is a norm on l^∞. [5]

(b) Let $(E, ||\cdot||)$ be a normed vector space.

(i) Define a Cauchy sequence in E. [1]

(ii) Show that

$$|||x|| - ||y||| \leq ||x - y||$$

for any $x, y \in E$. [4]

(c) Suppose (x_n) is a Cauchy sequence in a normed vector space E. Show that the sequence of norms $(||x_n||)$ form a convergent sequence in $\mathbb{R}$.

[4]

4. **(a)** Let X be a vector space.

(i) When is a map $T : X \to \mathbb{R}$ said to be a linear functional? [1]

(ii) When is a map $T : X \to \mathbb{R}$ said to be a bounded linear functional?

[1]

(b) Let $(X, ||\cdot||)$ be a normed vector space and let X^* denote the set of all bounded linear functionals on X.

(i) Show that X^* is a vector space. [6]

(ii) Show that $||\cdot||_{op} : X^* \to [0, \infty)$ defined by

$$||\cdot||_{op} = \inf\{M : |T(x)| \leq M||x|| \quad \forall x \in X\}$$

is a norm on X^*, $T \in X^*$. [6]

(c) (i) Let X be a vector space. When is a function $p : X \to \mathbb{R}$ said to be a sublinear functional? [1]

(ii) Let X be a normed linear space. Show that $p(x) = ||x||$ is a sublinear functional. [2]

(iii) State, without proof, the real version of the Hahn Banach Theorem.

[3]

5. **(a)** (i) Define an inner product space. [4]

(ii) Let $X = C[a, b]$ be the space of all continuous complex valued functions on the interval $[a, b]$. Define $\langle \cdot, \cdot \rangle : X \to \mathbb{C}$ by

$$\langle f, g \rangle = \int_a^b f(x)\overline{g(x)}dx.$$

Show that $\langle \cdot, \cdot \rangle$ is an inner product on X. [6]

(b) For any two elements x and y in an inner product space, prove that

$$|\langle x, y \rangle| \leq ||x|| \cdot ||y||.$$

[5]

(c) For any two elements x and y in an inner product space, prove that

$$||x + y||^2 + ||x - y||^2 = 2(||x||^2 + ||y||^2).$$

[5]

6. **(a)** (i) When are two vectors x and y in an inner product space said to be orthogonal? [1]

(ii) Prove that for any pair of orthogonal vectors, we have

$$||x + y||^2 = ||x||^2 + ||y||^2.$$

[2]

(b) (i) Let S be a nonempty subset of an inner product space E. When is $x \in E$ said to be orthogonal to S? [1]

Turn Over/...

(ii) For any subset S of an inner product space E, show that the orthogonal complement $S^{\perp}$ of S is a closed subspace of E. [5]

(iii) Prove that if S is a closed subspace of a Hilbert space H, then

$$S^{\perp\perp} = S.$$

[5]

(c) Prove that if f is a non-trivial bounded linear functional on a Hilbert space H, then

$$\dim N(f)^{\perp} = 1,$$

where $N(f)$ is the null space of f. [6]

END!

The University of Zambia
School of Natural Sciences
Department of Mathematics & Statistics

2020/21 ACADEMIC YEAR
FINAL EXAMINATIONS

MAT4600 - MULTIVARIATE STATISTICAL ANALYSIS

TIME ALLOWED: THREE (3) Hours.

INSTRUCTIONS: (i) There are a total of six questions in this examination paper.

(ii) All questions are of the same weight.

(iii) Answer any five (5) Questions.

(iv) Statistical tables will be provided.

---

1. (a) Let $\bar{X}$ be the mean of a random sample $X_1, X_2, \ldots, X_n$ from a Normal population $N_p(\mu, \Sigma)$.

(i) Find $E(\bar{X})$

(ii) Find $COV(\bar{X})$

(iii) Specify distribution of $\sqrt{n}(\bar{X} - \mu)$.

(iv) Specify distribution of $n(\bar{X} - \mu)' \Sigma^{-1} (\bar{X} - \mu)$.

(b) Random variables X and Y are jointly normally distributed with mean vector $\mu = \begin{pmatrix}\mu_1 \\ \mu_2\end{pmatrix}$ *and covariance matrix* $\begin{pmatrix}\sigma_1^2 & \sigma_1\sigma_2 \\ \sigma_1\sigma_2 & \sigma_2^2\end{pmatrix}$. Show that random variables $W = X - \mu_1$ *and* $Z = Y - \mu_2 - \left(\frac{\sigma_2}{\sigma_1}\right)X$ are independent.

(c) In a certain population of married couples, the height X_1 of the husband and the height X_2 of the wife have a bivariate normal distribution with parameters $\mu_1 = 5{\cdot}8$ feet, $\mu_2 = 5{\cdot}3$ feet, $\sigma_{11} = \sigma_{22} = 0{\cdot}4$ feet and $\rho = 0{\cdot}6$. Given that the height of the wife is 5·1 feet, find the probability that her husband has a height between 5·28 and 5·92 feet.

You may use the following information: The conditional distribution of X_1 *given* $X_2 = x_2$ is normal with mean $\mu_1 + \rho\sqrt{\frac{\sigma_{11}}{\sigma_{22}}}(x_2 - \mu_2)$ and variance $\sigma_{11} - \rho^2\sigma_{11}$.

2. (a) The annual rate of return from the dividends on the stocks of Zambia Sugar Company for the year 2009 to 2018 are

4.8	5.2	6.7	-1.6	-5.7	4.8	3.7	6.7	8.0	9.6

(i) Construct a Q – Q plot

(ii) Comment on the assumption that the data is drawn from a normal population.

(b) Let a random vector X be distributed as $N_2(\mu, \Sigma)$ where Σ is a positive definitive matrix. Show that $(X-\mu)' \Sigma^{-1} (X-\mu)$ is a chi – square variate with two degrees of freedom.

(c) Let X_1, X_2, X_3 and X_4 be mutually independent random vectors with X_j distributed as $N_2(\mu, \Sigma)$, j = 1, 2, 3,4. Consider two random vectors Y_1 and Y_2 defined as $Y_1 = \frac{1}{2}X_1 + \frac{1}{2}X_3 + X_4$, $Y_2 = X_1 + 2X_2 + X_3$

Find

(i) $E(Y_1)$

(ii) $COV(Y_2)$

(iii) $COV(Y_1, Y_2)$

3. (a) Let a random vector X have covariance matrix $\Sigma = \begin{pmatrix} 4 & 0 & 0 \\ 0 & 9 & 0 \\ 0 & 0 & 1 \end{pmatrix}$.

Find

(i) Σ^{-1}

(ii) The eigen values and eigen vectors of Σ.

(iii) The eigen values and eigen vectors of Σ^{-1}.

(iv) What is noticeable about the eigen values in (ii) and (iii).

(b) A production plant produces three types of undesirable pollutants P_1, P_2 *and* P_3. To analyze the severity of the pollutants, measured in centigrams, 30 days were randomly selected and measurements were taken at the end of production on each day.

The sample mean and variance covariance matrix were found as follows :

$$\bar{P} = \begin{bmatrix} 70 \\ 64 \\ 38 \end{bmatrix} \text{ and } S = \begin{bmatrix} 25 & -2 & 4 \\ -2 & 4 & 1 \\ 4 & 1 & 9 \end{bmatrix}$$

Calculate the sample means, variances and covariance of

(i) $P_1 - 2P_2 + P_3$

(ii) $P_2 + P_1 - 3P_3$

(c) A random sample of size N was drawn from a bivariate normal population with coefficient of correlation ρ. Let r be the correlation coefficient of the sample. Test $\rho = 0{\cdot}5$ against $\rho \neq 0{\cdot}5$, based on sample statistics $r = 0{\cdot}407$, $N = 24$.

4 (a) Let V be a random vector with mean vector μ_v and variance covariance matrix Σ_v.

(i) Show that $E(VV') = \Sigma_v + \mu_v\mu_v'$

(ii) Let b′ be a row of constants.

Show that COV $(b'V) = b'\,\Sigma_v\, b$.

(b) Let $X_1, X_2, \ldots, X_{100}$ be a random sample from a p- dimensional joint distribution whose mean vector is μ and covariance matrix is Σ.

Let $\bar{X}$ be the sample mean vector. Find

$E(\sum_{j=1}^{100}(X_j - \bar{X})(X_j - \bar{X})')$.

(c) Given the random vector

$X' = [X_1, X_2, X_3, X_4]$ with variance covariance matrix

$$\sum_X = \begin{bmatrix} 3 & 0 & 2 & 2 \\ 0 & 1 & 1 & 0 \\ 2 & 1 & 9 & -2 \\ 2 & 0 & -2 & 4 \end{bmatrix}$$

Consider the following partition of X

$$X = \begin{bmatrix} X_1 \\ X_2 \\ \hline X_3 \\ X_4 \end{bmatrix} = \begin{bmatrix} X^{(1)} \\ X^{(2)} \end{bmatrix}$$

Let A = [1 2], B = [1 −2]
Find the following:

(i) $V(X^{(1)})$ *and* $V(X^{(2)})$ (ii) COV $(X^{(1)}, X^{(2)})$

(iii) COV $(AX^{(1)}, BX^{(2)})$ (iv) COV $\begin{bmatrix} AX^{(1)} \\ BX^{(2)} \end{bmatrix}$

5. (a) A random sample of size 20 was drawn from the distribution $N_4(\mu, \Sigma)$. The following sample statistics was computed:

$$\bar{x} = \begin{pmatrix} 5\cdot 2 \\ 5\cdot 3 \\ 4\cdot 3 \\ 4\cdot 0 \end{pmatrix}, \quad S = \begin{pmatrix} 22\cdot 2 & 29\cdot 1 & -3\cdot 4 & 12\cdot 5 \\ & 25\cdot 2 & 6\cdot 2 & 19 \\ & & 30\cdot 5 & 20\cdot 2 \\ & & & 26\cdot 3 \end{pmatrix}$$

(i) Find one at a time 95% confidence intervals for component means μ_1 and μ_2.

(ii) Find 95% simultaneous confidence intervals for component means μ_1 and μ_2.

(iii) Find 95% Bonferroni simultaneous confidence intervals for component means
μ_1 and μ_2

** You may leave the end points of the intervals as raw numbers without simplifying.

(b) It is suspected that the excretion levels of two biochemical compounds during a stress situation in human are correlated. The biological processes that are involved imply that this correlation ρ could only be positive. Random samples from males and females were taken. Sample size (n) and sample correlation coefficient (r) are given in the following table:

	Males	Females
r	.81	0.72
n	24	95

Assume that the samples were drawn from bivariate normal density.

Test $H_0 : \rho_M = \rho_F$ against $H_a : \rho_M > \rho_F$ at 5% level of significance .

(c) Consider two response variables Y_1 and Y_2 and three predictor variables Z_1 Z_2 and Z_3 . Ten independent trials were run. Write the multivariate multiple regression model in the matrix form, stating the elements of each of the matrix in detail using general naming. State the assumptions made.

6. (a) The scores in Physics and Biology for 101 students from 2018 class of NS at UNZA gave the following statistics

$$\bar{x} = \begin{pmatrix} 55 \\ 35 \end{pmatrix}, \quad s = \begin{pmatrix} 210\cdot 6 & 127 \\ 127 & 120 \end{pmatrix}$$

Test at $\alpha = 0{\cdot}01$ level, the null hypothesis that the observations came from a population with mean vector $\mu = \begin{bmatrix} 60 \\ 50 \end{bmatrix}$. State the alternative hypothesis for the test you have performed.

(b) Continue with information given in part (a). Without simplifying, write down the 99% confidence ellipsoid for the mean vector μ. Explain if $\mu = \begin{bmatrix} 60 \\ 50 \end{bmatrix}$ will lie in the confidence ellipsoid.

(c) Four abilities represented by random variables Y_1 = pictorial inconsistencies, Y_2= description details, Y_3 = reaction time and Y_4 = vocabulary were assessed on 32 men and 32 women is a psychological test. The mean vectors and covariance matrices of the two samples are given below.

$$\overline{Y_M} = \begin{pmatrix} 16.0 \\ 15.9 \\ 27.2 \\ 22.8 \end{pmatrix}, \overline{Y_F} = \begin{pmatrix} 12.3 \\ 13.9 \\ 16.71 \\ 21.9 \end{pmatrix}$$

$$S_M = \begin{pmatrix} 5.2 & 4.5 & 6.5 & 5.3 \\ 4.5 & 13.1 & 6.8 & 6.2 \\ 6.5 & 6.7 & 28.7 & 14.5 \\ 5.3 & 6.3 & 14.5 & 16.7 \end{pmatrix}, \quad S_F = \begin{pmatrix} 9.1 & 7.5 & 4.9 & 4.2 \\ 7.5 & 18.6 & 10.2 & 5.4 \\ 4.9 & 10.2 & 30 & 13.5 \\ 4.2 & 5.4 & 13.5 & 28.0 \end{pmatrix}$$

Let μ_M *and* μ_F be the population mean scores in the psychological test for males and females. Assume normal populations of scores in the psychological test for males and females with equal variance covariance matrix $\sum$.

(i) Find an estimate of $\sum$ using $\hat{\sum} = \frac{(n_1-1)S_1+(n_2-1)S_2}{n_1+n_2-2}$.

(ii) The test statistic for H_0: $\mu_M = \mu_F$ is $T^2 = \frac{n_1 n_2}{n_1+n_2}(\overline{Y_M} - \overline{Y_F})'\hat{\sum}^{-1}(\overline{Y_M} - \overline{Y_F})$.

Given that $T^2 = 97.6$ *and* $\frac{n_1+n_2-p-1}{(n_1+n_2-2)p}T^2 = F_{p,n_1+n_2-p-1}$, test H_0: $\mu_M = \mu_F$ at 5% level of significance.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

2020/21 ACADEMIC YEAR FINAL EXAMINATIONS

MAT4615 NONPARAMETRIC METHODS

INSTRUCTIONS

1. Answer any five questions.
2. Calculators are allowed.
3. Statistical tables will be provided. You may use them if necessary.
4. Show detailed work to earn full marks.

TOTAL TIME ALLOWED

Three hours.

1 (a) Define the following in reference to a statistical test of hypothesis:

(i) Level of significance

(ii) Power of the test

(iii) p-value

(b) A coin is tossed five times and the sequence of heads and tails observed is the outcome. The critical region is the event " at least four heads". If the null hypothesis H_0 is true, all outcomes in the sample space are equally likely. If the alternative hypothesis H_1 is true, "head" has probability 0.6 of occurring on each toss.

(i) Find the size of the critical region.

(ii) Find the power.

2. (a) (i) Explain major differences between parametric and non parametric statistical methods.

(ii) Show that $\sum_{k=1}^{n} k^2 = \frac{n(n+1)(2n+1)}{6}$

(b) Two farmers A and B, each with two animals are competing in an agricultural show. The animals are ranked 1 to 4 based on some characteristics. Let W be the sum of the ranks assigned to animals of farmer A.

(i) Copy and complete the table below showing all 24 possible permutations of the ranks 1,2,3,4 and the corresponding value of W.

FARMER A		FARMER B		W
1	2	3	4	3
1	2	4	3	3
1	3	2	4	4
:	:	:	:	:
4	3	2	1	7

(ii) Copy and complete the table below showing the distribution of W. Leave the probabilities in a/b form.

W	3	4	5	6	7
P(W=w)					

(iii) Let the null hypothesis be that the animals of farmers A and B are of identical characteristics versus a two sided alternative. Find the smallest type I error possible with the distribution in part (ii).

3. (a) A retired police commissioner recalls that in the "good old days" the upper quartile for time required to complete the obstacle course was 42 minutes. He suspects that the new recruits are not as fit as the recruits in the old good days. When offered a voluntary assignment, he conducted the obstacle course for 38 recruits and found that only 10 of them completed the course within 42 minutes time period. Test the hypothesis that upper quartile is 42 minutes against the one sided alternative at 5% level of significance.

(b) Let x^* be the pth quantile of a population described by the probability distribution of random variable X. Hence $P(X \leq x^*) = p$.

Let $X^{(1)}, X^{(2)}, \ldots, X^{(n)}$ be an ordered random sample from the population.

Show that

(i) $P(x^* < X^{(1)}) = (1-p)^n$

(ii) $P(x^* < X^{(2)}) = \sum_{k=0}^{1} \binom{n}{k} p^k (1-p)^{n-k}$

(iii) Extend (i) and (ii) to write $P(x^* < X^{(r)})$ *where* $r < n$.

4. (a) Let (X_i, Y_i), i=1,2,…,n be a random sample from a bivariate distribution where X_i and Y_i are paired by a natural phenomena. Let X_i represent the choice of the ith subject for political party ND or DP. Let Y_i denote the choice of the ith subject after hearing the manifesto of each of the two parties. The data can be summarized in the following table:

$X \setminus Y$	ND	DP
ND	a	b
DP	c	d

(i) Explain the following in words:

$H_0: P(X_i = ND, Y_i = DP) = P(X_i = DP, Y_i = ND), \forall i = 1,2, \ldots n$

(ii) In designing a test of hypothesis stated in (i), explain why the events

$X_i = ND, Y_i = ND$ *and* $X_i = DP, Y_i = DP$ are considered ties.

(iii) Show that the null hypothesis stated in (i) can also be written as

$H_0: P(X_i = DP) = P(Y_i = DP), \forall i = 1,2, \ldots n$

(b) One hundred and thirty five citizens were selected at random and were asked to state their opinion regarding the new Climate Change policy. Forty three were opposed to the policy. After attending a sensitization program about the CC policy, these 138 citizens were again asked about their opinion. The information collected is summarized in the following table. Test at 5% level of significance if the number of people opposing to the new policy has reduced significantly.

X \ Y	Opposed	Not Opposed	
Opposed	7	36	43
Not Opposed	30	65	95
	37	101	

You are given the following information:

McNemar test statistic in the usual nomenclature is $T = \frac{(b-c)^2}{b+c}$

5. (a) Ten customers are numbered consecutively from 1 to 10. Two of customers are selected randomly for an interview. Let random variate X_i represent the number assigned to the ith customer picked for interview. Find the following:

(i) $E(X_i), i = 1,2$
(ii) $V(X_i), i = 1,2$
(iii) $COV(X_1, X_2)$
(iv) $E(X_1 + X_2)$
(v) $V(X_1 + X_2)$

(b) Seven students were taught Algebra in a face to face learning environment and six students were taught the same material online. All the 13 students wrote the same examination. Their achievement scores are given below. Test if the mean scores of the students taught by two methods are same against one sided appropriate hypothesis at 5% significance level.

Face to Face	68	71	79	69	84	80	78
Online	64	60	68	73	72	70	

6 (a) Two drugs labelled as A and B were administered in ten medical facilities in Lusaka during 2020 period for treating Malaria. The drugs were prescribed alternately to patients in each of the medical facility. The data on percentage recovery are shown in the table below.

Medical Facility	% Recovered from Drug A	% Recovered from Drug B
1	75.0	85.0
2	69.8	83.1
3	85.7	80.2
4	74.0	74.5
5	69.0	70.0
6	83.3	81.5
7	68.9	75.4
8	77.8	79.2
9	72.2	85.4
10	77.4	80.4

Determine whether there is sufficient evidence to indicate a higher recovery rate for one of the two drugs. Use Wilcoxon Signed Rank Test utilizing the

p-value approach with $\alpha = .1$

In the usual nomenclature, the Wilcoxon Signed Rank test statistic

$$T = \frac{\sum R_i}{\sqrt{\sum R_i^2}}$$

(b) Highway accidents killed more than 7500 occupants of passenger cars during 2019-2020 in Zambia. Using this grim statistics as a starting point, researchers at the Road Traffic Safety Agency computed death rates for 103 types of vehicles which were further categorized as large, midsize or small. Looking at the rates (deaths per 1000 registered), the figures ranged from 1.1 to 4.1. Ranks for the figures were as follows:

Large	4.5	9	13	17	17	17	22	29						
Midsize	1.5	4.5	4.5	4.5	9	9	9	9	13	13	17	22	22	22
	26	26	29	31	34	37	37	39	41	43	45			
Small	1.5	17	22	26	29	34	34	37	41	43	44			

(i) Obtain the summary statistics of the given ranks.

(ii) Use the Kruskal -Wallis Test Statistics to test whether the three population means are equal using α=0.05.

The Kruskal – Wallis Test Statistics in usual nomenclature is

$$T = \frac{12}{N(N+1)} \sum \frac{R_i^2}{n_i} - 3(N+1)$$

Exam of Examination Paper

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

DEPARTMENT OF MATHEMATICS AND STATISTICS

2021 ACADEMIC YEAR

Tuesday, November 16, 2021 (14:00-17:00)

MAT 4645-TIME SERIES ANALYSIS

FINAL EXAMINATION

TIME ALLOWED: Three (3) hours

INSTRUCTIONS TO THE CANDIDATE

1. **Attempt any four (4) questions**, beginning your answer to each question on a fresh page.
2. Full credit will only be given when necessary working is shown.
3. Graph paper is NOT required for this paper
4. In addition to the paper you should have available an extract of the Chi-square percentage points table and your own electronic calculator

This examination paper consists of 7 printed pages, each printed on one side only.

The front cover is page 1.

Question 1 starts on page 2

QUESTION 1

(a) The following $MA(1)$ process is given:

$$X_t = e_t + 0.5e_{t-1}, \quad e_t \sim N(0,4)$$

Calculate the partial autocorrelation function, $\phi_k, k = 0,1,2,3, \ldots$ **[10]**

(b) Consider a moving average process of order 2 given by the equation

$$X_t = e_t + 0.6e_{t-1} - 0.2e_{t-2}$$

(i) Determine whether the time series is

(a) Invertible **[2]**

(b) Stationary **[1]**

(c) Purely indeterministic **[1]**

(d) Markov **[2]**

(ii) Calculate the mean **[1]**

(c) (i) Outline why stationarity is an important concept in the context of modelling financial time series. **[3]**

(ii) Strict stationarity is the stronger of the two conditions. Discuss whether strict stationarity implies weak stationarity **[2]**

(iii) State the meaning of a white noise process (in words, not formulae), and why it is an important concept in the context of modelling financial time series. **[3]**

[25 marks]

QUESTION 2

(a) An actuary is considering the time series model defined by

$$X_t = \alpha X_{t-1} + e_t$$

where $\{e_t\}$ is a sequence of independent normally distributed random variables with mean 0 variance σ^2. The series begins with the fixed value $X_0 = 0$.

(i) Show that the conditional distribution of X_t given X_{t-1} is normal and hence show that the likelihood of making observations $x_1, x_2, \ldots, x_n$ from this model is:

$$L = \prod_{i=1}^{n} \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2\sigma^2}(x_i - \alpha x_{i-1})^2}$$

[3]

(ii) Show that the maximum likelihood estimate of α can also be regarded as a least squares estimate. [2]

(iii) Find the maximum likelihood estimates of α and σ^2. [4]

(iv) Derive the Yule-Walker equations for the model and hence derive estimates of α and σ^2 based on observed values of the autocovariance function. [5]

(v) Comment on the difference between the estimates of α in parts (iii) and (iv). [1]

(b) The following data is observed from $n = 500$ realisations from a time series:

$$\sum_{i=1}^{n} x_i = 13153.32, \quad \sum_{i=1}^{n} (x_i - \bar{x})^2 = 3153.67 \text{ and } \sum_{i=1}^{n} (x_i - \bar{x})(x_{i+1} - \bar{x}) = 2176.03$$

Estimate, using the data above, the parameters μ, α_1 and σ from the model

$$X_t - \mu = a_1(X_{t-1} - \mu) + \varepsilon_t$$

where ε_t is a white noise process with variance σ^2. [7]

(c) If possible, classify the following process as an $ARIMA(p, d, q)$.

$$X_t = 1.2X_{t-1} - 0.2X_{t-2} + Z_t - 0.5Z_{t-1}$$

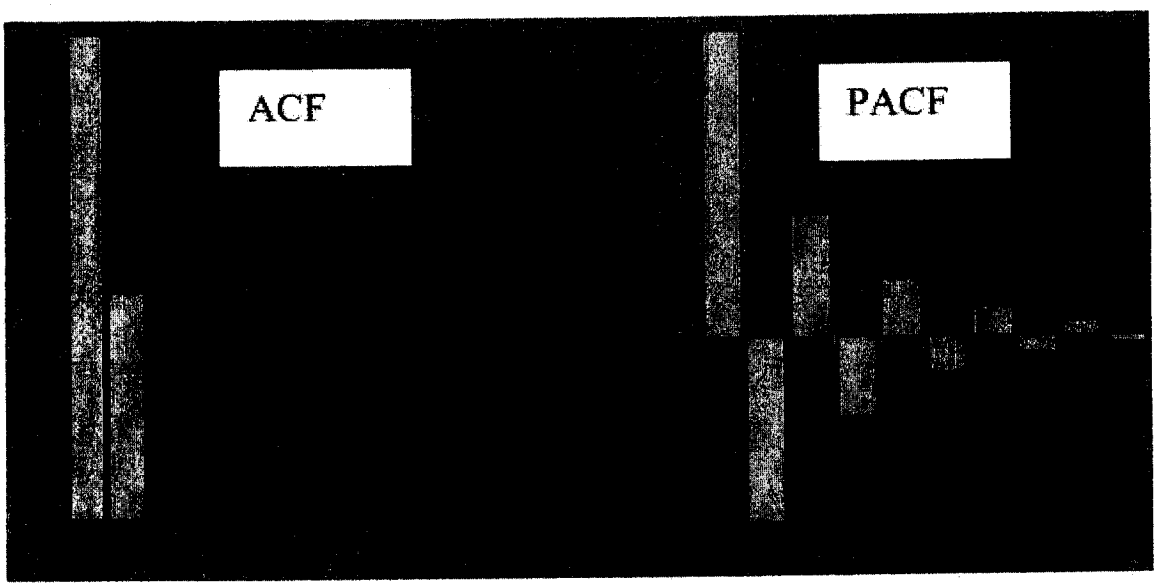
[3]

[25 marks]

QUESTION 3

(a) (i) State the three main stages in the Box-Jenkins approach to fitting an ARIMA time series model. [3]

(ii) Explain, with reasons, which ARIMA time series would fit the observed data in the charts below. [2]



Now consider the time series model given by

$$X_t = \alpha_1 X_{t-1} + \alpha_2 X_{t-2} + \beta_1 e_{t-1} + e_t$$

where e_t is a white noise process with variance σ^2 .

(iii) Derive the Yule-Walker equations for this model. [6]

(iv) Explain whether the partial auto-correlation function for this model can ever give a zero value. [2]

(b) The sample ACF and PACF values at lags 1 to 10 of a time series of length 500, are as given below.

Lag	1	2	3	4	5	6	7	8	9	10
SACF	−0.7793	0.6180	−0.4824	0.386	−0.341	0.3172	−0.2989	0.2728	−0.2181	0.163
SPACF	−0.7793	00275	0.0188	0.0232	−0.084	0.538	0.0289	0.0004	0.0616	−0.0301

(i) Determine through a statistical test whether the time series can be regarded as white noise. **[4]**

(ii) Indicate, with reasons, if an $AR(p)$ or an $MA(q)$ model may be appropriate for this time series, and if so, what could be the model order. **[3]**

(c) An economics student fits an $AR(2)$ model to a data set. The 100 residuals for this model has 70 turning points. Calculate an approximate 95% confidence interval for the number of turning points and comment on your answer. **[4]**

[25 marks]

QUESTION 4

(a) The time series X_t is assumed to be stationary and to follow an $ARMA(2,1)$ process defined by:

$$X_t = 1 + \frac{8}{15}X_{t-1} - \frac{1}{15}X_{t-2} + Z_t - \frac{1}{7}Z_{t-1}$$

where Z_t are independent $N(0,1)$ random variables.

(i) Determine the roots of the characteristic polynomial, and explain how their values relate to the stationarity of the process. **[2]**

(ii) (a) Find the autocorrelation function for lags 0, 1 and 2.

(b) Derive the autocorrelation at lag k in the form

$$\rho_k = \frac{A}{c^k} + \frac{B}{d^k}$$

[12]

(iii) Determine the mean and variance of X_t. [3]

(b) Explain the concept of cointegrated time series. Give two examples of circumstances when it is reasonable to expect that two processes may be cointegrated. [4]

(c) Define, giving relevant equations, the three main linear models used for modeling stationary time series. [4]

[25 marks]

QUESTION 5

(a) (i) You are given the time series data:

$$55, 35, 52, 40, 46, 42$$

Fit an $AR(1)$, that is $X_t = \alpha_0 + \alpha_1 X_{t-1} + e_t$, model to this data and hence calculate the estimated variance of the error term. [6]

(ii) An AR(1) process is fitted to the observed time series data $x_1, x_2, \ldots, x_n$. The estimated parameters are $\alpha_0 = 5$, $\alpha_1 = 0.6$. Given that the last observed value is $x_n = 32$. Calculate the forecast of x_{n+2}. [3]

(b) The model fitted to the data is

$$\hat{x}_t = 5.67 + 0.61x_{t-1} + e_t - 0.23e_{t-1}$$

The most recently observed value in the series is $x_{20} = 8.2$, with estimated residual $e_{20} = -1.38$.

(i) Evaluate estimates $\hat{x}_{20}(1)$ and $\hat{x}_{20}(2)$ for x_{21} and x_{22}. [3]

(ii) The simplest form of the method of exponential smoothing used at time 19 gave a forecast for x_{20} of 8.32. Assuming the smoothing parameter is equal to 0.2, find the forecast of x_{21}. [3]

(iii)Give an example of a circumstance in which a form of exponential smoothing might be expected to outperform Box-Jenkins forecasting in the prediction of future values of the time series. **[2]**

(c) The following ARIMA model has been fit to a time series:

$$\hat{y}_t = 25 + 0.8y_{t-1} - 0.3y_{t-2} + e_t$$

(i) Suppose that we are at the end of time period $T = 100$ and we know that $y_{100} = 40$ and $y_{99} = 38$. Determine forecasts for periods 101, 102 and 103 from this model at origin 100. **[5]**

(ii) Suppose that the observation for time period 101 turns out to be $y_{101} = 35$. Revise your forecasts for periods 102 and 103 using period 101 as the new origin of time. **[3]**

[25 marks]

END OF EXAMINATION

Percentage Points for the χ^2 distribution

P =	50%	40%	30%	20%	10%	5%	2.5%	1%	0.5%	0.1%	0.05%
ν											
1	0.4549	0.7083	1.074	1.642	2.706	3.841	5.024	6.635	7.879	10.83	12.12
2	1.386	1.833	2.408	3.219	4.605	5.991	7.378	9.210	10.60	13.82	15.20
3	2.366	2.946	3.665	4.642	6.251	7.815	9.348	11.34	12.84	16.27	17.73
4	3.357	4.045	4.878	5.989	7.779	9.488	11.14	13.28	14.86	18.47	20.00
5	4.351	5.132	6.064	7.289	9.236	11.07	12.83	15.09	16.75	20.51	22.11
6	5.348	6.211	7.231	8.558	10.64	12.59	14.45	16.81	18.55	22.46	24.10
7	6.346	7.283	8.383	9.803	12.02	14.07	16.01	18.48	20.28	24.32	26.02
8	7.344	8.351	9.524	11.03	13.36	15.51	17.53	20.09	21.95	26.12	27.87
9	8.343	9.414	10.66	12.24	14.68	16.92	19.02	21.67	23.59	27.88	29.67
10	9.342	10.47	11.78	13.44	15.99	18.31	20.48	23.21	25.19	29.59	31.42
11	10.34	11.53	12.90	14.63	17.28	19.68	21.92	24.73	26.76	31.26	33.14
12	11.34	12.58	14.01	15.81	18.55	21.03	23.34	26.22	28.30	32.91	34.82
13	12.34	13.64	15.12	16.98	19.81	22.36	24.74	27.69	29.82	34.53	36.48
14	13.34	14.69	16.22	18.15	21.06	23.68	26.12	29.14	31.32	36.12	38.11
15	14.34	15.73	17.32	19.31	22.31	25.00	27.49	30.58	32.80	37.70	39.72
16	15.34	16.78	18.42	20.47	23.54	26.30	28.85	32.00	34.27	39.25	41.31
17	16.34	17.82	19.51	21.61	24.77	27.59	30.19	33.41	35.72	40.79	42.88
18	17.34	18.87	20.60	22.76	25.99	28.87	31.53	34.81	37.16	42.31	44.43
19	18.34	19.91	21.69	23.90	27.20	30.14	32.85	36.19	38.58	43.82	45.97
20	19.34	20.95	22.77	25.04	28.41	31.41	34.17	37.57	40.00	45.31	47.50
21	20.34	21.99	23.86	26.17	29.62	32.67	35.48	38.93	41.40	46.80	49.01
22	21.34	23.03	24.94	27.30	30.81	33.92	36.78	40.29	42.80	48.27	50.51
23	22.34	24.07	26.02	28.43	32.01	35.17	38.08	41.64	44.18	49.73	52.00
24	23.34	25.11	27.10	29.55	33.20	36.42	39.36	42.98	45.56	51.18	53.48
25	24.34	26.14	28.17	30.68	34.38	37.65	40.65	44.31	46.93	52.62	54.95
26	25.34	27.18	29.25	31.79	35.56	38.89	41.92	45.64	48.29	54.05	56.41
27	26.34	28.21	30.32	32.91	36.74	40.11	43.19	46.96	49.65	55.48	57.86
28	27.34	29.25	31.39	34.03	37.92	41.34	44.46	48.28	50.99	56.89	59.30
29	28.34	30.28	32.46	35.14	39.09	42.56	45.72	49.59	52.34	58.30	60.73
30	29.34	31.32	33.53	36.25	40.26	43.77	46.98	50.89	53.67	59.70	62.16
32	31.34	33.38	35.66	38.47	42.58	46.19	49.48	53.49	56.33	62.49	64.99
34	33.34	35.44	37.80	40.68	44.90	48.60	51.97	56.06	58.96	65.25	67.80
36	35.34	37.50	39.92	42.88	47.21	51.00	54.44	58.62	61.58	67.98	70.59
38	37.34	39.56	42.05	45.08	49.51	53.38	56.90	61.16	64.18	70.70	73.35
40	39.34	41.62	44.16	47.27	51.81	55.76	59.34	63.69	66.77	73.40	76.10
50	49.33	51.89	54.72	58.16	63.17	67.50	71.42	76.15	79.49	86.66	89.56
60	59.33	62.13	65.23	68.97	74.40	79.08	83.30	88.38	91.95	99.61	102.7
70	69.33	72.36	75.69	79.71	85.53	90.53	95.02	100.4	104.2	112.3	115.6
80	79.33	82.57	86.12	90.41	96.58	101.9	106.6	112.3	116.3	124.8	128.3
90	89.33	92.76	96.52	101.1	107.6	113.1	118.1	124.1	128.3	137.2	140.8
100	99.33	102.9	106.9	111.7	118.5	124.3	129.6	135.8	140.2	149.4	153.2

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

DEPARTMENT OF MATHEMATICS AND STATISTICS

2020/21 ACADEMIC YEAR

Thursday, November 25, 2021 (09:00-12:00)

MAT 4671-STATISTICAL METHODS IN RISK

FINAL EXAMINATION

TIME ALLOWED: Three (3) hours

INSTRUCTIONS TO THE CANDIDATE

1. **Attempt any four (4) questions**, beginning your answer to each question on a fresh page.
2. Full credit will only be given when necessary working is shown.
3. **Graph paper is NOT required for this paper**
4. In addition to the paper you should have available Actuarial Tables and your own electronic calculator

This examination paper consists of 7 printed pages, each printed on one side only.

The front cover is page 1.

Question 1 starts on page 2

QUESTION 1

(a) In the context of generalized linear models, explain what you understand by the following terms:

(i) Covariate, [2]

(ii) Linear predictor, and [2]

(iii) Link function [2]

(b) Consider a Generalised Linear Model (GLM) with independent Poisson responses with structure $g(\mu) = \eta$ comprising a linear predictor, η, linked to the mean response, μ, through a link function, g.

(i) Prove that the model belongs to an exponential family, and identify the different aspects of the exponential family for this model. [3]

(ii) Identify the canonical link function. [1]

(iii) Derive ***(But do not solve)*** the equations for the maximum likelihood estimates of the model parameters from the following data on the response (y) and a single covariate (x). [6]

Serial No. (i)	*Covariate* (x_i)	*Response* (y_i)
1	2	3
2	4	3
3	6	9

(c) Use the data values given below to find their deviance residuals:

$$y_1 = 2, \quad y_2 = 5, \quad y_3 = 6$$

Given that $Y_i \sim Poisson(\lambda)$ and $\eta = \alpha$ is the linear predictor. [4]

(d) Two models have been fitted to data $y_1, \ldots, y_{12}$:

Model	***Parameters***	***Scaled deviance***
Model 1	α	24.82
Model 2	$\alpha_i (i = 1, 2, 3)$	17.65

Test whether Model 2 is a significant improvement (in terms of fit) over Model 1. [5]

[Total: 25 marks]

QUESTION 2

(a) Show that, under absolute error loss function, the Bayesian estimate for the parameter, θ, is the median of the posterior distribution. [5]

(b) A single observation, x, is drawn from a distribution with the probability density function:

$$f(x) = \frac{1}{\theta}, \qquad 0 < x < \theta$$

The prior PDF of θ is given by:

$$f(\theta) = \theta e^{-\theta}, \qquad \theta > 0$$

Derive an expression in terms of x for the Bayesian estimate of θ under absolute error loss. [6]

(c) A coin is biased so that the probability of throwing a head is an unknown constant p. It is known that p must be either 0.4 or 0.75. Prior beliefs about p are given by the distribution:

$$P(p = 0.4) = 0.6\, P(p = 0.75) = 0.4$$

The coin is tossed 6 times and 4 heads are observed. Find the posterior distribution of p. [5]

(d) An insurance company has a portfolio of policies, where claim amounts follow a Pareto distribution with parameters $\alpha = 3$ and $\lambda = 100$. The insurance company has entered into an excess of loss reinsurance agreement with a retention of M, such that 90% of claims are still paid in full by the insurer.

(i) Calculate M. [4]

(ii) Calculate the average claim amount paid by the reinsurer, on claims which involve the reinsurer. [5]

[Total: 25 marks]

QUESTION 3

(a) You are given the following random sample of 30 auto claims:

54	140	230	560	600	1100	1500	1800	1920	2000
2450	2500	2580	2910	3800	3800	3810	3870	4000	4800
7200	7390	11750	12000	15000	25000	30000	32300	35000	55000

Use 0.025 level of significance to test the hypothesis that auto claims follow a continuous distribution $F(x)$ with the following percentiles:

x	310	500	2498	4876
$F(x)$	0.16	0.27	0.55	0.81

[10]

(b) The following 20 claim amounts were recorded by an insurance office. It is desired to estimate the probability that a claim exceeds 200. When a parametric model is called for, use the single-parameter type I Pareto distribution for which $F(x) = 1 - \left(\frac{100}{x}\right)^{\alpha}, x > 100, \alpha > 0$.

132	149	476	147	135	110	176	107	147	165
135	117	110	111	226	108	102	108	227	102

(i) Determine the empirical estimate of the probability that a claim exceeds 200. **[1]**

(ii) Determine the method of moments estimate of the single-parameter Pareto parameter α and use it to estimate the probability that a claim exceeds 200. **[6]**

(c) A random sample of 10 claims obtained from a gamma distribution is as follows:

1500	6000	3500	3800	1800	5500	4800	4200	3900	3000

Suppose it is known that $\alpha = 12$. Determine the maximum likelihood estimate of λ and use it to estimate the probability that a claim does not exceeds 2850. **[5]**

(d) Individual claim amounts on a portfolio of motor insurance policies follow a gamma distribution with parameters α and β. It is known that $\beta = 0.8$ for all drivers, but the value of α varies across the population. Given that $\alpha \sim Gamma(200,0.5)$, calculate the mean and variance of a randomly chosen claim amount. **[5]**

[Total: 25 marks]

QUESTION 4

(a) The aggregate claims process for a risk is a compound Poisson process with parameter λ. Individual claim amounts X are independent and identically distributed with density function

$$f(x) = \frac{1+2x}{3}e^{-x}, x > 0$$

The insurer's premium is paid continuously at a constant rate and is calculated so that the premium loading factor $\theta = \frac{3}{8}$

(i) Define the adjustment coefficient for such a process and calculate its value. [11]

(ii) Define the probability of ruin $\psi(u)$ with initial capital of $u(> 0)$. [1]

(b) The total claim amount arising from a portfolio of insurance policies over a given month has a compound Poisson distribution with parameter 0.5. Individual claim amounts, X_i, have the following distribution:

$$P(X_i = 1) = \frac{3}{4} \;\&\; P(X_i = 2) = \frac{1}{4}$$

An aggregate excess of loss reinsurance contract has been arranged with a retention limit of 2. Calculate the mean aggregate claim payment made by the insurer in a month.

[5]

(c) Aggregate annual claims, S, have a compound binomial distribution with $n = 20$ and $p = 0.01$ (so $N \sim Bin(20,0.01)$). Individual claim amounts, X, have the following distribution: $P(X = 1) = 0.6$ & $P(X = 2) = 0.4$. Calculate $P(S = 3)$. [3]

(d) Let N be the number of claims on a risk in one year. Suppose claims $[X_1, X_2, \ldots]$ are independent, identically distributed random variables, independent of N. Let S be the total amount claimed in one year.

(i) Derive $E(S)$ and $Var(S)$ in terms of the mean and variance of N and X_i.

(ii) Derive an expression for the moment generating function $M_S(t)$ of S in terms of the moment generating functions $M_X(t)$and $M_N(t)$ of X_i and N respectively.

(iii) If N has a Poisson distribution with mean μ, show that:

$$M_S(t) = e^{\mu(M_X(t)-1)}$$

(iv) If N has a binomial distribution with parameters μ and q, determine the moment generating function of S in terms of μ, q and $M_X(t)$.

[5]

[Total: 25 marks]

QUESTION 5

(a) For each of k independent policies, the probability of no claim in a year is $1 - p$ and there is a maximum of one claim per policy. The total number of claims in one year is a random variable X. Independent observations $x_1, \ldots, x_n$ of X are available. The prior distribution of p is a beta distribution with parameters α and β, with $\alpha = \beta$.

(i) Calculate the credibility estimate of p and the value of Z if $\sum_{i=1}^{6} x_i = 12, k = 10$ and when $\beta = 4$. **[11]**

(ii) Comment on the effect on Z of increasing n and β, and relate this effect to the quality of the risk data and prior information about p in each case. **[3]**

(b) Suppose the Poisson parameter is $\lambda = 4$ and the premium rate is $c = 7$. Further suppose the individual loss amount distribution is given by

$$P(X = 1) = 0.6, \quad P(X = 2) = 0.4$$

Determine the adjustment coefficient. **[5]**

(c) Identify any three features of the individual risk model, which distinguishes it from the collective risk model. **[3]**

(d) (ii) Give an intuitive explanation of what $E(m(\theta)), Var[m(\theta)]$ and $E[s^2(\theta)]$ represent: $Var[m(\theta)]$ and $E[s^2(\theta)]$ for Empirical Bayes Credibility theory Model 1. **[3]**

[Total: 25 marks]

END OF EXAMINATION

The University of Zambia

School of Natural Sciences

Department of Mathematics & Statistics

2019/2020 Examinations - December 4, 2020

MAT5122 - Partial Differential Equations

Time allowed : Three (3) hours Full marks : 100

Instructions:

- Attempt **any (5) five** questions out of the **(6) six**. All questions carry equal marks.
- **Full credit** will only be given when **necessary work** is shown.
- Indicate your **computer number** on all answer booklets used.
- Mark allocations are shown in brackets.

This paper consists of 4 pages of questions.

---

1. (a) Consider the Cauchy problem

$$yu_y - uu_x = x, \quad u(x,1) = x.$$

(i) Show that the problem has a unique solution. [3]

(ii) Find the unique solution and state it's maximal domain of existence. [4]

(b) Given the equation

$$u_x - u_y = u :$$

(i) Determine its canonical form. [4]

(ii) Find the solution which satisfies the initial condition [3]

$$u(0, y) = 1.$$

(c) Use the Lagrange method to solve the Cauchy problem

$$(x + y)uu_x + (x - y)uu_y = x^2 + y^2, \quad u = 0 \text{ on } y = 2x. \qquad [6]$$

2. The one dimensional Wave equation is given by

$$u_{tt} - c^2 u_{xx} = 0, \quad x \in \mathbb{R}, \quad , t > 0.$$

(a) Obtain its canonical form and find the general solution $u(x, t)$. [6]

(b) Use the general solution obtained in (a) to derive the solution of the problem

$$u_{tt} - c^2 u_{xx} = 0, \quad -\infty < x < \infty, \quad t > 0,$$

$$u(x, 0) = f(x), \quad u_t(x, 0) = g(x), \quad -\infty < x < \infty. \qquad [6]$$

(c) Solve the problem [8]

$$u_{tt} - 9u_{xx} = 0, \quad u_t(x, 0) = 0,$$

$$u(x, 0) = \begin{cases} \cos \frac{\pi}{2} x, & \text{if } |x| \leq 1 \\ 0, & \text{if } |x| > 1. \end{cases}$$

3. (a) Prove that the Cauchy problem

$$u_{tt} - c^2 u_{xx} = 0, \quad -\infty < x < \infty, \quad 0 \le t \le L$$

$$u(x,0) = f(x), \quad u_t(x,0) = g(x)$$

is well posed. [8]

(b) Use D'Alembert's formula to solve the problem

$$u_{tt} - 9u_{xx} = e^x + e^{-x}, \quad -\infty < x < \infty, \quad t > 0,$$

$$u(x,0) = x, \quad u_t(x,0) = \cos x. \qquad [6]$$

(c) Use the weak maximum principle to prove that there is at most one solution of the problem [6]

$$u_t - ku_{xx} = f(x,t), \quad t > 0 \quad 0 < x < L,$$
$$u(x,0) = \phi(x), \quad u(0,t) = g(t) \quad u(L,t) = h(t).$$

4. (a) Use separation of variables to show that the problem [6]

$$u_t - u_{xx} = e^{-t} \sin 3x, \quad 0 < x < \pi, \quad t > 0$$
$$u(0,t) = u(\pi,t) = 0, \quad u(x,0) = x \sin x.$$

has a solution of the form

$$u(x,t) = \sum_{n=1}^{\infty} T_n(t) \sin nx.$$

(b) By substituting the solution found in (a) into the given PDE, find the complete solution to the problem in (a). [8]

(c) Solve the problem

$$u_t - ku_{xx} = 0, \quad x > 0, \quad t > 0, \quad u(x,0) = 1, \quad u(0,t) = 0.$$

Express your solution in terms of the error function. [6]

5. (a) Use the energy method to prove that the diffusion problem

$$u_t - ku_{xx} = f(x,t), \quad u(x,0) = f(x),$$

$$u(0,t) = g(t), \quad u(L,t) = h(t), \quad t > 0, \quad 0 < x < L$$

has a unique solution. [7]

(b) Solve the problem [6]

$$u_x + u_y + u = 1, \quad u = \sin x \text{ on } y = x + x^2.$$

(c) Use Laplace transform method to solve the following initial boundary value problem [7]

$$u_t - u_{xx} = 0, \quad t > 0 \quad x > 0,$$
$$u(x,0) = 0, \quad u(0,t) = 1 \quad |u(x,t)| < \infty.$$

NOTE:

$$\mathrm{L}^{-1}\left(e^{-\sqrt{s}x}\right) = \frac{x}{\sqrt{4\pi t^2}} e^{-\frac{x^2}{4t}};$$

$\mathrm{L}^{-1}(F(s)G(s)) = (f*g)(t)$ where $\mathrm{L}(f(t)) = F(s)$, and $\mathrm{L}(g(t)) = G(s)$.

6. (a) (i) State the weak maximum and the weak minimum principles for a harmonic function $u \in C^2(D) \cap C(\bar{D})$, where $D \subseteq \mathbb{R}^2$. [4]

(ii) Use the weak maximum and minimum principles to prove the uniqueness of the solution to the Dirichlet problem

$$\triangle u = f \quad \text{on} \quad D \subseteq \mathbb{R}^2, \quad u = g \text{ on } \partial D,$$

where g is a continuous function on ∂D. [5]

(b) Use separation of variables method to show the problem [7]

$$u_{xx} + u_{yy} = 0, \quad u(x,0) = 0, \quad , u(x,b) = u_0, \quad u(0,y) = 0 = u(a,y).$$

(c) Given that in (b) above, $a = \pi$, $b = 1$, $u_0 = \pi$, find $u(x,y)$. [4]

The End

THE UNIVERSITY OF ZAMBIA
DEPARTMENT OF MATHEMATICS AND STATISTICS
2020/2021 ACADEMIC YEAR SESSIONAL EXAMS
MAT5342 OPERATOR THEORY AND TOPOLOGICAL VECTOR SPACES

DURATION: THREE (3) HOURS
INSTRUCTIONS:

- **There are six (6) questions in this question paper**
- **Answer any five (5) questions**
- **All questions carry equal marks**
- **Show all necessary work to earn full marks**

---

1. (a) Define the following terms:
   i. A projection operator.
   ii. Isomorphic normed spaces.

   (b) Prove the following:
   i. The dual space of ℓ^1 is ℓ^∞.
   ii. A bounded linear operator $P : H \to H$ on a Hilbert space H is a projection if and only if P is idempotent and self-adjoint.

   (c) Show that $P : \ell^2 \to \ell^2$ defined by $Px = (x_1, x_2, ..., x_n, 0, 0, 0, ...)$, where $x \in \ell^2$, is a projection operator.

2. (a) Define the following terms:
   i. The continuous spectrum of a linear operator.
   ii. The residual spectrum of a linear operator.

   (b) Let $T : X \to X$ be a compact linear operator on a normed space X, and let $\lambda \neq 0$ be a scalar. For $T_\lambda = T - \lambda I$, prove the following:
   i. The range of T_λ is closed.
   ii. The null space $N(T_\lambda)$ is finite dimensional.
   iii. For every $n \in \mathbb{N}$, $\dim(N(T_\lambda^n)) < \infty$ and $\{0\} \subset N(T_\lambda^0) \subset N(T_\lambda) \subset N(T_\lambda^2) \subset \cdots$.

   (c) Show that the spectrum $\sigma(A)$ of a Hermitian matrix $A = (\alpha_{ij})$ is real.

3. (a) Define the following terms:

i. The spectral radius of a bounded linear operator.

ii. The resolvent operator of a bounded linear operator.

(b) Let $T : H \to H$ be a bounded, self-adjoint linear operator on a complex Hilbert space H. Prove the following:

i. The spectrum $\sigma(T)$ of T is real.

ii. All the eigenvalues of T, if they exist, are real.

iii. Eigenvectors corresponding to different eigenvalues of T are orthogonal.

(c) Find the spectral radius of the linear operator $T : \mathbb{C}^2 \to \mathbb{C}^2$ defined by $(z_1, z_2) \mapsto (z_1 - z_2, z_1 + z_2)$.

4. (a) Define the following terms:

i. A topological vector space.

ii. A Frechet space.

(b) Let X and Y be topological vector spaces. Prove the following:

i. X is connected.

ii. Y is compact if and only if $Y = \{0\}$.

iii. If $T : X \to Y$ is a linear operator, then T is continuous at 0 if and only if it is continuous at every point of X.

(c) Show that every normed space is a topological vector space.

5. (a) Define the following terms:

i. A Banach algebra.

ii. An invertible element in a Banach algebra.

(b) Let A be a Banach algebra with identity e. Prove the following:

i. If $x \in A$ satisfies $||x|| < 1$, then $e - x$ is invertible and $(e - x)^{-1} = \sum_{j=0}^{\infty} x^j$.

ii. For any $x \in A$, the spectrum $\sigma(a)$ of A is compact and the spectral radius satisfies $r(x) \leq ||x||$.

(c) Show that the algebra $C[a, b]$ of all continuous functions complex valued functions on $[a, b]$ is a Banach algebra.

6. (a) Define the following terms:

i. The Hilbert adjoint of a linear operator.

ii. A normal linear operator.

(b) Let $T : H \to H$ be a linear operator on a Hilbert space H. Prove the following:

i. $||T^*T|| = ||TT^*|| = ||T||^2$.

ii. T is unitary if and ony if it is isometric and surjective.

(c) Consider the linear operator $T : \mathbb{C}^2 \to \mathbb{C}^2$ defined by $(z_1, z_2) \mapsto (iz_1 + z_2, z_1 - 2z_2)$. Compute $S = T^*T$ and show that S is normal.

END OF EXAM

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
DEPARTMENT OF MATHEMATICS AND STATISTICS

MAT 5352-TOPICS IN ANALYSIS
FINAL EXAM

Date: **30 November 2020** **Duration:** Three (3) hours.

INSTRUCTIONS:

A. This exam question paper consists of four (4) questions.

B. You are requested to attempt all the questions.

C. Full answers are expected.

==========

Question 1. 1.1 Give the definitions for of each notion of differential geometry in the list below:

(a) An Euclidean curve.

(b) A regular parametric representation of an Euclidean curve.

(c) A regular parametric representation of an Euclidean surface.

(d) The arclength of a smooth curve in the interval $[a, b] \subset \mathbb{R}$.

1.2 Find a regular parametric representation for each geometric locus given by the Cartesian equation below:

(a) $\dfrac{x^2}{a^2} + \dfrac{y^2}{b^2}, \quad a, b \in \mathbb{R}^* = \mathbb{R} - \{0\}.$

(b) $\dfrac{x^2}{a^2} - \dfrac{y^2}{b^2}, \quad x > 0, \ a \in \mathbb{R}^+ - \{0\}.$

(c) $y = \tanh x + e^{\sin x}, \qquad |x| \leq 1.$

(d) $x = y^2 + z^2, \quad 0 \leq y \leq z \leq 1.$

[16, 16 Total: 32]

Question 2. 2.1 The arclength of a regular curve given by $c = c(t)$ is given by the function

$$s = s(t) = \int_{t_0}^{t} \left| \frac{d\gamma}{dt} \right| dt$$

(a) Using the Fundamental Theorem of calculus, show that

$$\left|\frac{dc}{ds}\right| = 1.$$

(b) Find the natural parametric representation for the helix (H_a) given by the parametric representation

$$\gamma(t) = (a\cos t, a\sin t, bt), \quad 0 \leq t \leq 1.$$

(c) Now, verify the assertion in (a) for the parametrisation in (b).

2.2 A curve (L) is given by the equation $ax + by = 0, \quad a, b \in \mathbb{R}$. Find a regular parametric representation for (L), and a parametric representation of (L) which is not regular everywhere. Then find a necessary and sufficient condition on a and b for which the parametric representation of (L) will be arclength (natural) parametrisation.

2.3 A curve (Γ) is given by the equations $y = \frac{x^2}{2}, \quad z = \frac{x^3}{6}$. Find a regular parametrisation for (Γ). Using this parametrisation, calculate the arclength of (Γ) in the interval $[0, 6]$.

[6, 6, 6, 4, 4 Total: 26]

Question 3. A surface (S) is described by the parametrisation

$$r(u,v) = (u - \frac{u^3}{3} + uv^2, v - \frac{v^3}{3} + u^2v, u^2 - v^2).$$

Calculate r_u, r_v, r_{uu}, r_{uv}, r_{vv}. Hence record the inner products $E =< r_u, r_u >$, $F =< r_u, r_v >$, and $G =< r_v, r_v >$. That is, $< r_i, r_j >= r_i \cdot r_j$.

(3.1) Then write down the first fundamental quadratic form (called the metric) of the surface (S), given by the formula

$$I = ds^2 = Edu^2 + 2Fdudv + Gdv^2,$$

which describes the interior geometry of the surface in the neighborhood of a given point.

(3.2) Find the principal normal given by

$$\mathcal{N} = \frac{r_u \times r_v}{|r_u \times r_v|}.$$

(3.3) Calculate the quantities

$$L = \mathcal{N} \cdot r_{uu},\ M = \mathcal{N} \cdot r_{uv},\ N = \mathcal{N} \cdot r_{vv},$$

then write down the second fundamental quadratic form of the surface (S) given by

$$II = L\ du^2 + 2M dudv + N dv^2$$

by Gauss, and which describes the shape of this surface in the neighborhood of each point.

(3.4) Calculate the Gaussian curvature K, given in the neighborhood of each point by

$$K = \frac{LN - M^2}{EG - F^2}.$$

(3.5) Calculate the mean curvature H, given by the formula

$$H = \frac{1}{2}\frac{EN - 2FM + GL}{EG - F^2}.$$

[5, 5, 5, 5, 5 Total: 25]

Question 4. A torus is decribed by the parametric equations

$$r(u,v) = ((a+b\cos u)\cos\theta, (a+b\cos u)\sin\theta, b\sin u), \quad u = u(t),\ v = v(t).$$

Write down the differential equations below, which define the necessary and sufficient condition for a curve on the surface of this torus to be a geodesic.

$$\begin{aligned} eu'' + fv'' + \Gamma_{111}u'^2 + 2u'v'\Gamma_{121} + v'^2\Gamma_{221} &= 0 \\ fu'' + gv'' + \Gamma_{112}u'^2 + 2u'v'\Gamma_{122} + v'^2\Gamma_{222} &= 0, \end{aligned}$$

[**Hints**: $e =< r_1, r_1 >$, $f =< r_1, r_2 >$, $g =< r_2, r_2 >$, $\Gamma_{ijk} =< r_i, r_{jk} >$ example $\Gamma_{121} =< \mathrm{r}_1, \mathrm{r}_{21} >$]

[Total: 17]

[TOTAL MARKS: 100]

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

DEPARTMENT OF MATHEMATICS AND STATISTICS

2020 ACADEMIC YEAR
FINAL EXAMINATIONS

MAT5632 : DESIGN AND ANALYSIS OF EXPERIMENTS

TIME ALLOWED: Three (3) Hours

INSTRUCTIONS: 1. Answer any **Four** (4) Questions
2. Show All Essential Working

---

1. (a) (i) State and define two principals of experimental design.
(ii) Give one reason why each principal in (i) is important.

(b) An animal nutritionist wanted to investigate the effect of five different kinds of diets on weight gain in cattle. The investigator selected 30 calves from three breeds of cattle and randomly assigned them to the 5 diets and measured weight gain (in kg) after three days. The following results were obtained:

		Breed			
		1	2	3	Total
Diet	1	2.7	3.5	3.0	
		3.4	4.0	3.5	20.1
	2	1.4	1.9	1.4	
		2.3	2.9	3.0	12.9
	3	4.0	4.1	4.8	
		2.8	3.5	3.9	23.1
	4	2.0	1.8	2.6	
		1.5	2.2	2.5	12.6
	5	3.1	3.7	3.4	
		3.5	3.4	3.9	21.0
Total		26.7	31.0	32.0	89.7

Consider fitting the model $Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ijk}$, $i = 1, 2, 3, 4, 5$; $j = 1, 2, 3$; $k = 1, 2$ where

α_i = effect of ith diet and β_j = effect of jth breed.

(i) State all the model assumptions.
(ii) Estimate the parameters β_2 and $(\alpha\beta)_{31}$.
(iii) Copy and complete the following ANOVA table:

Source	SS	df	MS	F*
Diet				
Breed				
Interaction	0.954			
Error	4.445			
Total	22.747			

(iv) Test whether diet has a significant effect on weight gain using a 5% level of significance.

(v) Test whether diet 1 gives a higher average weight gain compared to diet 2. Use a 5% level of significance.

(vi) Compute the sum of squares associated with the contrast that compares diets 1 and 3 to diets 2 and 4.

(vii) Using the result in (vi), test whether diets 1 and 3 are significantly different from diets 2 and 4. Use $\alpha = 0.05$.

2. (a) (i) Find a contrast for the ACD effect in a 2^4 factorial experiment with factors A, B, C and D.

(ii) Explain how you would obtain a half fraction of the 2^k factorial design with the highest resolution.

(b) A 2^2 factorial design was used in an experiment to study the effect of gear housing clearance (A) and gear ratio (B) on oil flow rate (in litres/second) of an automobile engine oil pump. Eight prototype pumps were built and connected in a random order to a test engine and the following measurements were made at idling speed:

		replicate		
A	B	I	II	Total
−	−	2.1	2.4	4.5
+	−	2.1	1.7	3.8
−	+	2.3	2.5	4.8
+	+	1.9	1.8	3.7
				16.8

(i) Estimate A, B and AB effects

(ii) Prepare an ANOVA table for the experiment.

(iii) Test for the significance of the main effects A and B. Use $\alpha = 0.05$.

(iv) Compute a 95% confidence interval for the AB interaction effect.

(v) Compute an ANOVA table for the above data considering the experiment as a one way layout with four treatments (the four combinations of A and B).

(vi) Compare the ANOVA tables in (ii) and (v). How are they related?

3. (a) Define the following:
   (i) partially confounded design.
   (ii) factorial experiment.

(b) Consider a single replication of a 2^4 factorial experiment with factors A, B, C and D in two blocks of eight runs each with ABD confounded with blocks.
   (i) Generate the design showing the observations in each block. Explain clearly how each block is generated.
   (ii) Given that the experiment conducted gave the following data:

(1) = 24	$d = 22$
$a = 20$	$ad = 18$
$b = 30$	$bd = 28$
$ab = 26$	$abd = 24$
$c = 27$	$cd = 25$
$ac = 23$	$acd = 21$
$bc = 33$	$bcd = 31$
$abc = 29$	$abcd = 27$

Estimate the effects A, CD and ABD if possible and explain why where not possible.

   (iii) Copy and complete the following ANOVA table for the data in (ii):

Source	SS	df	MS	F*
A				
B				
C	36			
Error	16			
Total	260			

   (iv) Test for the significance of the effects A, B and C in (iii) using a 5% level of significance.

4. (a) Define the following
   (i) orthogonal contrasts.
   (ii) principal block.

   (b) Consider a 2^{5-2} factorial design with generators $I = ABCE$ and $I = ABD$.
   (i) Write down a complete alias structure of the design.
   (ii) Find the resolution of the design.
   (iii) Find all the quarter fractions of the design.
   (iv) Given that the actual experiment conducted gave the following data:

(l) = 21	$d = 33$	$e = 30$	$de = 29$
$a = 33$	$ad = 29$	$ae = 31$	$ade = 36$
$b = 28$	$bd = 30$	$be = 33$	$bde = 25$
$ab = 26$	$abd = 27$	$abe = 24$	$abde = 29$
$c = 34$	$cd = 22$	$ce = 26$	$cde = 31$
$ac = 34$	$acd = 36$	$ace = 26$	$acde = 35$
$bc = 24$	$bcd = 27$	$bce = 35$	$bcde = 27$
$abc = 25$	$abcd = 36$	$abce = 30$	$abcde = 24$

   Using the quarter fraction containing the treatment combination (1), estimate the effects B, D and CD.

5. (a) Define the following:
   (i) a completely confounded design.
   (ii) a 2^{k-p} fractional design.

   (b) The effects of four factors on some response are studied. Each factor is varied at two levels in a 2^4 factorial experiment and the following data recorded:

Treatment Combination	response
(1)	24
a	22
b	28
ab	25
c	25
ac	22
bc	30

abc	29
d	20
ad	17
bd	28
abd	25
cd	25
acd	23
bcd	30
abcd	28

(i) Estimate all the main effects.

(ii) Assuming two and higher order interactions effects are negligible, copy and complete the following ANOVA table:

Source	SS	df	MS	F*
A				
B				
C				
D				
Error			1.608	
Total				

(iii) Test for the significance of the main effects at the 5% level.

(iv) Write down a regression equation that includes only the significant main effects identified in (iii).

(v) Test whether the effect for factor B is significantly different from 7.5. Use a 5% level of significance.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

2019/20 ACADEMIC YEAR FINAL EXAMINATIONS

MAT 5642: STATISTICAL METHODS IN EPIDEMIOLOGY

INSTRUCTIONS:

1. Answer any FIVE (5) questions.
2. Calculators are allowed.
3. You may use statistical tables or formulae provided if necessary.
4. Show all your work to earn full marks.

TIME: THREE (3) Hours

Question 1

(a) The pattern of reasoning in epidemiology is outlined as follows:

i. Develop a hypothesis

ii. Identify an exposed group and an appropriate control group

iii. Collect data

iv. Test the hypothesis

Assume a project is commissioned to study the association between addiction to social media and gender, among boys and girls 20 years of age or younger. For each of the steps i, ii, iii and iv, give specific examples required to conduct such a research. That is, state the hypotheses as they relate to this study of addiction, state the exposed and control groups you would use and so on.

(b) The Zambia Statistical Agency in its report of 2018 states that 12% of women and 26% of men aged 15-49 had used the internet in the past 12 months prior to the survey. It interviewed 13,683 women and 12,132 men. Test whether there was a significant difference in the use of the internet between males and females. Use the odds ratio as a measure of effect at $\alpha = 0.05$.

Question 2

(a) The world is experiencing a pandemic as a result of the COVID19 and when it is over, if ever it will be, various etiologic studies will be conducted. The case-control study design will feature frequently, in bullet format list:

(i) The strengths of this design compared to other analytical designs.

(ii) The weaknesses of this design compared to other analytical designs.

(b) The function f(X), of a random variable X, may be approximated by First-order Taylor's series about μ_X as; $f(X) \cong f(\mu_X) + f'(\mu_X)(X - \mu_X)$

(i) Obtain the variance of f(X) in terms of the variance of X when $f(\mu_X)$ and $f'(\mu_X) = \frac{df(X)}{dx}\Big|_{x=\mu_X}$ are treated as constants.

(ii) Obtain the variance of $\ell n\left(\frac{\hat{\pi}_1}{\hat{\pi}_2}\right)$ where $E(\hat{\pi}_i) = \pi_i$ and $\hat{\pi}_i$ is an estimate of π_i of the binomial distribution with parameter n_i and π_i, i =1, 2. Assume $\hat{\pi}_i s$ are independent.

(iii) What is a reasonable estimate of $Var\left[\ell n\left(\frac{\hat{\pi}_1}{\hat{\pi}_2}\right)\right]$ based on your result in (ii)?

(iv) From March to August 2020, Zambia experienced 264 deaths out of 9979 cases of COVID19 and Zimbabwe experienced 141 deaths out of 5379 cases. Obtain a 95% confidence interval of the true cumulative incidence ratio (CIR) for the two countries.

Question 3

(a) In follow-up studies where the interest is in the association of disease and exposure the incidence density (ID) is a preferred measure of effect.

(i) State the reason why ID may be preferred to a cumulative incidence (CI).

(ii) To determine total person-time at risk during the follow-up period, required in the calculation of an ID, problems are sometimes encountered, list some of them.

(b) An individual, new to gardening, acquired some vegetable seedlings and was instructed to spray some chemical after germination. Unfortunately, the individual didn't have sufficient chemical to spray all the crops. Assume the data below is the individual's record of the number of weeks it took for the crops to die (9 among those sprayed and 11 among those not sprayed).

Crops sprayed	1	2	3	4	5	6	7	8	9
Weeks observed	4.4	9.1	7.1	7.1	7.4	4.6	9.7	5.3	9.7

Crops not sprayed	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
Weeks observed	1.5	4.3	4.8	6.2	0.9	3.4	8.0	4.7	3.2	1.6	2.3

(i) Calculate the estimate of the incidence density for each group.

(ii) Test for the association of death of the crop and spraying at $\alpha = 0.05$.

Question 4

Causes of high blood pressure (hypertension or HBP) are not known, but several factors have been identified and they include high salt intake. Assume that the table below shows the true status of the association of hypertension and salt intake in a community.

		Hypertension status		
		Yes	No	
Salt intake	High	A	B	M_1
	Normal	C	D	M_2
		N_1	N_2	

Assume that samples are taken from this population for a cohort study in the following manner.

- A random sample from M_1 (high salt intake) represented by the fraction f_1 is taken.
- A random sample from M_2 (normal salt intake) represented by the fraction f_2 is taken.

(a) (i) Show that exposure odds will be distorted in the cohort study.

(ii) Show that disease odds will not be distorted in the cohort study.

(b) Assume now that another follow-up study is to be conducted in which the association of alcohol intake and hypertension are of interest. Individuals who are not hypertensive are enrolled into the study. The exposure group consist of those who take alcohol and the unexposed group, those who do not take alcohol. The research would like to determine the sample size fixing type I error (α) at 5%, and type II error (β) at 10%, in which a relative risk (RR) of 5 is considered important. Let $p_1 = \Pr(H+|A-)$ be the probability that a person who does not take alcohol (A-) is hypertensive (H+) in the general

community and $p_2 = \Pr(H+|A+)$, be the probability that a person who takes alcohol (A+) is hypertensive in the community.

(i) If the sample size n for each group is given by

$$n = \frac{\left[Z_{1-\frac{\alpha}{2}}\times\sqrt{2pq}+Z_{1-\beta}\times\sqrt{p_1(1-p_1)+p_2(1-p_2)}\right]^2}{(p_1-p_2)^2},$$

show that in terms of RR it is equivalent to:

$$n = \frac{\left[Z_{1-\frac{\alpha}{2}}\times\sqrt{2pq}+Z_{1-\beta}\times\sqrt{p_1(1+RR-p_1(1+RR^2))}\right]^2}{(p_1(1-RR))^2}$$

(ii) Determine the sample size for each group if $p_1 = 0.03$.

Question 5

Consider a community of 12,000 individuals in which issues to water quality and diarrhoea are of concern to community leaders. You have been tasked to study the issue and you decide to carry out a case-control study on data from a hospital that serves the community. The table below gives the true classification of diarrhoea and quality of water in the community since last year.

		Has/had diarrhoea		
		Yes	No	
Quality of drinking water	Unsafe	1440	3360	4800
	Safe	960	6240	7200
		24000	9600	12000

(a) Determine the odds ratio between having diarrhoea and the quality of water.

(b) In the use of the hospital data you decide to choose, for the control group, those individuals admitted to the hospital due to mobility-related injuries. Let;

- $\Pr(H_{D+}) = 0.12$ be the probability that an individual is hospitalized due to diarrhoea.
- $\Pr(H_{E+}) = 0.03$ be the probability that an individual is hospitalized due to waterborne diseases, a measure of the quality of drinking water.
- $\Pr(H_{D*}) = 0.20$ be the probability that an individual is hospitalized due to mobility-related injuries.

(i) Construct a Venn diagram of how hospital admissions might look like assuming independence of hospitalization due to the three factors. Round off the values to the nearest whole number.

(ii) Based on (i) construct a 2×2 of your study data.

(iii) Calculate the odds ratio from your data (ii).

(iv) Determine the bias, if any, from the measure in (iii).

Question 6

(a) A confounder is considered to be an extraneous factor that might be explanatory of the magnitude of the estimate of effect.
Briefly, explain how stratification in analysis may be used to control for confounding.

(b) The Zambia Demographic and Health Survey of 2018 reports on page 26, children's living arrangements and orphanhood by various background characteristics from the survey it conducted. The data below, an extract from its report, show *who the children lived with* by *gender* and stratified by *region.*

Urban areas

		Who the child lives with		
		At least one parent	Other people	
Gender	Male	5067	922	5989
	Female	4972	1121	6093
		9920	2162	12082

Rural areas

		Who the child lives with		
		At least one parent	Other people	
Gender	Male	9264	1686	10950
	Female	9092	2050	11142
		18356	3736	22092

(i) Obtain an estimate of the crude odd ratio of who the child lives with and gender by collapsing region, i.e. combining the tables.

(ii) Determine the stratum specific odd ratio of who the child lives with and gender to 3 decimal places.

(iii) Determine whether there is any bias, and if present its nature.

(iv) Test for the association between *who the child lives with* and *gender* using the data you obtain in (i), use 5% level of significance.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

Department of Mathematics and Statistics

2019/2020 Academic Year

MAT5662: Theory of Non – Parametric Statistics

Final Examination

Time Allowed: Three (3) Hours **December 2020**

Instructions:

1. You must write your **Computer Number** on each answer booklet used.
2. There are Five (5) questions in this paper, Attempt any **Four (4)** questions.
3. Full credit will only be given where all the necessary work is shown.

1. (a) Define the following:
   (i) Signed rank statistics.
   (ii) Equal in distribution.
   (iii) Convergence in quadratic mean.

   (b) Prove the following:
   (i) If $F_r(x)$ denotes the *cdf* of the r^{th} order statistic in a random sample of size n, then;
   $$F_r(x) = F_{r+1}(x) + \binom{n}{r}(P(x))^r(1-P(x))^{n-r}$$
   (ii) $$\sum_{j=k}^{n}\binom{n}{j}(P(x))^j(1-P(x))^{n-j} = \frac{1}{B(k, n-k+1)}\int_0^{P(x)} y^{k-1}(1-y)^{n-k}\,dy.$$

   (c) (i) Develop a general expression for the variance of a $U-$ statistic.
   (ii) Find the variance for the $U-$ statistic estimator of the variance.

2. (a) Given a random sample of size n from a continuous distribution with *pdf* $p(x)$ and *cdf* $P(x)$, derive the following:
   (i) Joint *pdf* for the r^{th} and the s^{th} order – statistics with $r < s$.
   (ii) Conditional *pdf* of the s^{th} order – statistic given the r^{th} order – statistics.
   (iii) *pdf* for the range $W = X_{(n)} - X_{(1)}$.

   (b) Let $p(x) = \theta x^{\theta-1}e^{-x^\theta}$, $x > 0$, $\theta > 0$ be the *pdf* of x. Find the following:
   (i) Joint *pdf* for the r^{th} and the s^{th} order – statistics with $r < s$.
   (ii) Conditional *pdf* of the s^{th} order – statistic given the r^{th} order – statistics.
   (iii) *pdf* for the range $W = X_{(n)} - X_{(1)}$.

   (c) Let $X_1, X_2, X_3, ..., X_n$ and $Y_1, Y_2, ..., Y_m$ be two independent random samples, with $R = (Q_1, Q_2, ..., Q_n, R_1, R_2, ..., R_m)$ as the rank vector for combined sample. Prove that $W_y = \sum_{j=1}^{m} R_j$ the.Wilcoxon rank statistic under H_0 (The medians are equal) is symmetric about its mean $\mu = m\frac{(n+m+1)}{2}$.

3. (a) Define the following:
   (i) Convergence in probability.
   (ii) Limiting distribution.
   (iii) Distribution – free statistics.

   (b) Prove the following:
   (i) If $X_1, X_2, X_3, \ldots, X_n$ is a random sample of size n from a continuous distribution whose *pdf* is symmetrical about its mean μ, then the *pdfs* of $X_{(r)}$ and $X_{(n-r+1)}$ are mirror images. That is,
   $$f_r(\mu + x) = f_{n-r+1}(\mu - x).$$
   (ii) If W is a continuous random variable with distribution that is symmetric about zero, then the random variables $|W|$ and $\psi = \psi(W)$ are stochastically independent.

   (c) (i) State Slutsky's Theorem.
   (ii) Prove that if a sequence of random variables $\{V_n\}$ has asymptotic distribution with *cdf* $F(v)$ and $\{W_n\}$ is a sequence of random variables such that the sequence $\{W_n - V_n\}$ converges in probability to zero, then the limiting distribution of $\{W_n\}$ is also given by the *cdf* $F(w)$.

4. (a) Define the following:
   (i) Estimable parameter.
   (ii) U – statistic for an estimable parameter.
   (iii) Projection of a U – statistic.

   (b) (i) Show that the projection V^* of a U – statistic for $\gamma = \text{var}(X)$ is given by $V^* = \frac{1}{n}\sum_{i=1}^{n}(X_i - \mu)^2 - \gamma$ where $\mu = E(X)$.
   (ii) Prove that if $U(\cdot)$ is a U – statistic for an estimable parameter γ with symmetric kernel $h(\cdot)$, the projection of $U(X_1, X_2, \ldots, X_n) - \gamma$ on ν is given by $V^* = \frac{k}{n}\sum_{i=1}^{n}\{h_1(x_i) - \gamma\}$ where $h_1(X) = E\{h(x, X_1, X_2, \ldots, X_k)\}$.

   (c) Let $X_1, X_2, \ldots, X_n$ be a random sample from a distribution with mean μ, variance $\sigma^2 < \infty$, and $\tau^2 = E\{(X_i - \mu)^2\} - \sigma^4 < \infty$. Find the limiting distribution of $W_n = \sqrt{n}\left\{\frac{1}{n}\sum_{i=1}^{n}(X_i - \overline{X})^2 - \sigma^2\right\}$.

5. (a) Let $X_1, X_2, \ldots, X_n$ be a random sample from a continuous distribution with *cdf* $P(\cdot)$ and denote the *cdf* of $X_{(r)}$ by $F_r(\cdot)$. Prove the following:

(i) $\mu_r = \int_{-\infty}^{\infty} (1 - F_r(z) - F_r(-z))dz$

(ii) $E(W) = \int_{-\infty}^{\infty} (1 - (P(z))^n - (1 - P(z))^n)dz$ where $W = X_{(n)} - X_{(1)}$.

(b) (i) ~~Prove that~~ if $X_1, X_2, \ldots, X_n$ is a random sample from uniform $(0, \theta)$, ~~then~~ find the asymptotic distribution of $X_{(n)}$ ~~is exponential~~.

(ii) Prove that the random variable X has a distribution that is symmetric about some value μ if and only if $(X - \mu) \stackrel{d}{=} (\mu - X)$.

(c) Let $Z_1, Z_2, Z_3, \ldots, Z_n$ be a random sample from a continuous distribution that is symmetric about zero. Let R^+ be the vector of absolute ranks of $Z_i's$ and define $\psi_i = \psi(Z_i)$, for $i = 1, 2, 3, \ldots, n$. Prove the following:

(i) The n+1 random variables $\psi_1, \psi_2, \ldots, \psi_n, R^+$ are mutually independent.

(ii) Each ψ_i is a Bernoulli random variable with $P = \frac{1}{2}$.

(iii) R^+ is uniformly distributed over $\mathfrak{B}$, the set of all permutations of the integers $(1, 2, 3, \ldots, n)$

End of Exam

Physics Department
University Examinations 2020/21
PHY 1010: Introductory Physics

All questions carry equal marks. The marks are shown in brackets. Question 1 is compulsory. Attempt four more questions. Clearly indicate on the answer script left column on the cover page the questions you have answered.

Time : Three hours. **Maximum marks = 100.**

Do not forget to write your computer number clearly on the answer book as well as on the answer sheet for Question 1. Tie them together.

==========

Wherever necessary use :

$g = 9.8 m/s^2$ 1 metric ton = 1000 kg

$P_A = 1.01 \times 10^5 N/m^2$

1 cal. = 4.18 J

$\varepsilon_0 = 8.85 \times 10^{-12} C^2/Nm^2$

$c = 3 \times 10^8$ m/s

$h = 6.63 \times 10^{-34}$ J-s

1 pascal =1 N/m^2

$1eV = 1.6 \times 10^{-19}$ J

$e = 1.6 \times 10^{-19}$ C

$m_e = 9.11 \times 10^{-31}$ kg

$k = 9 \times 10^9 Nm^2/C^2$

$\mu_0 = 4\pi \times 10^{-7} N/A^2$

$\rho_{water} = 1000 kg/m^3$

$G = 6.67 \times 10^{-11} Nm^2/kg^2$

For Question 1, you must use the blank answer sheet provided.

Question 1: For <u>each</u> correct answer, 2 marks will be given. For <u>each</u> wrong answer, 0.67 will be deducted. For no answer, zero mark will be given. The minimum total mark for Question 1 is zero.

(A) The magnitude of the resultant of two forces is minimum when the angle between them is:

(a) 0^0 (b) 45° (c) 90° (d) 180°

(B) A ball dropped loses potential energy. Gravity is an example of:

(a) A non-conservative force.
(b) A conservative force.
(c) Dissipative force.
(d) Any of the above, depending on the reference level.

(C) The acceleration of gravity on the planet Mars is 3.7 m/s^2. Compared with her mass and weight on Earth, an astronaut on Mars has:

(a) Less mass and less weight.
(b) Less mass and more weight.
(c) The same mass and less weight.
(d) Less mass and the same weight.

(D) The coefficient of friction is defined as:

(a) The ratio of the force needed to induce motion to the force needed to maintain motion.
(b) The ratio of the pressure to the force pressing the surfaces together.
(c) The ratio of the frictional force to the normal force.
(d) The ratio of the normal force to the frictional force.

(E) The work done in lifting 30 kg of bricks to a height of 20m on a building under construction is:

$wd = PE$
$wd =$

(a) 600 J.
(b) 61 J.
(c) 5880 J.
(d) 2940 J.

(F) The period of a simple pendulum is independent of

(a) Length
(b) Acceleration due to gravity
(c) Mass
(d) Total energy

The University of Zambia
Physics Department
University Examinations 2020/21
PHY 1010 : Introductory Physics

Answer sheet for Question 1

Computer Number ..2020983344..

Q1. Put a cross (×) or tick mark (√) in the appropriate box. If it is on the dividing line, it will not be counted.

	a	b	c	d
A			×	
B		×		
C			×	
D				×
E			×	
F				×
G				×
H		×		
I	×			
J				

Do NOT write here.
For official use only :

	Number of parts N	Factor f	Marks f × N
Correct		2	
Wrong		-(0.67)	
	Net Marks :		

Attach this sheet firmly with the main answer book with the string provided. If you lose this sheet, you will lose the marks for Question 1.

(G) The moment of inertia of an object does not depend on:

(a) Its size and shape.
(b) Its mass.
(c) Its angular speed.
(d) The location of the axis of rotation.

(H) The total angular momentum of a system of particles:

(a) Changes when a net external torque acts on the system.
(b) Remains constant under all circumstances.
(c) Changes when a net external force acts on the system.
(d) May or may not change under the influence of a net external torque, depending on the direction of the torque.

(I) In an equilibrium problem the point about which torques are computed:

(a) Must pass through the object's centre of gravity.
(b) May be located anywhere.
(c) Must pass through one end of the object.
(d) Must intersect the line of action of at least one force acting on the object.

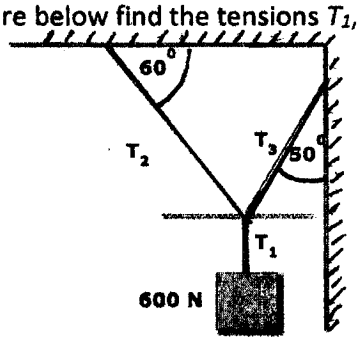
(J) Gamma (γ) for a gas is defined as the ratio of:

(a) C_p/R
(b) C_v/C_p
(c) C_p/C_v
(d) $(C_v-R)/C_p$

ATTEMPT ANY FOUR QUESTIONS FROM BELOW:

2 (a) A car is driven east for a distance of 50 km, then north for 30 km, and lastly in the direction 30^0 east of north for 25 km. Find the total displacement of the car from its starting point using the vector method. [10]

(b) For the setup shown in the figure below find the tensions T_1, T_2 and T_3. [8]



(c) State the two conditions of equilibrium. [2]

3 (a) A girl throws a ball vertically upward at 10 m/s from the roof of a building 20 m high.

i) How long will it take the ball to reach the bottom? [4]

ii) What will be its velocity when it strikes the ground [6]

(b) One end of a spring of spring constant k =1200 N/m. is fixed to a rigid wall and the other end is connected to a 3 kg mass on a frictionless horizontal surface. The mass is pulled horizontally a distance of 2cm from its equilibrium position and released. Calculate the:

iii) frequency of oscillation; [2]

iv) maximum speed and maximum acceleration; [4]

v) speed of the mass when the spring is compressed by 1 cm; and [2]

vi) potential energy when the spring is at its maximum compression. [2]

4 (a) A car starts from rest and accelerates uniformly to reach a velocity of 25 m/s after travelling 100 m. It travels at this velocity for 750 m, and then takes 5 s with uniform deceleration (slowing down), to come to rest. Draw a velocity time-graph and use it to:

i. find its displacement in the first 20 s of the motion; [6]

ii. find its total displacement; and [2]

iii. find the total time taken [2]

(d) An ideal gas is taken through a Carnot cycle. The isothermal expansion occurs at 250^0 C, while the isothermal compression takes place at 50^0 C. the gas takes in 1.2×10^3 J of energy from the high-temperature reservoir during the isothermal expansion.
Find:

i) the heat energy expelled to the low-temperature reservoir in each cycle of operation; and [8]

ii) the net work done by the gas in each cycle. [2]

5 (a) A 1 kg block starts sliding up a 35^0 inclined plane with an initial speed of 3 m/s. It stops after sliding 50 cm and then slides back down the incline. Assuming that the friction force impeding the motion of the block is constant, find:

i) The friction force and the coefficient of kinetic friction; and [6]

ii) The speed of the block when it reaches the bottom. Use the energy conservation method. [4]

(b) How deep is a pond if bubbles forming at the bottom grow 4 times in size in rising to the top? The temperature at the bottom is taken to be 10^0 C, and that at the surface to be 20^0 C [10]

6 (a) A gun of mass 4 kg recoils (pushes back) with a speed of 0.5 m/s when it fires a bullet of mass 10 g horizontally.

i) Find the speed with which the bullet is fired. [3]

ii) If the bullet embeds itself in a 1.990 kg block of wood at rest on a horizontal table, with what velocity does the block and bullet begin to move? [3]

iii) If the block-and-bullet stops after 10 cm, what is the coefficient of sliding friction between the block and table [4]

(b) A ceramic cup contains 0.25 kg of water initially at 23^0 C. How much ice, initially at -19^0 C, must one add to obtain a final temperature of 0^0 C with all the ice melted? Neglect the heat capacity of the ceramic cup. Given that c_{water} = 4184 J/kg.^{0}C, and $H_f = 3.35 \times 10^5$ J/kg. [10]

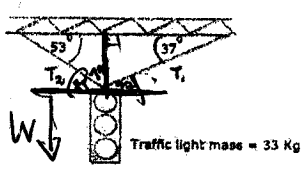
7 (a) A merry-go-round has a mass of 100 kg and a radius of 1.6 m. Consider it as a uniform disc of moment of inertia $I = \frac{1}{2}mr^2$. A man pushes with a horizontal force of 80 N tangential to the edge of the merry-go-round.

i. What is the angular acceleration produced? [3]

ii. Starting from rest, how fast will the merry-go-round be moving in rev/s after 12 s of pushing by the man? [3]

iii. How many revolutions will the merry-go-round have made in 12 s? [2]

(b) Find the tension in each of the two wires supporting the traffic light shown below. Take the left side as T_2 and the right side as T_1. [10]



END OF EXAMINATION

Some Useful Equations

Uniformly accelerated motion:

$x = \bar{v}t \quad \bar{v} = \frac{1}{2}(v_f + v_i) \; v_f = v_i + at \qquad v_f^2 = v_i^2 + 2ax \; x = v_i t + \frac{1}{2}at^2$

Projectile motion:

$v_x = v_i \cos\theta_i = \text{constant} \qquad v_y = v_i \sin\theta_i - gt \qquad y = (v_i \sin\theta_i)t - \frac{1}{2}gt^2$

$y = (\tan\theta_i)x - \left[\frac{g}{2v_i^2(\cos^2\theta_i)}\right]x^2 \qquad R = \frac{v_i^2}{g}\sin 2\theta \qquad t = \frac{2v_i \sin\theta}{g}$

Force and motion:

$F = ma \qquad w = mg \qquad F_{AB} = -F_{BA} \qquad F_f = \mu F_N$

Work and Energy:

$PE = wh = mgh \qquad KE = \frac{1}{2}mv^2 \qquad W = Fx\cos\theta \qquad P = \frac{W}{t} = Fv\cos\theta$

Linear momentum: $p = mv \qquad F\Delta t = \Delta mv = m\ v_f - v_0$

Circular motion and gravitation:

$T = \frac{2\pi r}{v} \; a_c = \frac{v^2}{r} \qquad F_c = \frac{mv^2}{r} \qquad F_{grav} = G\frac{m_A m_B}{r^2} \; 1rev = 360^0 = 2\pi\, rad$

$v_T = \frac{(2\pi r)}{T} \; : \quad \tan\theta = \frac{v^2}{rg} :$

Rotational motion and angular momentum:

$\theta = \frac{s}{r} = \left(\frac{\omega_i + \omega_f}{2}\right)t \quad \omega = \frac{\theta}{t} \; \theta = \omega_i t + \frac{1}{2}\alpha t^2 \; \omega_f = \omega_i + \alpha t \; v = \omega r$

$I = mk^2 \; \omega_f^2 = \omega_i^2 + 2\alpha\theta \qquad \alpha = \frac{\Delta\omega}{\Delta t} = \frac{a_T}{r} \; I = \sum mr^2 \; KE_{rot} = \frac{1}{2}I\omega^2$

$\tau = FL = I\alpha \quad W = \tau\theta \; P = \tau\omega \qquad L = I\omega \; KE_{total} = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$

Properties of matter:

$\rho = \frac{m}{V} \; F = -kx \qquad \frac{\Delta L}{L_i} = \frac{1}{Y}\frac{F}{A} \qquad \phi = \frac{s}{d} = \frac{1}{s}\frac{F}{A} \quad B = -\frac{\Delta P}{\Delta V / V_0} \; W_{app} = W\left(1 - \frac{\rho_{fluid}}{\rho}\right)$

$F_B = \rho V g$, (submerged object) $\qquad F_B = Mg$ (floating *M)*

Thermal Properties of matter:

$PV = nRT$: $\Delta Q = mc\Delta T = nC\Delta T$: $\Delta L = \alpha L \Delta T$: $L_t = L_0(1+\alpha t)$: $\Delta V = \gamma V \Delta T$:

$W = P\Delta V$ $(\Delta Q / \Delta t) = (kA\Delta T)/\Delta L$: $m = V \times \rho$ $\frac{Q}{t} = eA\sigma T^4$ $C_P = C_V + R$

$Q = n.C.\Delta T = \frac{3}{2} n.R.\Delta T$ for isobaric and iso-volumetric processes

Thermodynamics:

$\Delta Q = \Delta U + \Delta W$: $W = p.\Delta V$ $PV = nRT$ $n = \frac{m}{M}$ $P_1V_1^{\gamma} = P_2V_2^{\gamma}$ $T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$

$COP_{ref} = \frac{Q_C}{W}$ $COP_{heat\ pump} = \frac{Q_H}{W}$ $W_{isothermal} = nRT \ln\frac{V_2}{V_1}$ $W_{adiabatic} = \frac{1}{\gamma-1}(P_1V_1 - P_2V_2)$:

$COP_{\max-refr} = \frac{T_C}{W}$ $COP_{\max-heat\ pump} = \frac{T_H}{W}$ $e = 1 - \frac{T_c}{T_h} = \frac{work\ done}{input\ heat\ at\ high\ temp}$

Waves and Sound:

$f = \frac{1}{\tau} v = \pm\sqrt{\frac{k}{m}(x_0^2 - x^2)}$ $v = \sqrt{\frac{T}{m/L}}$ $\tau = \frac{1}{f} = 2\pi\sqrt{\frac{m}{k}}$ $a = -\left(\frac{k}{m}\right)x$ $v = \sqrt{\frac{Y}{\rho}}$ $v = \sqrt{\frac{B}{\rho}}$ $f' = f$

$\frac{v \pm v_L}{v \mp v_S}$ (dB) = 10. log $\frac{I}{I_0}$: velocity of sound = 331.45 + 0.61t (°C)

$\tau = \frac{2\pi x_0}{v_0} = 2\pi\left(\frac{x_0}{v_0}\right) = \frac{2\pi}{\omega}$ $f = \frac{1}{2L}\sqrt{\frac{T}{m}}$ $x = x_0\cos(\omega t)$ $I_0 = 10^{-12}\ W/m^2$

Electric Field:

$F \propto \frac{q_1 q_2}{r^2}$ or $F = k.\frac{q_1 q_2}{r^2}$; k = 8.9874 × 10^9 N.m^2.C^{-2}. $k = (1/(4\pi\varepsilon_0)$ where ε_0 is the permittivity constant = 8.85 × 10^{-12} C^2.(N.m^2)$^{-1}$.

e = 1.60 × 10^{-19} C; $E = \lim_{q_{test}\to 0}\frac{F}{q_{test}}$; **F** = q**E**; $\frac{mv^2}{2} = F_x\Delta x = eE_x\Delta x$;

Electric Potential:

$W_{AB} = q.E.d.$; $V_B - V_A = \frac{W_{AB}}{q} = \frac{\sigma}{\varepsilon_0}.d = \frac{q}{A}.\frac{d}{\varepsilon_0}$; $V_B - V_A = \frac{W_{AB}}{q} = E.d.$;

$C = \frac{q}{V} = \frac{A\varepsilon_0}{d}$ for a parallel plate capacitor.

The University of Zambia

Department of Physics

University Examinations 2020-21

PHY1015: Introductory Medical Physics

Time: Three hours. **Maximum marks = 100.**

All questions carry equal marks. The marks are shown in brackets. Question 1 is compulsory. Attempt only four more questions. Clearly indicate on the cover page of the answer script which questions you have attempted.

Write clearly only your computer number on the answer book as well as on the answer sheet for Question 1. Tie them together. Organise the answer script properly.

Show your working clearly. Omission of essential work will lead to loss of marks.

For Question 1, you must use the blank answer sheet provided.

SECTION A

A. A footballer throws a soccer ball at 45^{o} above horizontal with a velocity of 3.5 m/s. The horizontal component of the velocity will be:

(a) 3.0 m/s (b) 2.0 m/s (c) 3.5 m/s (d) 2.5 m/s

B. Which of the following physical quantities is not a vector:

(a) acceleration (b) current(c) momentum(d) speed

C. A hunter on a hill aims at the head of a monkey hanging from a branch of a tree. The hunter and the monkey are at the same height from the ground. Just the instant he fires, the monkey drops. The bullet:

(a) will hit the head of the monkey. (b) will pass over the head of the monkey. (c) will pass below the head of the monkey. (d) may or may not hit the head of the monkey

D. A person stands on a scale in an elevator. His apparent weight will be the greatest when the elevator

(a) is standing still. (b) is accelerating downward. (c) is accelerating upward. (d) is moving upward at constant velocity.

E. In an automobile collision, how does an airbag lessen the blow to the passenger? Assume as a result of the collision, the passenger stops.

(a) The stopping impulse is the same for either the hard objects or the airbag. Unlike the windshield or dashboard, the air bag increases the stopping time and thus reduces the average force on the passenger. (b) The airbag is there to insure the seatbelt holds. (c) The air bag decreases the momentum change of the passenger in the collision. (d) During the collision, the force from the air bag is greater than would be the force from the windshield or dashboard so the passenger cannot hit the hard objects.

F. A body of radius R and mass m is rolling horizontally without slipping with speed m. It then rolls up a hill to a maximum height $h = \frac{3v^2}{4g}$. The body's rotational inertia is:

(a) $\frac{1}{2}mR^2$. (b) $\frac{3}{4}mR^2$. (c) $\frac{3}{5}mR^2$. (d) mR^2

G. Steam at 100^{o}C is more dangerous than the same mass of water at 100^{o}C because the steam

(a) contains more internal energy. (b)moves faster. (c) is less dense. (d) has a higher specific heat capacity.

H. When the temperature of the ambient is equal to the body temperature, how does the body lose heat to maintain constant internal temperature?

(a) a. through convection. (b) through sweating. (c) through conduction. (d) through radiation.

I. The amount of work a 0.6 kW electric drill can do in 1 minute is:

(a) A. 36 J. (b) 36kJ. (c) 0.6J. (d) 0.6 kJ.

K. The first law of thermodynamics states that

(a) a. the heat energy pumped into a system goes to raise its internal energy and enable it to perform work. (b) the heat energy pumped into a thermodynamic system goes into performing work only. (c) the work done by a system raises its internal energy (d) the heat energy pumped into a thermodynamic system goes into lowering its internal energy and performing work by the system.

SECTION B : Answer any four.

Question two

(a) A 23 g bullet travelling at 230 m/s penetrates a 2.0 kg block of wood and emerges cleanly at 170 m/s. If the block is stationary on a frictionless surface when hit, how far does it move after the bullet emerges? **[6]**

(b) The speed of a nerve impulse in a human body is about 100 m/s. If you accidentally stub your toe in the dark, estimate the time it takes the nerve impulse to travel to your brain. What would happen if the speed of the nerve impulse was much lower say 1 m/s? Assume you are 1.7 m tall **[4]**

(c) While exploring a cave, a person starts at the entrance and moves the following successive distances. She goes 75.0 m north, 250 m east, 125 m at an angle 30.0 ^{o} north of west, and 150 m south. Find the resultant displacement from the cave entrance. **[6]**

(d) A horizontal force of 140N is needed to pull a 60.0kg box across the horizontal floor at a constant speed. what is the coefficients of friction between the floor and box?

[4]

Question three

(a) Explain how a body moving at constant speed can be accelerating. **[2]**

(b) An aeroplane carrying out a parcel drop releases a parcel while travelling a steady speed of 90 m/s at an altitude of 200 m. Calculate the :

(i) the time between the parcel leaving the aeroplane and it striking the ground, **[5]**

(ii) the horizontal distance travelled, **[5]**

(c) A car towing a caravan travels along a steady speed of 20 m/s If the force exrted by the engine is 2 kN, what is the power output of the engine? **[3]**

(d) A 15-cm-long tendon was found to stretch 3.7 mm by a force of 13.4 N. The tendon was approximately round with an average diameter of 8.5 mm. Calculate Young's modulus of this tendon. **[5]**

Question four

(a) How long will a 500 W heater take to melt 500 g of ice at -8 ^{o}C? Data: c(ice) = 2100 J/kg.K, Heat of fusion = 334000 J/kg [6]

(b) Police investigators examining the scene of an accident involving two cars, measure 72 -m long skid marks of one of the cars, which nearly came to a stop before colliding. The coefficient of kinetic friction between the rubber and the pavement is about 0.80. Estimate the initial speed of the car assuming a level road. [6]

(c) Describe two situations when friction is welcome to human body functions and two when it is undesirable. [4]

(d) A horizontal force of 140 N is needed to pull a 60.0 kg box across the horizontal floor at a constant speed. what is the coefficients of friction between the floor and box?

[4]

Question five

(a) A person has a reasonable chance of surviving a car crash if the deceleration is no more than 30 'g's (g=9.8m/s2). Calculate the force on a 70 kg person undergoing this acceleration. What distance is travelled if the person is brought to rest at this rate from 100 km/h? [4]

(b) A weight lifter lifts a 350-N set of weights from ground level to a position over his head, a vertical distance of 2.00 m. How much work does the weight lifter do, assuming he moves the weights at constant speed? [4]

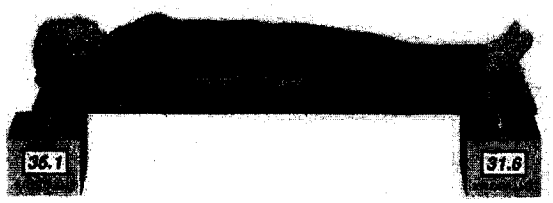
(c) A Zambeef delivery track travels 18 km north, 10 km east, and 16 km south. What is its final displacement from the origin? [6]

(d) Zambian footballer Patson Daka kicks a football vertically upward in celebration after scoring an Austrian Cup winning penalty with a speed of 35 m/s. What time does it take for the football to reach maximum height [6]

Question six

(a) Why is the world record for 100 m swimming slower than for 100 m sprinting? **[2]**

(b) A 166-cm-tall person lies on a light (massless) board which is supported by two scales, one under the top of her head and one beneath the bottom of her feet. The two scales read, respectively, 35.1 and 31.6 kg. What distance is the center of gravity of this person from the bottom of her feet? **[8]**



(c) Calculate the pressure 150 m below the surface of the sea. The density of sea water is 1.026 g/cm^3 **[4]**

(d) A ball bearing of mass 180 g is hung on a thread in oil of density 800 kg/m^3. Calculate the tension in the string, if the density of the ball bearing is 8000 kg/m^3. **[6]**

Question seven

(a) A hot tungsten wire filament has a radius of 0.060 cm, a temperature of 3000 K, and an emissivity of 0.74. Calculate the rate of energy emission by a 1 m length of the wire. Ignore the radiation received from the surrounding environment. **[8]**

(b) A merry-go-round takes 22 s to accelerate from rest to its operating speeed of 3.75 rpm. Calculate

(i) its acceleration in rev/s^2. **[4]**

(ii) the number of revolutions turned in this time. **[4]**

(c) A car has an initial velocity of 15m/s and an acceleration of $1.0m/s^2$. How far does the car go in the first 10s after the acceleration begins? **[4]**

Some Useful Equations

Uniformly accelerated motion:

$x = \bar{v}t \quad \bar{v} = \frac{1}{2}(v_f + v_i) \quad v_f = v_i + at \qquad v_f^2 = v_i^2 + 2ax \quad x = v_i t + \frac{1}{2}at^2$

Projectile motion:

$v_x = v_i \cos\theta_i = \text{constant} \qquad v_y = v_i \sin\theta_i - gt \qquad y = (v_i \sin\theta_i)t - \frac{1}{2}gt^2$

$y = (\tan\theta_i)x - \left[\frac{g}{2v_i^2(\cos^2\theta_i)}\right]x^2 \qquad R = \frac{v_i^2}{g}\sin 2\theta \qquad t = \frac{2v_i \sin\theta}{g}$

Force and motion:

$F = ma \qquad w = mg \qquad F_{AB} = -F_{BA} \qquad F_f = \mu F_N$

Work and Energy:

$PE = wh = mgh \qquad KE = \frac{1}{2}mv^2 \qquad W = Fx\cos\theta \qquad P = \frac{W}{t} = Fv\cos\theta$

Linear momentum: $p = mv \qquad F\Delta t = \Delta mv = m\ v_f - v_0$

Circular motion and gravitation:

$T = \frac{2\pi r}{v} \quad a_c = \frac{v^2}{r} \qquad F_c = \frac{mv^2}{r} \qquad F_{grav} = G\frac{m_A m_B}{r^2} \quad 1rev = 360^0 = 2\pi\ rad$

$v_T = \frac{(2\pi r)}{T} \ : \quad \tan\theta = \frac{v^2}{rg} :$

Rotational motion and angular momentum:

$\theta = \frac{s}{r} = \left(\frac{\omega_i + \omega_f}{2}\right)t \quad \omega = \frac{\theta}{t} \quad \theta = \omega_i t + \frac{1}{2}\alpha t^2 \quad \omega_f = \omega_i + \alpha t \quad v = \omega r$

$I = mk^2 \quad \omega_f^2 = \omega_i^2 + 2\alpha\theta \qquad \alpha = \frac{\Delta\omega}{\Delta t} = \frac{a_T}{r} \quad I = \sum mr^2 \quad KE_{rot} = \frac{1}{2}I\omega^2$

$\tau = FL = I\alpha \quad W = \tau\theta \quad P = \tau\omega \qquad L = I\omega \quad KE_{total} = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$

Properties of matter:

$\rho = \frac{m}{V} \quad F = -kx \qquad \frac{\Delta L}{L_i} = \frac{1}{Y}\frac{F}{A} \qquad \phi = \frac{s}{d} = \frac{1}{s}\frac{F}{A} \quad B = -\frac{\Delta P}{\Delta V / V_0} \quad W_{app} = W\left(1 - \frac{\rho_{fluid}}{\rho}\right)$

$F_B = \rho V g$, (submerged object) $\qquad F_B = Mg$ (floating M)

Thermal Properties of matter:

$PV = nRT$: $\Delta Q = mc\Delta T = nC\Delta T$: $\Delta L = \alpha L \Delta T$: $L_t = L_0(1+\alpha t)$: $\Delta V = \gamma V \Delta T$:

$W = P\Delta V$ $(\Delta Q/\Delta t) = (kA\Delta T)/\Delta L$: $m = V \times \rho$ $\frac{Q}{t} = eA\sigma T^4$ $C_P = C_V + R$

$Q = n.C.\Delta T = \frac{3}{2} n.R.\Delta T$ for isobaric and iso-volumetric processes

Thermodynamics:

$\Delta Q = \Delta U + \Delta W$: $W = p.\Delta V$ $PV = nRT$ $n = \frac{m}{M}$ $P_1V_1^{\gamma} = P_2V_2^{\gamma}$ $T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$

$COP_{ref} = \frac{Q_C}{W}$ $COP_{heat\ pump} = \frac{Q_H}{W}$ $W_{isothermal} = nRT \ln\frac{V_2}{V_1}$ $W_{adiabatic} = \frac{1}{\gamma-1}(P_1V_1 - P_2V_2)$:

$COP_{max-refr} = \frac{T_C}{W}$ $COP_{max-heat\ pump} = \frac{T_H}{W}$ $e = 1 - \frac{T_c}{T_h} = \frac{work\ done}{input\ heat\ at\ high\ temp}$

Waves and Sound:

$f = \frac{1}{\tau} v = \pm\sqrt{\frac{k}{m}(x_0^2 - x^2)}$ $v = \sqrt{\frac{T}{m/L}}$ $\tau = \frac{1}{f} = 2\pi\sqrt{\frac{m}{k}}$ $a = -\left(\frac{k}{m}\right)x$ $v = \sqrt{\frac{Y}{\rho}}$ $v = \sqrt{\frac{B}{\rho}}$ $f' = f$

$\frac{v \pm v_L}{v \mp v_S}$ (dB) = 10. log $\frac{I}{I_0}$: velocity of sound = 331.45 + 0.61t (°C)

$\tau = \frac{2\pi x_0}{v_0} = 2\pi\left(\frac{x_0}{v_0}\right) = \frac{2\pi}{\omega}$ $f = \frac{1}{2L}\sqrt{\frac{T}{m}}$ $x = x_0\cos(\omega t)$ $I_0 = 10^{-12}\ W/m^2$

Electric Field:

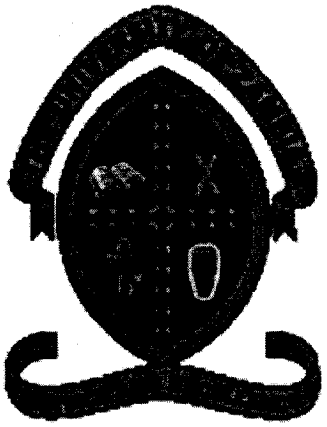
$F \propto \frac{q_1 q_2}{r^2}$ or $F = k.\frac{q_1 q_2}{r^2}$; k = 8.9874 × 10^9 N.m^2.C^{-2}. $k = (1/(4\pi\varepsilon_0)$ where ε_0 is the permittivity constant = 8.85 × 10^{-12} C^2.(N.m^2)$^{-1}$.

e = 1.60 × 10^{-19} C; $E = \lim_{q_{test}\to 0}\frac{F}{q_{test}}$; $F = qE$; $\frac{mv^2}{2} = F_x\Delta x = eE_x\Delta x$;

Electric Potential:

$W_{AB} = q.E.d.$; $V_B - V_A = \frac{W_{AB}}{q} = \frac{\sigma}{\varepsilon_0}.d = \frac{q}{A}.\frac{d}{\varepsilon_0}$; $V_B - V_A = \frac{W_{AB}}{q} = E.d.$;

$C = \frac{q}{V} = \frac{A\varepsilon_0}{d}$ for a parallel plate capacitor.



THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
Department of Physics
2020/2021 ACADEMIC YEAR
End of Year University Examinations
PHY 2231 - Thermodynamics and Properties of Matter

Duration : 3 Hours
Total marks: 100
INSTRUCTIONS
This question paper contains seven questions.
Answer any five questions. Each question carries 20 total marks.
Write clearly your computer number on the answer booklet provided.
All working should be shown clearly.
Omission of essential work will lead to loss of marks.
Additional information can be found at the end of this question paper.

QUESTION 1

(a) A circular disc of Mass M and radius R is set rolling on a table with velocity v. Show that the total kinetic energy is 0.75 Mv^2. [4]

(b) Derive Poiseuille's formula. [8]

(c) A cylindrical vessel of diameter 10 cm has at its bottom a horizontal capillary tube of length 20 cm and internal radius 0.5 mm. If the vessel is filled with water, find the time in which the water level becomes half the initial height. Viscosity of water = 10^{-3} Ns/m^{-3}. [8]

QUESTION 2

(a) A copper wire (Y=11.5x10^{10} N/m^2) with a cross section area of 0.005 cm^2 is to be used in lifting a 2 kg box. How fast can the object be accelerated if the wire is to stretch no more than 0.1 %? [6]

(b) If a cantilever is pulled down and released, it will move up and down. Show that such motion is simple harmonic motion. [6]

(c) Two cylindrical shafts have the same length, and are made from the same material. One is solid and the other is hollow with the external radius twice the internal radius. Compare the torsional

rigidities produced by equal twisting torques. [8]

QUESTION 3

(a) Describe Jaeger's method for determining the surface tension of a liquid. [7]

(b) In an experiment to measure the surface tension of water (for which $\gamma = 7.50\text{x}10^{-2}\text{N/m}$), a tube of average radius 0.1mm is placed vertically in the water so that a length of 12 cm is out of the water. What will happen? [5]

(c) Calculate the work done in spraying a spherical drop of mercury of radius 10^{-3}m into a million drops of equal size [6]

(d) Water flows through a horizontal pipe line of varying cross section at a rate of 0.2 m^3/s. Calculate the velocity of water at a point where the area of cross section of the pipe is 0.02 m^3 [2]

QUESTION 4

(a) A copper wire 2 m long is stretched by 1 mm. If the energy stored in the stretched wire is converted into heat, calculate the rise in temperature of the wire. Take $Y_{Cu} = 1.2\text{x}10^{11}$ N/m^2, $c_{Cu} = 0.1$ J/kg, and $\rho_{Cu} = 9000$ kg/m^2. [7]

(b) A composite flat sheet is made of 1.2 cm thickness of the

material of conductivity (K_1) $3x10^{-3}$ cal/cm°C and thickness 0.8 cm of another material of conductivity (K_2) $6x10^{-4}$ cal/cm°C joined together. If the open face of the first material is at a temperature of -30 °C and the open face of the second material is at 40 °C, calculate the temperature of the interface between the two materials. [5]

(c) Along the axis of a long uniform cylindrical shape of inner and outer radii 4 and 12 cm respectively, there is a wire in which 7 watts of energy is developed per cm length. If the conductivity of the material is 0.3 J/cm°Cs and it is at a steady state temperature of 20 °C for outer surface, find the temperature at the inner face of the cylinder and at r = 8 cm. [8]

.....

QUESTION 5

.....

(a) The opposite faces of a rectangular block of iron are kept in contact with a block of ice and steam at 100 °C. The area of cross section of the iron block is 4 cm^2, and the thickness is 1 cm. Find the mass of ice that melts in 20 minutes. Take H_f to be equal to 333 kJ/kg and K for iron to be equal to 59 W/m.k. [4]

(b) Show that the total depression (y) of cantilever whose beam's weight is negligible, and with an external load of W at the free end

is given by

$$y = \frac{WL^3}{3YI}.$$

Where Y is the Young modulus of the material from which the cantilever is made, L is the length of the cantilever and I is the moment of inertia. [8]

(c) One mole of a gas is isothermally expanded at 27 °C until it's volume is doubled. Then it is adiabatically compressed to its original volume. Find the total work done by the gas. Take $\gamma = 1.4$ and R = 8.314 J/K. [8]

QUESTION 6

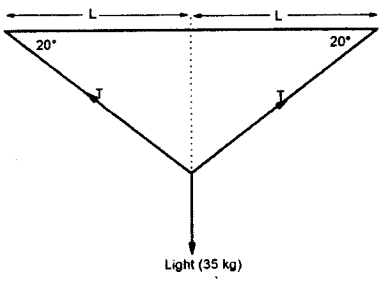
(a) A 0.05 kg bar square of length 1 m and cross section 5×10^{-3} square meter is supported at its two ends and loaded in the middle. The depression observed in the middle is $1.96\times10^{-3}m$ when a load of 0.1 kg is placed. Calculate the Young modulus of the material. [8]

(b) Briefly explain what is meant by a variable state and a steady state. [2]

(c) Calculate the increase in entropy when 5 kg of ice at -20 °C is converted into steam at 100 °C. Take specific heat of ice to be 0.5 kcal/kg°C, latent heat of fusion of ice to be 340 kJ/kg and latent heat of vaporisation to be 2268 kJ/kg.. [10]

QUESTION 7

(a) Consider the diagram below. By what fraction are cables stretched because of the weight of the light (Area = $0.18\text{X}10^{-4}\text{m}^2$; Y = $2\text{x}10^{11}\text{N/m}^2$). [6]



(b) If internal energy (U) is a function of temperature (T) and pressure (P) i.e., U = f(P,T), show that

$$dQ = \left[\left(\frac{\delta U}{\delta T}\right)_P + P\left(\frac{\delta V}{\delta T}\right)_P\right] dT + \left[\left(\frac{\delta U}{\delta P}\right)_T + P\left(\frac{\delta V}{\delta P}\right)_T\right] dP.$$

[7]

(c) What considerations led van der Waals to modify the equation of state? Deduce the van der Waals gas equation $(\text{P}+\frac{a}{v^2})(\text{V-b}) = \text{RT}$. What are the dimensions of a and b? [7]

——— END OF EXAMINATION ———

ADITIONAL INFORMATION

Planck's constant h = $6.62\text{x}10^{-34}$ Js,
electron charge e = $1.602\text{x}10^{-19}$ C,
electron mass m_e = $9.11\text{x}10^{-31}$ kg,
proton mass m_p = $1.67\text{x}10^{-27}$ kg,
neutron mass m_n = $1.67\text{x}10^{-27}$ kg,
Bohr magneton μ_B =$9.274\text{x}10^{-24}$ Am^2
Avogadro's constant N_A = $6.022\text{x}10^{23}$ mol^{-1},
Boltzmann constant k_B = $1.38\text{x}10^{-23}$ JK^{-1},
Permitivity of free space ϵ_0 = $8.85\text{x}10^{-12}s^2m^{-2}$,
permeability of free space μ_0 = $4\pi\text{x}10^{-7}$,
Bohr magneton μ_B =$9.274\text{x}10^{-24}$ Am^2

$$dQ = dU + PdV; dQ = TdS; Tds = dU + PdV; W = -\int_{V_1}^{V_f} PdV$$

$$C_V - C_P = R; PV = nRT; \left[P + \frac{a}{v^2}\right][v - b] = RT; PV^{\gamma} = constant$$

$$\eta = 1 - \frac{T_2}{T_1}; L = L_0[1 + \alpha\Delta T]; A = A_0[1 + \beta\Delta T]; V = V_0[1 + \gamma\Delta T]$$

$$Y = \frac{F/A}{\Delta L/L_0}; \eta = \frac{F/A}{\Theta}; W = \frac{1}{2}kx^2; U_e = \frac{1}{2}XstressXstrain; \sigma = \frac{\beta}{\alpha}$$

$$y = \frac{l^3}{3YI}\left[W + \frac{3W_1}{8YI}\right]$$

$$y = \frac{Wl^3}{3YI}$$

$$y = \frac{Wl^3}{48YI}$$

$$y = \frac{5W_1 l^3}{384YI}$$

$$y = \frac{Wl^3}{48YI} + \frac{5W_1 l^3}{384YI}$$

$$C = \frac{\pi\eta}{2L}\left[r_0^4 - r_i^4\right]; \rho = \frac{m}{V}; \tau = YI_g\frac{d^2y}{dx^2}; \gamma = \frac{F}{2L}; \Delta P = 2\gamma\left[\frac{1}{R_1} + \frac{1}{R_2}\right]$$

$$P = \frac{2\gamma}{R}; P = \frac{4\gamma}{R}; \gamma = \frac{gR}{2}[\rho_i h_i - \rho h]; V = \frac{\pi P r^4}{8\eta l}; \gamma = \frac{r[h + \frac{r}{3}]\rho g}{2cos\Theta}$$

$$K = -\frac{dP}{\Delta V/V}$$

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

DEPARTMENT OF PHYSICS

2020/2021 ACADEMIC YEAR

END OF YEAR EXAMINATIONS

PHY2511: INTRODUCTION TO CLASSICAL MECHANICS

MARKS: 100

TIME ALLOWED: 3 HOURS

INSTRUCTIONS

- Attempt any 5 of the 7 questions given.
- All questions have 20 marks each.
- Omission of essential work will result in loss of marks.
- Clearly write your computer number on all answer sheets used.

You may use the following information where necessary

$$x = rcos\theta$$

$$y = rsin\theta$$

$$\bar{v} = \dot{\rho}\hat{\rho} + \rho\dot{\phi}\hat{\phi} + \dot{z}\hat{k}$$

$$\bar{a} = (\ddot{\rho} - \rho\dot{\phi}^2)\hat{\rho} + (\rho\ddot{\phi} + 2\dot{\rho}\dot{\phi})\hat{\phi} + \ddot{z}\hat{k}$$

(a) What are the two approaches to study conservation laws as applied to a system of particles.

[2 marks]

(b) For a single particle of mass m moving with velocity $\mathbf{v}$ and linear momentum $\mathbf{p}$, show that

$$m\frac{d\mathbf{v}}{dt} = m\mathbf{a} = \mathbf{F} \tag{1}$$

Hence, if $\mathbf{F} = 0$, $\mathbf{p} =$ constant, linear momentum is conserved for a single particle.

[3 marks]

(c) The angular momentum $\mathbf{L}$ of a single particle is defined in terms of a cross product as

$$\mathbf{L} = \mathbf{r} \times \mathbf{p} = \mathbf{r} \times m\dot{\mathbf{r}} = \mathbf{r} \times m\mathbf{v} \tag{2}$$

Extending this definition to a system of N particles, what is the total angular momentum taken about the origin?

[5 marks]

(d) Obtain the time rate of change of the angular momentum of a system of particles.

[5 marks]

(e) What is the total torque τ due to all the net external forces acting on the system.

[5 marks]

2. (a) Determine the velocity and acceleration of a bead sliding on a wire bent into the form of a helix. The motion of the bead is given in cylindrical coordinates by $\rho = b$, $\phi = \omega t$, and $z = ct$, where b, ω, and c are constants.

[10 marks]

(b) The position vector of a particle is given by $\vec{r} = \hat{i}b\sin\omega t + \hat{j}b\cos\omega t$, where b and ω are constants.

i. Determine its plane polar coordinates.

[4 marks]

ii. Find its acceleration.

[3 marks]

iii. Describe its motion.

[3 marks]

3. (a) If $\mathbf{p}$ is the linear momentum of a particle of mass m, what is the torque τ about an axis passing through the centre of force?

[8 marks]

(b) Show that $\mathbf{L} = \mathbf{r} \times \mathbf{p} =$ constant if the angular momentum $\mathbf{L}$ of mass m is constant, its magnitude and direction are fixed in space.

[4 marks]

(c) Draw a schematic diagram to illustrate that the motion of a particle under the influence of a central force is confined to an XY plane perpendicular to $\mathbf{L}$.

[8 marks]

4. (a) What is a central force? Give **FOUR** examples.

[5 marks]

(b) For a central force, show that $(\nabla \times F)_z = 0$.

[5 marks]

(c) Show that the velocity and acceleration of the centre of mass for a system of particles are respectively, $\mathbf{V} = \dot{\vec{R}} = \frac{1}{M}\sum m_k \dot{\vec{r}}_k$ and $\mathbf{A} = \ddot{\vec{R}} = \frac{1}{M}\sum m_k \ddot{\vec{r}}_k$.

[4 marks]

(d) Hence, obtain the components V_x, V_y, V_z, A_x, A_y, and A_z of the system.

[6 marks]

5. (a) Consider an isolated system consisting of two bodies that are separated by a distance $r = |\mathbf{r}|$, with the interaction between them described by a central force $F(r)$. If the forces are spherically symmetric, a system consisting of two particles can be described by means of six coordinates. If $\mathbf{r}_1$ and $\mathbf{r}_2$ are the radii vectors of particles of masses m_1 and m_2, then the six components of these radii describe the system completely. Write equations of motion of the two particles.

[6 marks]

(b) Instead of describing the system by the six coordinates of $\mathbf{r}_1$ and $\mathbf{r}_2$, it is convenient to use an alternate set of six coordinates: three coordinates describing the centre of mass $\mathbf{R}$ and the other three coordinates describing the relative position by $\mathbf{r}$. What are the two relations describing this scenario?

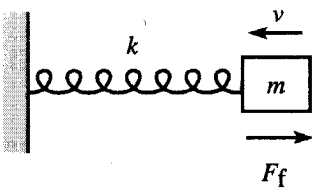
[5 marks]

(c) Draw a schematic diagram of a system of two particles described by means of six coordinates: three coordinates describing the centre of mass by $\mathbf{R}$ and the other three coordinates describing the relative position by $\mathbf{r}$.

[9 marks]

6. (a) Consider a mass m attached to the end of a spring with spring constant k. Let the mass be subject to a drag force proportional to its velocity, $F_f = -bv$ (the subscript f stands for *friction*). State the two main reasons why we study this damping force?

[4 marks]



(b) Solve for the general position as a function of time for the system in the figure.

[16 marks]

(a) State three Kepler's laws that describe the motion of planets around the Sun.

[3 marks]

(b) In tabular form, outline the fundamental differences between Newton's and Kepler's laws of motion.

[4 marks]

(c) Let T be the period of an elliptical orbit. If the motion is periodic, express Kepler's second law in terms of the area and period.

[3 marks]

(d) Hence, find the area of an ellipse and explain all parameters involved in your expression.

[5 marks]

(e) Express the length of the major axis in terms of the energy of a particle.

[5 marks]

THE END OF PHY2511 EXAM - HAPPY FESTIVE SEASON

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
DEPARTMENT OF PHYSICS

2020/2021 ACADEMIC YEAR

END YEAR UNIVERSITY EXAMINATIONS

PHY-2522: ANALYTICAL MECHANICS AND SPECIAL THEORY OF RELATIVITY

Time allowed: **3 Hours**

Instructions

- **This examination paper contains 7 questions. Each question carries 20 marks. Attempt any 5 questions out of the 7 questions given.**
- **This paper has a total of 100 marks. All questions carry equal marks**
- **Show all your working clearly. Omission of essential work will result in loss of marks**
- **Write your computer number clearly on the answer sheets**

Where necessary, you may use the following:

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{q}_k}\right)-\frac{\partial L}{\partial q_k}=Q_k, \qquad \dot{q}_k=\frac{\partial H}{\partial p_k}, \qquad \frac{\partial H}{\partial t}=-\frac{\partial L}{\partial t}, \qquad -\dot{p}_k=\frac{\partial H}{\partial q_k}, \qquad x'=\gamma(x-vt),$$

$$t'=\gamma\left(t-\frac{Vx}{c^2}\right), \qquad y'=y, \quad z'=z, \qquad \gamma=\frac{1}{\sqrt{1-\frac{v^2}{c^2}}}, \text{ speed of light } c=3\times10^8 \text{ m/s}$$

$$\frac{\partial^2 u(x,t)}{\partial t^2}=\frac{T}{\mu}\frac{\partial^2 u(x,t)}{\partial x^2}, \qquad \gamma L=L_0, \quad I_{sphere}=\frac{2}{5}Ma^2, \quad I_{disk}=\frac{1}{2}Ma^2$$

$$x=r\cos\theta, \qquad y=r\sin\theta$$

$$\vec{v}=\dot{r}\hat{\vec{r}}+r\dot{\theta}\hat{\vec{\theta}} \qquad \vec{a}=\left(\ddot{r}-r\dot{\theta}^2\right)\hat{\vec{r}}+\left(r\ddot{\theta}+2\dot{r}\dot{\theta}\right)\hat{\vec{\theta}}$$

Q1 A sinusoidal travelling wave represented by

$$\psi_i = A' \cos(\omega t - k z + \phi')$$

coming from the left reaches a fixed end at $z = 0$

(i) Show that after reflection, the resulting standing wave can be described by

$$\psi_r = A \sin k z \cos(\omega t + \phi)$$

where $A = 2A'$ and $\phi = \phi' - \frac{1}{2}\pi$ **[10 marks]**

(ii) Describe what happens at points on the string for which

$$kz = m\pi \qquad (m = 0, \pm 1, \pm 2, \pm 3....)$$ **[5 marks]**

(iii) What are the points in (ii) above called? **[1 mark]**

(iv) In terms of wavelength, how far apart are the points in (iii)? **[3 marks]**

(v) What are the points midway along the string in which condition in (ii) hold called? **[1 mark]**

Q2 A particle of mass m moves in a horizontal plane under a central force $\overline{F} = -(k\,m/r^2)\hat{e}_r$, where k is a positive constant and $\hat{e}_r$ is a unit vector in the radial direction. Assuming that the angle to the centre varies as ϕ.

(a) Find the Lagrangian of the system. **[6 marks]**

(b) By use of the Lagrangian formalism, obtain the expression for the equations of motion. **[10 marks]**

(c) State the cyclic coordinate for the system. **[1 mark]**

(d) Obtain the expression for the conserved quantity. **[3 marks]**

Q3 Consider a disk of mass m and radius R that starts at rest and rolls without slipping from the top of an inclined plane of total length ℓ; the plane is inclined at an angle α relative to the horizontal. The distance from the top position on the plane to the disk's centre of mass-its geometric centre-is denoted s, and θ is the angle of a selected point on the disk's rim relative to an axis perpendicular to the inclined plane.

Using the Hamiltonian method,

(a) find the Lagrangian of the system, **[6 marks]**

(b) obtain the expression of the Hamiltonian, and **[4 marks]**

(c) show that the equation of motion of the disk is given as

$$\ddot{\theta} = \frac{2g \sin\alpha}{3R}$$ **[10 marks]**

[**Hint:** The non-slip condition imply that $s = R\theta$]

Q4 The Lagrangian of a particle of mass m sliding frictionlessly around the interior of a conical vase of opening angle θ is given as

$$L = \frac{1}{2}m\dot{r}^2 + \frac{1}{2}mr^2\sin^2\theta\dot{\phi}^2 - mgr\cos\theta$$

(a) Find the expression of the conjugate momentum corresponding to the generalized coordinate r. **[3 marks]**

(b) Find the expression of the conjugate momentum corresponding to the generalized coordinate ϕ. **[3 marks]**

(c) From your results in (a) and (b) above, obtain the expression of the Hamiltonian given by

$$H = \sum_{i=r,\phi} p_i\dot{q}_i - L$$ **[4 marks]**

(d) From your expression of the Hamiltonian, determine the ignorable coordinate and state what it signifies. **[3 mark]**

(e) Using Hamilton's equations, show that

$$\ddot{r} = \frac{p_\phi^2}{m^2r^3\sin^2\theta} - g\cos\theta$$ **[7 marks]**

Q5 Frame S' has a speed of $v = 0.6c$ relative to S. The two frames are in standard configuration and clocks are adjusted so that $t = t' = 0$ at $x = x' = 0$. Two events occur in the frames. Event 1 occurs at $x_1 = 20\,\text{m}$, $t_1 = 2\times10^{-7}\,\text{s}$ in frame S. Event 2 occurs at $x_2 = 60\,\text{m}$, $t_2 = 3\times10^{-7}\,\text{s}$.

(a) What is the distance between the two events as measured in the S' frame?

[7 marks]

(b) What is the time difference between the same two events as measured in the S' frame?

[6 marks]

(c) In the laboratory frame, momentum transforms relativistically according to

$$p_x = \gamma m_0 v$$

Show that the force is given by

$$F_x = \gamma^3 m_0 a_x$$ **[7 marks]**

where a_x is the acceleration associated with the momentum p_x.

Q6(a) Suppose that two sine waves $y_1(x,t) = A\sin(kx - \omega t)$ and $y_2(x,t) = A\sin(kx + \omega t)$ traveling in opposite directions superimpose on each other, by using complex trigonometry

$$e^{i\theta} = \cos(\theta) + i\sin(\theta) \text{ and that } \sin(\theta) = \mathrm{Im}(e^{i\theta}) \text{ and } \cos(\theta) = \frac{1}{2}\left(e^{i\theta} + e^{-i\theta}\right),$$

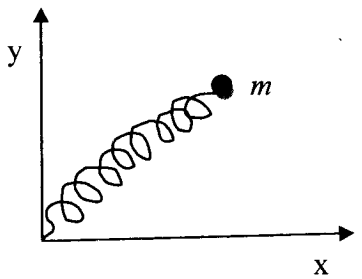
or otherwise, obtain the expression of the resultant wave. **[7 marks]**

(b) Show that your expression in (a) above is a solution to the wave equation

$$\frac{\partial^2 y}{\partial x^2} = \frac{1}{v^2}\frac{\partial^2 y}{\partial t^2}$$ **[7 marks]**

(c) Write the equation for a (harmonic) wave travelling either in the negative or positive direction along the x axis and having an amplitude of 0.010 m, a frequency of 550 Hz, and a speed of 330 ms^{-1} in the form $A\sin(kx \pm \omega t)$. **[6 marks]**

Q7 A particle of mass m moves in a horizontal plane. It is connected to the origin by a spring with spring constant k and relaxed length zero (so the potential energy is $kr^2/2 = k(x^2 + y^2)/2$), as shown in the figure below.



(a) Find the Lagrangian L of the particle in terms of Cartesian coordinates. **[4 marks]**

(b) Find the Lagrangian L of the particle in terms of polar coordinates. **[6 marks]**

(c) Show that the total energy in polar coordinates is **[6 marks]**

$$E = H = \frac{\partial L}{\partial \dot{r}}\dot{r} + \frac{\partial L}{\partial \dot{\theta}}\dot{\theta} - L \quad \text{Eq(1)}$$

where H is the Hamiltonian (total energy).

(d) Using equation (1) or otherwise, obtain the expression of the energy in Cartesian coordinates. **[4 marks]**

**********END OF PHY 2522 EXAMINATION**********

The University of Zambia

Department of Physics

PHY 2611 ELECTRICITY AND MAGNETISM

UNIVERSITY FINAL EXAMINATIONS

2020/2021 Academic year

Time Duration: Three (3) hours.

Instructions: Answer any **five** any **(5)** questions only. They carry equal marks. All working must be shown.

Formulas and constants you may find useful:

$F = k\frac{q_1 q_2}{r^2}$	$E = k\frac{q}{r^2}$	$\omega = 2\pi f$	$F=BIL$
$\int E.dS = \frac{q}{\varepsilon_o}$	$\Delta W = -q\int_A^B E.ds$	$C = \frac{\varepsilon_o A}{d}$	$r = \frac{mv}{qB}$
$V = -\int E.ds$	$-\frac{dV}{dr} = E_r$	$e = 1.6 \times 10^{-19} C$	$P = \frac{V^2}{R}$
$I = \frac{\Delta Q}{\Delta t}$	$\Delta Q = v_d Ane$	$C = kC_o$	$P = I^2R$
$P = I^2R$	$R = \rho\frac{L}{A}$	$X_C = \frac{j}{\omega C}$	$\varepsilon = -\frac{d\varphi}{dt}$
$\varphi = B.A$	$B = \frac{\mu_o I}{2\pi r}$	$I_{rms}^2 = \frac{I_{max}^2 \int_0^T sin^2(\omega t)dt}{T}$	$F_m = qvB$
$V = \frac{Q}{4\pi\varepsilon_o r}$	$\oint B.dl = \mu_o I$	$V = vlB,$ $X_L = j\omega L$	$B = \mu_o nI$
$F = BIL$	$r = \frac{mv}{qB}$	$Z = \sqrt{R^2 + (X_L - X_C)^2}$	

Q1 (a) A circular coil of radius R is uniformly charged with a positive charge of magnitude Q, figure 1.

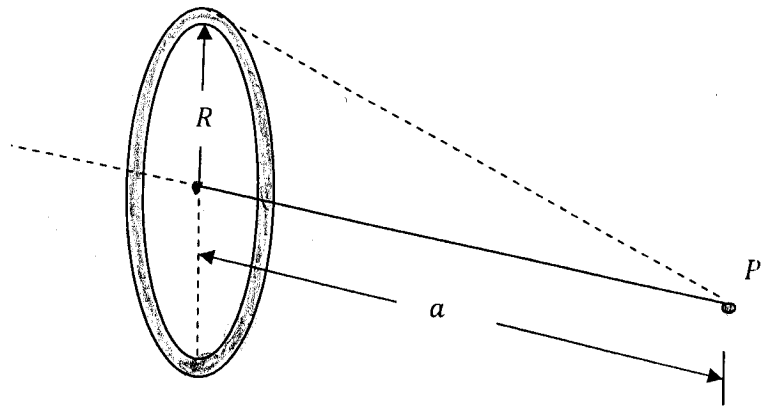


Figure 1

(i) Prove that the **resultant electric field, E_R** at the center of the coil is zero while the **resultant electric potential, V** at the same center is given by

$$V = \frac{1}{4\pi\varepsilon_o}\frac{Q}{R}$$ ..... [8]

(ii) Show that the resultant electric field at any arbitrary point such as P is given by

$$E = \frac{aQ}{4\pi\varepsilon_o}\frac{1}{(a^2+R^2)^{3/2}}$$ ....[8]

(b) A conducting hollow and thin shell of radius R is charged with a charge Q. Determine

(i) the surface charge density, σ on the outer surface of the sphere. [2]

(ii) Using Gauss's law, show that the electric field inside the hollow sphere is zero. [2]

Q2 (a) A coil of inductance $L = 0.1$ H is connected in series to a resistance of 10Ω. The two are then connected in series to a 200 μF capacitor, figure 2. The supply voltage is 230 V at 50 Hz. [12]

Calculate

(i) the current in the circuit,

(ii) the voltage, v_L across the inductor,

(iii) the voltage, v_C across the capacitor and

(iv) the resonant frequency, f_o

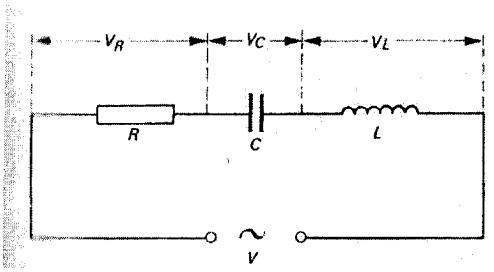


Figure 2

(b) A voltage v varies with time (in seconds) according to the following graphical plot.

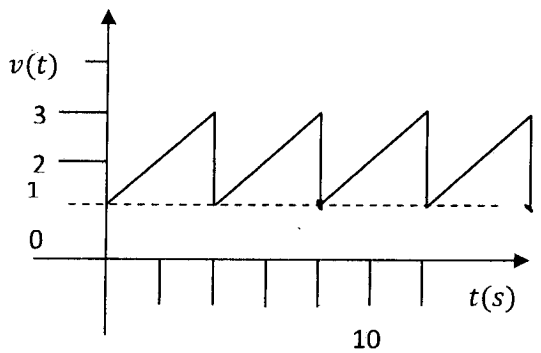


Figure 3

(i) Hence find the function for the waveform [2]

(ii) Find the $r.m.s$ of the voltage [6]

Q3 (a) The semicircular arc of radius R is uniformly charged with a charge Q.

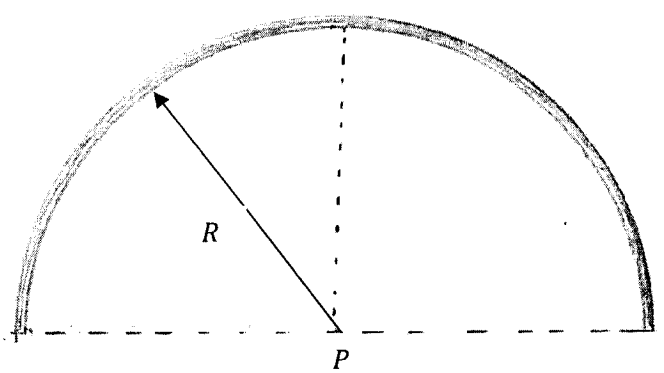


Figure 4

(i) State an expression for the linear charge density on the arc

(ii) Derive an expression for the electric field at the center of The arc i.e. at point P. [8]

(b) A tiny ball at the end of the thread has a mass of 0.60 gram. It is placed in a horizontal electric field of intensity 700 N/C. It is in equilibrium in the position shown. [7]

Determine the charge, q on the ball and its sign i.e. whether it is positive or negative.

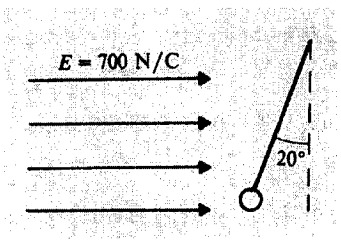


Figure 5

(c) A sphere of radius R is made of an insulating material and has charge $+Q$

Distributed throughout its volume with charge density $\rho_o r$.

Find the electric field due to the charge for $r < R$ i.e. inside the sphere. [5]

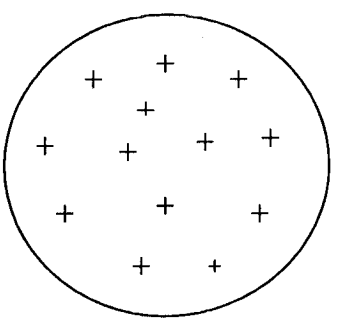


Figure 6

Q4 (a) A particle with charge q and mass m is shot with kinetic energy K into a region between two plates. If the magnetic field between the plates is B as shown. Show that for the particle to avoid colliding with the opposite plate, the magnetic field B must be of magnitude

; $B = \frac{(2mK)^{1/2}}{(qd)}$, where K is the kinetic energy of the particle. [7]

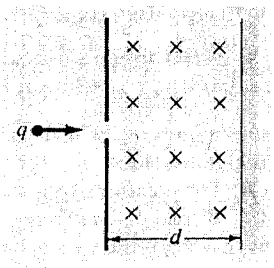


Figure 7

(b) A long straight wire carries a current I. In the neighborhood of the wire is placed a loop of wire measuring a in breadth and b in length as shown. Show that the flux threading the loop is given by

$$\varphi = \frac{\mu_o Ib}{2\pi} ln\left(1 + \frac{a}{c}\right) \quad [7]$$

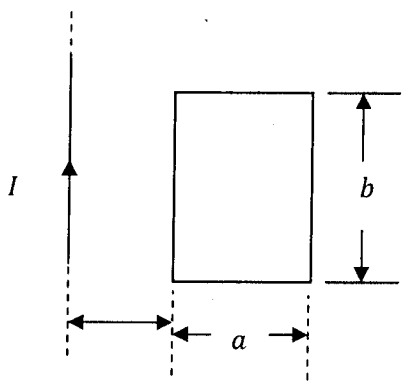


Figure 8

(c) A thick wire of radius R carries a current that varies from the center of the wire according to the relation $j(r) = I_o r^2$, where j is the current density. Find the total current in the cross section of the wire. Hint: select an element of integration, dA. [6]

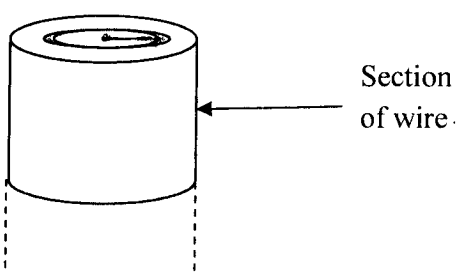


Figure 9

Q5 (a) The current in the long, straight wire $I_1 = 5.00\text{A}$ and the wire lies in in the plane of a rectangular loop which carries 10.00 A. The dimensions are $c = 0.100$ m, $a = 0.150$ m, and $l = 0.45$ m. Find an expression for the net force exerted on the loop by the magnetic field created by the wire. [7]

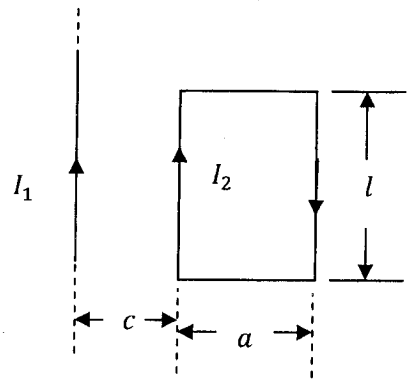


Figure 10

(b) What current is required in the windings of a long solenoid that has 1 000 turns uniformly distributed over a length of 0.400 m, to produce a magnetic field of magnitude 1.00×10^{-4}T at the center of the solenoid? [5]

(c) (i) A flat conducting loop is positioned in a uniform magnetic field directed along the $+x$ axis. For what orientation of the loop is the flux threading the loop maximum and what orientation is the flux minimum? [2]

(ii) A battery has an emf of 15 V. When it is delivering 20.0 W of power to an external load of resistance R, the terminal voltage is found to be 11.6V. Find the value of R and the internal resistance r of the battery. [6]

(a) (i) State the two conservation laws on which Kirchhoff's rules are based. [3]

(ii) Determine the currents I_1, I_2 and I_3 in the figure below. [9]

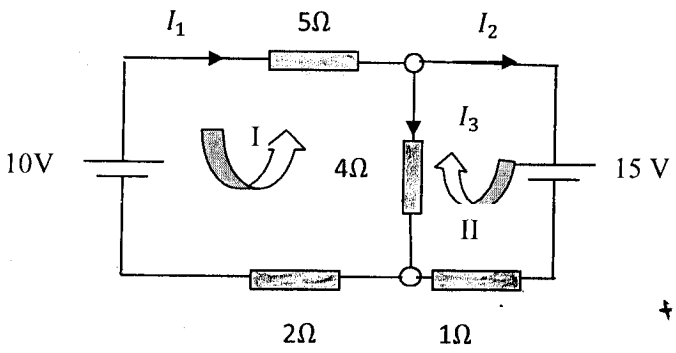


Figure 11

(b) Two straight wires separated by a distance of 50 cm are carrying current in the same direction as shown below. Find the resultant magnetic field (magnitude and direction) due to the two currents at the following points:

(i) mid-way between the two wires and [4]

(ii) at a point 0.5 m to the left of the wire carrying the 5A current [4]

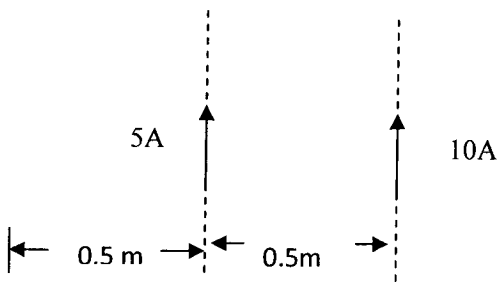


Figure 12

Q7 (a) A conductor of mass m and length l can slide along a pair of vertical metal guides connected by a resistor R as shown below. Neglect friction and resistance of the conductor and guides are negligible. There is a uniform horizontal magnetic field of strength B normal to the plane of the page directed outward.

(i) state the direction of the induced current in the resistance and [2]

(ii) show that the final steady speed of fall under the influence of gravity is given by [8]

$$v = \frac{mgR}{(B^2l^2)}$$

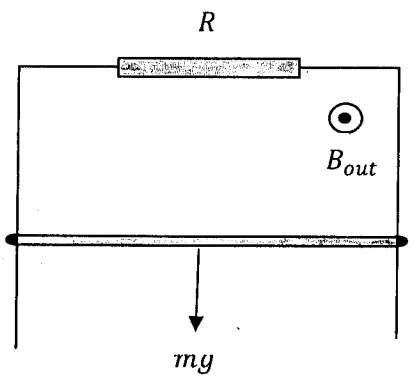


Figure 13

(b) (i) A 50m circular loop coil has a radius 30 mm. It is oriented in such a way that magnetic field lines are parallel to the area normal. of the coil. Suppose that the magnetic field is varied so that B increases from 0.10 to 0.35 T in a time of 2 ms, determine the average e.m.f. induced in the coil. [6]

(ii) A magnet is pushed towards a coil as shown in the following figure. [4]

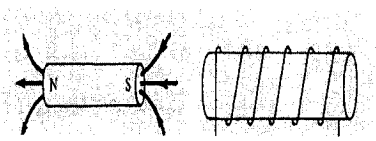


Figure 14

Determine the direction of the current induced in the coil and the pole created by the current in the coil.

END OF EXAMINATION

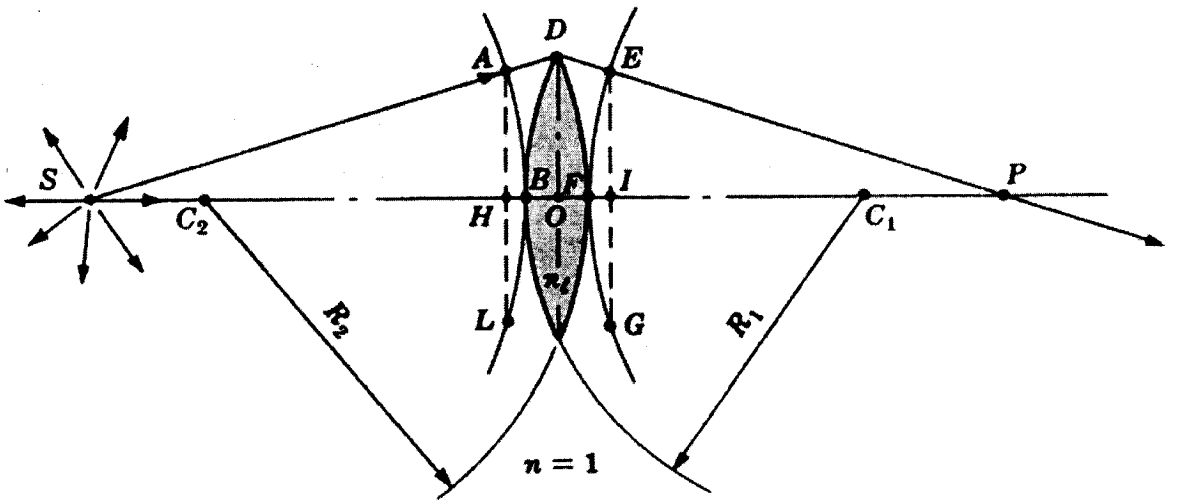
THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
Department of Physics
2020/2021 ACADEMIC YEAR
End of Year University Examinations
PHY 2712 - OPTICS

Duration : 3 Hours
Total marks: 100
INSTRUCTIONS
This question paper contains seven questions.
Answer any five questions. Each question carries 20 total marks.
Write clearly your computer number on the answer booklet provided.
All working should be shown clearly.
Omission of essential work will lead to loss of marks.
Additional information can be found at the end of this question paper.

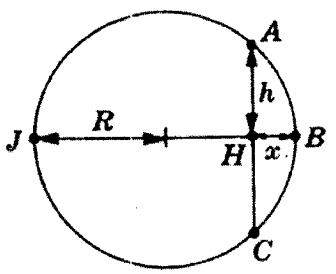
QUESTION 1

(a) State Fermats principle. [2]

(b) With the aid of the figure below, derive the thin lens equation (Note: Use the arguments and the fact that a spherical wave enters and a spherical wave leaves the lens). [10]



(a)



(b)

Fig. 4-15

(c) Light from a sodium lamp $\lambda_0 = 589nm$ passes through a tank of glycerin (of refractive index 1.47) 20 m long in a time t_1. If it takes the time t_2 to traverse the same tank when filled with carbon

disulfide (of refractive index 1.63), determine the difference t_2-t_1. [5]

(d) Why do the sky appear blue at mid-day, while it is red at sun rise and sun set. [3]

QUESTION 2

(a) Define the following terms

(i) optical path. [1]

(ii) optical density. [1]

(b) Imagine an electromagnetic plane wave in a vacuum whose E-Field in SI units is given by

$$E_x = 10^2 sin\pi(3 \times 10^6 z - 9 \times 10^{14} t), E_y = 0, E_z = 0.$$

Determine the

(i) speed, [2]

(ii) wavelength, [2]

(iii) frequency, [2]

(iv) period, [2]

(v) amplitude, and [2]

(vi)polarisation [2]

of this plane wave.

(c) Write an expression for magnetic field associated with the wave of [6]

$$E_x = 10^2 sin\pi(3 \times 10^6 z - 9 \times 10^{14} t), E_y = 0, E_z = 0.$$

disulfide (of refractive index 1.63), determine the difference t_2-t_1. [5]

(d) Why do the sky appear blue at mid-day, while it is red at sun rise and sun set. [3]

.....

QUESTION 2

.....

(a) Define the following terms

(i) optical path. [1]

(ii) optical density. [1]

(b) Imagine an electromagnetic plane wave in a vacuum whose E-Field in SI units is given by

$$E_x = 10^2 sin\pi(3 \times 10^6 z - 9 \times 10^{14} t), E_y = 0, E_z = 0.$$

Determine the

(i) speed, [2]

(ii) wavelength, [2]

(iii) frequency, [2]

(iv) period, [2]

(v) amplitude, and [2]

(vi) polarisation [2]

of this plane wave.

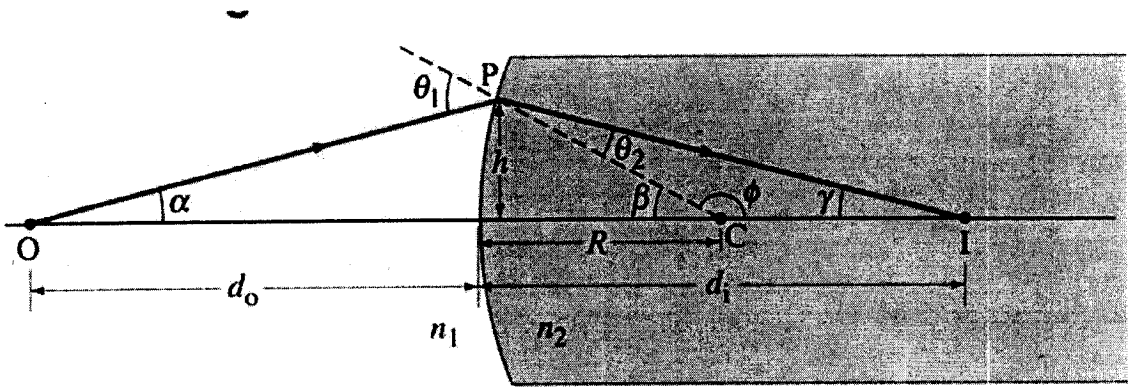
(c) Write an expression for magnetic field associated with the wave of [6]

$$E_x = 10^2 sin\pi(3 \times 10^6 z - 9 \times 10^{14} t), E_y = 0, E_z = 0.$$

$$tan\Theta_r = \frac{n_0 n_1 sin\Theta_i}{n_e\sqrt{n_e^2 - n_1^2 sin^2\Theta_i}},$$

reduces to Snells law. [5]

(c) For the figure shown below,



show that

$$\frac{n_2}{d_o} + \frac{n_1}{d_i} = \frac{n_2 - n_1}{R}$$

[6]

(d) State and briefly describe the two categories of diffraction phenomena. [4]

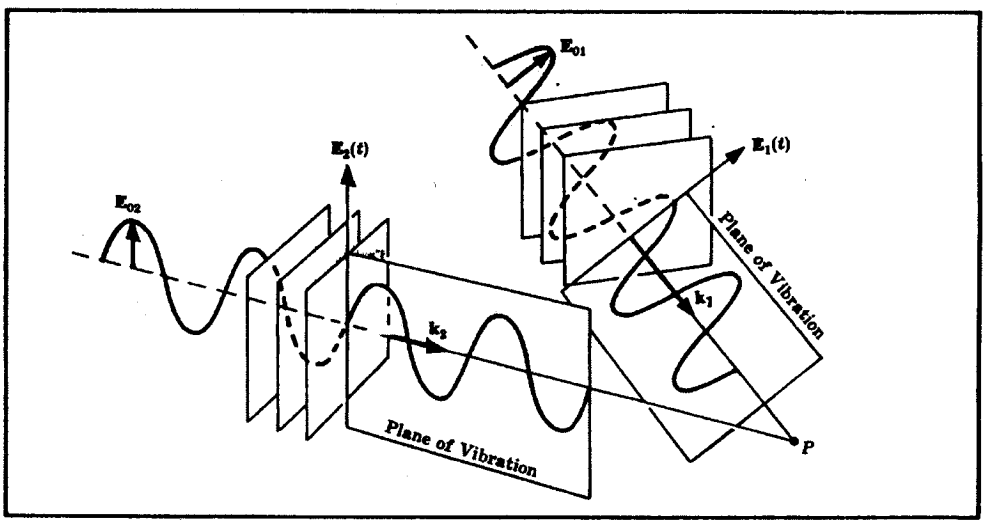
.....

QUESTION 5

.....

(a) Looking into the Michelson interferometer, one sees a dark central disc surrounded by concentric bright and dark rings. One arm of the device is 2 cm longer than the other arm and $\lambda_0 = 500$ nm. Determine

(i) the order of the central disc. [4]



and δ. [4]

.....

QUESTION 4

.....

(a) Differentiate an isotropic material from an anisotropic material. [2]

(b) In the refraction of rays at the interface between an isotropic medium and anisotropic medium,

$$tan\Theta_r = \frac{n_0 n_1 sin\Theta_i}{n_e\sqrt{n_e^2 - n_1^2 sin^2\Theta_i}},$$

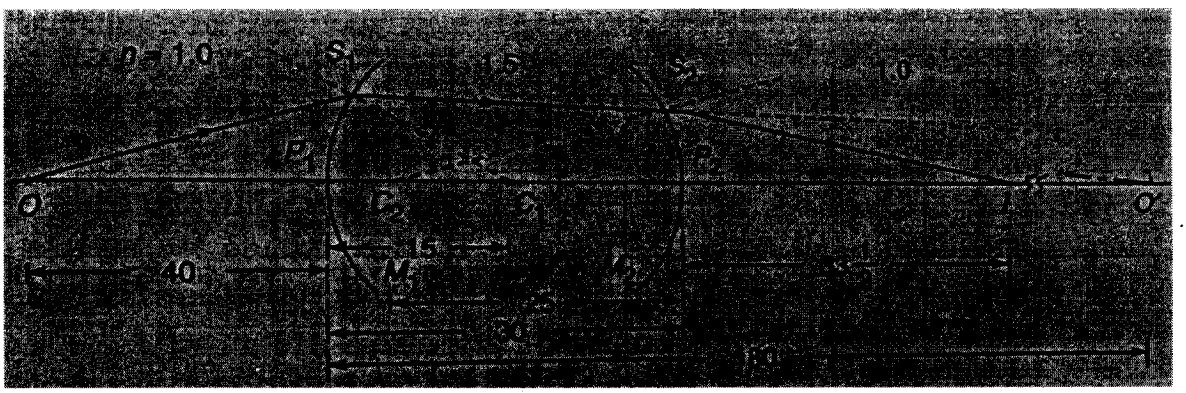
where Θ_r is the angle of refraction and Θ_i is the angle of incidence.

(i) Calculate the angle of refraction for a ray of light travelling from air into calcite at an angle of incidence of 45°, given that for calcite $n_0 = 1.65838$ and $n_e = 1.48641$. [3]

(ii) For $n_0 = n_e = n$, show that

(ii) the order of the sixth dark ring. [2]

(b) Consider a medium of refractive index 1.5 bounded by two curved spherical surfaces $S_1P_1M_1$ and $S_2P_2M_2$ as shown in the figure below. The radii of curvature of the surfaces are 15 cm and 25 cm with their centres being C_1 and C_2. There is an object (O) at a distance 40 cm



from P_1 on the line joining C_1 and C_2. Determine the position of the paraxial image. [10]

(c) (i)What is a laser? [1]

(ii) What are the three main components of any laser device? [3]

.....

QUESTION 6

.....

(a) List the five coefficients for specifying primary aberrations. [5]

(b) A chromatic doublet of focal length 20 ccm is to be made by placing a convex lens made of borosilicate crown glass in contact with a diverging lens of dense flint glass. Assuming $n_r = 1.51462$,

$n_b = 1.52264$, $n'_r = 1.61216$ and $n'_b = 1.62901$. Calculate the focal length of each lens.[Here, unprimed and primed quantities refer to borosilicate crown glass and dense flint glass respectively] [10]

(c) Define the following terms:

(i) Zeeman effect. [1]

(ii) Inverse Zeeman effect. [1]

(iii) Faraday effect. [1]

(iv) Kerr Magneto-optical effect. [1]

(v) Stark effect. [1]

QUESTION 7

(a) What are photons? [1]

(b) By considering an atom having two states N_1 and N_2, and taking advantage of Einstein coefficients, derieve Plancks radiation law in terms of light matter interaction. [7]

(d) State atleast nine basic principles involved in operation of most lasers. [9]

(c) Who built the first Laser? What type of laser was it? [3]

END OF EXAMINATION

ADITIONAL INFORMATION

e = 1.602x10^{-19} C, m$_e$ = 9.11x10^{-31} kg, m$_p$ = 1.67x10^{-27} kg,
m$_n$ = 1.67x10^{-27} kg, N$_A$ = 6.022x10^{23} mol^{-1}, k$_B$ = 1.38x10^{-23} JK^{-1},
ϵ_0 = 8.85x10^{-12}s^{2}m^{-2}, $\mu_0 = 4\pi$x10^{-7}, μ_B =9.274x10^{-24} Am^2,
h = 6.62x10^{-34} J/s, c = 3$\times$ 10^{8}m/s, n$_{water}$ = 1.33, n$_{glass}$ = 1.5,
n$_{air}$ = 1

$$n_1 sin\Theta_1 = n_2 sin\Theta_2; \frac{1}{f} = \frac{1}{s_o} + \frac{1}{s_i}; \frac{n_1}{s_o} + \frac{n_2}{s_i} = \frac{n_2 - n_1}{R}; D = P = \frac{1}{f}$$

$$\nu = \frac{1}{v} = \frac{n_D - 1}{n_F - n_c}; c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}; M_T = \frac{-s_i}{s_o}; n = \frac{sin\Theta_i}{sin\Theta_r}; f_0 = \frac{n_1}{n_2 - n_1} R;$$

$$\frac{1}{f} = \left(\frac{n_2}{n_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right); v = \nu\lambda; \omega = ck; k = \frac{2\pi}{\lambda}; \frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$$

$$-\frac{2}{R} = \frac{1}{s_o} + \frac{1}{s_i}; n = \frac{c}{v} = \sqrt{\frac{\mu\epsilon}{\mu_0\epsilon_0}}$$

The University of Zambia

School of Natural Sciences

Department of Physics
2020-21 Academic Year
University Examinations
PHY3242: Statistical and Thermal Physics

Time: Three hours. **Maximum Marks : 100**

1. **Attempt <u>ANY FOUR</u> questions. All questions carry equal marks.**
2. **Write clearly your computer number on each answer booklet.**
3. **Show all essential working**

==========

Some useful formulas

$$\beta = \frac{\partial \ln \Omega}{\partial E} \quad , \quad \beta \bar{X}_\alpha = \frac{\partial \ln \Omega}{\partial x_\alpha} \quad , \quad dS = \frac{dQ}{T} \quad , \quad c_v = \frac{1}{\nu}\left(\frac{\partial \bar{E}}{\partial T}\right)$$

$$G = \bar{E} + \bar{P}V - TS \quad , \quad S = \kappa\left(\ln Z + \beta \bar{E}\right) \quad , \quad S = \kappa \ln \Omega$$

$$Z = \sum_r e^{-\beta E_r} \quad , \quad \bar{X} = \sum_i p_i X_i \quad , \quad F = \overline{E} + \overline{p}V = -kT \ln Z$$

$$\overline{E} = \frac{\sum_r E_r e^{-\beta E_r}}{\sum_r e^{-\beta E_r}} \quad , \quad d \ln \Omega = \frac{\partial \ln \Omega}{\partial E} d\tilde{E} + \sum_\alpha \frac{\partial \ln \Omega}{\partial x_\alpha} d\tilde{x_\alpha}$$

$$P_N(m) = \frac{N!}{\left[\frac{N+m}{2}\right]! \left[\frac{N-m}{2}\right]!} p^{\left(\frac{N+m}{2}\right)} (1-p)^{\left(\frac{N-m}{2}\right)}$$

Question One

(a) A drunk starts out from a lamppost at the middle of a street, taking steps of equal length either to the right or to the left with equal probability. What is the probability that the man will again be at the lamppost after taking N steps if

(i) N is even [3]

(ii) N is odd [2]

(b) Two drunks start out together at the origin, each having equal probability of making a step to the left or to the right along the $x-$axis. Find the probability that they meet again after N steps. It is to be understood that the men make their steps simultaneously. [8]

(c) Explain what is meant by the following in terms of a statistical system:

(i) constraint,

(ii) the fundamental statistical postulate,

(iii) a quasi-static process,

(iv) accessible states

[5]

(d) Explain the difference between extensive and intensive parameters and give examples of each. [3]

(e) A system consist of 10 spin 1/2 particles which do not interact with one another. What are the maximum and minimum values of the spin entropy?
Boltzmann's constant is $k = 1.381 \times 10^{-23}\text{J/K}$ [4]

[Total 25 Marks]

Question two

(a) Distinguish between the macrocanonical and canonical ensembles. [3]

(b) State the difference between a purely thermal and a purely mechanical interaction, giving an example of each. [5]

(c) Using the first law of thermodynamics,

$$TdS = d\overline{E} + \overline{p}dV,$$

show that if the independent variables of the system is the entropy S and the pressure P, then the change in enthalpy of the system is.

$$dH = TdS + Vdp$$

where $H = E + pV$ is the enthalpy [5]

(d) The number of states ω of a system in the energy range E and $E+\delta E$ is given by $\Omega(E; x_1, \cdots, x_n)$, where x_i $(i = 1, 2, \cdots, n)$ are external parameters. Show that when the mean energy and the external parameters of a system are changed quasi-statically by any amount, the change in the entropy of the system is

$$dS = \frac{dQ}{T}$$

(Hint: You may need the result $\beta\bar{\chi}_\alpha = \partial \ln \Omega / \partial x_\alpha$. [12]

[Total 25 Marks]

Question Three

(a) The number of states in the energy range from E to $E + \delta E$of an ideal monatomic gas of N molecules in a volume V is

$$\Omega(E) = BV^N E^{3N/2}$$

while that of an ideal diatomic gas is

$$\Omega(E) = DV^N E^{5N/2}$$

where B and D are constants.

(i) show that the gases have the same equation of state. [5]

(ii) Assume the monatomic gas has N_1 molecules in a volume V_1 with energy E_1 and the diatomic gas has N_2 molecules in a volume V_2 with energy E_2. Suppose the two gases are brought into thermal contact, so that they form an insulated composite system. Show that when the equilibrium is achieved between them, the distribution of energy is such that

$$\tilde{E}_1 = \frac{3N_1\,(E_1 + E_2)}{3N_1 + 5N_2}$$

and

$$\tilde{E}_2 = \frac{5N_2\,(E_1 + E_2)}{3N_1 + 5N_2}$$

(*Hint: At equilibrium* $\partial \ln \Omega_1/\partial E_1 = \partial \ln \Omega_2/\partial E_2$ *and that total energy is* $E^0 = \tilde{E}_1 + \tilde{E}_2$) [10]

(iii) Show that the total amount of heat absorbed by the gases adds up to zero. [5]

(iv) Show that the final temperature of the system are indeed the same. [5]

[Total 25 Marks]

Question Four

(a) Explain the connection between the fundamental statistical postulate and the quasi-static processes and outline the importance of this connection in statistical mechanics [4]

(b) An isolated system consists of 2 spin-1 particles fixed in places and in equilibrium. Each particle has a magnetic moment μ. When the spin is parallel to an external field H, the energy is $-\mu H$, when the spin is anti-parallel, the energy is μH, while when the spin is perpendicular, the energy is 0.

(i) Enumerate all the states of the system [3]

(ii) State the energy macrostates available [2]

(iii) Use the fundamental statistical postulate to obtain the probability that in equilibrium, the system has zero total magnetic moment. [2]

(c) Both the volume and the temperature of material are macroscopic parameters used in the description of matter in bulk. Which one is an external parameter and why? Give another example of external parameter. [4]

(d) An ideal gas has a temperature-independent molar heat capacity c_v at a constant volume. Let $\gamma = c_p/c_v$ denote the ratio of its specific heats. The gas is thermally insulated and is allowed to expand quasi-statically from an initial volume V_i at temperature T_i to a final volume V_f

(i) use the relation pV^{γ} =constant to find the final temperature T_f of this gases. [4]

(ii) Use the fact that the entropy remains constant in this process to find the final temperature T_f [6]

[Total 25 Marks]

Question Five

(b) Two particles each of mass m are contained in a three-dimensional cube of length L. Hence the energy of each particle is given by

$$E = \frac{\hbar^2\pi^2}{2mL^2}\left(n_x^2 + n_y^2 + n_z^2\right)$$

where n_x, n_y and $n_z = 1, 2, 3, \cdots$. The particles do not interact at all, so that their total energy is simply the sum of their individual energies.

(i) What is the number of microstates corresponding to the ground state, the first excited state and the second excited states? [4]

(ii) Suppose that only the ground state, the first excited state and second excited states are accessible to the particle. What is the mean energy if the system is in equilibrium? [3]

(b) The heat absorbed by a mole of ideal gas in a quasi-static process in which its temperature T changes by dT and its volume V by dV is given by

$$dQ = cdT + \bar{p}dV$$

where c is its constant molar specific heat at constant volume and $\bar{p}$ is its mean pressure $\bar{p} = RT/V$. Assume the gas goes through a quasi static process which takes it from initial values of temperature T_i and volume V_i to the final values T_f and volume V_f

(i) Find an expression for the change of entropy of this gas. [5]

(ii) Does your answer depend on the process involved in going from the initial to the final state? [2]

(c) A system of two weakly-interacting particles, each of spin 1/2 and magnetic moment μ is located in an external magnetic field H. When the spin of the particle is aligned parallel to H, the energy of the particle is $-\mu H$ while when the spin is anti-parralel to the field, the energy is μH This system is in contact with a heat bath at temperature T.

(i) Use this system to distinguish between a macrostate and a microstate [3]

(ii) Using

$$P_0 = \frac{\sum_{E_r=0} e^{-\beta E_r}}{\sum_{E_r} e^{-\beta E_r}}$$

Show that the probability that the system has zero energy is

$$P_0 = \frac{2}{e^{2\beta\mu H} + e^{-2\beta\mu H} + 2}$$

[3]

(iii) Show that the mean energy of the system is

$$\overline{E} = -2\mu H \tanh(\beta\mu H)$$

[5]

[Total 25 Marks]

Question Six

(a) A system consists of 10 dipoles.

(i) How many states correspond to all the dipoles lying parallel to an applied external magnetic field H, and what is the total energy and total magnetic moment of the system for such states? [1]

(ii) How many states correspond to 7 of the dipoles pointing down and 3 pointing up, and what is the total energy and total magnetic moment of the system for those states? [2]

(iii) How many states are consistent with the constraint that the total energy is $-2\mu H$? [2]

(b) The partition function of a gas of N molecules in equilibrium in a volume V at absolute temperature T is given by

$$Z = V^N \left(\frac{2\pi mkT}{h_0^2}\right)^{3N/2}$$

where h_0 is a constant and m is the mass of a gas molecule

(i) Write out the expression for $\ln Z$ [2]

(i) Using $\beta\bar{p} = \partial \ln Z/\partial V$, write the equation of state and identify whether the gas is diatomic or monoatomic. [3]

(ii) Using $\bar{E} = -\partial \ln Z/\partial\beta$, obtain the mean energy, [2]

(iii) Using $S = \kappa(\ln Z + \beta\bar{E})$, obtain the entropy [2]

(iv) From $S = \kappa(\ln Z + \beta\bar{E}) = \kappa \ln \Omega$, show that the number of states of this gas in the energy range E and $E + \delta E$ is

$$\Omega(E) = V^N \left(\frac{4\pi m}{h_0^2}\frac{E}{3N}\right)^{3N/2} e^{3N/2}$$

[4]

(c) starting from $S = S(T, V)$ show that for any substance

$$c_V = \left(\frac{\partial E}{\partial T}\right)_V \qquad \text{and} \qquad \left(\frac{\partial E}{\partial V}\right)_T = T\left(\frac{\partial p}{\partial T}\right)_V - p$$

(Hint: You may use the Maxwell's relation)

$$\left(\frac{\partial S}{\partial V}\right)_T = \left(\frac{\partial p}{\partial T}\right)_V$$

[7]

[Total 25 Marks]

==========End of Examination==========

UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

DEPARTMENT OF PHYSICS

2020/2021 End of Year Final Examination

PHY3411: Analogue Electronics I

==========

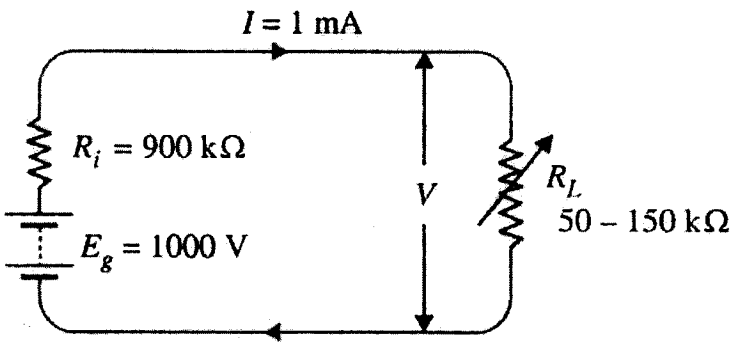
Instructions: Answer any **four** questions only. This examination paper has six questions. Each of the six questions carry equal marks. All essential working must be shown.

Time duration: three hours.

Some formulae that you might find useful:

$np = n_i^2$	$v = \eta V_T \ln\left(\frac{i}{I_s} + 1\right)$	$i = I_s\left(e^{v/\eta V_T} - 1\right)$	$r = \eta \frac{V_T}{I_Q}$
$V_{eff} = V_{rms} = \sqrt{\frac{1}{T}\int_0^T v(t)^2\, dt}$	$V_{av} = \frac{1}{T}\int_0^T v(t)dt$	$T = \frac{1}{\sqrt{1+\left(\frac{1}{\omega RC}\right)^2}}$	$T = \frac{1}{\sqrt{1+(\omega RC)^2}}$
$I_E = I_C + I_B$	$I_C = \beta I_B$	$R = \rho \frac{L}{A}$	$f(E_C) = \frac{1}{1+e^{E_g/2K_BT}}$
$\frac{n}{N} = e^{-E_g/k_BT}$	$\sigma \approx n\mu_n q$	$\sigma \approx p\mu_p q$	$n \approx \frac{n_i^2}{N_A}$
$V_T = \frac{T}{11586}$	$\rho = \frac{1}{\sigma}$	$W = \frac{1}{2}LI^2$	$X_C = \frac{1}{\omega C}$
$f(E_C) = \frac{1}{1+e^{E_g/2K_BT}}$	$p \approx \frac{n_i^2}{N_D}$	$r = \eta \frac{V_T}{I_Q}$	$\sigma = (n\mu_e + p\mu_h)$
$I = \frac{E_g}{R_L + R_i}$	$\sum_{x=1}^{n} I_x = 0$	$\sum_{y=1}^{n} V_y = 0$	$V = IR$, $v = iR$
$I_S = I_Z + I_L$	$P_{\max} = \frac{v_{oc}^2}{4R_L} = \frac{v_{oc}^2}{4R_o}\Big\vert_{R_L=R_O}$	$V = \frac{V_S R_L}{R_L + R_S}$	$E = I_F R + V_F$

1. a) A *d.c.* source generating 500 V has an internal resistance of 1000 Ω and is connected to a variable resistor in a similar set-up as shown in the circuit below. Find the load current if the load resistance is set to (i) 50 Ω, and (ii) 150 Ω. [2 + 2]



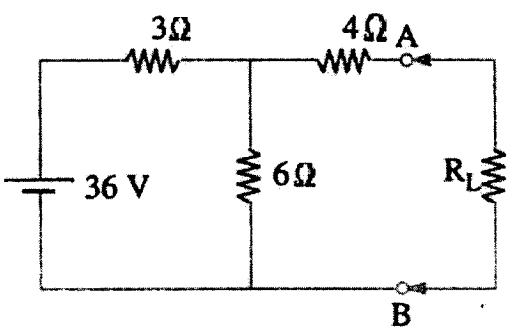
b) For the circuit given below,

(i) draw a circuit that would enable you to perform the maximum power transfer theorem calculations, [1]

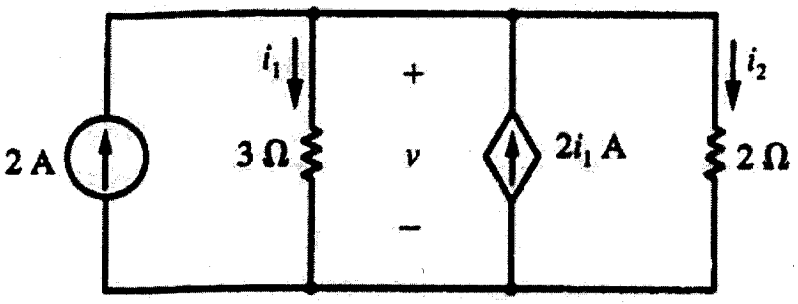
(ii) find the value of the load resistance (R_L) to be connected across terminals A and B which would extract maximum power from the circuit, and also [4]

(iii) calculate the open circuit voltage v_{oc} at terminals A and B. [4]

(iv) evaluate the value of this maximum power transferred to the load resistance. [4]



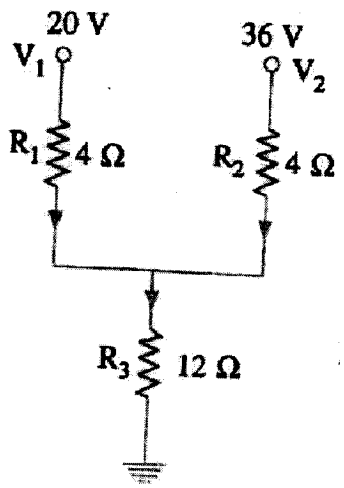
c) In the following circuit, the value of the dependent current source depends on the current i_1 through the 3-Ω resistor, the value of the dependent source is $2i_1$ with units of amperes. Find the currents i_1 and i_2, and also the value of the dependent current source. [8]



2. a) State Kirchhoff's current law. [1]

b) The circuit below is excited by two voltage sources both of zero internal resistances.

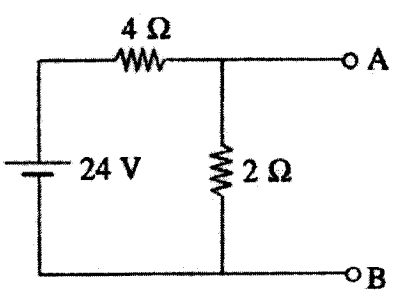
(i) Using the principle of superposition, calculate the current flowing in the network shown. [22]



(ii) Find the voltage drop across the common resistance R_3. [2]

3. a) State Thevenin's Theorem. [1]

b) For the circuit shown below,



Determine, by Norton's Theorem,

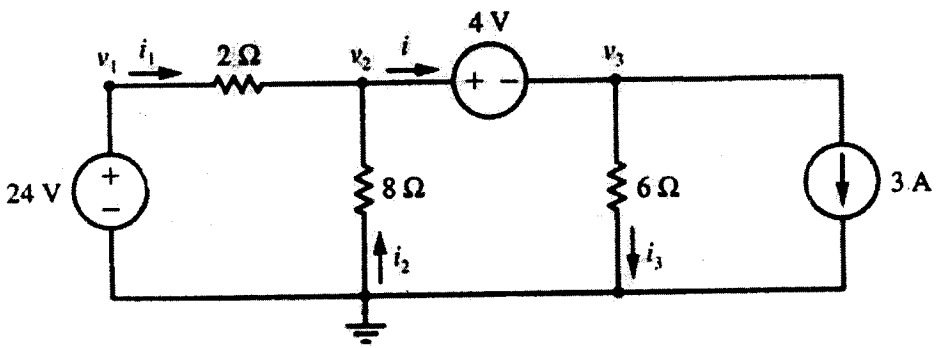
(i) the current I_N, and also [2]

(ii) the resistance R_N [3]

c) For the circuit shown below, the 4 V source is connected between two nonreference nodes. Find the

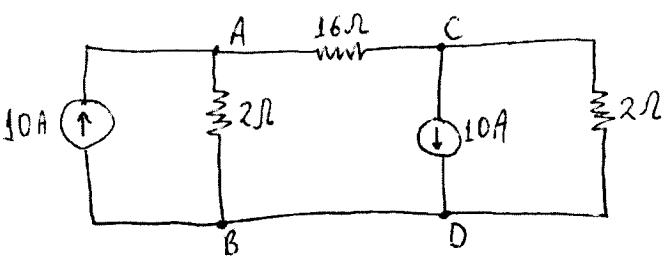
(i) node voltages v_1, v_2 and v_3, and hence [15]

(ii) the labelled currents i_1, i_2, i_3 and i. [1 + 1 + 1 + 1]

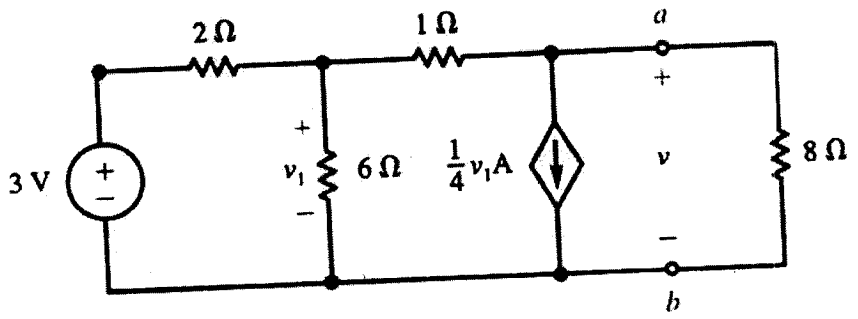


4. a) State Kirchhoff's voltage law. [1]

b) Determine the branch current through the 16 Ω resistor of the circuit in the figure below. [11]



c) For the circuit below, use Norton's Theorem to calculate the short-circuit current (i_{sc}) and the output resistance (R_o) by performing following steps:



(i) redraw the given circuit replacing the 8-Ω resistor with a short circuit and also highlighting the label v_1 at the node connecting the three resistances. [1]

(ii) show that $v_1 = 0.9$ V by applying KCL at the node associated. [4]

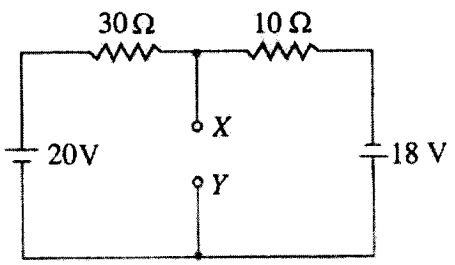
(iii) apply KCL at an appropriate node to determine i_{sc} as equaling 0.675 A. [3]

(iv) redraw the given circuit into a diagram for the determination of R_o showing the new node v_1 label clearly. [1]

(v) apply KCL at this new node to illustrate that this $v_1 = 0.6v_o$. [4]

5. a) State Norton's Theorem. [1]

b) Find the Thevenin equivalent circuit at terminals X and Y in the following figure by first finding the Thevenin equivalent circuit parameters and then drawing the resulting circuit. [13]



c) (i) Draw the *LC* filter circuit and explain how each of the two circuit elements work together in filtering an input signal from a rectifier. [6]

(ii) Describe with a suitable circuit diagram, the working of a simple Zener voltage regulator/stabilizer circuit. [5]

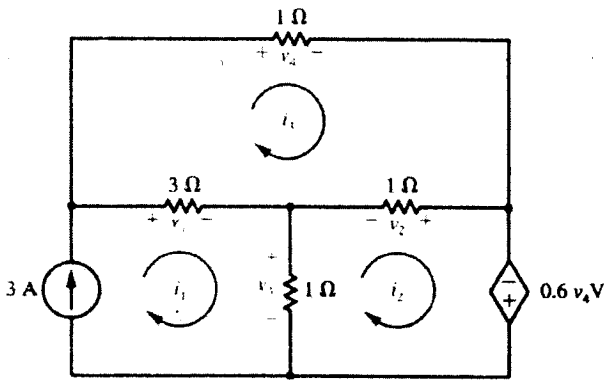
6. a) Transistors use mobile charge carriers in their operations. What kind of transistors operate as

(i) bipolar, and

(ii) unipolar

devices? [2]

b) Determine the mesh current i_1, i_2, and i_3 indicated in the circuit shown below. [13]



c) In the CE configuration circuit, also called grounded-emitter transistor amplifier circuit, shown below, base current and collector current are in milli-amperes.

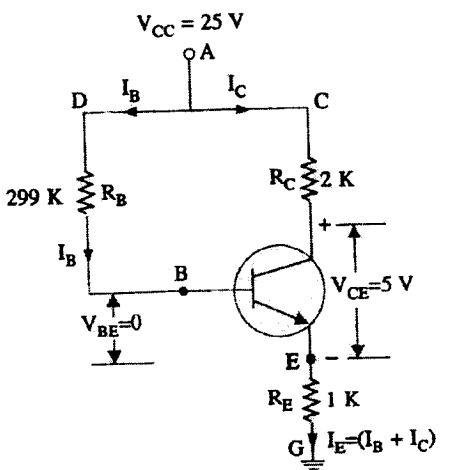
i) Apply KVL to the loop ADBEGA to show that [3]

$$300I_B + I_C = 25.$$

ii) Apply KVL to the loop ACBEGA to show that [3]

$$I_B + 3I_C = 20.$$

iii) Hence, compute I_B and I_C flowing in the circuit. [4]



END OF EXAMINATION

UNIVERSITY OF ZAMBIA

DEPARTMENT OF PHYSICS

SCHOOL OF NATURAL SCIENCES

2020/2021 Academic Year

End of Year University Examinations

PHY3422: Digital Electronics I

Instructions: Attempt any **four** questions. This examination paper has six questions. Each of the six questions carries equal marks. All essential working must be shown. **Positive logic system is assumed always unless** it is explicitly mentioned, **in a particular question**, that negative logic must be considered.

Time duration: three hours.

Some Boolean algebra, axioms and theorems that you might find useful:

$x \cdot y = y \cdot x$ $x + y = y + x$	*Commutative*	$0 \cdot 0 = 0$	$x \cdot 0 = 0$
$x \cdot (y \cdot z) = (x \cdot y) \cdot z$ $x + (y + z) = (x + y) + z$	*Associative*	$1 + 1 = 1$	$x + 1 = 1$
$x \cdot (y + z) = x \cdot y + x \cdot z$ $x + y \cdot z = (x + y) \cdot (x + z)$	*Distributive*	$1 \cdot 1 = 1$	$x \cdot 1 = x$
$x + x \cdot y = x$ $x \cdot (x + y) = x$	*Absorption* *Combining*	$0 + 0 = 0$	$x + 0 = x$
$x \cdot y + x \cdot \bar{y} = x$ $(x + y) \cdot (x + \bar{y}) = x$		$x + \bar{x} \cdot y = x + y$ $x \cdot (\bar{x} + y) = x \cdot y$	$x \cdot x = x + x = x$
$\overline{x \cdot y} = \bar{x} + \bar{y}$ $\overline{x + y} = \bar{x} \cdot \bar{y}$	*de Morgan's theorems*	$0 \cdot 1 = 0$	$x + \bar{x} = 1$
$x \cdot y + y \cdot z + \bar{x} \cdot z = x \cdot y + \bar{x}z$ $(x + y) \cdot (y + z) \cdot (\bar{x} + z) =$ $(x + y) \cdot (\bar{x} + z)$	*Consensus*	$0 + 1 = 1$ $x \cdot \bar{x} = 0$	If $x = 0$, Then $\bar{x} = 1$ and $\bar{\bar{x}} = 0$

1. a) Convert the binary number $(100110110011010.1101)_2$ to its octal equivalent. [2]

   b) (i) Convert the hexadecimal number $(A2F.9)_{16}$ to its decimal equivalent. [3]

   (ii) Convert the decimal number $(757.546875)_{10}$ to its hexadecimal equivalent. [6]

   c) Design the logic circuit using AND, OR or NOT gates, and where necessary a combination of all the types of gates for the following Boolean expressions:

   (i) $Y = \overline{P}\overline{Q} + PQ$ [7]

   (ii) $Y = A\overline{B} + \overline{A}B$ [7]

2. a) What is the difference between a half-adder and full-adder circuit operation? [2]

   b) (i) Draw a truth table showing the rules, followed or used, to perform binary subtraction of two bits. [4]

   (ii) Obtain an all NAND gates implementation of the logic function [9]

   $$Y = A + B\,.$$

   c) Find the Duals of the following Boolean expressions:

   (i) $(A + B) \cdot \overline{C}$ [2]

   (ii) $A\overline{B} + C$ [2]

   (iii) $x \cdot y + y \cdot z + \overline{x} \cdot z = x \cdot y + \overline{x}z$ [2]

   (iv) $B \cdot 0 = 0$ [2]

   (v) $C \cdot 1 = C$ [2]

3. a) Discuss the least significant digit and, also the, most significant digit of a number under any particular number system, giving an example in each case. [2]

   b) (i) Using normal/ordinary binary subtraction, subtract 3_{10} from 8_{10}, also $(3)_{10}$ from $(8)_{10}$. [3]

(ii) Prove that the result in part (i) is equivalent to 5_{10}, also $(5)_{10}$. [3]

c) The following truth tables are for a half adder (A) and a full adder (B) of binary digits, respectively, below.

Input		Output	
A	B	S	C
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

A

Input			Output	
A	B	C_i	S	C_o
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

B

(i) Draw a truth table of an XOR gate. [2]

(ii) Hence, draw a half adder circuit featuring logic gates using the above-given truth tables and your truth table of part (i). [2]

(iii) Draw a full adder block diagram. [2]

(iv) Design a full adder circuit, derived from two half adder block diagrams, using appropriate logic gates. [3]

(v) Using the block diagram model of a full adder, draw a 4-bit parallel binary adder. [8]

4. a) Obtain the truth table for the Boolean function $F = AB + \overline{B}\overline{C} + \overline{A}C$. [13]

b) (i) Using 1's complement method, subtract 1010.101 from 1000.110. [5]

(ii) Use 1's complement arithmetic to calculate 10110 - 00111. [4]

c) The R-S Flip-Flop (structure) can be modified to yield the JK Flip-Flop using the relations

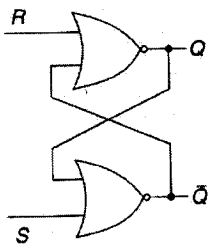
$$S = J\overline{Q}$$

$$R = KQ$$

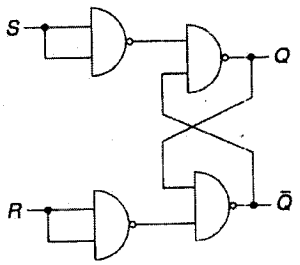
The R-S Flip-Flop truth table (i.e., S = R = 1 forbidden/invalid for the NOR gated flip-flop) is shown below. Its NOR gates as well as NAND gates circuit implementations are shown also.

R	S	Q
0	0	No change
0	1	1 (SET)
1	0	0 (RESET)
1	1	Forbidden

(a) Truth table



(b) Nor-gate implementation



(c) NAND-gate implementation

The JK Flip-Flop is a clocked flip-flop which produces a valid output for any input combination. Use any of the given implementations to draw a particular NOR or NAND gated JK Flip-Flip circuit construction. [3]

5. a) Express -52_{10}, or $(-52)_{10}$, in 2's complement form. Use 8 bits. [6]

b) Subtract

(i) 10101 from 11011, and also [4]

(ii) 11101 from 01011, [5]

using the 2's complement method.

c) Obtain the

(i) SOP, and the [6]

(ii) POS, [4]

equation for the logic function whose truth table is given below.

A	0	1	0	1	0	1	0	1
B	0	0	1	1	0	0	1	1
C	0	0	0	0	1	1	1	1
F	1	0	0	0	1	0	1	1

6. a) The output of a gate should be same as the input. Implement this function using a 2-input

(i) AND gate. [2]

(ii) OR gate. [2]

b) (i) Obtain the truth for the POS expression [12]

$$F = (A + B + \overline{C})(\overline{A} + B + \overline{C})(\overline{A} + \overline{B} + C)$$

(ii) Simplify the following expression using Boolean algebra [3]

$$Y = \overline{A}\,\overline{B}\,\overline{C} + \overline{A}B\overline{C} + A\overline{B}\,\overline{C} + AB\overline{C}\,.$$

c) What do the following acronyms stand for? In each case below, briefly describe each of the logic families

(i) CMOS [3]

(ii) TTL [3]

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

DEPARTMENT OF PHYSICS

2020/2021 ACADEMIC YEAR

END OF YEAR EXAMINATIONS

PHY3621: ELECTROMAGNETIC THEORY

MARKS: 100

TIME ALLOWED: 3 HOURS

INSTRUCTIONS

- Attempt any 4 of the 6 questions given.
- All questions have 25 marks each.
- Omission of essential work will result in loss of marks.
- Clearly write your computer number on all answer sheets used.

You may use the following information where necessary

$$\epsilon_o = 8.85 \times 10^{-12} \text{ farad/meter}$$

$$\mu_o = 4\pi \times 10^{-7} \text{ N/A}^2$$

$$\text{N}_a = 6.0 \times 10^{23} \text{ mol}^{-1}$$

$$\int \sec\theta d\theta = \text{In}(\sec\theta + \tan\theta)$$

Vector identities

$$\vec{\nabla} \times (\vec{\nabla} \times \vec{A}) = -\vec{\nabla}^2 A + \vec{\nabla}(\vec{\nabla} \cdot \vec{A})$$
$$\vec{\nabla} \cdot (f\vec{A}) = f\vec{\nabla} \cdot \vec{A} + \vec{A} \cdot \vec{\nabla} f$$
$$\vec{\nabla} \times (f\vec{A}) = \vec{\nabla} f \times \vec{A} + f(\vec{\nabla} \times \vec{A})$$
$$\vec{\nabla}((V\vec{\nabla}V) = (\vec{\nabla}V)^2 + V\vec{\nabla}^2 V$$

In spherical coordinates (r, θ, ϕ),

$$\vec{\nabla} f = \frac{\partial f}{\partial r}\hat{r} + \frac{1}{r}\frac{\partial f}{\partial \theta}\hat{\theta} + \frac{1}{rsin\theta}\frac{\partial f}{\partial \phi}\hat{\phi}$$
$$\vec{\nabla}^2 \equiv \frac{1}{r^2}\frac{\partial}{\partial r}(r^2\frac{\partial}{\partial r}) + \frac{1}{r^2 sin\theta}\frac{\partial}{\partial \theta}(sin\theta\frac{\partial}{\partial \theta}) + \frac{1}{r^2 sin^2\theta}\frac{\partial^2}{\partial \phi^2}$$
$$\vec{\nabla} \cdot \vec{A} \equiv \frac{2}{r}A_r + \frac{\partial A_r}{\partial r} + \frac{A_\theta}{r}cot\theta + \frac{1}{r}\frac{\partial A_\theta}{\partial \theta} + \frac{1}{rsin\theta}\frac{\partial A_\phi}{\partial \phi}$$
$$\vec{\nabla} \times \vec{A} = \frac{\hat{r}}{rsin\theta}[\frac{\partial}{\partial \theta}(sin\theta A_\phi) - \frac{\partial A_\theta}{\partial \phi}] + \frac{\hat{\theta}}{r}[\frac{1}{sin\theta}\frac{\partial A_r}{\partial \phi} - \frac{\partial}{\partial r}(rA_\phi)] + \frac{\hat{\phi}}{r}[\frac{\partial}{\partial r}(rA_\phi) - \frac{\partial A_r}{\partial \theta}]$$

In cylindrical coordinates (ρ, ϕ, z),

$$\vec{\nabla} f = \hat{\rho}\frac{\partial f}{\partial \rho} + \hat{\phi}\frac{1}{\rho}\frac{\partial f}{\partial \phi} + \hat{z}\frac{\partial f}{\partial z}$$
$$\vec{\nabla} \vec{A} = \frac{1}{\rho}\frac{\partial}{\partial \rho}(\rho A_\rho) + \frac{1}{\rho}\frac{\partial A_\phi}{\partial \phi} + \frac{\partial A_z}{\partial z}$$
$$\vec{\nabla} \times \vec{A} = \hat{\rho}(\frac{1}{\rho}\frac{\partial A_z}{\partial \phi} - \frac{\partial A_\phi}{\partial z}) + \hat{\phi}(\frac{\partial A_\rho}{\partial z} - \frac{\partial A_z}{\partial \rho}) + \hat{z}[\frac{1}{\rho}\frac{\partial}{\partial \rho}(\rho A_\phi) - \frac{1}{\rho}\frac{\partial A_\rho}{\partial \phi}]$$
$$\nabla^2 f = \frac{1}{\rho}\frac{\partial}{\partial \rho}(\rho\frac{\partial f}{\partial \rho}) + \frac{1}{\rho^2}\frac{\partial^2 f}{\partial \phi^2} + \frac{\partial^2 f}{\partial z^2}$$

For any arbitrary vector $\vec{A}$ **and a surface S bounding a volume** τ

$$\int_\tau (\vec{\nabla} \times \vec{A}) d\tau = -\int_s \vec{A} \times d\vec{s}$$

Poisson's equation

$$\vec{\nabla^2} V = -\frac{\rho}{\epsilon_o}$$

For a long solenoid of length L**, the magnetic induction is given by**

$$B = \frac{\mu_o NI}{L} \text{ inside}$$
$$= 0 \text{ outside}$$

The vector potential at a point due to a current carrying conductor is

$$\vec{A} = \frac{\mu_o I}{4\pi}\oint \frac{d\vec{l}}{r}$$

1. (a) Starting with the Gauss law and electric fields based on the potential, derive the Poisson and Laplace equations. Show all necessary steps.

[6 marks]

(b) Apply either the Poisson or Laplace equation to find the electric fields

i. outside and,

[4 marks]

ii. inside a spherical charge distribution of uniform volume density ρ and radius R.

[3 marks]

(c) For an isotropic, linear, and stationary medium **(ILSM)**, not necessarily homogeneous, write the four Maxwell's equations for magnetic fields that are sinusoidal functions of time.

[4 marks]

(d) Derive the wave equation for the magnetic field $\mathbf{B}$ for constant conductivity σ.

[8 marks]

2. (a) Find the gradient of each of the following functions where a and b are constants:

i. $f = ax^2y + by^3z$

[3 marks]

ii. $f = ar^2 sin\phi + brzcos2\phi$

[4 marks]

iii. $f = \frac{a}{r} + brsin\theta cos\phi$

[4 marks]

(b) Find the volume of a sphere of radius R centred at the origin using

i. cylindrical coordinates $r^2 + z^2 = R^2$

[3 marks]

ii. spherical coordinates $r = R$.

[3 marks]

iii. Which coordinate system is easier?

[1 mark]

(c) Using the Stokes' theorem, prove that $\oint_L f\mathbf{dl} = -\int_S \nabla f \times \mathbf{dS}$ (**Hint**: Let $\mathbf{A} = \mathbf{i}f$, where $\mathbf{i}$ is any constant unit vector).

[7 marks]

3. (a) Show that the permeability of free space μ_o can be defined as follows: If an infinitely long solenoid carries a current density of one ampere per metre, then the magnetic induction in teslas inside the solenoid is numerically equal to μ_o.

[5 marks]

(b) A length of tubing carries a current I in the longitudinal direction.

i. what is the value of B outside?

[2 marks]

ii. How is **A** oriented outside?

[2 marks]

iii. What is the value of B inside?

[2 marks]

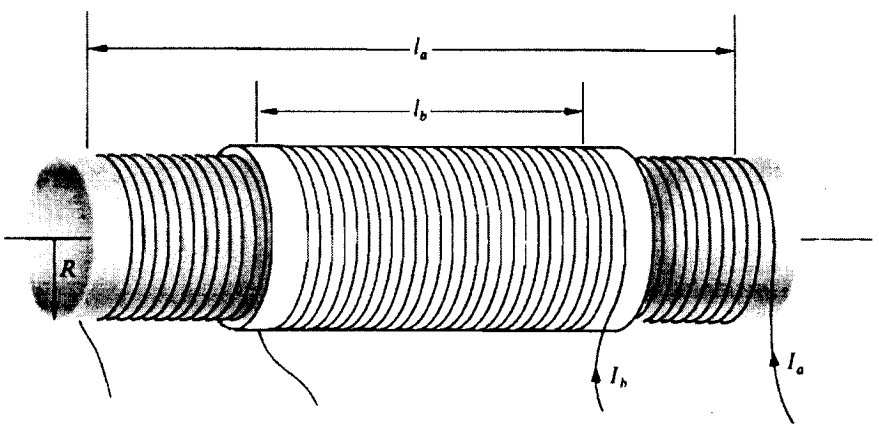
iv. Show that **A** is uniform inside.

[4 marks]

(c) A conducting sheet carries a current density of α amperes per metre. Show that, very close to the sheet, the magnetic induction **B** due to the current in the sheet is $\mu_o\alpha/2$ in the direction perpendicular to the current and parallel to the sheet.

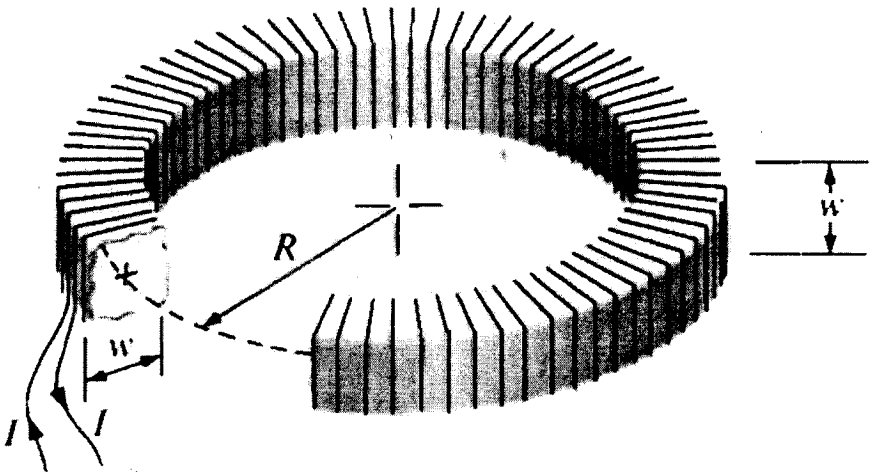
[10 marks]

4. (a) Consider coaxial solenoids shown below. The two radii are taken to be approximately equal. Assume that both windings are long, compared to their common diameter $2R$, that they have the same number of turns per metre N', and that they are wound in the same direction.



Now, assume currents I_a and I_b in coil a and b, respectively, calculate the mutual inductance values M_{ab} and M_{ba}. How do the two values compare?

[12 marks]



(b) A toroidal coil of N turns is wound on a non-magnetic material having a square cross-section as shown in the figure above.

Obtain the flux linkage and show that the self inductance of a toroidal coil is proportional to the square of the number of turns, like that of a long solenoid.

[13 marks]

5. (a) A sample of diamond has a density of 3.5×10^3 kilograms per cubic metre and a polarization of 10^{-7} coulomb per square metre. Compute the average dipole moment per atom.

[7 marks]

(b) Consider a block of dielectric with bound charge densities ρ_b and σ_b. Show mathematically that $\int_\tau \rho_b d\tau + \int_S \sigma_b da = 0$ where the τ is the volume of the dielectric and S is its surface. In other words, the total net bound charge is zero.

[7 marks]

(c) Show that the bound charge density at the interface between two dielectrics 1 and 2 that is crossed by an electric field is $(\mathrm{P}_1 - \mathrm{P}_2) \cdot \mathbf{n}$. The polarization in 1 is P_1 and is directed into the interface; the polarization in 2 is P_2 and points away from the interface. The unit vector $\mathbf{n}$ is normal to the interface and points in the direction from 1 to 2.

[11 marks]

6. (a) Write expressions that best match the following descriptions:

i. **Total current density** in amperes/metre^2.

[3 marks]

ii. **B** and **H** being continuous across an interface.

[4 marks]

iii. **Magnetic field strength** in terms of **M** and **B**.

[3 marks]

(b) Prove that $c \approx 3.0 \times 10^8$ m/s given that the permittivity and permeability of free space parameters are ϵ_o and μ_o, respectively.

[5 marks]

(c) Show that in a linear and isotropic magnetic medium, the magnetization in terms of the magnetic field can be expressed as

$$\mathbf{M} = \frac{\chi_m \mathbf{B}}{\mu_o(1+\chi_m)}. \tag{1}$$

[10 marks]

THE END OF PHY3621 EXAM - HAPPY FESTIVE SEASON

The University of Zambia
School of Natural Sciences
Department of Physics
2021 Academic Year
Final Examinations
PHY 4031 - Computational Physics II

November 2021

Duration: 3 hours **Maximum Marks: 100**

Instructions

1. Write clearly your computer number on the answer booklets.
2. This examination paper contains six (6) questions.
3. Attempt any four (4) questions.
4. This examination paper has a total of 100 marks.
5. All questions carry equal marks.
6. Marks allocated for each question are indicated in brackets.

Question 1

Find the root of the equation

$$f(x) = \ln(x) + x - 5 = 0$$

with **regula falsi method** starting with interval $[a_0, b_0] = [3.2, 4.0]$. Compute the false points c_0 , c_1 and c_2. **[25 marks]**

Question 2

Solve the following system of linear equations

$$\begin{aligned} 10x - y + 2z &= 38 \\ -x + 15y + 3z &= 26 \\ 2x + 3y + 12z &= 14 \end{aligned}$$

using **Gauss – Seidel iterative method** starting with $P_0 = (x_0, y_0, z_0) = (0, 0, 0)$. Compute P_k for $k = 0, 1, 2$. **[25 marks]**

Question 3

Solve the integral

$$I = \int_0^3 xe^x dx$$

using **Monte Carlo integration** for $N = 10$ **[25 marks]**

Question 4

(a) Find the Fourier series of

$$f(t) = \begin{cases} 0 & -\pi < t < -\pi/2 \\ 4 & -\pi/2 < t < \pi \\ 0 & \pi < t < \pi \end{cases}$$

$$f(t + 2\pi) = f(t)$$

[12 marks]

(b) Find the complex Fourier series of

$$f(t) = \begin{cases} 0 & -2 < t < 0 \\ t & 0 < t < 2 \end{cases}$$

$$f(t+4) = f(t)$$

[13 marks]

Question 5

Find the Fourier transform of

$$f(t) = \begin{cases} 0 & t < -a/2 \\ 1/a & -a/2 < t < a/2 \\ 0 & a/2 < t \end{cases}$$

[25 marks]

Question 6

Apply the **Huen's Method** with $h = 0.1$ and $N = 4$ steps to the IVP

$$y' = 2xy + 1 \quad , \quad y(0) = 0$$

[25 marks]

USEFUL FORMULAS AND ALGORITHMS

Regula Falsi Method

To approximate a root of $f(x) = 0$ which lies in the interval [a,b]

1. check if product $f(a) \cdot f(b) < 0$, then

   (i) calculate the false point c as

   $$c = \frac{bf(a) - af(b)}{f(a) - f(b)}$$

   (ii) next, check the sign of product $f(a) \cdot f(c)$

   if $f(a) \cdot f(c) = 0$, then make

   $$a = c \quad , \quad b = c$$

   else if $f(a) \cdot f(c) > 0$, then make

   $$a = c \quad \text{and} \quad f(a) = f(c)$$

   else make

   $$b = c \quad \text{and} \quad f(b) = f(c)$$

   (iii) calculate a new false position c and go back to step (ii).

   (iv) Once the required number of iterations k is met or the bracket is small enough, calculate a final false position as

   $$c = \frac{bf(a) - af(b)}{f(a) - f(b)}$$

2. else if $f(a) \cdot f(b) > 0$ then

   no root exists in interval $[a, b]$.

Gauss Seidel Iterative Method

To solve a system of linear equations,

$$a_{11}x + a_{12}y + a_{13}y = b_1$$
$$a_{21}x + a_{22}y + a_{23}y = b_2$$
$$a_{31}x + a_{32}y + a_{33}y = b_1$$

by iteration using **Gauss Seidel Iterative Method**, the above linear equations are transformed into iterative formulas given by

$$x = \frac{b_1 - a_{12}y - a_{13}z}{a_{11}}$$
$$y = \frac{b_2 - a_{21}x - a_{23}z}{a_{21}}$$
$$z = \frac{b_3 - a_{31}x - a_{23}y}{a_{11}}$$

where

$$a_{11} = max(a_{11}, a_{12}, a_{13})$$

$$a_{22} = max(a_{21}, a_{22}, a_{23})$$
$$a_{33} = max(a_{31}, a_{32}, a_{33})$$

We get the jacobi iterative formulas as

$$x_{n+1} = \frac{b_1 - a_{12}y_n - a_{13}z_n}{a_{11}}$$
$$y_{n+1} = \frac{b_2 - a_{21}x_{n+1} - a_{23}z_n}{a_{21}}$$
$$z_{n+1} = \frac{b_3 - a_{31}x_{n+1} - a_{23}y_{n+1}}{a_{11}}$$

Monte Carlo integration

The integral

$$\int_a^b f(x)\ dx \simeq (b-a)\cdot \bar{f}$$

The mean value of the function $\bar{f}$ is given by

$$\bar{f} = \frac{f(x_i)}{N}$$

where

$x_i = a + (b-a)\epsilon_i$

N is the number of random values generated.

ϵ_i is a random number in interval [0,1].

Fourier Series

A periodic function $f(t)$ with period T such that

$$f(t+T) = f(t) \quad , \quad T = \frac{2\pi}{\omega}$$

can be expressed as a Fourier Series of sines and cosines as follows

$$f(t) = \frac{a_0}{2} + \sum_{n=1}^{\infty} \{a_n \cos n\omega t + b_n \sin n\omega t\}$$

where

$$a_0 = \frac{2}{T}\int_0^T f(t)dt = \frac{2}{T}\int_{-T/2}^{T/2} f(t)dt$$

$$a_n = \frac{2}{T}\int_0^T f(t)\cos n\omega t dt = \frac{2}{T}\int_{-T/2}^{T/2} f(t)\cos n\omega t dt$$

$$b_n = \frac{2}{T}\int_0^T f(t)\sin n\omega t dt = \frac{2}{T}\int_{-T/2}^{T/2} f(t)\sin n\omega t dt$$

Complex Fourier Series

A periodic function $f(t)$ with period T such that

$$f(t+T) = f(t) \quad , \quad T = \frac{2\pi}{\omega}$$

can be expressed as a complex Fourier Series as follows

$$f(t) = \sum_{n=-\infty}^{\infty} c_n e^{in\omega_o t}$$

where

$$c_n = \frac{1}{T}\int_0^T f(t)e^{-in\omega_o t}dt = \frac{1}{T}\int_{-T/2}^{T/2} f(t)e^{-in\omega_o t}dt$$

Fourier Tranform and Inverse Fourier Transform

The Fourier Transform $F(s)$ is defined as

$$F(s) = \int_{-\infty}^{\infty} f(t)e^{-i2\pi st}dt$$

The inverse Fourier Transform of $f(t)$ is defined as

$$f(t) = \int_{-\infty}^{\infty} F(s)e^{i2\pi st}ds$$

Huen's Method for First Order ODEs

Huen's Method computes the solution to the initial value problem (IVP)

$$y' = f(x,y) \quad , \quad y(x_0) = y_0$$

at equidistant points x_0, x_1, x_2. ....,x_{N-1}

For $n = 0, 1, 2, 3, ..., N-1$, do

$$k_1 = hf(x_n, y_n)$$

$$y^*_{n+1} = y_n + k_1$$

$$x_{n+1} = x_n + h$$

$$k_2 = hf(x_{n+1}, y^*_{n+1})$$

$$y_{n+1} = y_n + \frac{1}{2}(k_1 + k_2)$$

Output (x_{n+1}, y_{n+1})

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

DEPARTMENT OF PHYSICS

2020/2021 ACADEMIC YEAR

END OF YEAR EXAMINATIONS

PHY4121: NUCLEAR EXPERIMENTAL TECHNIQUES

MARKS: 100

TIME ALLOWED: 3 HOURS

INSTRUCTIONS

- Attempt any 4 of the 6 questions given.
- All questions have 25 marks each.
- Omission of essential work will result in loss of marks.
- Clearly write your computer number on all answer sheets used.

You may use the following information where necessary

$$1 \text{ u} = 931.494 \text{ MeV/c}^2 = 1.6605 \times 10^{-27} \text{ kg}$$

$$\text{m}_p = 1.672\,614 \times 10^{-27} \text{ kg} = 1.007\,276 \text{ u}$$

$$\text{m}_n = 1.674\,920 \times 10^{-27} \text{ kg} = 1.008\,665 \text{ u}$$

$$\text{m}_e = 9.109\,56 \times 10^{-31} \text{ kg} = 0.000\,549 \text{ u}$$

$$\text{e} = 1.602 \times 10^{-19} \text{ C}$$

$$\text{c} = 3.0 \times 10^{8} \text{ m s}^{-1}$$

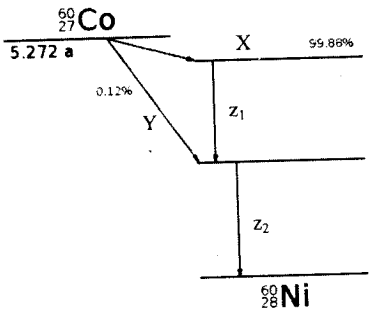
1. (a) State the difference between the decay scheme of a radioactive substance and its energy level diagram.

[2 marks]

(b) An example of a decay scheme is the decay of a nuclide $^{198}_{79}$Au, which can be produced by irradiating natural gold in a nuclear reactor. Gold-198 decays via a β particle to one of two excited states or to the ground state of the mercury isotope $^{198}_{80}$Hg. The excited states undergo γ decay after very short times to the ground state. Write the decay scheme using this information.

[10 marks]

(c) The decay scheme of Cobalt-60 to Nickel-60 is shown in the figure below with specific information missing. Complete the decay scheme by identifying



i. particle X,

[2 marks]

ii. particle Y,

[2 marks]

iii. particle z_1 and its associated energy in MeV,

[3 marks]

iv. particle z_2 and its associated energy in MeV.

[3 marks]

(d) While excited nuclear states are usually very short lived, decaying almost immediately after a β decay, the excited state of an isotope of technetium ($^{99}_{43}$Tc) is comparatively long lived. Write the decay scheme for this form of technetium.

[3 marks]

2. (a) Neutron activation analysis (NAA) allows a discrete sampling of elements as it disregards the chemical form of a sample, and focuses solely on its nucleus.

i. What is meant by neutron activation analysis (NAA)?

[1 mark]

ii. Briefly explain how you can study spectra of the emissions of the radioactive sample, and thus determine the concentrations of the elements within it.

[3 marks]

iii. Mention one property that makes NAA suitable for use in the analysis of works of art and historical artifacts.

[1 mark]

iv. How is instrumental neutron activation analysis (INAA) different from radiochemical neutron activation analysis (RNAA)?

[2 marks]

v. Even though NAA has a variety of useful applications, there are two noteworthy drawbacks to the use of NAA. What are these two drawbacks?

[2 marks]

(b) The neutrons used in NAA have a variety of sources.

i. List the three sources of these neutrons.

[3 marks]

ii. Most neutron energy distributions are quite broad and consist of three principal components. What are they?

[3 marks]

iii. NAA involves neutron capture by atomic nuclei, which get excited thereby inducing radioactive emission from excited nuclei forming product nuclei. Draw a well labelled schematic diagram illustrating this procedure.

[4 marks]

(c) Write nuclear reactions for the formation of neutrons used in NAA for

i. an alpha source such as americium mixed with beryllium, generates neutrons by (α, C + n + Q) reaction.

[1 mark]

ii. a gamma radiation, induces neutron emission from beryllium.

[1 mark]

iii. a gamma radiation, induces neutron emission from deuterium.

[1 mark]

(d) How would you calculate the net rate r at which a target reacts to produce radioactive atoms while being bombarded on all sides with neutrons.

[3 marks]

3. (a) Describe briefly how heavy charged particles, such as alpha particles, interact with matter.

[5 marks]

(b) In addition to stopping power S and the nature of the interaction, another characteristic to consider when studying heavy charged particle interaction is the Bragg curve.

i. What is the meaning of the terms Bragg curve and stopping power?

[4 marks]

ii. Draw the Bragg curve for a single alpha particle track and for the average behavior of a parallel beam of alpha particles of the same initial energy.

[4 marks]

iii. The two curves in 3 (b) ii are expected to be different. Give a reason for this difference.

[2 marks]

(c) With reference to 3 (b) ii above, briefly explain the trend

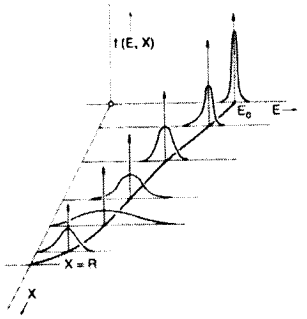
i. resulting from the two electronic charges on the alpha particle.

[2 marks]

ii. near the end of the track.

[2 marks]

(d) The figure below shows a schematic presentation of the energy distribution of a beam of initially mono-energetic particles at various points along its range.



i. Why does the distribution become wider (and more skewed) with penetration distance over the first portion of the distribution?

[2 marks]

ii. Give a reason why near the end of the range, the distribution narrows again.

[2 marks]

iii. Hence, briefly explain this energy straggling phenomenon.

[2 marks]

4. (a) The time required to stop a charged particle in an absorber can be deduced from its range R and average velocity v. For non-relativistic particles of mass m and kinetic energy E in MeV, show that the velocity can be expressed according to relation (1)

$$v = (3.00 \times 10^8 \frac{m}{s}) \sqrt{\frac{2E}{(931 MeV/amu) \cdot m_A}} \tag{1}$$

where m_A is the particle mass in atomic mass units (amu).

[10 marks]

(b) Assuming that the average alpha (α) particle velocity as it slows down is $\langle v \rangle = Kv$, where v is evaluated at the initial energy, show that the stopping time T can be calculated from the range R as

$$T = \frac{R}{K(3.00 \times 10^8 \frac{m}{s})} \cdot \sqrt{\frac{931 MeV/amu}{2}} \cdot \sqrt{\frac{m_A}{E}} \tag{2}$$

where K is a fraction associated with the rate of energy loss by charged particles.

[10 marks]

(c) If the α particle were uniformly decelerated, then $\langle v \rangle$ would be given by $v/2$ and K would be 0.5. However, charged particles generally lose energy at a greater rate near the end of their range, and K should be somewhat higher fraction. Obtain the value of the fraction K given that the estimated stopping time is

$$T \cong 1.2 \times 10^{-7} R \sqrt{\frac{m_A}{E}} \tag{3}$$

where T is in seconds, R in metres, m_A in amu, and E in MeV.

[5 marks]

5. (a) List five properties exhibited by each of the statistical models used in nuclear physics experiments.

i. Binomial distribution

[5 marks]

ii. Poisson distribution

[5 marks]

iii. Gaussian or normal distribution

[5 marks]

(b) A 10-min measurement results in a statistical uncertainty of 2.8%. How much additional time must be allocated to reduce the statistical uncertainty to 1.0%?

[10 marks]

6. (a) Two models of dead time behavior of counting systems have come into common usage. For low rates ($n \ll 1/\tau$), what approximations can you write for

   i. nonparalyzable, and

   [2 marks]

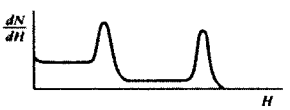
   ii. paralyzable cases.

   [2 marks]

   iii. A paralyzable detector system has a dead time of 1.5 μs. If a counting rate of 10^5 per second is recorded, find the two possible values for the true interaction rate and comment on your results.

   [5 marks]

   (b) A counter operated at a given voltage produces a differential pulse height spectrum as depicted on a plot below.



   i. Draw the corresponding integral pulse height spectrum.

   [2 marks]

   ii. Sketch the expected counting curve obtained by varying the voltage to the detector while counting above a fixed threshold.

   [2 marks]

   (c) A parallel plate ion chamber with 150 pF capacitance is operated in electron-sensitive mode. Calculate the pulse amplitude expected from 1000 ion pairs formed 2 cm from the anode if the total spacing between the plates is 5 cm.

   [4 marks]

   (d) A gamma-ray spectrometer records peaks corresponding to two different gamma-ray energies of 435 and 490 keV. What must be the energy resolution of the system in order just to distinguish these two peaks?

   [4 marks]

   (e) In a detector with a Fano factor of 0.1, what should be the minimum number of charge carriers per pulse to achieve a statistical energy resolution limit of 0.5%?

   [4 marks]

THE END OF PHY4121 EXAM - HAPPY FESTIVE SEASON

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

DEPARTMENT OF PHYSICS

2020/2021 ACADEMIC YEAR

END OF YEAR EXAMINATIONS

PHY4132: THEORETICAL NUCLEAR PHYSICS

MARKS: 100

TIME ALLOWED: 3 HOURS

INSTRUCTIONS

- Attempt any 4 of the 6 questions given.
- All questions have 25 marks each.
- Omission of essential work will result in loss of marks.
- Clearly write your computer number on all answer sheets used.

You may use the following information where necessary

$1\ \text{u} = 931.494\ \text{MeV/c}^2 = 1.6605 \times 10^{-27}\ \text{kg}$

$\text{m}_p = 1.672\,614 \times 10^{-27}\ \text{kg} = 1.007\,276\ \text{u}$

$\text{m}_n = 1.674\,920 \times 10^{-27}\ \text{kg} = 1.008\,665\ \text{u}$

$\text{m}_e = 9.109\,56 \times 10^{-31}\ \text{kg} = 0.000\,549\ \text{u}$

$\text{e} = 1.602 \times 10^{-19}\ \text{C}$

$\text{c} = 3.0 \times 10^{8}\ \text{m s}^{-1}$

1. (a) What is the change in the nucleus that results from the capture of an electron?

[4 marks]

(b) Technetium-99 is prepared from ^{98}Mo. Molybdenum-98 combines with a neutron to give ^{99}Mo, an unstable isotope that emits a β particle to yield an excited form of ^{99}Tc*. This excited nucleus relaxes to the ground state,^{99}Tc, by emitting a γ-ray. The ground state of ^{99}Tc then emits a β-particle. Write the equations for each of these nuclear reactions.

[8 marks]

(c) i. What is the Gamow factor?

[2 marks]

ii. Write an equation that yields the probability of two nuclear particles overcoming their electrostatic barriers.

[3 marks]

iii. Define each parameter in 1 (c) (ii) above using further equations where necessary.

[8 marks]

2. (a) Explain how unstable nuclides (Z $>$ 83) may decompose to form nuclides of greater stability if they are

i. below the band of stability.

[3 marks]

ii. above the band of stability.

[3 marks]

iii. past the band of stability.

[1 mark]

(b) i. What law relates the decay constant λ of a radioactive isotope with the energy of α particles emitted?

[1 mark]

ii. Express this law in its modern form.

[2 marks]

iii. Clearly define all parameters in 2 (b) ii above.

[4 marks]

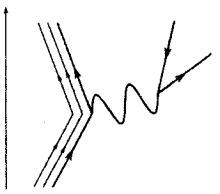
(c) The conservation of the baryon and lepton numbers can help us check possible reactions. For a beta-minus decay, ${}^{14}_{6}\mathrm{C} \rightarrow {}^{14}_{7}\mathrm{N} + {}^{0}_{-1}\beta + {}^{0}_{0}\bar{\nu}_e$, confirm whether or not this reaction can occur through the conservation of charge, baryon, and lepton numbers.

[11 marks]

3. (a) Clearly present the leading-order Feynman diagram for β^+ decay of a proton into a neutron, positron, and electron neutrino via an intermediate W^+ boson.

[12 marks]

(b) The β-minus Feynman diagram of a free neutron ($^1_0$n) decaying into a proton (p) is shown below with missing information.



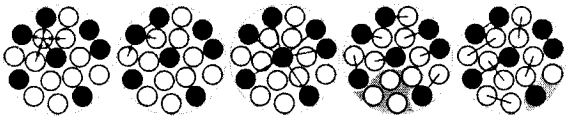
i. Complete the above figure by filling in all the necessary information.

[8 marks]

ii. Write a precise description of how the decay of a neutron into a proton by the β decay occurs at a fundamental particle level.

[5 marks]

4. (a) A schematic diagram illustrating the terms of the Bethe-Weizsäcker mass formula in the liquid-drop model of atomic nuclei is shown in the figure below.



i. Clearly label the diagram above with the five terms of the mass formula.

[5 marks]

ii. Hence, write explicitly the mass formula associated with the above diagram.

[5 marks]

(b) The figure below depicts low-lying energy levels in a single-particle shell model with an oscillator potential having a small negative l^2 term without the spin-orbit interaction. Complete the figure by including values of the:

i. spin-orbit coupling,

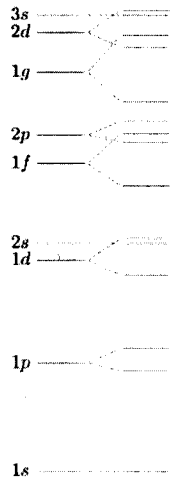
[4 marks]

ii. degeneracy (2j+1), and

[4 marks]

iii. predicted magic numbers up to 50 on the right side of the figure.

[3 marks]



(c) Using j, m_j, and *parity* instead of l, m_l, and m_s quantum numbers, the the first two shells are presented as level 0 (n = 0): 2 states (j = 1/2), even parity and level 1 (n = 1): 2 states (j = 1/2) + 4 states (j = 3/2) = 6, odd parity. Present in a similar fashion the next four shells, that is from level 2 up to level 5.

[4 marks]

5. (a) Draw a schematic plot showing stable and unstable isotopes using a zigzag line and shaded band, respectively. On the same plot, show nuclides having the number of neutrons (n) equal to the number of protons (Z) using a solid line.

[4 marks]

(b) Write nuclear reactions for the formation of $^{218}_{84}$Po from $^{238}_{92}$U via a series of decay reactions involving step-wise emission of α, β, β, α, α, α, α particles.

[7 marks]

(c) i. What is the binding energy per nucleon (in MeV) for $^{56}_{26}$Fe? (M_{Fe} = 55.9349, M_p = 1.0073, M_n = 1.0087, and M_e = 0.00055). All masses are in amu.

[4 marks]

ii. Discuss precisely the forces that hold nuclei together.

[2 marks]

iii. Give one reason α particles are preferentially emitted as opposed to particles like a single proton or neutron.

[1 mark]

(d) Uranium-232, an unstable nuclide, readily undergoes α decay to produce thorium-228. Determine the Q-value in both joules and mega-electron volts during this radioactive decay assuming that the atomic mass of uranium is 232.037156 u and that of thorium is 228.028731 u. (α particle has a mass of 4.001506 u).

[7 marks]

6. (a) What is the Woods-Saxon potential?

[3 marks]

(b) For large A, state the four desired properties of the Woods-Saxon potential.

[4 marks]

(c) The form of the Woods-Saxon potential is described by relation (1)

$$V(r) = -\frac{V_o}{1 + exp(\frac{r-R}{a})} \tag{1}$$

i. What are the parameters V_o, r, R, and a?

[4 marks]

ii. Give typical values for r_o, V_o, and a.

[3 marks]

(d) Draw this potential for $A = 50$, relative to V_o with $a = 0.5$ and $A = 4.6$ fm.

[7 marks]

(e) State one medical, construction, imaging, and household application for ^{60}Co, ^{137}Cs, ^{99m}Tc, and ^{241}Am, respectively.

[4 marks]

THE END OF PHY4132 EXAM - HAPPY FESTIVE SEASON

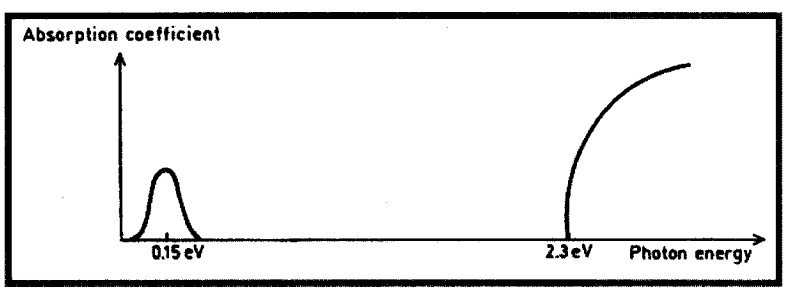
THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
Department of Physics
2020/2021 ACADEMIC YEAR
End of Year University Examinations
PHY 4222 - Solid State Physics II

Duration : 3 Hours
Total marks: 100
INSTRUCTIONS
This question paper contains six questions.
Answer any four questions. Each question carries 25 total marks.
Write clearly your computer number on the answer booklet provided.
All working should be shown clearly.
Omission of essential work will lead to loss of marks.
Additional information can be found at the end of this question paper.

QUESTION 1

(a) What is the Kronig-Penney model? What is supposed to be absent in this model for a material having no forbidden gap? [4]

(b) A sketch of the absorption coefficient for electromagnetic radiation is given for a non magnetic pure solid substance. The substance absorbs light in a narrow range in the infrared (0.15 eV) and then does not absorb light until the photon energy is 2.3 eV.

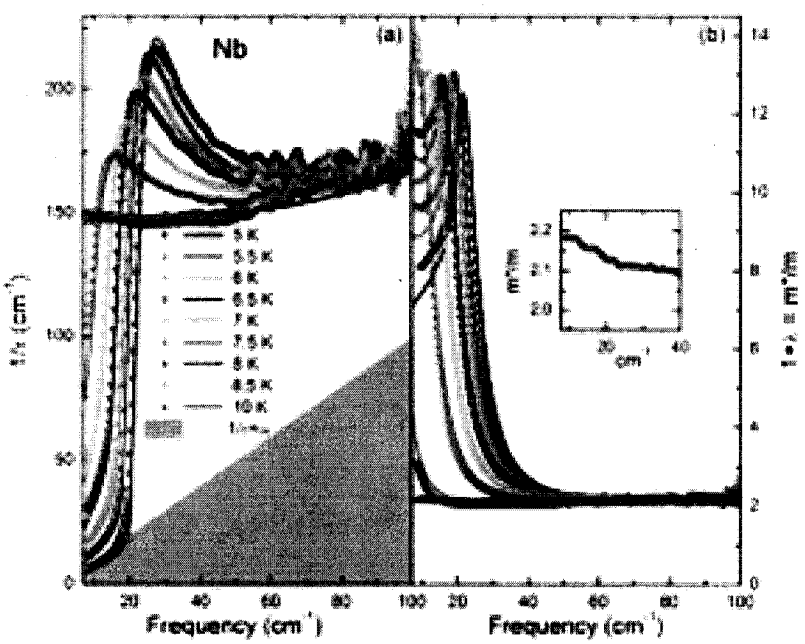


(i) Briefly explain this pattern of absorption. [4]

(ii) Is the material a metal or insulator? Why? [2]

(ii) Is there more than one atom per unit cell in the crystal of this material? Why? [2]

(c) The frequency dependence of the scattering rate and normalized effective mass for niobium(Nb) having a superconducting transition temperature of 8.04 K, are plotted in the figure below, panel **a** and panel **b** respectively.



(i) What is meant by

- scattering rate, and [2]
- effective mass of an electron? [2]

(ii) What is the significance of effective mass? [2]

(iii) Discuss the conditions when the effective mass of an electron becomes positive, negative and infinity. [3]

(iv) From the figure, estimate the superconducting energy gap for niobium at 5 K, and briefly explain how you have obtained such a value [4]

.....

QUESTION 2

.....

(a) Why are metallic bodies opaque? [1]

(b) Show that the effective mass of an electron in a crystal is inversely proportional to the second derivative of the dispersion relation (energy-wavevector) curve. [2]

(c) The energy near the valence band edge of a crystal is given by

$$E = Ak^2$$

where A = $1.5\text{x}10^{-38}$ Jm^2. An electron of wavevector k = $5\text{x}10^{10}\hat{i}$ m^{-1} is removed from an orbital in the completely filled valence band. Determine the effective mass, velocity, momentum and energy of the hole. [8]

(c) The electron and hole mobilities in a Si sample are 0.138 and

0.05 m^2/Vs respectively.

(i) Determine the conductivity of intrinsic Si at 300 K if the intrinsic carrier concentration is $1.65x10^{16}$ atoms/m^3. [3]

(ii) The sample is then doped with 10^{23} phosphorus atoms/m^3. Determine the equilibrium hole concentration, the conductivity and the Fermi level relative to the intrinsic level. [8]

(iii) Hence find the resistance of a doped Si rod which is 1 cm long and 1 mm wide at temperature 300K. μ_n =1350 cm^2/Vs and μ_p =480 cm^2/Vs. [3]

.....

QUESTION 3

.....

(a) What are soft and hard superconductors? [4]

(b) How does the energy gap in superconductors differ from the energy gap in insulators? How does it vary with temperature for superconductors? [6]

(c) The critical fields at 6 K and 9 K of NbTi alloy are 9.213 T and 4.345 T, respectively. Determine the transition temperature and the critical field at 0 K. [10]

(d) The transition temperature of mercury with an average atomic

mass of 200.9 amu is 4.2 K. Determine the transition temperature of its isotope ${}_{80}{}^{204}\mathrm{Hg}$. [5]

QUESTION 4

(a) Use the London equation to show that the penetration of a parallel magnetic field into a superconducting film of thickness d in the xy plane is described by

$$B = B_e \frac{\cosh(z/\lambda)}{\cosh(d/\lambda)}$$

where B_e is the applied magnetic field and the centre of the film is at z=0. [9]

(b) What are magnons? How do the dispersion relation of magnons differ from those of phonons? [4]

(c) Ho^{3+} has outer electronic configuration of $4f^{10}5s^2p^6$.

Calculate the magnetic susceptibility for a salt containing 1 kmole Ho^{3+} ions at 27°C. [9]

(d) Draw energy bands of a crystal as a function of interatomic spacing. [3]

QUESTION 5

(a) Tb^{3+} has outer electronic configuration of $4f^8 5s^2 p^6$.

Calculate the magnetic susceptibility for a salt containing 1.5 mole Tb^{3+} ions at 27°C. [7]

(b) Derive the Clausius-Mossotti relation. [7]

(c) The optical index of refraction and the dielectric constant of water are 1.327 and 8.21 respectively. Determine the percentage of ionic polarizability. [7]

(d) What is the difference between insulators and dielectrics? [2]

(e) What is the Bloch theorem? [2]

QUESTION 6

(a) The energy near the valence band edge is -2.5 $\times$ $10^{-32}k^2$ J.

An electron is removed from $k = 1.5 \times 10^9 \hat{i}$ m^{-1} of an otherwise full band. What is the sign and magnitude of the effective mass of a hole. [7]

(b) What is hysteresis in magnetic materials? Sketch a magnetic hysteresis loop indicating clearly the coercive field, the remanent magnetization and the saturation magnetization. [5]

(c) The transition from the normal to the superconducting state results in a discontinuity in specific heat capacity given by

$$c_n - c_s = \frac{T_c}{4\pi}\left[\left(\frac{dH_c}{dT}\right)^2 + H_c\frac{d^2H_c}{dT^2}\right]_{T=T_c}.$$

Calculate the fractional change in specific heat capacity for Niobium at T_c, if $T_c = 9.21$K, $\gamma = 2.5 * 10^4$ ergs/mol.K and $H_c(0) = 1500$ Gauss. [10]

(d) How is superconductivity without doping induced in the parent compounds of electron doped cuprates? [3]

.....END OF EXAMINATION.....

ADITIONAL INFORMATION

Planck's constant h = 6.62x10^{-34} Js, electron charge e = 1.602x10^{-19} C,

electron mass m_e = 9.11x10^{-31} kg, proton mass m_p = 1.67x10^{-27} kg,

neutron mass m_n = 1.67x10^{-27} kg,

Bohr magneton μ_B =9.274x10^{-24} Am^2

Avogadro's constant N_A = 6.022x10^{23} mol^{-1},

Boltzmann constant k_B = 1.38x10^{-23} JK^{-1},

Permitivity of free space ϵ_0 = 8.85x10^{-12}s^{2}m^{-2},

permeability of free space $\mu_0 = 4\pi$x10^{-7},

Bohr magneton μ_B =9.274x10^{-24} Am^2

$$n_i = p_i = 2\left[\frac{2\pi k_B T}{h^2}\right]^{\frac{3}{2}} (m_n^* m_p^*)^{\frac{3}{4}} exp\left(\frac{E_V - E_C}{2k_B T}\right);$$

Or

$$n = n_i exp\left(\frac{E_f - E_i}{k_B T}\right)$$

$$P\frac{\sin \alpha a}{\alpha a} + \cos \alpha a = \cos ka$$

$$M = Ng\mu_B J B_J(y)$$

where

$$y = \left(\frac{g\mu_B JB}{k_B T}\right); B_J(y) \approx \frac{y(J+1)}{3J}$$

$$\frac{\lambda(0)^2}{\lambda(T)^2} = 1 - \left(\frac{T}{T_c}\right)^2$$

$$\frac{\lambda(0)^2}{\lambda(T)^2} = 1 - \left(\frac{T}{T_c}\right)^4$$

$$H_c(T) = H_c(0)\left(1 - \left(\frac{T}{T_c}\right)^2\right)$$

$$\chi = \frac{\mu_0 N \mu_B^2}{3k_B T} g^2 J(J+1)$$

$$L = \sum m_l$$

$$\int_{-\infty}^{+\infty} \frac{x^3 e^x}{(e^x+1)^2} dx = \frac{\pi^2}{3}$$

$$\int_0^{+\infty} \frac{x}{e^x - 1} dx = 1.51$$

$$\int_0^{+\infty} \frac{x^3}{e^x - 1} dx = \frac{\pi^4}{15}$$

$$g = 1 + \frac{J(J+1) + S(S+1) - L(L+1)}{2J(J+1)}$$

$$\int_0^{\infty} x^{\frac{1}{2}} e^{-x} dx = \frac{\pi^{\frac{1}{2}}}{2}$$

$$\int_0^{\infty} x^4 e^{-x} dx = 24$$

$$\lambda_k = \frac{\hbar^2 k^2}{2m}$$

$$\alpha = \frac{2mE}{\hbar^2}$$

$$\cos(2\Theta) = \cos^2\Theta - \sin^2\Theta$$

$$\sin(2\Theta) = 2\sin\Theta\cos\Theta$$

$$\tan(2\Theta) = \frac{2\tan\Theta}{1-\tan^2\Theta}$$

$$\sinh(x) = \frac{e^x - e^{-x}}{2}$$

$$\cosh(x) = \frac{e^x + e^{-x}}{2}$$

$$\tanh(x) = \frac{e^x - e^{-x}}{e^x + e^{-x}}$$

FORMULAE SHEET

$$t = \frac{\left|\bar{X} - \bar{Y}\right|}{\sqrt{\frac{\sum x^2 / n_x - \bar{X}^2}{n_x - 1} + \frac{\sum y^2 / n_y - \bar{Y}^2}{n_y - 1}}}$$

$$r = \frac{n\sum xy - \sum x \sum y}{\sqrt{\left[n\sum x^2 - \left(\sum x\right)^2\right]\left[n\sum y^2 - \left(\sum y\right)^2\right]}}$$

$$r = \frac{\frac{\sum xy}{n} - \bar{X}\bar{Y}}{S_x S_y}$$

$$S_x = \sqrt{\frac{\sum x^2}{n} - \bar{X}^2}$$

$$S_y = \sqrt{\frac{\sum y^2}{n} - \bar{Y}^2}$$

$$H = \frac{12}{N(N+1)} \sum \frac{R^2}{n} - 3(N+1)$$

$$U_x = n_x n_y + \frac{n_x(n_x+1)}{2} - \sum r_x$$

$$U_y = n_x n_y + \frac{n_y(n_y+1)}{2} - \sum r_y$$

$$\hat{y} = a + bx$$

$$a = \bar{y} - b\bar{x} \quad OR \quad a = \frac{\sum y - b\sum x}{n}$$

$$b = \frac{\sum xy - n\bar{x}\bar{y}}{\sum x^2 - n\bar{x}^2} \quad OR \quad b = \frac{n\sum xy - \left(\sum x\right)\left(\sum y\right)}{n\sum x^2 - \left(\sum x\right)^2}$$

$$X^2 = \sum \frac{(O-E)^2}{E}$$

$$X^2 = \sum\sum \frac{\left(O_{i,j} - E_{i,j}\right)^2}{E_{i,j}}$$

$$S^2 = \frac{\sum x^2 - \frac{\left(\sum x\right)^2}{n}}{n-1}$$

$$\hat{\sigma}_w^2 = \frac{\sum^k \sum^n \left(x - \bar{x}\right)^2}{N-K} \quad OR \quad \hat{\sigma}_B^2 = \frac{\sum^k n\left(\bar{x} - \bar{x}G\right)^2}{K-1}$$

$$F = \frac{\hat{\sigma}_B^2}{\hat{\sigma}_w^2}$$

$$r_s = 1 - \frac{6\sum d^2}{n^3 - n}$$

$$s^2 = \frac{\sum_{i-j}^{k} f_j c_j{}^2 - \frac{\left(\sum_{i-j}^{k} f_j c_j\right)2}{n}}{n-1}$$

$$Mode = l + \frac{f_m - f_1}{(f_m - f_l) + (f_m - f_2)} h$$

$$Median = l + \frac{h}{f_m}\left(\frac{n}{2} - c\right)$$

$$X^2 = \frac{n\left(|AD - BC| - \frac{n}{2}\right)^2}{(A+B)(C+D)(A+C)(B+D)}$$

$$r_s = \frac{(A-B)+(A-C)-\sum d^2}{2\sqrt{(A-B)(A-C)}}$$

$$Z = \frac{x - \bar{x}}{s}$$

$$A = \frac{n^3 - n}{12}$$

$$B = \sum \left(\frac{t_x{}^3 - t_x}{12} \right)$$

$$C = \sum \left(\frac{t_y{}^3 - t_y}{12} \right)$$

$$0 : \frac{1^o}{e^z}$$

$$1 : \frac{z^o}{e^z}$$

$$2 : \frac{z^2}{2! e^z}$$

$$1 - \frac{\sum \left(t^3 - t \right)}{N^3 - N}$$

TABLES OF CRITICAL VALUES

Critical Values of Chi Square

Degrees of freedom	Significance level				
	0.1	0.05	0.01	0.005	0.001
1	2.7	3.84	6.64	7.88	10.83
2	4.60	5.99	9.21	10.60	13.82
3	6.25	7.82	11.34	12.84	16.27
4	7.78	9.49	13.28	14.86	18.46
5	9.24	11.07	15.09	16.75	20.52
6	10.64	12.59	16.81	18.55	22.46
7	12.02	14.07	18.48	20.28	24.32
8	13.36	15.51	20.09	21.96	26.12
9	14.68	16.92	21.67	23.59	27.88
10	15.59	18.31	23.21	25.19	29.59
11	17.28	19.68	24.72	26.76	31.26
12	18.55	21.03	26.22	28.30	32.91
13	19.81	22.36	27.69	30.82	34.53
14	21.06	23.68	29.14	31.32	36.12
15	22.31	25.00	30.58	32.80	37.70
16	23.54	26.30	32.00	34.27	39.29
17	24.77	27.59	33.41	35.72	40.75
18	25.99	28.87	34.80	37.16	42.31
19	27.20	30.14	36.19	38.58	43.82
20	28.41	31.41	37.57	40.00	45.32
21	29.62	32.67	38.93	41.40	46.80
22	30.81	33.92	40.29	42.80	48.27
23	32.01	35.17	41.64	44.18	49.73
24	33.20	36.42	42.98	45.56	51.18
25	34.38	37.65	44.31	46.93	52.62
26	35.56	35.88	45.64	48.29	54.05
27	36.74	40.11	46.96	49.65	55.48
28	37.92	41.34	48.28	50.99	56.89
29	39.09	42.56	49.59	52.34	58.30
30	40.26	43.77	50.89	53.67	59.70
40	51.81	55.76	63.69	66.77	73.40
50	63.17	67.51	76.15	79.49	86.66
60	74.40	79.08	88.38	91.95	99.61
70	85.53	90.53	100.43	104.22	112.32
60	96.58	101.88	112.33	116.32	124.84
90	107.57	113.15	124.12	128.30	137.21
100	118.50	124.34	135.81	140.17	149.45

Reject H_0 if calculated value of chi square is **greater than** the critical value at the chosen significance level

Critical Values of Student's t

Degrees of freedom	Significance level (one-tailed)				
	0.05	0.025	0.01	0.005	0.0005
	Significance level (two-tailed)				
	0.1	0.05	0.02	0.01	0.001
1	6.31	12.71	31.82	63.66	636.62
2	2.92	4.30	6.97	9.93	31.60
3	2.35	3.18	4.54	5.84	12.92
4	2.13	2.78	3.75	4.60	8.61
5	2.01	2.57	3.37	4.03	6.86
6	1.94	2.45	3.14	3.71	5.96
7	1.89	2.37	3.00	3.50	5.41
8	1.86	2.31	2.90	3.35	5.04
9	1.83	2.26	2.82	3.25	4.78
10	1.81	2.23	2.76	3.17	4.59
11	1.80	2.20	2.72	3.11	4.44
12	1.78	2.18	2.68	3.05	4.32
13	1.77	2.16	2.65	3.01	4.22
14	1.76	2.15	2.62	2.98	4.14
15	1.75	2.13	2.60	2.95	4.07
16	1.75	2.12	2.58	2.92	4.01
17	1.74	2.11	2.57	2.90	3.97
18	1.73	2.10	2.55	2.88	3.92
19	1.73	2.09	2.54	2.86	3.88
20	1.73	2.09	2.53	2.85	3.85
21	1.72	2.08	2.52	2.83	3.82
22	1.72	2.07	2.51	2.82	3.79
23	1.71	2.07	2.50	2.81	3.77
24	1.71	2.06	2.49	2.80	3.75
25	1.71	2.06	2.49	2.79	3.73
26	1.71	2.06	2.48	2.78	3.71
27	1.70	2.05	2.47	2.77	3.69
28	1.70	2.05	2.47	2.76	3.67
29	1.70	2.05	2.46	2.76	3.66
30	1.70	2.04	2.46	2.75	3.65
40	1.68	2.02	2.42	2.70	3.55
60	1.67	2.00	2.39	2.66	3.46
120	1.66	1.98	2.36	2.62	3.37
∞	1.65	1.96	2.33	2.58	3.29

Reject H_0 if calculated value of t is **greater than** the critical value at the chosen significance level

Critical Values of Pearson's Product-Moment Correlation Coefficient r

Degrees of freedom	Significance level (one-tailed) 0.05	0.025	0.01	0.005
	Significance level (two-tailed) 0.1	0.05	0.02	0.01
1	0.9877	0.9969	0.9995	0.9999
2	0.900	0.950	0.980	0.990
3	0.805	0.878	0.934	0.959
4	0.729	0.811	0.882	0.917
5	0.669	0.755	0.833	0.875
6	0.622	0.707	0.789	0.834
7	0.582	0.666	0.750	0.798
8	0.549	0.632	0.716	0.765
9	0.521	0.602	0.685	0.735
10	0.497	0.576	0.658	0.708
11	0.476	0.553	0.634	0.684
12	0.458	0.532	0.612	0.661
13	0.441	0.514	0.592	0.641
14	0.426	0.497	0.574	0.623
15	0.412	0.482	0.558	0.606
16	0.400	0.468	0.543	0.590
17	0.389	0.456	0.529	0.575
18	0.378	0.444	0.516	0.561
19	0.369	0.433	0.503	0.549
20	0.360	0.423	0.492	0.537
25	0.323	0.381	0.445	0.487
30	0.296	0.349	0.409	0.449
35	0.275	0.325	0.381	0.418
40	0.257	0.304	0.358	0.393
45	0.243	0.288	0.338	0.372
50	0.231	0.273	0.322	0.354
60	0.211	0.250	0.295	0.325
70	0.195	0.232	0.274	0.302
80	0.183	0.217	0.257	0.283
90	0.173	0.205	0.242	0.267
100	0.164	0.195	0.230	0.254

Reject H_0 if calculated value of r is **greater than** the critical value at chosen significance level (in absolute terms).

Critical Values for Spearman's Rank Correlation Coefficient r_s

Degrees of freedom	Significance level (one-tailed) 0.05	0.025	0.01	0.005
	Significance level (two-tailed) 0.1	0.05	0.02	0.01
4	1.000			
5	0.900	1.000	1.000	
6	0.829	0.886	0.943	1.000
7	0.714	0.786	0.893	0.929
8	0.643	0.738	0.833	0.881
9	0.600	0.683	0.783	0.833
10	0.564	0.648	0.745	0.794
11	0.523	0.623	0.736	0.818
12	0.497	0.591	0.703	0.780
13	0.475	0.566	0.673	0.745
14	0.457	0.545	0.646	0.716
15	0.441	0.525	0.623	0.689
16	0.425	0.507	0.601	0.666
17	0.412	0.490	0.582	0.645
18	0.399	0.476	0.564	0.625
19	0.388	0.462	0.549	0.608
20	0.377	0.450	0.534	0.591
21	0.368	0.438	0.521	0.576
22	0.359	0.428	0.508	0.562
23	0.351	0.418	0.496	0.549
24	0.343	0.409	0.485	0.537
25	0.336	0.400	0.475	0.526
26	0.329	0.392	0.465	0.515
27	0.323	0.385	0.456	0.505
28	0.317	0.377	0.448	0.496
29	0.311	0.370	0.440	0.487
30	0.305	0.364	0.432	0.478
35	0.282	0.336	0.399	0.442
40	0.263	0.314	0.373	0.413
45	0.248	0.296	0.351	0.388
50	0.235	0.280	0.332	0.368
55	0.224	0.267	0.317	0.351
60	0.214	0.255	0.303	0.335
65	0.206	0.245	0.291	0.322
70	0.198	0.236	0.280	0.310
75	0.191	0.228	0.271	0.300
80	0.185	0.221	0.262	0.290
85	0.180	0.214	0.254	0.281
90	0.174	0.208	0.247	0.273
95	0.170	0.202	0.240	0.266
100	0.165	0.197	0.234	0.259

Reject H_0 if calculated value of r_s is **greater than** the critical value at the chosen significance level (in absolute terms)

Critical Values of H for the Kruskal-Wallis Test

n_1	n_2	n_3	Significance level 0.1	0.05	0.01	0.005
2	1	1				
2	2	1				
2	2	2	4.571			
3	1	1				
3	2	1	4.286			
3	2	2	4.500	4.714	5.357	
3	3	1	4.571	5.143		
3	3	2	4.556	5.361		
3	3	3	4.622	5.600	7.200	7.200
4	1	1				
4	2	1	4.500			
4	2	2	4.056	5.208		
4	3	2	4.511	5.444	6.444	
4	3	3	4.709	5.727	6.746	
4	4	1	4.167	4.967	6.667	
4	4	2	4.555	5.455	7.036	
4	4	3	4.546	5.599	7.144	
4	4	4	4.654	5.692	7.654	
5	1	1				
5	2	1	4.200	5.000		
5	2	2	4.373	5.160	6.533	
5	3	1	4.018	4.960		
5	3	2	4.651	5.251	6.882	
5	3	3	4.533	5.649	7.079	
5	4	1	3.987	4.986	6.955	
5	4	2	4.541	5.268	7.118	
5	4	3	4.549	5.631	7.445	
5	4	4	4.619	5.618	7.760	
5	5	1	4.109	5.127	7.309	
5	5	2	4.508	5.339	7.269	
5	5	3	4.545	5.706	7.543	
5	5	4	4.523	5.643	7.791	
5	5	5	4.560	5.780	7.980	

Reject H_0 if calculated value of H is **greater than or equal to** critical value at chosen significance level.

Critical Values of U for a One-Tailed Test at the 0.05 Significance Level or a Two-Tailed Test at the 0.1 Level

n_y	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
n_x																			0	0
1										1	1	2	2	2	3	3	3	4	4	4
2					0	0	0	1	1	4	5	5	6	7	7	8	9	9	10	11
3					1	2	2	3	3	7	8	9	10	11	12	14	15	16	17	18
4				1	2	3	4	5	6	11	12	13	15	16	18	19	20	22	23	25
5		0	1	2	4	5	6	8	9	14	16	17	19	21	23	25	26	28	30	32
6		0	2	3	5	7	8	10	12	17	19	21	24	26	28	30	33	35	37	39
7		0	2	4	6	8	11	13	15	20	23	26	28	31	33	36	39	41	44	47
8		1	3	5	8	10	13	15	18	24	27	30	33	36	39	42	45	48	51	54
9		1	3	6	9	12	15	18	21	27	31	34	37	41	44	48	51	55	58	62
10		1	4	7	11	14	17	20	24	31	34	38	42	46	50	54	57	61	65	69
11		1	5	8	12	16	19	23	27	34	38	42	47	51	55	60	64	68	72	77
12		2	5	9	13	17	21	26	30	37	42	47	51	56	61	65	70	75	80	84
13		2	6	10	15	19	24	28	33	41	46	51	56	61	66	71	77	82	87	92
14		2	7	11	16	21	26	31	36	44	50	55	61	66	72	77	83	88	94	100
15		3	7	12	18	23	28	33	39	48	54	60	65	71	77	83	89	95	101	107
16		3	8	14	19	25	30	36	42	51	57	64	70	77	83	89	96	102	109	115
17		3	9	15	20	26	33	39	45	55	61	68	75	82	88	95	102	109	116	123
18		4	9	16	22	28	35	41	48	58	65	72	80	87	94	101	109	116	123	130
19	0	4	10	17	23	30	37	44	51	62	69	77	84	92	100	107	115	123	130	138
20	0	4	11	18	25	32	39	47	54	62	69	77	84	92	100	107	115	123	130	138

Reject H_0 if calculated value of U is **less than or equal to** critical value at chosen significance level.

Critical Values of U for a One-Tailed Test at the 0.025 Significance Level or a Two-Tailed Test at the 0.05 Level

n_y	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
n_x																				
1																				
2								0	0	0	0	1	1	1	1	1	2	2	2	2
3					0	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8
4				0	1	2	3	4	4	5	6	7	8	9	10	11	11	12	13	13
5			0	1	2	3	5	6	7	8	9	11	12	13	14	15	17	18	19	20
6			1	2	3	5	6	8	10	11	13	14	16	17	19	21	22	24	25	27
7			1	3	5	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34
8		0	2	4	6	8	10	13	15	17	19	22	24	26	29	31	34	36	38	41
9		0	2	4	7	10	12	15	17	20	23	26	28	31	34	37	39	42	45	48
10		0	3	5	8	11	14	17	20	23	26	29	33	36	39	42	45	48	52	55
11		0	3	6	9	13	16	19	23	26	30	33	37	40	44	47	51	55	58	62
12		1	4	7	11	14	18	22	26	29	33	37	41	45	49	53	57	61	65	69
13		1	4	8	12	16	20	24	28	33	37	41	45	50	54	59	63	67	72	76
14		1	5	9	13	17	22	26	31	36	40	45	50	55	59	64	76	74	78	83
15		1	5	10	14	19	24	29	34	39	44	49	54	59	64	70	75	80	85	90
16		1	6	11	15	21	26	31	37	42	47	53	59	64	70	75	81	86	92	98
17		2	6	11	17	22	28	34	39	45	51	57	63	67	75	81	87	93	99	105
18		2	7	12	18	24	30	36	42	48	55	61	67	74	80	86	93	99	106	112
19		2	7	13	19	25	32	38	45	52	58	65	72	78	85	92	99	106	113	119
20		2	8	13	20	27	34	41	48	55	62	69	76	83	90	98	105	112	119	127

Reject H_0 if calculated value of U is **less than or equal to** critical value at chosen significance level.

Critical Values of U for a One-Tailed Test at the 0.01 Significance Level or a Two-Tailed Test at the 0.02 Level

n_y	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
n_x																				
1																				
2													0	0	0	0	0	0	1	1
3							0	1	1	1	1	2	2	2	3	3	4	4	4	5
4					0	1	1	2	3	3	4	5	5	6	7	7	8	9	9	10
5				0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
6				1	2	3	4	6	7	8	9	11	12	13	15	16	18	19	20	22
7			0	1	3	4	6	8	9	11	12	14	16	17	19	21	23	24	26	28
8			1	2	4	6	8	10	11	13	15	17	20	22	24	26	28	30	32	34
9			1	3	5	7	9	11	14	16	18	21	23	26	28	31	33	36	38	40
10			1	3	6	8	11	13	16	19	22	24	27	30	33	36	38	41	44	47
11			1	4	7	9	12	15	18	22	25	28	31	34	37	41	44	47	50	53
12			2	5	8	11	14	17	21	24	28	31	35	38	42	46	49	53	56	60
13		0	2	5	9	12	16	20	23	27	31	35	39	43	47	51	55	59	63	67
14		0	2	6	10	13	17	22	26	30	34	38	43	47	51	56	60	65	69	73
15		0	3	7	11	15	19	24	28	33	37	42	47	51	56	61	66	70	75	80
16		0	3	7	12	16	21	26	31	36	41	46	51	56	61	66	71	76	82	87
17		0	4	8	13	18	23	28	33	38	44	49	55	60	66	71	77	82	88	93
18		0	4	9	14	19	24	30	36	41	47	53	59	65	70	76	82	88	94	100
19		1	4	9	15	20	26	32	38	44	50	56	63	69	75	82	88	94	101	107
20		1	5	10	16	22	28	34	40	47	53	60	67	73	80	87	93	100	107	114

Reject H_0 if calculated value of U is **less than or equal to** critical value at chosen significance level.

Critical Values of U for a One-Tailed Test at the 0.001 Significance Level or a Two-Tailed Test at the 0.002 Level

n_y / n_x	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1																				
2																				
3																	0	0	0	0
4										0	0	0	1	1	1	2	2	3	3	3
5							0	0	1	1	2	2	3	3	4	5	5	6	7	7
6						0	1	2	2	3	4	4	5	6	7	8	9	10	11	12
7					0	1	2	3	3	5	6	7	8	9	10	11	13	14	15	16
8					0	2	3	4	5	6	8	9	11	12	14	15	17	18	20	21
9					1	2	3	5	7	8	10	12	14	15	17	19	21	23	25	26
10				0	1	3	5	6	8	10	12	14	17	19	21	23	25	27	29	32
11				0	2	4	6	8	10	12	15	17	20	22	24	27	29	32	34	37
12				0	2	4	7	9	12	14	17	20	23	25	28	31	34	37	40	42
13				1	3	5	8	11	14	17	20	23	26	29	32	35	38	43	45	48
14				1	3	6	9	12	15	19	22	25	29	32	36	39	43	46	50	54
15				1	4	7	10	14	17	21	24	28	32	36	40	43	47	51	55	59
16				2	5	8	11	15	19	23	27	31	35	39	43	48	52	56	60	65
17			0	2	5	9	13	17	21	25	29	34	38	43	47	52	57	61	66	70
18			0	3	6	10	14	18	23	27	32	37	42	46	51	56	61	66	71	76
19			0	3	7	11	15	20	25	29	34	40	45	50	55	60	66	71	77	82
20			0	3	7	12	16	21	26	32	37	42	48	54	59	65	70	76	82	88

Reject H_0 if calculated value of U is **less than or equal to** critical value at chosen significance level.

Note: All the Tables of Critical Values presented in this document were adapted from Ebdon, D. (1985). *Statistics in Geography, 2nd Edition.* Basil Blackwell, Oxford.

The University of Zambia

Department of Physics

PHY 4242, Fundamentals of Medical Physics

Final Examination Academic Year 2020/2021

All questions carry equal marks. The marks are shown in brackets.

Time: 3 hours. **Maximum marks = 100**

Instructions:

Attempt any 4 questions, all questions carry equal marks

Useful Equations:

$$\text{SI}=\frac{4500}{\left(v/c\right)^2} \qquad \frac{\text{Radiation energy loss}}{\text{Ionisation energy loss}}=\frac{E_k Z}{820} \qquad I=I_o e^{-\mu x} \qquad \text{HVL}=\frac{\ln 2}{\mu}$$

$$\mu_{\text{en}}=\mu\frac{E_a}{h\nu} \qquad \lambda=\frac{1.24}{h\nu}\,(\text{nm}) \qquad \Delta\lambda=0.00243(1-\cos\phi) \qquad E_{\max}=h\nu_{\max}=\frac{hc}{\lambda_{\min}}$$

$$\Phi=\frac{N}{A} \qquad \phi=\frac{\Phi}{t}=\frac{N}{A.t} \qquad \Psi=\Phi E=\frac{NE}{A} \qquad I=\psi=\phi E=\frac{NE}{At}$$

$$I=\psi=\sum_{i=1}^{m} f_i\phi E_i \qquad X=\frac{Q}{m}, \qquad \frac{\Phi}{X}=\frac{2.11\times10^{14}}{h\nu\left(\mu_{en}\right)_m} \qquad D(\text{Gy})=\frac{E/m}{1\text{J/kg}}$$

$$\text{DE}(\text{Sv})=D(\text{Gy})\times\text{QF} \qquad \text{ED}(\text{mSv})=D(\text{mGy})\times W_R \qquad E=JW$$

$$\Psi=\frac{JW}{\rho\left(\mu_{en}\right)_m} \qquad \frac{V}{X}=\frac{1.29v}{C+C_e} \qquad \overline{Z}=\left(a_1Z_1^{2.94}+a_2Z_2^{2.94}+.....a_nZ_n^{2.94}\right)^{\frac{1}{2.94}}$$

Constants:

$W=33.85\text{eV}$: Avagadro's number = 6.023 x 10^{23}/mol : 1R = 2.58 x 10^{-4}C/kg-air
1 R = 1electrostatic unit (ESU)/0.001293 g air = 1 ESU/cm^3 air at STP : 1J = 1HU

Q 1 **a)** A 200 keV photon is scattered at an angle of 75^0 during a Compton interaction. What are the energies of the scattered photon and the Compton electron? [10]

b) Perspex is normally used as a tissue equivalent material to make measurements and it has a density of 1.019 g/cm^3. The composition of Perspex is given below. Calculate the approximate effective atomic number of this material. [5]

Atomic No.	Fraction by weight
1	0.080583
6	0.599848
8	0.319614

c) A narrow mono-energetic beam containing 12,000 photons is reduced to 6000 photons by a slab of aluminium 2 mm thick. What is the total linear attenuation coefficient of aluminium for the photons? [5]

d) Find the power dissipated in a 3-phase diagnostic x-ray tube at 100 kV and 300 mA settings. If the tube is operated for 1.2 seconds with these parameters, calculate the number of calories deposited in the anode. [5]

Q 2 **a)** For a target angle of 17^0 the apparent focal spot has dimensions of 1.2 mm x 1.2 mm.

i) What is the dimension of the longer side of the true focal spot? Answer with the aid of a diagram. [5]

ii) Sketch a pin-hole camera for determining the size of the apparent focal spot of an x-ray tube, label the key features and explain how the determination is made. [10]

b) Show that, regardless of the energy of the incident photon scattered at an angle greater than 60^0 during Compton scattering, the scattered photon cannot undergo pair-production. [10]

Q 3 **a)** An abdominal X-ray beam uses 10^{17} photons to expose a film with an area of 30 cm x 40 cm for 0.2 second. Assume all photons have energy of 90 keV. Find:

i) The photon fluence
ii) The photon flux
iii) The energy fluence, and
iv) The intensity I. [8]

b) Describe in detail the operation of a Thimble chamber. [8]

c) Give a brief explanation of the principles on which the following dosimetry systems are based:

i) Calorimeter

ii) Scintillation

iii) Solid-state [9]

Q 4 **a)** Copper has a density of 8.9 g/cm^3 and a molecular mass of 63.56. The total attenuation of copper is 8.8 x 10^{-24} cm^2/atom for 500 keV photons. What thickness (in cm) of copper is required to attenuate 500 keV photons to one eighth of the original number? [7]

b) A 180 keV photon is scattered at an angle of 80^0 during a Compton interaction. What is the energy of the scattered photon? [6]

c) A Condenser ionisation chamber has a sensitivity of 7700 V/C-kg. The volume of the chamber is 0.40 cm^3. The capacitance is five times the capacitance of the charge-reader. What is the capacitance of the Condenser ionisation chamber? [7]

d) Draw a well labelled diagram of a cyclotron. [5]

Q 5 **a)** Draw a basic diagram of a linear accelerator and explain how particles are accelerated in order to achieve high energies that are used in producing high energy electrons or x-rays. [10]

b) Explain the principles used in radiation therapy to treat cancerous tumors in patients undergoing radiation therapy. [8]

c) Explain the following:

i) Teletherapy [2]

ii) Brachytherapy [2]

iii) Phantom [1]

iv) LD_{50} [2]

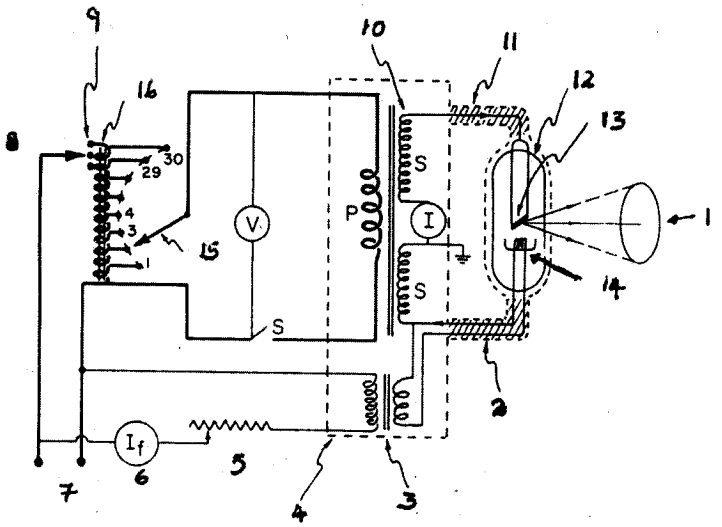
Q 6 **a)** Assuming that the average specific ionization is 4 x 10^6 ion pairs per metre (IP/m), calculate the average linear energy transfer of α-particles in air, and calculate the range in air for 6 MeV α-particles with an average LET in the preceding calculation. [5]

b) The total mass attenuation of coefficient for lead is 5.46 cm^2/g for 100 keV photons and the density is 11.4 g/cm^3.To what fraction will a narrow beam of 100 keV be reduced by a slab of lead 0.5 cm thick? [5]

NB, part c) on page 4

c) In the schematic diagram below of a self-rectified x-ray generator connected to an x-ray tube identify the numbered items on the diagram. [15]

Simple Self-Rectified X-ray Circuit



End of Exam

UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES
DEPARTMENT OF PHYSICS
END-OF-YEAR UNIVERSITY EXAMINATIONS
2020/2021 ACADEMIC YEAR

BSc PHYSICS
PHY4535
QUANTUM MECHANICS II

DURATION:	Three hours.
INSTRUCTIONS:	Answer any **four** questions from the six given. *Each question carries 25 marks, with the marks for parts of questions indicated.*
MAXIMUM MARKS:	100
DATE:	Wednesday, 26th November 2021

Formulae that may be needed

All symbols used have their usual meaning.

1. The harmonic oscillator ladder operators are defined as

$$a = \left(\frac{m\omega_c}{2\hbar}\right)^{1/2} x + i\left(\frac{1}{2m\hbar\omega_c}\right)^{1/2} p, \quad \text{and} \quad a^\dagger = \left(\frac{m\omega_c}{2\hbar}\right)^{1/2} x - i\left(\frac{1}{2m\hbar\omega_c}\right)^{1/2} p$$

2. $$\hat{H} = \left(\hat{a}^\dagger\hat{a} + \tfrac{1}{2}\right)\hbar\omega$$

3. $$\hat{J}_+ = \hat{J}_x + i\hat{J}_y, \quad \text{and} \quad \hat{J}_- = \hat{J}_x - i\hat{J}_y$$

4. $$\begin{aligned} J_z|j,m\rangle &= m\hbar|jm_j\rangle, \quad J^2|jm_j\rangle = j(j+1)\hbar^2|jm_j\rangle, \\ J_\pm|jm_j\rangle &= \hbar[j(j+1) - m(m\pm 1)]^{\frac{1}{2}}|jm_j \pm 1\rangle, \end{aligned}$$

5.

$$\frac{d\ln[\rho(x)]}{dx} = \frac{1}{\rho(x)}\frac{d\rho(x)}{dx}$$

QUESTION 1

(i) Give the definition of the Hermitian conjugate of an operator. (4 marks)

(ii) Give the definition of a Hermitian operator and prove that $\hat{A} = \hat{A}^\dagger$. (5 marks)

(iii) Give the proof that eigenvalues of a linear Hermitian operator are real and that its eigenfunctions are orthoganol. (16 marks)

QUESTION 2

(i) Given that $[x, p] = i\hbar$, derive $[a, a^\dagger] = 1$. (7 marks)

(ii) Beginning with

$$|u_n\rangle = \frac{(a^\dagger)^n}{\sqrt{n!}}|u_0\rangle, \quad n = 0, 1, 2, \ldots$$

derive the two results

$$a^\dagger|u_n\rangle = \sqrt{n+1}\,|u_{n+1}\rangle \quad \text{and} \quad a|n\rangle = \sqrt{n}\,|u_{n-1}\rangle.$$

(9 marks)

(iii) Given that $(a^\dagger a)u_n = nu_n$, determine the eigenvalues of the harmonic oscillator Hamiltonian operator H. What physical quantity do these eigenvalues represent. (4 marks)

(iv) From your result from part (iii), state the lowest energy of a quantum harmonic oscillator. State a fundamental element of the quantum theory which shows that a quantum harmonic oscillator cannot have zero energy, hence cannot have zero momentum. (5 marks)

QUESTION 3

(i) Beginning with the expansion postulate and using Dirac notation, show how a ket and a bra can be represented by matrices. (6 marks)

(ii) Obtain the matrix representing the Hamiltonian $H = (a^\dagger a + \frac{1}{2})\hbar\omega$ and the raising operator $a^\dagger$ of the harmonic oscillator in the harmonic oscillator energy representation. (11 marks)

(iii) Draw a diagram to show the allowed orientation of the angular momentum vector for $j = \frac{1}{2}$ by first determining its magnitude and the allowed values of its z component. Also for $j = \frac{1}{2}$, determine the matrix representing $\hat{J}_z$ in the angular momentum representation.

(8 marks)

QUESTION 4

(i) Derive the zeroth- and first-order terms of time-independent perturbation theory,

$$(H_0 - W^{(0)})v^{(0)} = 0, \quad (1)$$

$$(H_0 - W^{(0)})v^{(1)} + (H' - W^{(1)})v^{(0)} = 0, \quad (2)$$

which are approximations to the eigenvalue equation

$$Hv = Wv, \quad \text{where} \quad H = H_0 + \lambda H',$$

and where λ is a small real parameter. (9 marks)

(ii) State the solutions $W^{(0)}$ and $v^{(0)}$ of the zeroth term, Eq. (1), for the nondegenerate case.

(4 marks)

(iii) By substituting

$$v^{(1)} = \sum_{n=0}^{\infty} c_n^{(1)} u_n$$

into the first-order equation, Eq. (2), derive the first order approximations

$$W^{(1)} = \langle u_m | H' | u_m \rangle,$$

$$c_k^{(1)} = -\frac{\langle u_k | H' | u_m \rangle}{E_k - E_m}, \quad k \neq m \quad (3)$$

again, for the nondegenerate case. Do **not** determine $c_m^{(1)}$. (12 marks)

QUESTION 5

(i) By substituting

$$\psi(x,t) = \sum_{n=0}^{\infty} a_n(t) u_n(x) e^{-iE_n t/\hbar}$$

into the Shrödinger equation

$$i\hbar \frac{\partial \psi}{\partial t} = H\psi, \quad \text{where} \quad H = H_0 + \lambda H',$$

derive the equation

$$\frac{da_f}{dt} = \frac{1}{i\hbar} \sum_n \lambda a_n e^{i\omega_{fn} t} H'_{fn}, \quad H'_{fn} = \langle f | H' | n \rangle, \quad \omega_{fn} = \frac{E_f - E_n}{\hbar},$$

which forms the basis for time-dependent perturbation theory. (15 marks)

(ii) Use your results for part (i) to derive the zeroth, first order and second order approximations $a_f^{(0)}$, $a_f^{(1)}$ and $a_f^{(2)}$. (7 marks)

(iii) State, without calculation, the condition used to obtain the initial condition:

$$a_f(t=0) = a_f^{(0)}(t=0) = \delta_{if}, \quad a_f^{(1)}(t=0) = a_f^{(2)}(t=0) = \ldots = a_f^{(r)}(t=0) = 0.$$

(3 marks)

QUESTION 6

The WKB approximation is used to solve the time independent Schrödinger,

$$\frac{d^2\psi(x)}{dx^2} + \frac{2m}{\hbar^2}(E - V_0)\psi(x) = 0 \tag{1}$$

when $V(x)$ varies slowly over the de Broglie wavelength. It will be convenient to use $\rho(x) = \sqrt{2m[E - V(x)]}$ in deriving your answers.

(i) By substituting $\psi(x) = Ae^{iS(x)/\hbar}$ into Eq. (1) derive the equation

$$-\frac{i\hbar}{2m}\frac{d^2S(x)}{dx^2} + \frac{1}{2m}\left(\frac{dS(x)}{dx}\right)^2 + V(x) - E = 0. \tag{2}$$

(6 marks)

(ii) Eq. (2) is exact. By expanding $S(x)$ in powers of $\hbar$, derive the following approximations

$$\frac{1}{2m}\left(\frac{dS_0(x)}{dx}\right)^2 + V(x) - E = 0, \tag{3}$$

$$-\frac{i}{2}\cdot\frac{d^2S_0(x)}{dx^2} + \frac{dS_0(x)}{dx}\frac{dS_1(x)}{dx} = 0, \tag{4}$$

$$-i.\frac{d^2S_1(x)}{dx^2} + \left(\frac{dS_1(x)}{dx}\right)^2 + \frac{dS_0(x)}{dx}\frac{dS_2(x)}{dx} = 0. \tag{5}$$

(8 marks)

(iii) Solve Eq. (3) to find $S_0(x)$ and Eq. (4) to find $S_1(x)$ for the case $E > V(x)$. Use your solutions to write the WKB approximation to first order to the solution $\psi(x)$ of the Schrödinger equation when the potential is slowly varing.

(11 marks)

END

THE UNIVERSITY OF ZAMBIA
PHYSICS DEPARTMENT
UNIVERSITY EXAMINATIONS – 2021

PHY4815 - PHYSICS OF RENEWABLE ENERGY RESOURCES AND ENVIRONMENT

TIME: 3 HOURS MAX MARKS: 100

ATTEMPT ANY **FOUR** QUESTIONS. ALL QUESTIONS CARRY EQUAL MARKS. THE MARKS ARE SHOWN IN SQUARE BRACKETS

You may use the following information and equations:

Boltzmann constant k = 1.38 x 10^{-23} JK^{-1}
Gas constant R = 8314 J/kmol.K
1 electron volt = 1.6 x 10^{-19} J
Stefan's constant σ = 5.67 x 10^{-8} W/m^2K^4
Sun's radius R_s = 6.96x10^8m
Mean Earth-Sun distance r_0 = 1.496x10^{11}m
Solar constant I_{sc} = 1367 Wm^{-2}
Earth's radius R_e = 6.37x10^6m
Planck's constant h = 6.6 x 10^{-34}J.s
Speed of light c = 3 x 10^8m.s^{-1}

In usual notations

$$E_0 = \left(\frac{r_0}{r}\right)^2 = 1 + 0.033\cos\left(\frac{360\,d_n}{365}\right)$$

$$\delta = 23.45^\circ \sin\left[\frac{360}{365}(d_n + 284)\right]$$

$$\cos\theta_z = \sin\delta\sin\varphi + \cos\delta\cos\varphi\cos\omega$$

$$\tan\psi = \frac{\cos\delta\sin\omega}{\cos\delta\sin\varphi\cos\omega - \sin\delta\cos\varphi}$$

$$\cos\psi = \frac{\sin\alpha \sin\varphi - \sin\delta}{\cos\alpha \cos\varphi}$$

$$\cos\theta = (\sin\varphi \cos\beta - \cos\varphi \sin\beta \cos\gamma) \sin\delta + (\cos\varphi \cos\beta + \sin\varphi \sin\beta \cos\gamma) \cos\delta \cos\omega + \cos\delta \sin\beta \sin\gamma \sin\omega$$

$$\omega = 15^{\circ}(12 - t): \quad \omega_s = \cos^{-1}(-\tan\phi \tan\delta)$$

Solar time = clock time + $4(L_l - L_s)$ min + EOT

Wien's Law: $\lambda_{max} T = 2898\ \mu m.K$

The emissive power of a black body $B_\lambda(T)$ (in W/m^2 per unit wavelength range) is

$$B_\lambda(T) = \frac{2\pi h c^2}{\lambda^5 \left(e^{\frac{hc}{\lambda kT}} - 1 \right)}$$

Direct flux on an inclined surface

$$F^{dir} = I_{sc} \cos\theta \exp\left(-\frac{\tau}{\cos\theta_z}\right)$$

Fresnel's equations

$$r_{\parallel} = \left[\frac{n_r^2 \cos\theta_i - n_i \sqrt{n_r^2 - n_i^2 \sin^2\theta_i}}{n_r^2 \cos\theta_i + n_i \sqrt{n_r^2 - n_i^2 \sin^2\theta_i}} \right]^2$$

$$r_{\perp} = \left[\frac{n_i \cos\theta_i - \sqrt{n_r^2 - n_i^2 \sin^2\theta_i}}{n_i \cos\theta_i + \sqrt{n_r^2 - n_i^2 \sin^2\theta_i}} \right]^2$$

$$r_{\perp} = \left[\frac{n_i \cos\theta_i - \sqrt{n_r^2 - n_i^2 \sin^2\theta_i}}{n_i \cos\theta_i + \sqrt{n_r^2 - n_i^2 \sin^2\theta_i}} \right]^2$$

Overall reflectance and transmittance of a single glazing are

$$R = r\left[1 + \frac{\alpha^2(1-r)^2}{1-\alpha^2 r^2}\right]$$

$$T = \frac{\alpha(1-r)^2}{1-\alpha^2 r^2}$$

In a single heat exchanger the exit temperature is

$$T_{fe} = T_B - (T_B - T_{fi}) \exp\left(-\frac{U_L L}{\dot{m} C_f}\right),$$

and the heat extraction rate is

$$\dot{Q} = \dot{m} C_f (T_B - T_{fi}) \left[1 - \exp\left(-\frac{U_L L}{\dot{m} C_f}\right)\right].$$

The carrier concentration in an intrinsic semiconductor is

$$n_i = p_i = AT^{3/2} exp\left(-\frac{\varepsilon_g}{2kT}\right)$$

The resistivity of an extrinsic material is

$$\rho = \frac{1}{e(n\mu_n + p\mu_p)}$$

In a p-n junction the reverse saturation current density is

$$J_0 = DT^3 exp\left(-\frac{\varepsilon_g}{kT}\right)$$

and the forward current density is

$$J = J_0 (e^{\frac{eV}{kT}} - 1)$$

The J-V characteristic equation for a single cell is

$$J = \overline{K} F - J_0\left(e^{\frac{eV}{kT}} - 1\right)$$

Yearly variation of the equation of time

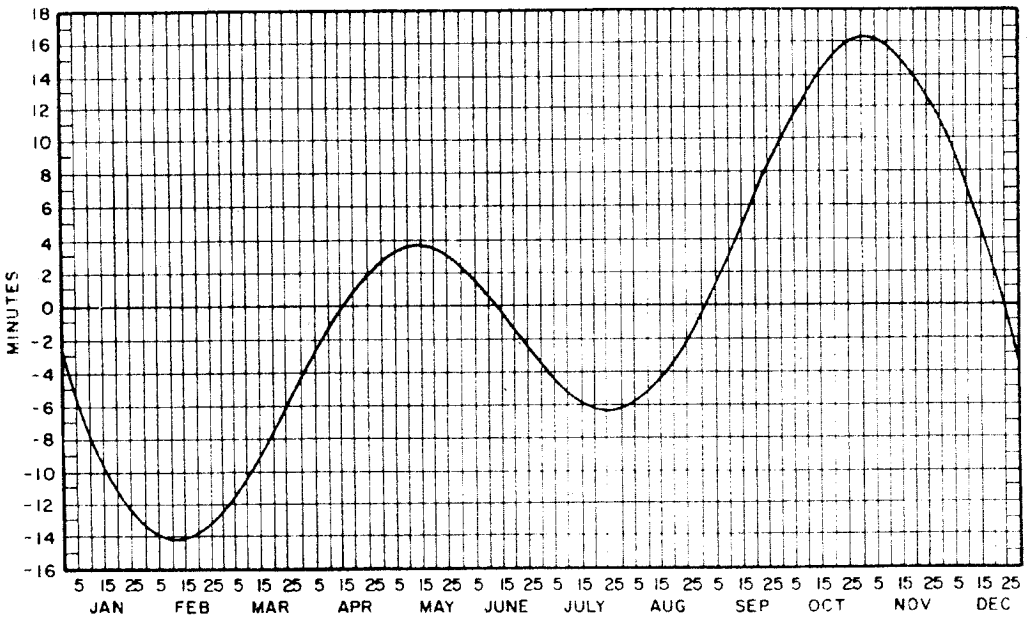


TABLE *The function $f(x)$*

$x(\mu m\text{-}K)$	$f(x)$	$x(\mu m\text{-}K)$	$f(x)$	$x(\mu m\text{-}K)$	$f(x)$
1100	0.001	4600	0.580	8100	0.860
1200	0.002	4700	0.594	8200	0.864
1300	0.004	4800	0.608	8300	0.868
1400	0.008	4900	0.621	8400	0.871
1500	0.013	5000	0.634	8500	0.875
1600	0.020	5100	0.646	8600	0.878
1700	0.029	5200	0.658	8700	0.881
1800	0.040	5300	0.669	8800	0.884
1900	0.052	5400	0.680	8900	0.887
2000	0.067	5500	0.691	9000	0.890
2100	0.083	5600	0.701	9100	0.893
2200	0.101	5700	0.711	9200	0.895
2300	0.120	5800	0.720	9300	0.898
2400	0.140	5900	0.730	9400	0.901
2500	0.161	6000	0.738	9500	0.903
2600	0.183	6100	0.746	9600	0.905
2700	0.205	6200	0.754	9700	0.908
2800	0.228	6300	0.762	9800	0.910
2900	0.251	6400	0.770	9900	0.912
3000	0.273	6500	0.776	10000	0.914
3100	0.296	6600	0.783	11000	0.932
3200	0.318	6700	0.790	12000	0.945
3300	0.340	6800	0.796	13000	0.955
3400	0.362	6900	0.802	14000	0.963
3500	0.383	7000	0.808	15000	0.969
3600	0.404	7100	0.814	16000	0.974
3700	0.424	7200	0.819	17000	0.978
3800	0.443	7300	0.824	18000	0.981
3900	0.462	7400	0.830	19000	0.983
4000	0.483	7500	0.834	20000	0.986
4100	0.499	7600	0.840	30000	0.995
4200	0.516	7700	0.844	40000	0.998
4300	0.533	7800	0.848	50000	0.999
4400	0.549	7900	0.852		
4500	0.564	8000	0.856		

Q. 1. A solar panel is situated in Lusaka. The panel is tilted at an angle of 30° from the horizontal and is facing North. The average optical thickness of the atmosphere is T=0.2. Given the latitude of Lusaka is 15°S and the longitude is 28°E, find at 10.00 hour on 1 March:

(i) declination [3]
(ii) solar time [4]
(iii) hour angle [2]
(iv) angle of incidence of direct radiation on the panel [6]
(v) the zenith angle [5]
(vi) direct flux incident on the panel [5]

Q.2.

(i) Define solar constant. [2]
(ii) Taking the Sun as a blackbody at temperature T_s prove that the solar constant on a planet varies inversely as the square of the planet's distance from the Sun. [5]
(iii) The value of the solar constant on the Earth is 1367 W/m^2. What will be its value if the mean Earth-Sun distance were increased by 1%. [5]
(iv) Using the value of the solar constant, the value of the Earth-Sun distance and radius of the Sun, and assuming the Sun to be a black body, calculate the effective blackbody temperature of the Sun. [5]
(v) Find the characteristic wavelength of the Sun's spectrum. [2]
(vi) Assuming that the human eyes can see electromagnetic radiation in the range of 0.4μm – 0.8 μm, estimate the fraction of the Sun's radiation which human eye does not see. [6]

Q.3.

(a) A pipe carrying water passes through a tank containing fluid at a given temperature. Explaining the physics involved and assumptions made obtain expressions for
(i) the exit temperature of the water, and [9]
(ii) the rate of heat extracted. [3]

(b) A large solar storage tank contains a fluid at 70°C. A coiled copper pipe is inserted in the tank and is used to warm a stream of water from 20°C to 50°C. The pipe is 5m long and has an average heat transfer coefficient of 12W/m-°C. Assuming that the tank temperature remains constant and the specific heat capacity of water is 4200 J/°C-Kg,

(i) What flow rate is being used to warm water to the desired value? [5]
(ii) Calculate the heat extraction rate from the tank. [4]
(iii) If the flow rate is doubled, what will the exit temperature of the water be? [4]

Q.4.

(a)

(i) Briefly explain the use of selective absorber coatings and their main characteristics. Show graphically an ideal selective coating and a real coating? [4]

(ii) A grey plate (ϵ=0.6) is hung above the atmosphere facing the Sun such that solar radiation is incident normally on it. The back side of the plate is insulated. Find the steady state temperature of the plate. [6]

(b)

(i) Define surface reflectance, overall reflectance, surface transmittance, overall transmittance and bulk transmittance. [5]

(ii) Explaining the physics involved, obtain expressions for overall reflectance and overall transmittance of a plane sheet. [10]

5.

(a) A solar heating panel under stagnant conditions is in thermal equilibrium with its surroundings when no solar radiation is incident upon it. The panel is then placed in the Sun.

(i) Briefly explain what you mean by stagnant conditions [2]

(ii) Write down the equation of heat balance under non-steady stagnant conditions. [2]

(iii) Use eqn in (ii) above to show that

$$T_p - T_a = \frac{F_{abs}}{\bar{U}_c}\left[1 - \exp\left(-\frac{\bar{U}_c t}{C_A}\right)\right].$$

[8]

(iv) What is time constant and its physical significance? [2]

(v) Find the expression for T_p - T_a when steady-state stagnant condition is reached? [2]

(b) An absorber plate of a collector is made of copper (C = 389 J/kg-°C) and has an area of 5 m^2 and a mass of 30 kg. The overall heat transfer coefficient to the surroundings is $\bar{U}_c$ = 8 W/m^2.

(i) Find the time constant of the collector. [3]

(ii) If the insolation suddenly changes from zero to some constant value, how much time will it take for $(T_p - T_a)$ to reach 90% of the steady state limit? [6]

Q.6

(a)

(i) Why is it important to keep silicon PV cells cool while operating? [2]

(ii) If you short-circuit a battery, it can be damaged. Explain what happens to a panel if it is short-circuited during operation. [2]

(iii) You are provided with identical 60 PV cells each of 0.5 V and 1A current under given radiation conditions. You are asked to prepare an array which can give a minimum of 15 V and 2A. How will you arrange the PV cells into an array? [2]

(iv) A major area of research worldwide is to produce silicon PV cells with increasingly higher efficiency. Give reason to explain if one can hope to achieve an efficiency of close to 100%, say 70-80%, for silicon solar cells. sometime in future? [2]

(v) The PV panel of a Solar Home System is under the shade of a tree. Giving reasons explain if it will have any significant influence on the output voltage, current and power of the panel. [2]

(b) A photovoltaic cell has constant spectral responsivity K_λ = 0.2 A/W for $0.5\mu m \leq \lambda \leq 2\mu m$, and $K_\lambda = 0$ otherwise. The cell is circular with a diameter of 10 cm, the incident flux is 1 Sun and the temperature of the cell is 300 K.

(i) Taking the Sun to be a blackbody at temperature 6000K, calculate the average responsivity and the photocurrent density. [9]

(ii) Calculate the open circuit voltage and the short circuit current density if the reverse saturation current density $J_0 = 5 \times 10^{-9} A/m^2$. [6]

---------- END OF THE EXAMINATION ----------

The University of Zambia

School of Natural Sciences
Department of Physics
2019/20 Academic Year
End of Year University Examinations
PHY5031: Computational Physics & Modeling I

Answer <u>any four</u> questions. All questions carry equal marks. The marks are shown in brackets.

Time: Three (3) hours. **Maximum marks = 100.**

Write clearly your computer number on the answer book. Show your working clearly. Omission of essential work will lead to loss of marks. All computer codes should have accompanying comments explaining code blocks.

Wherever necessary, include appropriate comments when writing programs.

Programming Languages: Modern Fortran with GNUPLOT and/or Python 3

SOME USEFUL PHYSICAL CONSTANTS

$g = 9.81\ \mathrm{ms}^{-2}$	$R = 8.314\ \mathrm{Jmol}^{-1}\mathrm{K}^{-1}$
$\rho_{\mathrm{mercury}} = 13600\ \mathrm{kg/m}^3$	$\rho_{\mathrm{water}} = 1000\ \mathrm{kg/m}^3$
$G = 6.674\times10^{-11}\ \mathrm{m}^3\mathrm{kg}^{-1}\mathrm{s}^{-2}$	$\sigma = 5.672\times10^{-8}\ \mathrm{Wm}^{-2}\mathrm{K}^{-4}$
$h = 6.6261\times10^{-34}\ \mathrm{J.s}$	$k_{\mathrm{B}} = 1.38066\times10^{-23}\ \mathrm{J/K}$
$c = 2.9979\times10^{8}\ \mathrm{m/s}$	$c_{\mathrm{water}} = 4184\ \mathrm{Jkg}^{-1}\mathrm{K}^{-1}$

Q1. (a) Let $u(z)$ be a continuous and differentiable function. Use the Taylor series expansion to show that the Central Finite Difference Scheme (CFDS) for the second derivative of a function $u(z)$ is given by

$$u''(z) \approx \frac{u(z+h)+u(z-h)-2u(z)}{h^2}; \; h \neq 0,$$

with an error term given by

$$\varepsilon(h^2) = 2\left[f^{(4)}(x)\frac{h^2}{4!} + f^{(6)}(x)\frac{h^4}{6!} \ldots + f^{k}(x)\frac{h^{k-2}}{k!} + \ldots \right]. \qquad \textbf{[11]}$$

(b) Consider the function

$$u(z) = \exp(-4z).$$

(i) Use the CFDS with a step size of 0.001 to show that, correct to 6 decimal places, $u''(1.00) \approx 0.300000$, **[8]**

(ii) Show that the percentage error in the solution in (i) is 2.37%. **[6]**

Q2. Consider the function given by

$$f(x,y) = \frac{1}{4\pi}\exp\left(x^2 + 2y^2\right).$$

Evaluate

$$\int_{-0.5}^{0.5}\int_{-0.5}^{0.5} f(x,y)\,dxdy,$$

using step size 0.1 along the x-direction and 0.2 along the y-direction and applying the:

(i) Composite Trapezoidal in the x-direction and use your results to complete table1

Table 1: Values of the integral as a function of x

y	V_y	W_y	dx	$f(y) \approx \frac{dx}{2}\left[V_y + 2W_y\right]$
-0.5		1.264400		0.143287
-0.3				
-0.1				
0.1				
0.3				
0.5	0.336932			

[19]

(ii) Composite Simpson's rule in the y-direction, and show correct to 1 decimal place, that the numerical value of the double integral is 0.10. **[6]**

Q3. (a) Define the following terms:

(i) an array **[2]**

(ii) rank/dimension of an array **[2]**

(iii) shape of an array **[2]**

(iv) extent of an array **[2]**

(v) size of an array **[2]**

(b) A matrix n – rows and m – columns can be expressed as

$$\mathbf{A} = \left[a_{ij} \right] = \begin{bmatrix} a_{11} & a_{12} & . & . & . & a_{1m} \\ a_{21} & a_{22} & . & . & . & . \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ a_{n1} & a_{n2} & . & . & . & a_{nm} \end{bmatrix},$$

where a_{ij} for $i = 1,2,3,...,n$ are rows while $j = 1,2,3,...,$ m are columns. Consider a matrix whose elements are given by

$$a_{ij} = \exp\left(-x_i^2 - 2y_j^2\right),$$

where $x_i = i$ for $i = 1,2,3,...,n$ and $y_j = j^2$ for $j = 1,2,3,...,m$. Write a code (using either modern Fortran or Python 3) which can

(i) populate the matrix **A** for $n = 10$ and $m = 8$, **[4]**

(ii) slices the 3rd and 7th column and save the values into 1-dimensional arrays whose variable names are **col_3** and **col_7**, respectively,

(iii) compute the sum of all elements of **A**, **[2]**

(iv) determines the dot product of **col_3** and **col_7**, **[3]**

(v) determines the transpose of **A**, **[3]**

(vi) compute the product **A** × ~~row_3~~ correction **[3]**

A × col-5

Q4. The Bessel function of order m, where $m = 0,1,2,3,4,...$, arises frequently in physics, engineering and mathematics and can be expressed as

$$J_m(u) = \int_0^{2\pi} f(x)\,dx,$$

where

$$f(x) = \frac{i^{-m}}{2\pi} e^{i(mx + u\cos(x))},$$

is a complex function with $i = \sqrt{-1}$ while $u \geq 0$ is a real number.

Write a code (using modern Fortran or Python 3) which implements the Simpson's rule to estimate $J_0(u)$ for $0.0 \leq u \leq 2.9$ in steps of 0.1. In particular, your code should have a

(i) user defined complex function $f(x)$, **[6]**

(ii) module implementing the Simpson's rule, **[12]**

(iii) loop that uses the routine in (ii) to estimate values of $J_0(u)$ and for $0.0 \leq u \leq 2.9$ in steps of 0.1. **[7]**

Q5. Consider the double distribution function given by

$$f(x,y) = \exp\left(-x^2 - 2y^2\right).$$

Write a code (using modern Fortran or Python 3) that implements the Trapezoidal rule with 10^6 subintervals to estimate

$$\int_{-y_{\min}}^{y_{\max}} \int_{-x_{\min}}^{x_{\max}} f(x,y)\,dxdy,$$

where $x_{\min} = -4$, $x_{\max} = 5$, $y_{\min} = -4$ and $y_{\max} = 5$. In particular, your code should **array construct** and have a

(i) driver `codeblock` supplying the limits of integration to a module, **[5]**

(ii) module containing a routine that implements the Trapezoidal rule, **[15]**

(iii) an external function containing the integrand. **[5]**

Q6. (a) Consider an interval of integration $[a,b]$. Use the Quadratic Lagrange Interpolation formula to show that

$$\int_{x_0}^{x_2} f(x)\,dx \approx \frac{h}{3}\left[f(a)+4f\left(\frac{a+b}{2}\right)+f(b)\right],$$

where $x_i = x_0 + ih$ for $i = 0,1,2$, $x_0 = a$ and $x_2 = b$. **[13]**

(b) Ten pseudo-random numbers rnd in the interval $0 \le \text{rnd} < 1$ were generated by a computer code and shown in Table 1.

Table 2: Ten Pseudo-random numbers rnd between 0 and 1 generated by a computer code.

	1	2	3	4	5	6	7	8	9	10
rnd	0.4739	0.2842	0.9192	0.8282	0.4341	0.1650	0.8152	0.7673	0.4860	0.1803

(i) Using these pseudo-random numbers, generate ten pseudo-random numbers x, correct to 4 decimal places, in the interval $1 \le x < 1.5$, **[5]**

(ii) Compute values of $f(x)$, correct to 4 decimal places, for each value of x given that

$$f(x) = \exp\left(-x^2\right), \quad \textbf{[4]}$$

(iii) Show via Monte Carlo implementation that, correct to 4 decimal places,

$$\int_1^{1.5} f(x)dx \approx 0.1041. \quad \textbf{[3]}$$

END OF PHY5031 EXAMINATION

FORMULAE THAT MAY BE USEFUL

1. TAYLOR SERIES EXPANSION

$$f(x)=\sum_{n=0}^{\infty}\frac{f^n(x_0)}{n!}[x-x_0]^n .$$

2. LAGRANGE INTERPOLATION

For a set of $n+1$ data points $\{(x_i,y_i)|i=1,2,3,.....,n\}$, the Lagrange Interpolating Polynomial of degree n is generally

$$p_n(x)=\sum_{k=0}^{n}L_k(x)y_k\ ,\quad \text{where}\quad L_k(x)=\prod_{\substack{i=0\\ i\neq k}}^{n}\frac{x-x_i}{x_k-x_i}\quad \text{for } k=0,1,2,.....,n .$$

3. NEWTON RAPHSON ALGORITHM

$$x_{i+1}=x_i-\frac{f(x_i)}{f'(x_i)};\quad f'(x_i)\neq 0 .$$

4. RUNGE-KUTA ALGORITHM

$$k_1=hf(x_i,y_i);\qquad k_2=hf\left(x_i+\tfrac{1}{2}h,y_i+\tfrac{1}{2}k_1\right);\qquad k_3=hf\left(x_i+\tfrac{1}{2}h,y_i+\tfrac{1}{2}k_2\right);$$

$$k_4=hf(x_i+h,y_i+k_3);\quad x_{i+1}=x_i+h;\qquad y_{i+1}=y_i+\tfrac{1}{6}[k_1+2k_2+2k_3+k_4].$$

5. SIMPSONS RULE

$$\int_{x_{\min}}^{x_{\max}}f(x)dx\approx\frac{h}{3}[U+2V+4W];\ h=\frac{x_{\max}-x_{\min}}{N};\qquad U=f(x_{\min})+f(x_{\max});$$

$$V=\sum_{i=1}^{N-1}f(x_i)\ ;\ W=\sum_{i=2}^{N-2}f(x_i)\ \text{ and }\ N=2m,\ \text{where } m \text{ is a positive integer.}$$

6. MONTE CARLO ALGORITHM

For n randomly distributed points $\{x_i|i=1,2,3,...,n\}$ and $a\le x_i<b$, we have

$$\int_a^b f(x)dx\approx[b-a]\hat{f}\ ,\ \text{where}\ \ \hat{f}=\frac{1}{n}\sum_{i=1}^{n}f(x_i).$$

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
DEPARTMENT OF PHYSICS

2020 MID-YEAR UNIVERSITY EXAMINATIONS

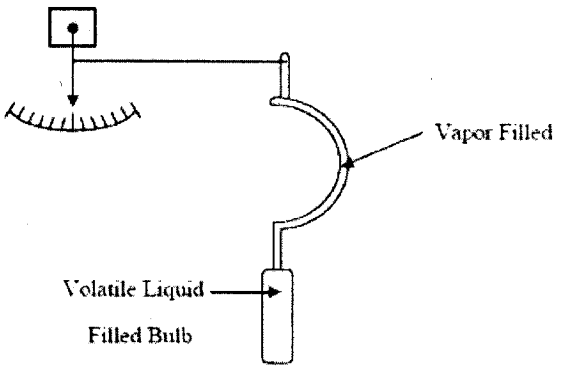
PHY5051 : Instrumentation I

Time : Three hours. **Maximum marks = 100.**

Attempt any **FOUR** questions.
All questions carry equal marks.
The marks are shown in brackets.

Q1. (a) (i) Draw block diagram for generalized measurement system and explain its components. [12]

(ii) Identify the functional elements of the following measurement system. [5]



(b) (i) The moving coil meter has 100 turns, and length and depth of 10mm and 20 mm respectively. It is a uniform radial flux density of 200mT. The coil carries current of 50mA. Calculate the torque on the coil. [3]

(ii) A deflection of 90°is produced when a current of 10 A flows through a PMMC instrument. What is the deflection produced if a current of 8 A flows through it when the instrument is spring controlled? [2]

(c) Write short notes on impedance matching in electrical circuits. [3]

Q2. (a) Show that the output in a closed loop system due to modifying inputs is reduced by the method of high gain feedback. [15]

(b) An unknown resistance is connected in series with a milliammeter of very small internal resistance. A voltmeter with internal resistance 150 kΩ is connected across the unknown resistance. Determine the loading error when: [10]

(i) the voltmeter and milliammeter read 200 V and 7 mA respectively

(ii) the same voltmeter and milliammeter with another resistance read 60 V and 1.2 A respectively.

Comment upon the results.

Q3. (a) (i) A weather balloon carrying a temperature sensing device (of first order, time constant=10s) rises through the atmosphere at 6 m/s. It supplies information about temperature and altitude through radio signals. At 2800 m height a temperature indication of 35°C has been received. If the temperature varies with altitude at a uniform rate of 0.01°C/m, determine the true altitude at which 35 °C temperature occurs. [5]

(ii) A first order system having a time constant of 0.1s is used to measure a signal prescribed by the relation

$$I_i = 3 \sin 2t + 0.4 \cos 10t.$$

Develop an expression for the corresponding output. [6]

(b) Explain briefly zero drift, span drift and zonal drift. [4]

(c) Derive an equation for the deflection of a Permanent Magnet Moving Coil (PMMC) instrument. [10]

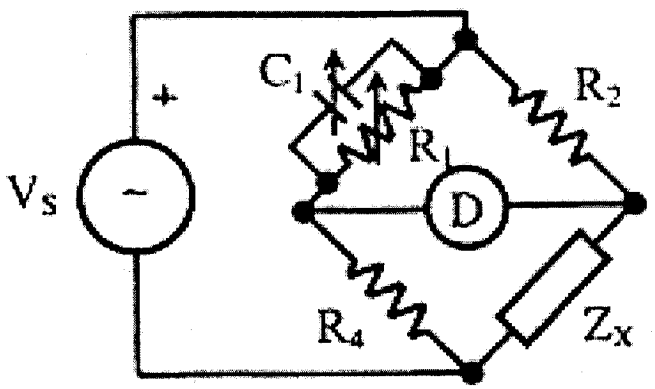
Q4. (a) With the help of a circuit diagram explain how capacitance and power factor can be measured by the use of a Schering Bridge. [12]

(b) A Bakelite sheet of 5 mm thickness is tested at 50Hz between the electrodes 12 cm in diameter. The Schering bridge used has an air capacitor C_3 of 106 pF, a non-reactive resistance R_1 of $(1000/\pi)$ Ω in parallel with a variable capacitor C_1 and a non-reactive variable resistance R_2. Balance is obtained with C_1=0.55 μF and R_2 =270 Ω. Determine the capacitance and power factor. [5]

(c) The following data relate to the bridge shown in figure below.

R_1=600 Ω C_1=1 μF R_2=100 Ω R_4= 1000 Ω

Find the series equivalent of the unknown impedance Z_X. [8]



Q5. (a) (i) Derive the standard form of transfer operator for a first order system. [6]

(ii) Derive the expression for the magnitude and phase of a first order system when subjected to a sinusoidal input signal. [3]

(iii) Draw the magnitude and phase versus frequency plots. [1]

(b) The temperature of a furnace is found to vary sinusoidally between 500°C and 560°C with a periodic time of 50 s. A thermocouple system with a time constant of 10 s is employed to measure the furnace temperature. Determine

(i) the maximum and minimum values that will be indicated by the thermocouple. [7]

(ii) the phase shift and the corresponding time lag between the temperature signals and the thermocouple input signals. [4]

(iii) Draw a graph of the actual and indicated temperatures of furnace. [4]

Q6. (a) Explain the following performance parameters of Digital-to Analogue Converter (DAC).

(i) Resolution [4]

(ii) setting time [4]

(b) Explain the process of quantization and encoding. [8]

(c) Design a 3-bit parallel comparator A/D convertor. [9]

END OF PHY5051 EXAMINATION

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

Department of Physics

2019/2020 Academic Year Final Examinations

PHY 5062 - INSTRUMENTATION II

11 December 2020

Time Allowed: 3 Hours

Maximum Marks : 100

Instructions:

The paper contains 7 questions each carrying 20 marks.

Answer 5 questions.

Show all your working to earn credit.

Write your computer number clearly on all the answer sheets.

Question One

(a) What are the main elements in a measurement system and what are their functions? Include diagrams. [8]

(b) What is the difference between a sensor and a transducer? [2]

(c) You happen to be working in a mine in the smelter section and you are tasked to develop a measurement application software to measure temperature using a T-thermocouple. The user should have an option to view in °F or °C. Use the DAQ Assistant to configure the DAQ device and acquire the analog voltage signals. In the program use the formula node to convert to temperature according to the formula

$T = T_o + \frac{P_1(V-V_o)+P_2(V-V_o)^2+P_3(V-V_o)^3+P_4(V-V_o)^4}{1+q_1(V-V_o)+q_2(V-V_o)^2+q_3(V-V_o)^3}$. Write the program. [10]

Question Two

(a) Explain the following terms :

(i) calibration chain [2]

(ii) traceability [2]

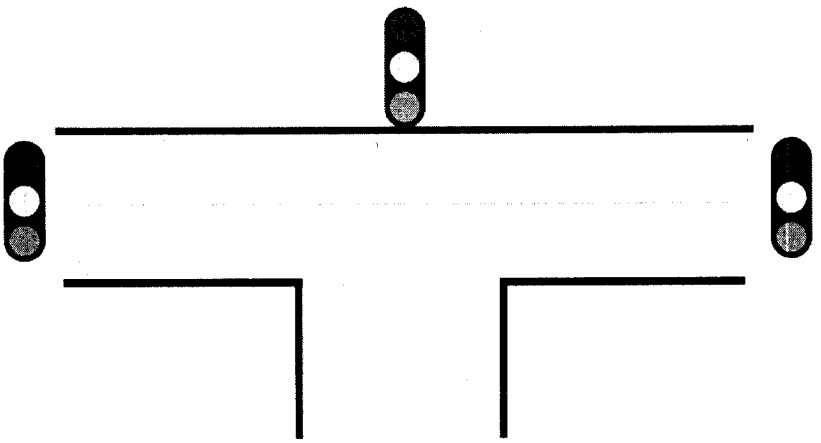
(ii) standards laboratory. [2]

(iv) Legal metrology. [2]

(v) Forensic metrology. [2]

(b) Explain the meaning of instrument calibration and why it is necessary [2]

(c) You have won a contract to develop a working code to control the soon to be erected traffic lights at the UNZA Main entrance T-junction on the Great East Road. Develop the code. [8]



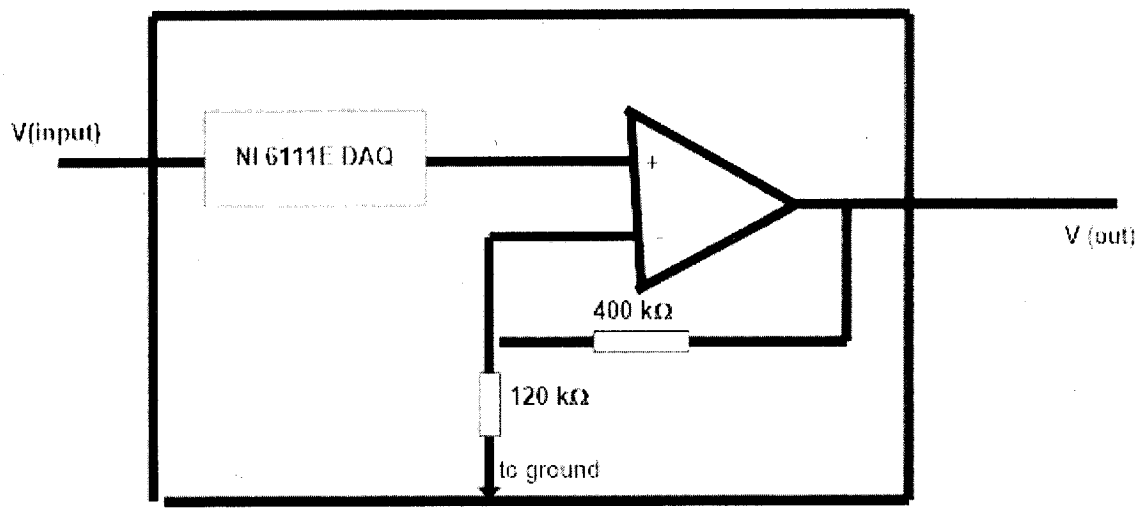
Question Three

(a) An analog to digital converter (ADC) measures voltages in the range of 0 to 25 V and has 12-bit accuracy. What is the smallest voltage step that the ADC can resolve?. **[2]**

(b) An NI 611E 12 bit DAQ board can support an input ranges of +/- 0.2 to +/- 42 V. In the +/- 1 V range,

(i) Calculate the absolute resolution of the board. **[2]**

(ii) If it is connected the amplifier, what will be the overall resolution at the output. **[2]**



(c) Define the following

(i) Watchdog timer [2]

(ii) Interrupt [2]

(iii) Microprocessor [2]

(iv) Microcontroller [2]

(v) Embedded system. [2]

(d) In any measurement system, regardless of any hardware you use, you much send information to the hardware and receive from the hardware. The information exchange is accomplished by software. Name two types of software that do this and describe their functions. [4]

Question Four

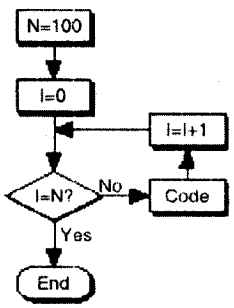
(a) In the LabVIEW programming language,

(i) what are the two main components of the programming environments and what are their functions? [4]

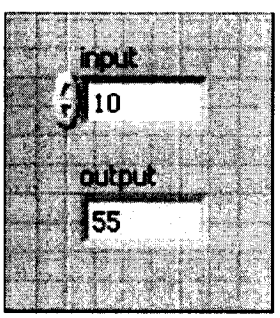
(ii) identify at least one icon that is found in one component and can not be found in the other. [1]

(iii) programmers prefer WHILE loops to FOR loops. What is the major advantage of using the WHILE loop over the FOR loop? [2]

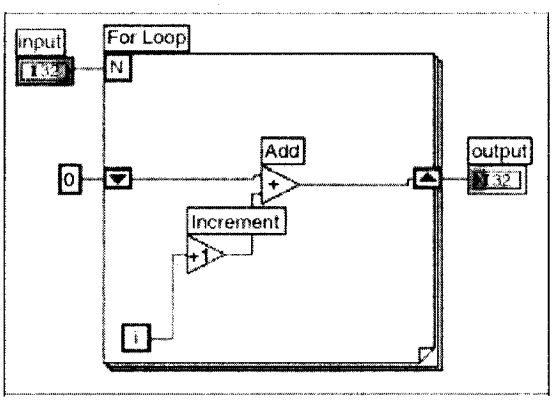
(b) Wire this algorithm using LabVIEW and create and numeric indicator for the iteration count. [5]



(c) Describe in detail what the code below does, including what the different functions and icons do. [10]



Front panel

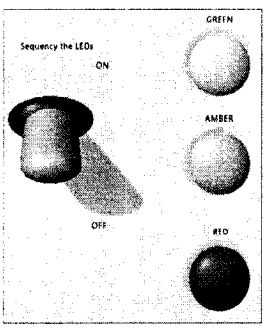


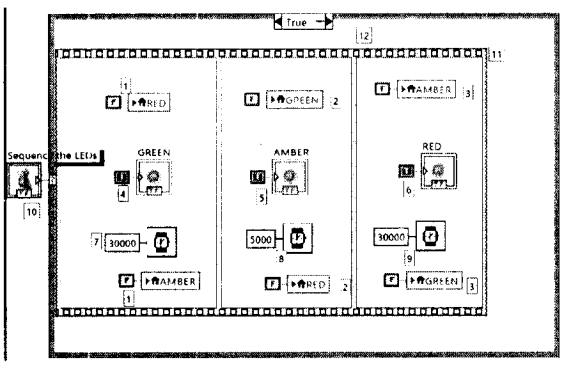
Block diagram

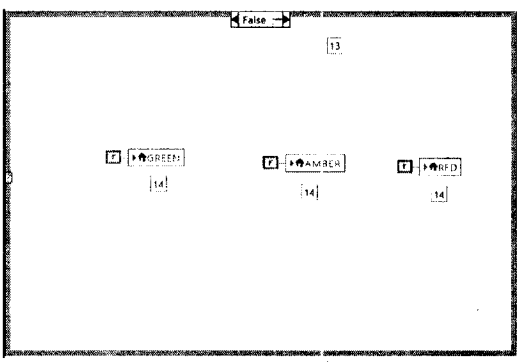
(d) What will happen if the output indicator is placed inside the FOR loop? [3]

Question Five

(a) The following proposed working code was written by Mazuba to control a one way traffic light section on Great East Road near Chelstone Market street. It is ready to be deployed by sending to the microprocessor. Describe in detail the functions of the numbered nodes and icons. [14]







(b) To prohibit parallel operations in program executions sequential structures can be used. ,

(i) What is the advantage and disadvantage of using a **stacked** and the **flat** sequence structure? [4]

(ii) Give one disadvantage of using a sequential structure. [2]

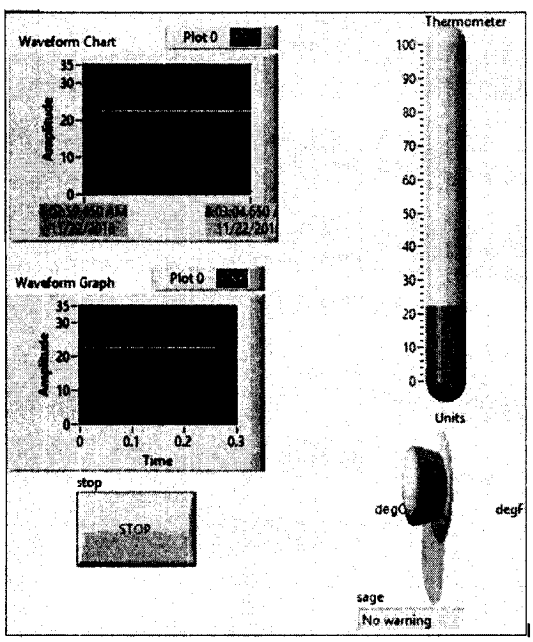
(c) Describe three components of an embedded system. [6]

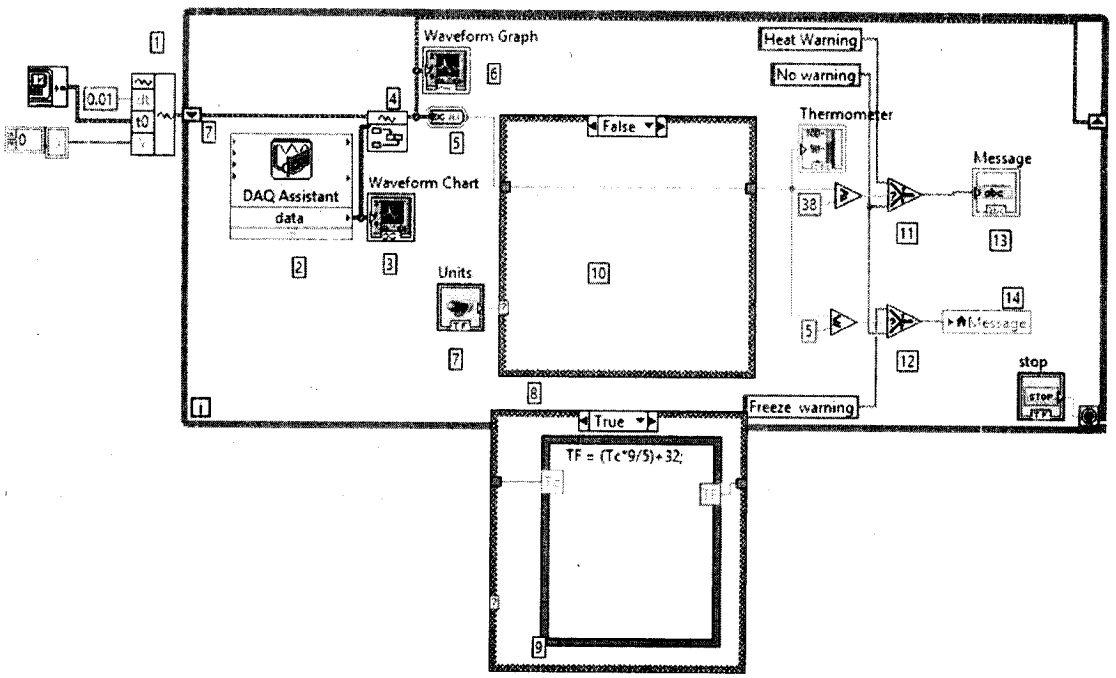
Question Six

(a) What is System on Chip (SoC) and how does the definition of embedded system change with SoC?. [4]

(b) List at least four embedded hardware units and devices in a system. Explain what they do ? [8]

(c) Delton BM Inc. developed a measurement acquisition program to measure temperature using a NI TC01 thermocouple and DAQ and is ready to be uploaded into the microprocessor. Below are the is the front panel and block diagram. Describe in detail the functions of the numbered nodes and icons. [13]





Question Seven

(a) What are the essesntial structural units in the following;

(i) microprocessor [3]

(ii) embedded processor [3]

(ii) microcontroller. [3]

(iv) digital signal processor (DSP). [3]

(c) Give a practical example of an embedded system. [3]

(b) The difference in voltage between the emfs of the two junctions of the thermocouple is being amplified. If a temperature difference between the thermocouple junctions of 10 deg C produces an emf difference of 530 μV, when the values of $R_1 = 10$ kΩ and $R_2 = 189$ kΩ are used, Determine the smallest voltage step that the will measured at the output of the 12 bit National Instrument's 6111E DAQ. [5]