THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

2017/2018 ACADEMIC YEAR

BIO 1401 BIOMOLECULES AND CELLS

BIO 1412 MOLECULAR BIOLOGY AND GENETICS

BIO 2002 STATISTICAL ANALYSIS OF BIOLOGICAL DATA

BIO 2302 BASIC MICROBIOLOGY

BIO 2701 BASIC PHYSIOLOGY

BIO 2812 DIVERSITY OF ANIMALS

BIO 3011 BIOLOGICAL DATA ANALYSIS AND EXPERIMENTAL DESIGN

BIO 3022 BIOLOGY OF SEED PLANTS

BIO 3132 COMMUNITY ECOLOGY

BIO 3412 GENETICS I

BIO 3412 GENETICS II

BIO 3601 PARASITOLOGY

BIO 3721 PLANT PHYSIOLOGY

BIO 3841 EVOLUTIONARY BIOLOGY

BIO 4060 VERTEBRATE BIOLOGY

BIO 4182 WILDLIFE AND RANGELLAND MANAGEMENT {THEORY}

BIO 4182 WILDLIFE AND RANGELLAND MANAGEMENT {PRACTICAL}

BIO 4341 INDUSTRIAL MICROBIOLOGY

BIO 4621 ECOLOGY AND EPIDEMIOLOGY AND PARASITIC DISEASES

BIO 4641 IMMUNOLOGY

C 2615 BASIC PHYSICAL CHEMISTRY

CHE 1000 INTRODUCTION TO CHEMISTRY

CHE 2511	BASIC ORGANIC CHEMISTRY (DEFERRED)
CHE 2522	FUNCTIONAL GROUP AND ARENE CHEMISTRY
CHE 2522	FUNCTIONAL GROUP AND ARENE CHEMISTRY (DEFERRED)
CHE 3111	CELLULAR BIOCHEMISTRY (DEFERRED)
CHE 3122	ENERGY TRANSDUCTION SYSTEMS (DEFERRED)
CHE 3422	ORGANOMETALLICS AND REACTION MECHANISMS
CHE 3422	ORGANOMETALLICS AND REACTION MECHANISMS
CHE 3522	POLYFUNCTIONAL COMPOUNDS, MOLECULAR - REARRANGEMENTS AND ORGANIC SYNTHESIS
CHE 4102	BIOCHEMICAL RESEARCH TECHNIQUES
CHE 4111	INFORMATION STORAGE AND BIOCHEMICAL GENETICS
CHE 4422	METAL CHEMISTRY AND ITS APPLICATION TO - ORGANOMETALLICS AND CATALYSIS
CHE 4511	SYNTHETIC REACTIONS, NEIGHBOURING GROUPS AND CHEMOTHERAPEUTIC AGENTS
CHE 4522	PHYSICAL ORGANIC CHEMISTRY AND NATURAL PRODUCTS - CHEMISTRY
CHE 4622	THERMODYNAMICS AND INTRODUCTION TO STATISTICAL MECHANICS
CHE 4622	THERMODYNAMICS AND INTRODUCTION TO STATISTICAL MECHANICS
CHE 4822	INORGANIC INDUSTRIAL CHEMISTRY II
CHE 4822	INORGANIC INDUSTRIAL CHEMISTRY II (DEFERRED)
GES 1310	INTRODUCTION TO GEOGRAPHY
GES 2130	THE GEOGRAPHY OF AFRICA WITH SPECIAL REFERNCE TO ZAMBIA
GES 2322	FUNDAMENTALS OF NATURAL RESOURCES ECONOMICS
GES 3262	BIOGEOGRAPHY
GES 4342	ENVIRONMENT AND NATURAL RESOURCES MANAGEMENT
GES 4451	CARTOGRAPHY
GES 4461	LAND RESOURCES SURVEY
GES 4181	URBAN GEOGRAPHY AND PLANNING

MAT 3110 ENGINEERING MATHEMATICS II

MAT 3200 ABSTRACT ALGEBRA (DISTANCE, AUGUST)

MAT 3200 ABSTRACT ALGEBRA (DECEMBER)

MAT 3300 REAL ANALYSIS

MAT 3601 MATHEMATICAL STATISTICS

MAT 3622 LINEAR REGRESSION

MAT 3632 FUNDAMENTALS OF SURVIVAL MODELS

MAT 3902 PROBABILITY THEORY

MAT 4119 ENGINEERING MATHEMATICS III

MAT 4300 ELEMENTS OF FUNCTIONAL ANALYSIS

MSE 9040 ADVANCED BIOLOGY TEACHING METHOD

PHY 1010 INTRODUCTORY PHYSICS

PHY 1010 INTRODUCTORY PHYSICS (DISTANCE)

PHY 2112 ATOMIC PHYSICS , MAGNESTISM IN MATTER

PHY 2231 THERMALDYNAMICS AND PROPERTIES OF MATTER

PHY 2522 ANALYTICAL MECHANICS AND SPECIAL THEORY OF RELATIVITY

PHY 2611 ELECTRICITY AND MAGNETISM

PHY 2712 OPTICS (DEFERRED)

PHY 3032 COMPUTATIONAL PHYSICS I

PHY 3411 ANALOGUE ELECTRONICS I (DEFERRED)

PHY 3531 INTRODUCTION TO QUANTUM MECHANICS

PHY 4021 MATHEMATICAL MATHODS FOR PHYSICS

PHY 4031 COMPUTATIONAL PHYSICS 11

PHY 4121 NUCLEAR EXPERIMENTAL TECHNIQUES

PHY 4132 THEORETICAL NUCLEAR PHYSICS

PHY 4221 SOLID STATE PHYSICS I

PHY 4222 SOLID STATE PHYSICS II

PHY 4242

PHY 4411 ANALOGUE ELECTRONICS II

PHY 4422 DIGITAL ELECTRONICS II

PHY 4535 QUANTUM MECHANICS II

PHY 4815 PHYSICS OF RENEWABLE ENERGY RESOURCES

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2017 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 1401: BIOMOLECULES AND CELLS
THEORY PAPER

TIME: THREE HOURS

Instructions:

1. Answer **all** questions.
2. Each question carries +4 marks.
3. A wrong answer carries –1 mark.
4. The option "I do not know" carries 0 mark.
5. Use the answer sheet provided to record the answers.
6. Use ink to record the answers on the mark sheet.
7. Cross out a wrong entry and write the correct one by the side.
8. Handover both the answer sheet and question paper at the end of the examination.
9. Any communication with another candidate will lead to disqualification.
10. Use of cell phones is not allowed.

DO NOT TURN OVER UNTIL YOU ARE TOLD TO DO SO.

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1. 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.

2. Choose the **correct** statement.
   1. The first atomic orbital to be filled by electrons is the '1p'.
   2. The first three electrons in the 'p' orbitals of the second shell will be unpaired.
   3. The '1s' atomic orbital can have a minimum of two protons.
   4. The function of neutrons is to neutralise electrons in the atom.
   5. The hydrogen atom has two electrons in its shell.
   6. I do not know.

3. Determine the maximum number of electrons in the second shell of an atom.
   1. Two
   2. Four
   3. Six
   4. Eight
   5. Ten
   6. I do not know.

4. Determine the number of valence electrons in an atom with an atomic number of seventeen?
   1. Three
   2. Four
   3. Five
   4. Six
   5. Seven
   6. I do not know.

5. Choose the **correct** statement.
   1. Nitrogen gas contains two atoms linked together through covalent double bonds.
   2. Water contains one oxygen atom linked to two hydrogen atoms through hydrogen bonds.
   3. Carbon dioxide has a carbon atom linked to two oxygen atoms through ionic double bonds.
   4. Sodium chloride contains sodium linked to a chloride through an ionic bond.
   5. A hydrogen bond can only be formed between two water molecules.
   6. I do not know.

6. A double covalent bond refers to sharing of ... electron(s).
   1. one
   2. two
   3. three
   4. four
   5. five
   6. I do not know.

7. In a water molecule, the non-bonding electron(s) in oxygen is/are ...
   1. one.
   2. two.
   3. three.
   4. four.
   5. five.
   6. I do not know.

8. Which of the following statements describes a covalent bond between carbon and oxygen.
   1. The electrons are shared equally between carbon and oxygen atoms.
   2. Electrons in the bond are closer to the carbon nucleus.
   3. Each atom in the molecule keeps its electrons.
   4. Electrons in the bond are closer to the oxygen nucleus.
   5. The electrons in the molecule are evenly distributed.
   6. I do not know.

9. Identify the **correct** description of a hydrogen bond.
   1. A bond between oxygen and hydrogen atoms of the same water molecule.
   2. A bond between oxygen of water and nitrogen of other molecules like ammonia.
   3. A bond between oxygen and hydrogen of different water molecules.
   4. A bond between two hydrogen atoms of different molecules.
   5. Options 2 and 3 above are correct.
   6. I do not know.

10. Choose the statement which distinguishes liquid water from ice.
    1. In liquid water, each molecule is surrounded by four other molecules.
    2. In liquid water, molecules are more densely packed.
    3. In liquid water, the molecules are arranged in a regular pattern.
    4. In ice the hydrogen bonds between molecules constantly make and break.
    5. In liquid water, molecules are less densely packed.
    6. I do not know.

11. Capillarity of water in a vessel depends on ...
    1. adhesion.
    2. water's density properties.
    3. cohesion.
    4. 1 and 2 above.
    5. 1 and 3 above.
    6. I do not know.

12. The meniscus of water in a narrow tube...
    1. curves upwards due to high cohesive forces between water molecules.
    2. is flat because of the force of gravity.
    3. curves downwards due to cohesive forces between water molecules.
    4. is flat because of the high surface tension.
    5. curves downwards due to adhesive forces between water molecules and the tube wall.
    6. I do not know.

13. Which of the following statements is true about water?
    1. Hydrogen bonds are a result of electrical attraction between water molecules.
    2. Water is capable of sticking to the sides of glass using cohesive forces.
    3. Water molecules form spheres on a polar surface.
    4. Water is a polar molecule because the electrons on oxygen and hydrogen are equally shared.
    5. Adhesive forces help water to stick together.
    6. I do not know.

14. Which of the following statements is **not true** about water?
    1. When water boils covalent bonds are broken.
    2. Water molecules are hydrophilic.
    3. A water molecule is not linear.
    4. Water is an excellent solvent for polar substances.
    5. Water has a very high latent heat of vaporisation.
    6. I do not know.

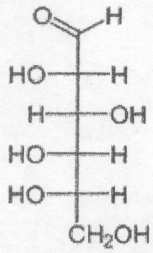
15. Choose the statement that is **correct** in relation to isomerism in monosaccharides.
    1. D and L galactose are structural isomers of each other.
    2. Glucose and fructose are optical isomers of each other.
    3. Alpha glucose and beta galactose are stereoisomers of each other.
    4. The open chain and ring form of glucose are optical isomers of each other.
    5. Galactose and fructose are stereoisomers of each other.
    6. I do not know.

16. Choose the statement that is **correct** in relation to ring formation in monosaccharides.
    1. Carbon 4 combines with carbon 1 of the ribose open chain to form a pyranose ring.
    2. Carbon 4 combines with carbon 1 of the glucose open chain to form a furanose ring.
    3. Carbon 2 combines with carbon 1 of the galactose open chain to form a pyranose ring.
    4. Carbon 4 combines with carbon 1 of the fructose open chain to form a pyranose ring.
    5. Carbon 4 combines with carbon 1 of the deoxyribose open chain to form a furanose ring.
    6. I do not know.

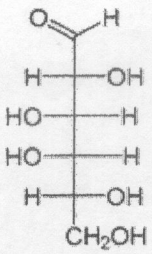
17. The formula $C_3H_6O_3$ represents...
    1. a disaccharide.
    2. a hexose sugar.
    3. glyceraldehyde.
    4. deoxyribose.
    5. fructose
    6. I do not know.

18. Which of the following molecules is used for the synthesis of nucleic acids?
    1. Disaccharides
    2. Oligosaccharides
    3. Polysaccharides
    4. Tetroses
    5. Pentoses
    6. I do not know

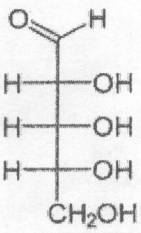
19. Study structures A, B and C and then choose the option that gives the **correct** match between the structure and its name.



A



B



C

#	**Structure A**	**Structure B**	**Structure C**
1	α-Galactose	β -Glucose	β –Ribose
2	β –Glucose	L-Fructose	L-Deoxyribose
3	L-Glucose	D-Galactose	D- Ribose
4	D-Galactose	D-Deoxyribose	L-Glucose
5	L-Ribose	β-Glucose	α-Fructose
6	I do not know		

20. Identify the carbon with a polar bond in dihydroxyacetone?
    1. One
    2. Two
    3. Three
    4. Four
    5. Six
    6. I do not know.

21. Choose the statement that is **correct** in relation to the structure of disaccharides.
    1. Maltose is composed of β-glucose and α-glucose.
    2. Sucrose has a glycosidic bond between C-1of glucose and C-4 of fructose.
    3. Lactose is composed of two α-glucose molecules.
    4. Sucrose is composed of α-glucose and β-fructose.
    5. Maltose is composed of α-glucose and β-fructose.
    6. I do not know.

22. Choose the **correct** statement.
    1. Maltose is a non-reducing sugar because of the 1, 2 glycosidic bond.
    2. Sucrose is a reducing sugar because it contains only two monosaccharides.
    3. Lactose is a non-reducing sugar because it is animal milk.
    4. Sucrose is a non-reducing sugar because of its 1, 2 glycosidic bond.
    5. Options 1 and 2 are correct.
    6. I do not know.

23. The most suitable molecule for translocation of carbohydrates in plants is ...
    1. sucrose.
    2. cellulose.
    3. galactose.
    4. glycogen.
    5. starch.
    6. I do not know.

24. Milk sugar is made from ...
    1. maltose and fructose.
    2. sucrose and galactose.
    3. glucose and fructose.
    4. glucose and galactose.
    5. galactose and galactose.
    6. I do not know.

25. Choose the **correct** statement.
    1. Branching is important in the function of structural polysaccharides.
    2. An energy storage polysaccharide should be fibrous in nature.
    3. Amylopectin is highly branched and hence more difficult to digest than cellulose.
    4. The structure of glycogen is similar to that of amylopectin.
    5. Amylose gives a blue-black colour with iodine solution.
    6. I do not know.

26. Choose the **correct** statement.
    1. Amylose has α-1, 4 and β-1, 4 glycosidic bonds.
    2. Amylopectin has α-1, 4 and β-1, 6 glycosidic bonds.
    3. Cellulose has α-1, 4 and β-1, 4 glycosidic bonds.
    4. Amylose has α-1, 4 and β-1, 4 glycosidic bonds.
    5. Amylose has α-1, 6 glycosidic bonds.
    6. I do not know.

27. The complete hydrolysis of amylopectin yields ...
    1. amylose.
    2. galactose.
    3. glucose
    4. fructose.
    5. starch
    6. I do not know.

28. Which of the following statements is **true**?
    1. Polysaccharides are chemically reactive substances.
    2. Amylose is a starch.
    3. Carbon one is the asymmetric carbon in glucose.
    4. Starch, glycogen and cellulose are oligosaccharides.
    5. Sucrose has its asymmetric carbon free for further chemical reactions.
    6. I do not know.

29. The hydrolysis of lipids produces ...
    1. glucose.
    2. glycerol.
    3. fatty acids.
    4. amino acids.
    5. (2) and (3) above
    6. I do not know.

30. How many electrons are there in the third shell of the atom with atomic number 23?
    1. 8
    2. 13
    3. 03
    4. 10
    5. 11
    6. I do not know.

31. The number of electrons in the highest energy level of calcium, atomic number is 20.
    1. 8
    2. 6
    3. 5
    4. 4
    5. 2
    6. I do not know.

32. Water is liquid at room temperature because of ... of water.
    1. the high boiling point
    2. the high melting point
    3. the high heat of vaporisation
    4. adhesive forces
    5. both 1 and 2.
    6. I do not know.

33. Polar molecules can readily dissolve in water because...
    1. polar molecules can form hydrogen bonds with water
    2. polar molecules can replace water-water interaction with more energy provided
    3. water can interact with charged solute molecules
    4. all molecules form solutions with water.
    5. of both options 1 and 3.
    6. I do not know

34. The most important reason for the unique shape of water is ...
    1. the covalent bonding pattern in water molecules.
    2. the bond angle between the two hydrogen atoms in water.
    3. the presence of a lone pair of electrons in water.
    4. that water can be ionised at room temperature.
    5. All options above are correct.
    6. I do not know.

35. Hydrogen bonds can be expected to form only between hydrogen and …
    1. carbon.
    2. hydrogen.
    3. oxygen.
    4. nitrogen.
    5. Options 3 and 4.
    6. I do not know.

36. Adhesive forces lead to … which is the process through which water is absorbed into roots of plants.
    1. surface tension
    2. polarity
    3. formation of a tough film of water
    4. elasticity of water
    5. capillary action
    6. I do not know.

37. Which one of the following represents functional groups in carbohydrates?
    1. Alcohol and Carboxyl groups
    2. Aldehyde and Ketone groups
    3. Hydroxyl and hydrogen groups
    4. Carboxyl and amine groups
    5. Carbon and hydrogen groups
    6. I do not know.

38. Which of the following is a **true** statement about glucose?
    1. It is used for storage of energy.
    2. It has four asymmetric carbon atoms.
    3. It is stored as starch in animals.
    4. It has six asymmetric carbon atoms.
    5. It is oxidized to form fructose.
    6. I do not know.

39. Which of the following is a carbohydrate with six carbon atoms and a keto group as its functional group?
    1. Glyceraldehyde
    2. Dihydroxyacetone
    3. Galactose.
    4. Fructose
    5. Ribose
    6. I do not know

40. Choose the **correct** statement(s).
    1. Collagen is a globular protein consisting of three polypeptide chains.
    2. The beta-pleated sheet is found in fibrous proteins.
    3. Haemoglobin is a fibrous protein with a quaternary structure.
    4. Statements 1 and 3 are correct.
    5. Statements 2 and 3 are correct.
    6. I do not know.

41. The peptide bond in a dipeptide is located between the ... group and the ...
    1. amine/α carbon.
    2. alkyl group /C=O group.
    3. carboxylic/ alkyl group.
    4. C=O/ N-H group.
    5. carboxylic/α carbon.
    6. I do not know.

42. Hydrogen bonding between neighbouring beta pleated sheets is between ... and ...
    1. oxygen/ an alkyl group.
    2. nitrogen/ hydrogen.
    3. hydrogen/ oxygen.
    4. hydrogen/ an alkyl group.
    5. hydrogen/ hydrogen.
    6. I do not know.

43. Choose the true statement.
    1. All enzymes have the same optimum pH and temperature.
    2. All enzymes have the same optimum pH but different optimum temperatures.
    3. All enzymes have different optimum pH values but the same optimum temperature.
    4. Enzymes have different optimum pH values and different optimum temperatures.
    5. Some enzymes have optimum temperature and pH values while others do not.
    6. I do not know.

44. The effect of a reversible competitive inhibitor can be nullified by ...
    1. decreasing the product concentration.
    2. increasing the substrate concentration.
    3. increasing the temperature.
    4. decreasing the temperature.
    5. increasing pH.
    6. I do not know.

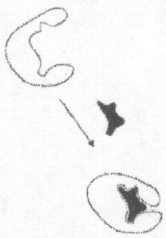
45. Study Figure 1 below and answer the question that follows.



Figure 1. Model of the enzyme active site.

Choose the statement which is **false** about the model in Figure 1.
    1. Figure 1 shows the induced-fit model.
    2. The active site fits the substrate tightly after binding.
    3. In this model, the enzyme is the 'lock' while the substrate is the 'key'.
    4. The structure of the active site changes slightly as it binds the substrate.
    5. The active site can bind a number of different but closely related substrates.
    6. I do not know.

46. Study Figure 1 below and answer the question that follows.



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3. In this model, the enzyme is the 'lock' while the substrate is the 'key'.
4. The structure of the active site changes slightly as it binds the substrate.
5. The active site can bind a number of different but closely related substrates.
6. I do not

47. Which of the following statements is **true**?

1. DNA bases vary from one species to another.
2. DNA bases change with the age of the organism.
3. DNA bases are different in different tissues of an organism.
4. All cells are made up of the same type of DNA bases.
5. All the above statements are true.
6. I do not know.

48. DNA is a polyanion because of the presence of …

1. carboxylic groups.
2. deoxyribose sugars.
3. purine bases.
4. pyrimidine bases.
5. phosphate groups.
6. I do not know.

49. The condensation of a nitrogenous base with a pentose sugar results in a …

1. **nucleoside.**
2. nucleotide.
3. nucleic acid.
4. ribonucleic acid.
5. 3 and 4 above.
6. I do not know.

50. A nucleotide has a …

1. pentose sugar, a phosphate and an amino acid.
2. glycosidic bond and a phosphoester bond.
3. pentose sugar, a phosphate and a lipid.
4. pentose sugar, an amino acid and a nitrogenous base.
5. glycosidic bond and a phosphodiester bond.
6. I do not know.

51. Choose the **correct** statement(s).
    1. Purines are single ringed structures.
    2. Pyrimidines are two ringed structures.
    3. Adenine and thymine are examples of pyrimidines.
    4. Uracil, cytosine and thymine are examples of pyrimidines.
    5. All the above statements are correct.
    6. I do not know.

52. The reaction between a pentose sugar and nitrogenous base results in the formation of a(n) ...
    1. nucleotide.
    2. ester bond.
    3. nucleic acid.
    4. glycosidic bond.
    5. 1 and 3 above.
    6. I do not know.

53. The sedimentation coefficient of a complete ... ribosome is ... while its large subunit is...
    1. eukaryotic/70S/50S.
    2. prokaryotic/50S/20S.
    3. eukaryotic/80S/60S.
    4. prokaryotic/80S/50S.
    5. eukaryotic/60S/40S.
    6. I do not know.

54. During synthesis of a DNA strand, the incoming nucleotide attaches at the...
    1. phosphate end of the nucleotide.
    2. 5' end of the growing chain.
    3. 3' end of the nucleotide.
    4. 2' end of the growing chain.
    5. phosphate end of the growing chain.
    6. I do not know.

55. In the DNA molecule ... normally pairs with ... through a ... hydrogen bond.
    1. thymine/adenine/triple
    2. uracil/adenine/double bond
    3. guanine/cytosine/double
    4. adenine/guanine/triple
    5. thymine/adenine/double
    6. I do not know.

56. Choose the **false** statement.
    1. RNA can be used for temporal storage of genetic material.
    2. DNA is used for long-term storage of genetic material.
    3. RNA is a single strand of nucleotide units.
    4. Transfer RNA carries a codon.
    5. Messenger RNA carries codons.
    6. I do not know.

57. The sugar in RNA is …, whereas the sugar in DNA is …
    1. deoxyribose/ribose.
    2. ribose/deoxyribose.
    3. ribose/phosphate.
    4. ribose/fructose.
    5. glycerol/cholesterol.
    6. I do not know.

58. The … end of tRNA is used by the acceptor arm to receive its amino acids.
    1. 1'
    2. 2'
    3. 3'
    4. 4'
    5. 5'
    6. I do not know.

59. Which of the following is **not** a characteristic of eukaryotes?
    1. DNA
    2. Cell membrane
    3. Cell wall
    4. Endoplasmic reticulum
    5. Plasmid
    6. I do not know.

60. In bacteria, respiration is performed by the … membrane.
    1. vesicle
    2. lysosomal
    3. ribosomal
    4. plasma
    5. mitochondrial
    6. I do not know.

61. Choose the **correct** statement.
    1. Bacterial cells use flagella to stick to other bacterial cells.
    2. Bacteria use pili for movement.
    3. Plasmids are DNA on their own.
    4. Lysosomes control all metabolic activities of a cell.
    5. Bacteria do not have a true nucleus but have a structure called a nucleolus.
    6. I do not know.

62. The bacterial cell wall is made up of …
    1. chitin.
    2. cellulose.
    3. wax.
    4. peptidoglycan.
    5. cellulose and chitin.
    6. I do not know.

63. The rough endoplasmic reticulum is abundant in cells that synthesise…
    1. carbohydrates.
    2. lipids.
    3. enzymes.
    4. cholesterol.
    5. nucleic acids.
    6. I do not know

64. The smooth endoplasmic reticulum is abundant in cells that synthesize…
    1. carbohydrates.
    2. proteins.
    3. enzymes.
    4. lipids.
    5. nucleic acids.
    6. I do not know.

65. Which of the following correctly matches an organelle with its function?

#	**Organelle**	**Function**
1	mitochondrion	photosynthesis
2	nucleus	cellular respiration
3	ribosome	storage
4	lysosome	digestion
5	central vacuole	manufacture of lipids
6	I do not know	

66. The location where eukaryotic ribosomal RNA is produced is called …
    1. nucleoid.
    2. nuclear membrane.
    4. Golgi complex.
    3. nucleolus.
    5. centriole.
    6. I do not know.

67. Choose the **false** statement.
    1. Animal cells have mitochondria but no chloroplasts.
    2. Animal cells have both mitochondria and Golgi body.
    3. Plant cells have chloroplasts but no mitochondria.
    4. Animal cells have ribosomes and lysosomes.
    5. Plant cells have large vacuoles.
    6. I do not know.

68. The functions of the central vacuole of plant cells include …
    1. regulating turgor pressure.
    2. storing waste materials.
    3. storing products of metabolism.
    4. absorbing excess water.
    5. All the functions above are correct.
    6. I do not know.

69. The plasma membrane consists of ...
    1. two layers of phospholipids with embedded proteins.
    2. a protein bilayer with embedded phospholipids.
    3. a phospholipid single layer with embedded proteins.
    4. a phospholipid bilayer with glycoproteins in between.
    5. two layers of lipoproteins with phospholipids in between.
    6. I do not know.

70. Choose the **correct** statement.
    1. All life is made of cells.
    2. Cells are the smallest units of life.
    3. New cells come from pre-existing cells.
    4. Cells must remain small for them to be successful in the environment.
    5. All the statements above are correct.
    6. I do not know.

71. Chlorophyll is located in the ... of chloroplasts.
    1. membrane
    2. cristae
    3. matrix
    4. cell wall
    5. in between the outer and inner membranes
    6. I do not know.

72. The backbone of DNA is...
    1. hydrophilic.
    2. hydrophobic.
    3. neutral.
    4. both hydrophilic and hydrophobic.
    5. None of the above.
    6. I do not know

73. Thymidine 5' monophosphate ...
    1. is a nucleotide of DNA.
    2. is replaced by uridine 5' monophosphate in RNA.
    3. normally forms two hydrogen bonds with adenosine 5' monophosphate.
    4. forms three hydrogen bonds with adenosine 5' monophosphate.
    5. The options 1, 2 and 3 are correct
    6. I do not know

74. Which molecule carries amino acids to ribosomes?
    1. rRNA
    2. **tRNA**
    3. mRNA
    4. DNA
    5. RNA
    6. I do not know

75. Given that the sequence for one DNA strand is 5‘ TTCAGTACATTG 3‘, determine the sequence of the complementary strand.
    1. 3‘ UUGTCUTGTUUC 5‘
    2. 3‘ AAGTCATGTAAC 5‘
    3. 3‘ CCTUCCUTUAAC 5‘
    4. 5‘ CAATGTACTGAA 3‘
    5. 5‘ AAGTCATGTAAC 3‘
    6. I do not know.

76. Choose the **correct** statement.
    1. All cells are enclosed in a membrane that keeps internal conditions different from their environment.
    2. All cells can synthesise organic molecules.
    3. All cells have DNA as the genetic material.
    4. All cells can produce energy.
    5. All statements above are correct.
    6. I do not know.

77. Which of the following is a common feature of all cells?
    1. Organelles
    2. Plasma membrane
    3. Nuclear membrane
    4. Centrioles
    5. Chloroplasts
    6. I do not know.

78. Which of the following statements is **true**?
    1. Eukaryotic cells are simple while prokaryotic cells are complex.
    2. Eukaryotic cells do not have a nucleus while prokaryotic cells do.
    3. Prokaryotic cells are larger than eukaryotic cells.
    4. Prokaryotic cells existed before eukaryotic cells.
    5. Eukaryotic cells do not have lysosomes while prokaryotic cells do.
    6. I do not know.

79. Carbon has four (4) valence electrons because...
    1. the electrons in the four ‘2p’ orbitals are unpaired.
    2. the second shell has four ‘2s’ orbitals.
    3. the electrons occupy the ‘2s’ and ‘2p’ orbitals.
    4. it has a total 8 electrons.
    5. it always forms four single bonds with other atoms.
    6. I do not know.

80. Which of the following is the correct order for filling electrons in orbitals?
    1. 1s, 2s, 2p
    2. 2p, 2s, 1s
    3. 2s, 2p, 1s
    4. 1s, 2p, 2s
    5. 2p, 1s, 2s
    6. I do not know.

81. The number of orbitals in the second shell of an atom is …
    1. 1
    2. 2
    3. 3
    4. 4
    5. 5
    6. I do not know.

82. Which of the following statements is **true** regarding the electronegativity of atoms in a water molecule?
    1. Hydrogen is more electronegative than oxygen.
    2. Hydrogen is less electronegative than oxygen.
    3. Electronegativity of hydrogen and oxygen is the same.
    4. Neither oxygen nor hydrogen is electronegative.
    5. None of the above.
    6. I do not know.

83. The formula $C_6H_{12}O_6$ represents …
    1. glycerol.
    2. lactose.
    3. maltose.
    4. sucrose.
    5. alpha and beta glucose.
    6. I do not know.

84. The structural difference in disaccharides is due to the...
    1. number of hydrogen atoms.
    2. arrangement in its atoms.
    3. number of carbon atoms.
    4. number of oxygen atoms.
    5. Options 1 and 2 above.
    6. I do not know.

85. Which of the following is a storage polysaccharide?
    1. Glycogen
    2. Wax
    3. Starch
    4. Cellulose
    5. Options 1 and 3 above.
    6. I do not know.

86. Which of the following is similar to starch?
    1. Cellulose
    2. Glycogen
    3. Glucose
    4. Sucrose
    5. Wax
    6 I do not know.

87. Indentify the bond associated with cellulose.
    1. β (1-2) linkage
    2. β (1-4) linkage
    3. α (1-4) linkage
    4. α (1-2) linkage
    5. α (1-6) linkage
    6. I do not know

88. The following substances are lipid in nature except …
    1. glycerides.
    2. wax.
    3. cholesterol.
    4. fatty acids.
    5. insulin.
    6. I do not know.

89. Lysosomes are especially abundant in ... cells.
    1. actively respiring
    2. protein synthesising
    3. secretory
    4. lipid synthesising
    5. carbohydrate synthesising
    6. I do not know.

90. Lysosomes...
    1. destroy harmful bacteria engulfed by white blood cells.
    2. help to digest worn-out or damaged cellular particles.
    3. are double membrane organelles.
    4. can hydrolyse food in vacuoles.
    5. All the options above are correct.
    6 I do not know.

91. Many bacteria adhere to surfaces by structures called …
    1. cilia.
    2. mitochondria.
    3. flagella.
    4. pili.
    5. microtubules.
    6. I do not know

92. In eukaryotic cells, internal membranes …
    1. provide additional area for metabolic processes.
    2. form membrane-bound compartments called organelles.
    3. contain proteins essential for metabolic processes.
    4. increase a cell's total membrane area.
    5. All of the above are correct.
    6. I do not know.

93. The function of mitochondria is …
    1. intracellular transport of proteins.
    2. photosynthesis.
    3. intracellular digestion.
    4. cellular respiration.
    5. lipid synthesis.
    6. I do not know.

94. What is the main difference between prokaryotes and eukaryotes?
    1. Prokaryotes do not reproduce.
    2. Prokaryotes do not have membrane-bound internal compartments.
    3. Prokaryotes have no DNA.
    4. Prokaryotes have no cytoplasm.
    5. Prokaryotes have no lysosomes.
    6. I do not know.

95. Which pyrimidine base contains an amino group at Carbon 4?
    1. Thymine
    2. Cytosine
    3. Uracil
    4. Guanine
    5. Adenine
    6. I do not know.

96. At which carbon in the pentose sugar of a nucleotide is a base attached?
    1. At the oxygen bridge
    2. At carbon 5
    3. At carbon 3
    4. At carbon 1
    5. At carbon 2
    6. I do not know.

97. The forces which hold two strands of DNA together are …
    1. electrostatic bonds.
    2. van der Waals.
    3. hydrogen bonds.
    4. covalent bonds.
    5. phosphodiester bonds.
    6. I do not know.

98. Which of the following is **true** about tRNA?
    1. It carries the genetic code.
    2. It is a component of ribosomes.
    3. Some of its portions are double stranded
    4. It consists of two arms.
    5. It is a double helix.
    6. I do not know.

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2017 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 1412: MOLECULAR BIOLOGY AND GENETICS
THEORY PAPER

TIME: THREE HOURS

INSTRUCTIONS

1. Answer **all** questions.
2. All questions carry equal marks.
3. Use the answer sheet provided to record the answers.
4. A correct answer carries +4 marks.
5. A wrong answer carries –1 mark.
6. The option "I do not know." carries 0 mark.
7. Use ink to record the answers on the mark sheet.
8. Cross out a wrong entry and write the correct one by the side.
9. Handover both the answer sheet and question paper at the end of the examination.
10. Any communication with another candidate will lead to disqualification.
11. Use of cell phones is not allowed.

1. Choose the relationship which is true regarding the central dogma of molecular biology.
    1. DNA -- transcription → RNA -- translation → DNA -- replication → Protein.
    2. DNA -- replication→ DNA -- transcription → RNA -- translation→ Protein.
    3. RNA -- transcription → DNA -- translation → Protein -- modification→ DNA
    4. RNA -- replication → RNA -- transcription → DNA -- translation → Protein.
    5. DNA -- transcription → RNA -- translation → Protein -- modification → DNA.
    6. I do not know.

2. During DNA replication nucleotides are added ...
    1. to both the 5' end and the 3' end of the DNA primer.
    2. either to the 5' end or to the 3' end of the RNA primer.
    3. to the 5' end of the RNA primer.
    4. to the 3' end of the RNA primer.
    5. to the 3' end of the DNA primer.
    6. I do not know.

3. The stages of DNA replication can be represented by the following order:
    1. Initiation, separation of daughter DNA, , proof reading, elongation.
    2. Separation of daughter DNA, initiation, elongation, proof reading.
    3. Initiation, separation of daughter DNA, elongation, proof reading.
    4. Elongation, initiation, separation of daughter DNA, proof reading.
    5. Initiation, elongation, proof reading, separation of daughter DNA.
    6. I do not know.

4. Choose the statement which is **false**.
    1. After replication, each daughter DNA contains one old strand and one new strand.
    2. In their experiment, Meselson and Stahl used *E.coli* cells.
    3. Meselson and Stahl initially grew *E.coli* cells in a medium containing nitrogen 15 isotope for many generations.
    4. Meselson and Stahl initially grew *E.coli* cells in a medium containing nitrogen 14 isotope for many generations.
    5. Meselson and Stahl analysed DNA samples using caesium chloride density-gradient equilibrium centrifugation.
    6. I do not know.

5. Choose the molecule which opens the DNA, creating a replication fork.
    1. DNA helicase
    2. DNA ligase
    3. DNA polymerase
    4. Single strand binding protein
    5. Topoisomerase
    6. I do not know.

6. At the end of the lagging strand DNA synthesis, ...
   1. phosphodiester bonds between adjacent nucleotides break.
   2. bonds between the nitrogen base and deoxyribose sugar break .
   3. the leading strand produces Okazaki fragments.
   4. hydrogen bonds between the nucleotides of the two strands break.
   5. DNA ligase catalyses the sealing of the gap between adjacent DNA fragments.
   6. I do not know.

7. Bacterial cells grown in a heavy nitrogen isotope and allowed to replicate three times in a culture of a light nitrogen isotope will show the following results:
   1. 100% heavy DNA
   2. 100% light DNA
   3. 50% hybrid and 50% heavy DNA
   4. 25% hybrid and 75% light DNA.
   5. 25% light, 25% heavy and 50% hybrid.
   6. I do not know.

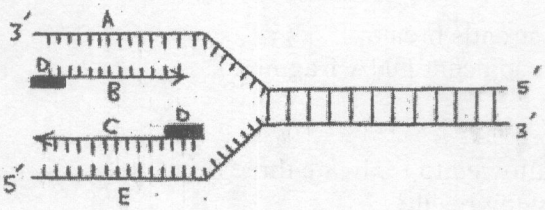
8. Choose the enzyme which is correctly matched with its function.

1	Topoisomerase	Causes the initial strand separation of template DNA
2	dnaA protein	Removes supercoiling from DNA
3	Helicase	Produces RNA primers
4	Primase	Separates the two DNA strands
5	Single strand binding protein	Prevents separated DNA strands from rejoining
6	I do not know.	

9. Which reaction in DNA replication is catalyzed by DNA ligase?
   1. Addition of new nucleotides to the lagging strand.
   2. Addition of new nucleotides to the leading strand.
   3. Base pairing of the template and the newly formed DNA strand.
   4. Formation of a phosphodiester bond between the 3' OH of one Okazaki fragment and the 5' phosphate of the next on the lagging strand.
   5. Synthesis of a short RNA primer complementary to DNA.
   6. I do not know.

10. The elongation of the leading strand during DNA synthesis ....
   1. progresses away from the replication fork.
   2. occurs in 3'→5' direction.
   3. produces Okazaki fragments.
   4. uses a DNA primer.
   5. depends on the action of DNA polymerase.
   6. I do not know.

11. The diagram given below shows the process of DNA replication at a replication fork. Study it and then answer the question that follows.



The strand labeled B is the .....

1. template strand.
2. lagging strand.
3. leading strand.
4. Okazaki fragment.
5. RNA primer.
6. I do not know.

12. The first amino acid to be translated in prokaryotes is ...

1. methionine.
2. valine.
3. adenine.
4. formyl methionine.
5. cytosine.
6. I do not know.

13. The last amino acid to be translated in prokaryotes is ...

1. methionine.
2. formyl methionine.
3. dependent on the mRNA sequence.
4. dependent on the tRNA anticodon.
5. the stop codon
6. I do not know.

14. If the sequence of bases in non-template DNA is TAGC, then the corresponding sequence of bases in the transcribed RNA will be...

1. ATCG.
2. TAGC.
3. UAGC.
4. AUGC.
5. AUCG.
6. I do not know.

15. Which of the following occurs in both eukaryotic and bacterial transcription?
    1. 5' capping
    2. Poly A tail
    3. Promoter
    4. Splicing
    5. Nucleotide deletion
    6. I do not know

16. Which of the following is **not** part of RNA processing in eukaryotes?
    1. Addition of a 5' cap.
    2. Addition of poly A tail
    3. Intron removal.
    4. Addition of an RNA primer.
    5. Joining exons together.
    6. I do not know

17. Choose the statement which represents the degeneracy of the genetic code.
    1. The genetic code is very unstable.
    2. The genetic code is the same for all organisms.
    3. Two or more codons may specify one amino acid.
    4. Two or more amino acids may be specified by one codon.
    5. Each codon consists of three nucleotides.
    6. I do not know.

18. Which position of a codon is said to wobble?
    1. First
    2. Second
    3. Third
    4. Fourth
    5. 1 and 2
    6. I do not know.

19. Which of the following is **not** a property of the genetic code?
    1. Triplet
    2. Degenerate
    3. Non-overlapping
    4. Universal
    5. Ambiguous
    6. I do not know.

20. Of the ..... different possible codons of the genetic code, ...specify amino acids and .... signal stop.
    1. 20, 17, 3
    2. 64, 20, 3
    3. 64, 61, 3
    4. 61, 60, 1
    5. 64, 20, 1
    6. I do not know.

21. During the process of translation the ...
    1. first amino acid binds to the A site of the ribosome.
    2. first amino acid binds to the P site of the ribosome.
    3. second amino acid binds to the P site of the ribosome.
    4. second amino acid binds to the elongation factor.
    5. last amino acid binds to the stop codon.
    6. I do not know.

22. Identify the complex that is formed when tRNA binds to an amino acid.
    1. Aminoacyl synthetase
    2. Aminoacyl tRNA complex
    3. 70S initiation complex
    4. 30S initiation complex
    5. 40S initiation complex
    6. I do not know.

23. During translation, the ... site of the ribosome holds the growing polypeptide chain while the ... site holds the next amino acid to be to be added to the chain.
    1. A, P
    2. P, A
    3. A, B
    4. B, A
    5. None of the above
    6. I do not know

24. A messenger RNA is 336 nucleotides long, including the start and stop codons. The number of amino acids in the protein translated from this mRNA is .....
    1. 110
    2. 111
    3. 112
    4. 330
    5. 999
    6. I do not know

25. Which of the following steps is **correct** for the formation of a peptide bond between the two amino acids in the ribosome?
    1. The first amino acid is transferred to the NH_2 terminus of the second amino acid in the A site.
    2. The first amino acid is transferred to the NH_2 terminus of the second amino acid in the P site.
    3. The first amino acid is transferred to the COOH terminus of the second amino acid in the A site.
    4. The first amino acid is transferred to the COOH terminus of the second amino acid in the P site.
    5. The tRNA with the first amino acid shifts from the P site to the A site.
    6. I do not know.

26. Identify the role of the enzyme peptidyl transferase during translation.
    1. Transfer of phosphate group.
    2. Amino acid activation.
    3. Peptide bond formation between adjacent amino acids
    4. binding of ribosome subunits to mRNA.
    5. Dissociation of ribosome subunits.
    6. I do not know.

27. The *Lac* operon is a group of genes involved in the metabolism of …
    1. galactose.
    2. permease.
    3. glucose.
    4. lactase.
    5. lactose
    6. I do not know.

28. The *Lac* operon is switched **on** when …
    1. the repressor molecule binds the operator.
    2. glucose is present.
    3. lactose is absent.
    4. RNA polymerase binds to the operator site.
    5. the repressor molecule binds to lactose.
    6. I do not know.

29. What is the function of the permease enzyme in the *lac* operon?
    1. Hydrolysis of lactose
    2. Entry of lactose into the cell
    3. Attachment of lactose to the lac repressor protein
    4. Breakdown of lactose
    5. Exit of lactose from the cell
    6. I do not know.

30. The *Lac* repressor dissociates from the operator site when it binds to the ...
    1. promoter.
    2. operator.
    3. inducer.
    4. structural genes.
    5. regulator gene.
    6. I do not know.

31. In the *Lac* operon, binding of the repressor to the operator site will ...
    1. facilitate transcription of structural genes.
    2. inhibit the enzymatic activity of RNA polymerase.
    3. stimulate the enzymatic activity of RNA polymerase.
    4. inhibit transcription of the structural genes.
    5. increase glucose concentration.
    6. I do not know

32. Which of the following contains all the hereditary information passed on from one generation to next generation.
    1. messenger RNA.
    2. transfer RNA.
    3. ribosomal RNA.
    4. messenger RNA and transfer RNA.
    5. DNA.
    6. I don't know.

33. A dividing cell has 19 chromosomes, each consisting of two sister chromatids. Choose the stage(s) of cell division in which this cell is.
    1. Prophase II of meiosis.
    2. Telophase of meiosis I.
    3. Prophase I of meiosis.
    4. Options 1 and 2.
    5. Options 2 and 3.
    6. I do not know.

34. Which of the following statements is **false**?
    1. Chromosomes divide into two equal parts during mitosis.
    2. Sister chromatids are identical.
    3. Sister chromatids undergo crossing-over during cell division.
    4. Homologous chromosomes are always of the same length.
    5. Chromosomes are in form of chromatin fibres before cell division.
    6. I do not know.

35. Which of the following statements is false?
    1. The chromosomal theory agrees with Mendel's laws of inheritance.
    2. Homologous chromosomes separate during meiosis.
    3. Sorting of homologous pairs of chromosomes into gametes is random.
    4. Gametes contain the same number of parental chromosomes.
    5. Gametes combine during fertilisation.
    6. I do not know.

36. How many autosomal chromosomes are present in the human egg cell?
    1. 22
    2. 46
    3. 23
    4. 44
    5. 24
    6. I do not know.

37. Choose the statement which is **true**.
    1. The phase of the cell cycle in which DNA replicates is the S phase.
    2. The phase of the cell cycle in which the cell divided is designated G_1 phase.
    3. The phase of the cell cycle in which DNA replicates is designated M phase.
    4. Proteins and enzymes are synthesized during the S phase of the cell cycle.
    5. Organelles replicate during the M phase of the cell cycle.
    6. I do not know.

38. Choose the cells which undergo meiosis.
    1. Cells found in muscles.
    2. Cells found in somatic cells.
    3. Brain cells.
    4. Cells found in the skin.
    5. Cells found in gonads.
    6. I do not know.

39. What is the purpose of G1 phase?
    1. Cell rests and does not need to divide.
    2. Cell grows and checks for mistakes in DNA.
    3. Cell grows and prepares to replicate DNA.
    4. DNA is replicated.
    5. The cell divides.
    6. I do not know.

40. How many phases constitute the cell cycle?
    1. 1
    2. 2
    3. 3
    4. 4
    5. 5
    6. I do not know

41. Which pair is correct?
    1. M phase, cell growth.
    2. G_1 phase, DNA replication.
    3. S phase, cell division.
    4. G_2 phase, DNA replication.
    5. G_2 phase, preparation for mitosis.
    6. I do not know

42. Choose the genetic term which matches with the corresponding description

	Genetic term	Description
1	Haploid	Any chromosome other than the sex chromosome
2	Meiosis	Number of chromosomes in the gamete
3	Cytokinesis	Division of the nucleus
4	Autosomal chromosomes	Reduction division
5	Centromere	Site on the chromosome to which spindle fibres attach
6	I do not know.	

43. In which phase of cell cycle are chromosomes visible under the microscope for the first time?
    1. Interphase
    2. Prophase
    3. Metaphase
    4. Anaphase
    5. Telophase
    6. I do not know.

44. During mitosis the nuclear membrane disappears at ....
    1. prophase
    2. metaphase
    3. anaphase
    4. telophase
    5. cytokinesis
    6. I do not know.

45. Mitosis is similar to ....
    1. Meiosis I
    2. Meiosis II
    3. Synapsis
    4. Both I and II
    5. None of the above
    6. I do not know.

46. What is the role of the spindle during mitosis?
    1. It makes the chromosomes visible.
    2. It breaks down the nuclear membrane.
    3. It duplicates DNA.
    4. It helps to separate the chromosomes.
    5. It duplicates the centromere.
    6. I do not know

47. Chiasmata are clearly visible in a cell during ...
    1. interphase of meiosis.
    2. prophase of meiosis.
    3. prophase of mitosis.
    4. metaphase of mitosis.
    5. metaphase of meiosis.
    6. I do not know.

48. Choose the **correct** statement.
    1. The cells from which gametes are produced are haploid.
    2. Meiosis is a source of genetic variation.
    3. The male reproductive organs are called gametes.
    4. The female reproductive organs are called ova.
    5. Gametes are produced from somatic cells.
    6. I do not know.

49. Choose the **false** statement.
    1. Meiosis is a reductional division.
    2. Synapsis takes place during meiosis.
    3. Meiosis produces two haploid daughter cells.
    4. Mitosis produces daughter cells with identical chromosomes.
    5. Through meiosis daughter cells with recombinant chromosomes may be produced.
    6. I do not know.

50. Study the Figure 1 below and then choose the correct statement.

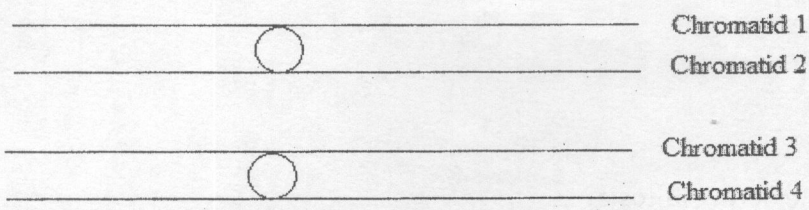


Figure 1: A tetrad of two homologous chromosomes

1. Crossing over can take place between chromatids 1 and 2.
2. Crossing over can take place between chromatids 1 and 3.
3. Crossing over can take place between chromatids 2 and 3.
4. Crossing over can take place between chromatids 3 and 4.
5. Statements 2 and 3 are correct.
6. I do not know.

51. Which of the following is **not** a characteristic of meiosis?
1. Chromosomes arrange themselves in pairs.
2. Daughter cells with half the normal number of chromosomes produced.
3. One cell undergoing two cell divisions, one after the other.
4. Division of somatic cells.
5. Recombination of alleles in the daughter cells.
6. I do not know.

52. A test cross is carried out to confirm whether the ...
1. F_1 individual is homozygous or not.
2. F_1 individual is heterozygous or not.
3. test cross individual with a dominant phenotype is heterozygous or not.
4. test cross individual with a recessive phenotype is heterozygous or not.
5. test cross individual with a dominant phenotype is recessive or not.
6. I do not know.

53. Choose the **false** statement.
1. Genetics is the study of how characteristics are passed on from one generation to the next.
2. Genetics can be applied to produce improved crops and livestock.
3. Mendel showed that each genetic characteristic is controlled by two alternative factors.
4. Multiple alleles control quantitative traits.
5. Two alternative forms of a gene occupy a specific locus in homologous chromosomes.
6. I do not know.

54. Choose the term which **correctly** describes the alleles responsible for blood groups A and B.
    1. Dominant
    2. Codominant
    3. Recessive
    4. Incompletely dominant
    5. Lethal
    6. I do not know.

55. A gene ....
    1. can be described as a unit of heredity.
    2. contains information to produce a particular protein.
    3. affects traits at the cellular level.
    4. can exist in many forms
    5. All of the above.
    6. I do not know.

56. An F_2 phenotypic ratio of 2:1 in a monohybrid cross suggests that ...
    1. there was sex linkage.
    2. a recessive allele is involved.
    3. a colour blindness trait is involved.
    4. a lethal allele is involved.
    5. Options 1 and 2 above.
    6. I do not know.

57. Which of the following is (are) true about lethal alleles?
    1. They cause the death of an organism that carries them.
    2. They are usually a result of mutations in genes.
    3. They may be recessive.
    4. They may be dominant.
    5. All of the above.
    6. I do not know.

58. When Mendel crossed pure breeding tall pea plants with pure breeding short pea plants, the progeny plants were all tall. This was because the ...
    1. alleles for tallness and shortness were codominant.
    2. alleles for tallness were in the homozygous state.
    3. alleles for tallness and shortness were assorting independently.
    4. allele for shortness was recessive.
    5. alleles for shortness were in the homozygous state
    6. I do not know.

59. The monohybrid F_2 phenotypic ratio of a trait with co-dominant alleles is ...
    1. 1:1.
    2. 3:1
    3. 1:2:1
    4. 1:1:1:1
    5. 9:3:4
    6. I do not know.

60. In pea plants, the allele for yellow flowers is dominant to the allele for green flowers. If a heterozygous yellow-flowered plant is crossed with a green flowered plant, what is the expected progeny phenotypic ratio?
    1. All yellow
    2. 1 yellow: 1 green
    3. 1 yellow: 2 pink: 1 green
    4. 3 yellow: 1 green
    5. 2 yellow: 1 green
    6. I do not know.

61. The alleles in the gametes of an F_1 individual in monohybrid cross are in the ratio ....
    1. 1:1
    2. 1:2
    3. 1:1:1:1
    4. 9:3:3:1
    5. 1:2:1
    6. I do not know

62. Mendel verified true-breeding pea plants for certain traits before undertaking his experiments. The term "true-breeding" refers to .....
    1. genetically pure lines.
    2. organism that have a high rate of reproduction.
    3. organism that will produce identical copies of themselves upon reproduction.
    4. organism that are homozygous for all possible traits.
    5. 1 and 3 above.
    6. I do not know

63. In one experiment, Mendel studied the inheritance pattern of two traits (seed shape and seed colour). Mendel's aim was to find out whether the ...
    1. two traits are linked to each other or not.
    2. genes of the two alleles are inherited together or separately.
    3. alleles of the two traits are inherited together or separately.
    4. alleles of the two traits segregate or not.
    5. traits of the two alleles segregate or not.
    6. I do not know.

64. If a cross between two sheep with black coat colour produced a white offspring, which of the following statements is true about this cross?
    1. The genotype of both parents is homozygous black.
    2. The genotype of both parents is heterozygous black.
    3. The alleles for coat colour are incompletely dominant to each other.
    4. The allele for white coat colour is dominant.
    5. The alleles for coat colour are codominant to each other.
    6. I do not know.

65. In a cross between a tall violet plant with the genotype TTVv and short white plant, what phenotypic ratio of the progeny would be expected from this cross?
    1. All tall violet.
    2. 1 tall violet: 1 short violet.
    3. 1 tall violet: 1 tall white: 1 short violet: 1 short white.
    4. 1 tall violet: 1 tall white.
    5. All short white.
    6. I do not know.

66. A farmer mates a homozygous tall, red tomato plant (TTRR) with a heterozygous tall, red tomato plant (TtRr). What is the percent chance that the offspring will be short plants with yellow fruits?
    1. 0%
    2. 25%
    3. 50%
    4. 75%
    5. 100%
    6. I do not know.

67. If the genotype of a dominant phenotype is not known, choose the cross which can be used to determine that genotype.
    1. RR x rr
    2. R_ x rr
    3. Rr x rr
    4. RR x RR
    5. rr x rr
    6. I do not know.

68. The progeny of a dihybrid test cross is expected to have ... phenotypes.
    1. 2
    2. 3
    3. 4
    4. 5
    5. 8
    6. I do not know.

69. Choose the expected dihybrid test cross progeny phenotypic ratio.
    1. 3:1
    2. 1:1:1:1
    3. 1:2:1
    4. 9:3:3:1
    5. 1:1
    6. I do not know.

70. If all the progeny of a monohybrid test cross have a dominant phenotype, it means the individual being tested is .....
    1. heterozygous dominant.
    2. homozygous recessive.
    3. homozygous dominant.
    4. heterozygous recessive.
    5. None of the above.
    6. I do not know

71. Choose the statement that is **correct** in relation to linked genes.
    1. Alleles of linked genes assort independently.
    2. Genes which are linked are found on different chromosomes.
    3. The number of parental phenotypes is the same as the number of recombinants among the dihybrid test cross progeny.
    4. The dihybrid test cross progeny phenotypes are in the ratio 1:1:1:1
    5. **The test cross progeny consist of both parental and recombinant phenotypes.**
    6. I do not know.

72. Autosomal gene linkage ....
    1. reduces the chances of segregation.
    2. prevents independent assortment.
    3. reduces the number of parental types in the F_2 generation.
    4. increases the number of recombinants in the F_2 generation.
    5. prevents synapsis.
    6. I do not know

73. Crossing over in diploid organisms is responsible for ....
    1. co-dominance of alleles.
    2. Incomplete dominance of alleles.
    3. independent assortment alleles of unlinked genes.
    4. recombination of alleles of linked genes.
    5. linkage between genes
    6. I do not know.

Use the information below to answer questions 74- 77.

One type of red flower colour in pea plants is controlled by two alleles R and r. The dominant allele R is responsible for red colour while the recessive allele r is responsible for white colour. A cross was carried out between two heterozygous red plants. The progeny plants consisted of 165 red flowered plants and 35 white flowered plants. A chi-squared test was carried out on the results of the progeny phenotypes.

74. The expected Mendelian progeny phenotypic ratio of this cross is ...
1. 1:1
2. 3:1
3. 4:1
4. 1:2:1
5. 9:3:31
6. I do not know.

75. The calculated χ^2 value is ...
1. 1.5
2. 3.84
3. 4.5
4. 6.0
5. 0.05
6. I do not know.

76. The tabulated χ^2 value at 0.05 probability is ...
1. 1.5
2. 3.84
3. 4.5
4. 6.0
5. 0.05
6. I do not know.

77. From the results of the chi-squared test it can be concluded that ...
1. the calculated χ^2 value is not significant.
2. the difference between the observed ratio and the expected ratio is not significant.
3. there are 2 degrees of freedom.
4. the two alleles are linked.
5. the progeny phenotypes are not in the expected Mendelian ratio.
6. I do not know.

78. If the blood group of a child is O, which of the following couples could not be biological parents of the child?
    1. Mother group A and father group B.
    2. Both mother and father group A.
    3. Mother group AB and father group O.
    4. Mother group B and father group O.
    5. Mother group A and father group O.
    6. I do not know.

79. The trait for plant height that Mendel studied in peas exhibited ..... variation.
    1. continuous
    2. discontinuous
    3. quantitative
    4. qualitative
    5. 2 and 4 above.
    6. I do not know

80. When heterozygous parents with recessive epistasis are crossed the progeny phenotype ratio is ...
    1. 9:1:1:3
    2. 9:3:1
    3. 9:3:4
    4. 9:3:3:1
    5. 12:3:1
    6. I do not know.

81. A typical dihybrid F_2 phenotypic ratio is ...
    1. 9:3:3:1
    2. 1:1:1:1
    3. 3:1
    4. 9:3:2
    5. 9:2:2:1
    6. I do not know.

82. A man suffering from haemophilia is married to a homozygous normal woman for the condition. Their offspring will ...
    1. all be haemophiliac.
    2. consist of haemophiliac boys only.
    3. consist of haemophiliac girls only.
    4. consist of 50% haemophiliac children and 50% normal children.
    5. all be normal.
    6. I do not know.

83. A female who is homozygous normal for colour vision marries a man who is colour blind. Choose the statement which is true about their offspring.
    1. All the children will be colour blind.
    2. All the children will have normal colour vision.
    3. All the sons will be colour blind.
    4. Half of the daughters will be carriers of colour blindness.
    5. Options 2 and 4 above are correct.
    6. I do not know.

84. The sex chromosomes of human females are .... and while the sex chromosomes for males are ....
    1. YY, XX
    2. XX, XY
    3. XX, YY
    4. XY, XY
    5. XX, XO
    6. I do not know

85. Haemophilia is more common in males because it is a ....
    1. recessive character carried by the Y chromosome.
    2. dominant character carried by the Y chromosome.
    3. dominant trait carried by the X chromosome.
    4. recessive trait carried by the X chromosome.
    5. mutant allele in males than in females.
    6. I do not know.

86. If a man and his son are both hemophiliac, but his wife is normal, her genotype must be ....
    1. $X^h X^h$
    2. $X^H X^h$
    3. $X^H X^H$
    4. $X^H Y$
    5. XY
    6. I do not know

87. Choose the principle of heredity that Gregor Mendel **did not** use in his work.
    1. Dominance
    2. Recessive
    3. Gene interaction
    4. Independent assortment
    5. Test cross
    6. I do not know.

88. Albinism is a condition in which the affected individual lacks skin and eye pigmentation due to an autosomal recessive allele. If a homozygous normal male is married to a heterozygous female ...
    1. all their children will be homozygous normal.
    2. all their children will be heterozygous.
    3. 50% of their male children will be heterozygous.
    4. 50% of their female children will be albino.
    5. all their children will be albino.
    6. I do not know.

89. Long radishes crossed with round radishes result in all oval radishes. The shape of radishes is controlled by ....
    1. two genes.
    2. multiple alleles.
    3. dominant alleles.
    4. codominant alleles
    5. incompletely dominant alleles.
    6. I do not know

90. The ABO blood group trait in humans is controlled by ....
    1. two alleles.
    2. incompletely dominant alleles.
    3. codominant alleles
    4. multiple alleles.
    5. 3 and 4 above.
    6. I do not know

91. A cross was made between blue flowered, short stalked plants and white flowered, long stalked plants. The results were as follows:

    400 blue, short
    400 white, long
    100 blue, long
    100 white, short

    Which of the above phenotypes are recombinants?
    1. blue, short
    2. white, short
    3. white, long
    4. blue, long
    5. 2 and 4 above
    6. I do not know.

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2017 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 2002: STATISTICAL ANALYSIS OF BIOLOGICAL DATA
THEORY PAPER

TIME: THREE HOURS

INSTRUCTIONS: ANSWER **FIVE** QUESTIONS. ILLUSTRATE YOUR ANSWER WHERE NECESSARY. A FORMULAE SHEET AND TWO STATISTICAL TABLES, THE NORMAL DISTRIBUTION AND THE *t* DISTRIBUTION ARE PROVIDED.

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1. (a) Define the following terms:
   i. Inferential statistics.
   ii. Measures of variation.
   iii. Correlation.
   iv. Type I error.

   (b) Briefly describe how the following samples are obtained.
   i. Systematic random sample.
   ii. Cluster sample.

   (c) Summarise the properties and uses of the mean, the median and the mode.

2. A group of women underwent an operation as part of cervical cancer treatment and urinary tract infection was observed in 12 of the subjects. The number of postoperative days until diagnosis of the urinary tract infection are shown below.

   16, 8, 10, 19, 49, 11, 15, 22, 6, 13, 15, 17

   Using the data set provided compute the following:
   (a) Mean.
   (b) Sample variance.
   (c) Sample standard deviation.
   (d) Coefficient of variation.
   (e) Interquartile range.

TURN OVER

3. Milligrams (mg) of sodium obtained by a dietician interested in comparing the sodium content of real eggs with the sodium content of artificial eggs are shown in below.

Artificial eggs (mg of sodium): 38, 16, 18, 24, 12, 30, 35, 32, 31, 30, 24, 35

Real eggs (mg of sodium): 26, 15, 12, 18, 24, 32, 14, 18, 16, 18, 22, 12

(a) Using the data provided construct two box plots on one graph.
(b) State which of the two has a higher content of sodium between artificial eggs and real eggs.
(c) Comment on the variability of the distribution of milligrams of sodium in real eggs and artificial eggs.

4. The number of grams of carbohydrates in a 340 milligrams serving of a regular soft drink for a random sample of soft drinks is shown below.

48	37	52	40	43	46	41	38
41	45	45	33	35	52	45	41
30	34	46	40				

(a) Calculate the point estimate of the mean number of carbohydrates in all brands of soft drinks.
(b) Determine which distribution between the z and t distributions should be used to find the confidence interval and explain why.
(c) Given that the sample variance, s^2 is 35.9, find the 95% confidence interval of the true mean.
(d) Explain why an interval estimate is better than a point estimate of a parameter.

5. (a) A survey of 500 men found that 60 of them were infected with athlete's foot, a contagious fungal infection that affects the skin on the feet. Find the 95% confidence interval of the true proportion of adults infected with athlete's foot.
(b) A researcher wishes to estimate the proportion of fish in Goma lakes infected with monogenean parasites. She wants to be 90% confident that her estimate is within 5% of the true proportion. Determine the sample size that should be taken if in a sample of 300 fish, 30 were infected with monogenean parasites.

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6. A physician claims that joggers' maximal volume oxygen uptake is greater than the average of all adults. A sample of 15 joggers has a mean of 40.6 millilitres per kilogram (ml/Kg) and a standard deviation of 6ml/kg.
   (a) State the hypotheses and identify the claim.
   (b) Given that the average of all adults is 36.7ml/Kg, compute the appropriate test value.
   (c) Determine whether there is enough evidence to support the physician's claim at $\alpha = 0.05$.

7. A student of Microbiology hypothesizes that the average number of coliform counts for male toilet floors are greater than the average number of coliform counts for female toilet floors. The student then collects 50 samples from male toilets and 50 samples from female toilets. She then processes the samples and obtains the following results:

   Mean coliform count for male toilets $\bar{X}_1 = 8.6$ and the sample standard deviation $s_1 = 3.3$.
   Mean coliform count for females toilets $\bar{X}_2 = 7.9$ and the sample standard deviation $s_2 = 3.3$.
   (a) State the hypotheses and identify the claim.
   (b) Compute the appropriate test value.
   (c) Determine whether there is enough evidence to support the student's claim at $\alpha = 0.10$.

8. Data obtained from a study of age(x) and systolic blood pressure(y) of 6 randomly selected subjects is shown in Table 1 below.

   Table 1: Age and systolic blood pressure of a random sample of 6 individuals.

Subject	Age x	pressure y
A	43	128
B	48	120
C	56	135
D	61	143
E	67	141
F	70	152

   (a) Compute the correlation coefficient for the data.
   (b) Determine the relationship between age and blood pressure.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
2017 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 2302: BASIC MICROBIOLOGY
THEORY PAPER

TIME: THREE HOURS

INSTRUCTIONS: ANSWER ANY **FIVE** QUESTIONS. ILLUSTRATE YOUR ANSWER WHERE NECESSARY. USE SEPARATE ANSWER BOOKS FOR EACH SECTION.

SECTION A

1. State three major methods of classification of culture media.

2. Describe Kochi's postulates.

3. Describe the process of endospore formation in two bacterial genera.

4. (a) Explain the function of the following in the bacterial cell:
   (i) Cell membrane.
   (ii) Cell wall.
   (b) Explain importance of the functions of cell membrane to the growth and persistence of prokaryotes.

SECTION B

5. Discuss types of virus symmetry.

6. Describe the replication process of a retrovirus.

7. (a) Discuss genome and mRNA formation in DNA viruses.
   (b) Discuss groups of viral proteins.

8. Summarise **each** of the following:
   (a) Mechanical transmission of plant viruses.
   (b) Ambiviruses.
   (c) Disease symptoms of plants infected by tobacco mosaic virus (TMV).
   (d) Viroid structure.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2017 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 2701: BASIC PHYSIOLOGY
THEORY PAPER

TIME: THREE HOURS

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

SECTION A: Plant Physiology

1. Summarise the light reactions of photosynthesis in oxygen-evolving organisms.

2. (a) List the inorganic nutrient elements essential for plant growth and development, distinguishing macronutrient elements and micronutrient elements.
   (b) For each nutrient element listed above state two functions of the inorganic nutrient element in plants.

3. (a) Discuss the chemiosmotic mechanism for polar auxin transport in stems and coleoptiles.
   (b) Outline the Cholodny-Went model for auxin action in phototropism.

4. Compare and contrast the actions of auxin and gibberellin in regard to stem elongation.

SECTION B: Animal Physiology

5. Discuss the roles of brainstem and receptors in the control of respiration in a human.

6. Summarise each of the following:
   (a) Feeding behavior.
   (b) Diabetes mellitus.
   (c) Parthenogenesis.
   (d) Oogenesis.

7. (a) Describe the digestive functions of the pancreas.
   (b) With reference to two specific examples, explain how homeostasis is achieved in animals.

TURN OVER

8. (a) Explain the role of Schwann cells and myelination in nerve fibres.
   (b) Discuss the transmission of action potentials from pre-synaptic to post-synaptic neurons.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2017 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 2812: DIVERSITY OF ANIMALS
THEORY PAPER

TIME: THREE HOURS

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

SECTION A: INVERTEBRATES

1. Describe the general characteristics of the phylum Sarcomastigophora.

2. Discuss the evolutionary theories on the origin of Metazoa.

3. Outline the major distinguishing characteristics of classes Polyplacophora, Gastropoda, Bivalvia and Cephalopoda.

4. Summarise each of the following:
   (a) Reproduction in protozoans.
   (b) Filter-feeding body forms in the phylum Porifera.
   (c) Habitat adaptations by free-living and parasitic Platyhelminthes.
   (d) Parasitism of nematodes.

SECTION B: VERTEBRATES

5. Summarise each of the following:
   (a) Cephalochordata.
   (b) Petromyzontiformes.
   (c) Sarcopterygii.
   (d) Tetrapoda.
   (e) Artiodactyla.

6. Compare and contrast classes Cyclostomata and Chondrichthyes.

7. Illustrate how the class Amphibia is representative of subphylum Gnathostomata.

8. Describe the subclasses of class Mammalia, giving examples of each subclass.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2017 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 3011: BIOLOGICAL DATA ANALYSIS AND EXPERIMENTAL DESIGN
THEORY PAPER

TIME: THREE HOURS

INSTRUCTIONS: ANSWER ANY **FIVE** QUESTIONS

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1. Data for a completely randomized design experiment with 3 treatments and 4 replications per treatment are shown in Table 1 below. The data represent protein percentage in maize at 2, 4 and 9 weeks (= treatments) after December 1 (2017) in Lusaka Province for the 2017/18 crop-growing season. Test the null hypothesis that there are no significant differences among the treatment means.

   Table 1. Protein percentage in maize at different periods of growth.

Replications	**Weeks after December 1, 2017 (= Treatments)**		
	2	**4**	**9**
1	38	16	13
2	24	20	7
3	26	18	9
4	29	14	13

2. A group of strawberry plants (n = 8) was grown in pots in a green house and the following measurements were taken on crop yield in grams and the corresponding level of nitrogen in parts per million present in the leaf at the time of harvesting.

Nitrogen (X):	2.50	2.55	2.54	2.56	2.68	2.55	2.62	2.57
Yield (Y):	247	245	266	277	284	251	275	241

   Calculate the correlation coefficient between X and Y and test the significance of the correlation.

TURN OVER

3. The measurements in Table 2, of the antennal length of 10 males and 10 females of the 6th developmental stage of the Armoured ground cricket, *Acanthoplus speiseri* Brancsik, were collected by a researcher.

Table 2. Measurements of length (mm) of antennae of the Armoured ground cricket.

Sex	Length of Antennae (mm)									
Male	76.1	70.0	61.0	62.5	53.0	52.0	37.4	62.0	89.0	76.7
Female	77.6	57.4	66.0	65.0	65.6	44.3	66.0	58.0	65.0	93.9

Assuming that population variances are equal, test the null hypothesis (NH) that the sexes have antennae of the same length.

4. A scientist studied the effect of auxin concentration (gm^{-2}) on root length on two genotypes, A and B of *Arabidopsis thaliana*, a model species commonly used in biological research, measured after 10 days exposure on growth media. The raw data is as presented in Table 3.

Table 3. Effect of Auxin on root length of *Arabidopsis thaliana* genotypes.

Auxin concentration (gm^{-2})	**Root Length (mm)**	
	Genotype A	**Genotype B**
1	2.8	5.2
2	2.4	5.4
3	3.1	6.1
4	2.5	4.4
5	3.5	10.8
6	3.6	9.1
7	6.7	8.1
8	8.6	11.0
9	5.3	14.5
10	10.1	12.4

Test the Null hypothesis that there is no significant difference in mean root length between genotypes A and B.

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5. The yields (Kg) of a crop in an experiment with three randomized blocks are shown in Table 4 below. The yield of crop D in block 1 was missing. Estimate the missing yield value and then conduct an ANOVA and test for the significance of the differences among yields.

Table 4. Crop yield in a Randomized Block Design experiment involving different crop varieties.

Crop variety	BLOCK		
	1	2	3
A	34.0	34.3	35.0
B	33.0	36.3	35.8
C	34.3	35.3	32,3
D	-	29.8	28.0

6. Results of an automobile exhaust emission study to compare the efficiency of four petrol additives (A, B, C & D) in reducing the amount of oxides emitted in exhaust gases are presented in Table 5.

Table 5. Amounts of nitrogen oxides emitted in automobile exhaust gases.

Driver	CAR			
	1	2	3	4
I	A = 28	B = 26	D = 20	C = 25
II	D = 23	C = 27	-	B = 27
III	B = 16	D = 13	C = 16	A = 19
IV	C = 17	A = 15	B = 20	D = 20

a. Indicate the additive with a missing value in the table and estimate the missing value.
b. Test the null hypothesis that there are no significant differences in efficiency among the additives.

7. The results of a survey in a rural area in Central Africa to compare the prevalence of infection with *Schistosoma mansoni*, a bilharzia parasite, among different occupations are presented in a 2x4 contingency Table 6. Test the N.H. that there was no association between risk of infection and occupation.

TURN OVER

Table 6. Risk of infection with *Schistosoma mansoni*, a bilharzia parasite in different occupations in a rural area in Central Africa.

Schistosoma mansoni	OCCUPATION				Total
	Fishermen	**Farmers**	**Traders**	**Craftsmen**	
Positive	22	21	17	15	75
Negative	13	22	41	14	90
Total	35	43	58	29	165

8. Display data presented in Table 7 in a scatter diagram and:
   a. Fit a regression line to the scatter diagram and
   b. Test the significance of the departure pf rho from zero.

Table 7. Regression analysis data.

X	1	2	4	5	8	10	12	15
Y	5	10	16	18	35	40	46	58

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2017 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 3022: BIOLOGY OF SEED PLANTS
THEORY PAPER

TIME: THREE HOURS

INSTRUCTIONS: ANSWER **FIVE** QUESTIONS. ILLUSTRATE YOUR ANSWER WHERE NECESSARY. USE SEPARATE ANSWER BOOKS FOR EACH SECTION.

SECTION A

1. Discuss the occurrence of stomata in eudicots, monocots and conifers, and the significance of leaf stomatal positions in relation to the epidermal layer and side of leaf.

2. Explain the distinction between C_3 and C_4 grasses based on the structure of the parenchyma bundle sheath.

3. Compare and contrast structure and function of the characteristic tissue types of seed plants.

4. Describe the phenomena of sapwood, heartwood and annual or growth rings in perennial seed plants.

SECTION B

5. Discuss the genetic control of pollination self-incompatibility in angiosperms.

6. Discuss the contribution of auxin and cytokinins to the formation and maintenance of the root apical meristem in angiosperms.

7. Discuss genetic determination of floral organ identity in the floral meristem following flowering induction.

8. Summarise the development, structure and function of endosperm types found in angiosperm seeds.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

2017 ACADEMIC YEAR

FINAL EXAMINATIONS

BIO 3132: COMMUNITY ECOLOGY
THEORY PAPER

TIME: THREE HOURS

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

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1. Describe the full sequence of an ecological succession after a terrestrial volcanic eruption.
2. Summarise each of the following:
   (a) Significance of first and second laws of thermodynamics in community ecology.
   (b) Energy flow in an ecosytem.
   (c) Species diversity.
   (d) Trophic structure.
3. Explain the theories of Climax community.
4. Discuss the Intermediate Disturbance Hypothesis.
5. Discuss the factors which affect primary production in aquatic ecosytems.
6. Compare and contrast the concept of dominance and species diversity in community organisation.
7. "Competition and predation are two forms of species interactions in a community that influence the co-existence of species". Discuss the validity of this statement.
8. Give a concise description of the impact of changes to a natural ecosytem system on species diversity.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2017 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 3412: GENETICS
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. Describe the lytic and lysogenic life cycles in bacteriophage.

2. Summarise each of the following:
   (a) Down syndrome.
   (b) Marfan Syndrome.

3. Explain the genetic cause, symptoms and inheritance pattern of cystic fibrosis.

4. Explain genetic exchange in bacterial cells.

SECTION B

5. (a) Explain how you can distinguish unlinked genes from completely linked and partially linked genes.
   (b) Explain how the Poisson distribution can be used to convert genetic distances in map units into distances in centiMorgans.
   (c) Explain the weaknesses of estimating genetic distance in map units.
   (d) Describe four types of genetics maps.

TURN OVER

6. Three genes of maize (Zea mays) R, D and Y lie on chromosome 8. The genetic distance between genes R and D is 15 map units and that between genes D and Y is 25 map units.

   (a) Draw the genetic map of chromosome 8 if the longest distance is between R and Y.
   (b) Write the genotypes of the double crossover progeny.
   (c) If the three genes were mapped based on 1000 progeny of a trihybrid testcross;
      (i) Estimate the number of double crossover plants that would be expected if there was no interference.
      (ii) Estimate the number of double crossover plants that would be expected if the coefficient of coincidence was 0.7.
      (iii)Express the distance between genes R and Y in map units and in centiMorgans.

7. A randomly mating human population has the following allele frequencies at the ABO blood group locus: $I^A = 0.152$ and $I^o = 0.719$. The I^A and I^B alleles are co-dominant with respect to each another, and both alleles are dominant over the I^o allele.

   (a) Express the Hardy Weinberg equilibrium formula for the ABO gene.
   (b) If you sample one thousand persons from this randomly mating population, calculate the number of persons that would fall into each of the following phenotypic categories:
      (i) Blood group A
      (ii) Blood group B
      (iii) Blood group AB
      (iv) Blood group O
   (c) Explain how the ABO blood group gene deviates from Mendel's monohybrid cross results.

8. Growth rate (body mass gained per day) and food conversion ratio (body mass gained per unit mass of feed taken) are very important polygenic characters in fish farming. Table 1 shows the variance estimates based on growth rate and food conversion ratio in a population of male Nile tilapia fish raised in a fish pond.

Table 1: Variance estimates on growth rate and food conversion ratio in male Nile tilapia fish.

Component of variance	Growth rate (grams/day)	Food conversion ratio (gram/gram)
V_A	52	43
$V_D + V_I$	9	6
V_E	39	51

(a) Using the results in Table 1, calculate the narrow-sense and broad-sense heritabilities for:
   (i) Growth rate.
   (ii) Food conversion ratio.
(b) Explain the importance of growth rate and food conversion ratio to a fish farmer.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2017 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 3412: GENETICS
THEORY PAPER

TIME: THREE HOURS

INSTRUCTIONS: ANSWER **QUESTION ONE** AND **ANY OTHER THREE** QUESTIONS.
A CHI-SQUARED TABLE IS PROVIDED.

SECTION A - COMPULSORY

1. In a triple test cross starting with parental types AABBCC and aabbcc, the testcross progeny phenotypes and their numbers are shown in Table 1.

Table 1: Results of a trihybrid test cross involving genes A, B and C

Phenotype	ABC	abc	Abc	aBC	ABc	abC	AbC	aBc
Progeny number	1761	1773	97	89	182	138	8	6

Study Table 1 and:

(a) Establish whether the three genes are linked or not
(b) Estimate the map distances in map units
(c) Estimate the map distances in centimorgans
(d) Calculate the value of interference

SECTION B – ANSWER ANY THREE QUESTIONS

2. In man the gene which controls the ability to taste the chemical phenyl thiocarbamide (PTC) has two alelles **T** and **t**. Tasting ability is conferred by the dominant allele **T** while the recessive allele **t** is for inability to taste. In one study, a group of 200 people were tested and it was found that 140 were tasters and 60 were non-tasters.

Determine:

(a) Genotype frequencies
(b) Allele frequencies

3. Describe the three major mechanisms of gene transfer in bacteria.

4. (a) List the assumptions made in the HWE.
   (b) Explain two applications of the Hardy-Weinberg Equilibrium.
   (c) Describe effective population size.

5. In a study of the genetic structure of a sample of 1000 humans, the frequencies of the ABO alleles where determined to be: $I^A = 0.43$; $I^B = 0.38$
   Use the results to estimate the number of individuals with each of the following blood groups:
   (a) Group A
   (b) Group B
   (c) Group AB
   (d) Group O

6. Supposing the mean height of the current population of eucalyptus trees is = 16.5m; variance = 2.5; Narrow sense heritability = 0.35. If the aim is to improve the height of these trees by breeding using the top 5%* of the current population to produce the next improved generation, estimate the following:
   (a) The intensity of selection, i
   (b) Selection coefficient, S
   (c) Response to selection, R
   (d) Mean of the offspring of select 5%.

   *The Z value consistent with 5% is *0.103*

END OF EXAMINATION

CHI SQUARED TABLE

		PROBABILITY										
		0.01	0.05	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
DEGREES OF FREEDOM	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

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2017 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 3601: PARASITOLOGY
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. (a) Describe the life cycle and pathogenesis of *Trypanosoma rhodesience.*
   (b) Describe the basic differences between Gambian and Rhodesian trypanosomiasis.

2. Describe the life cycle and pathogenesis of *Babesia bovis* in cattle.

3. Summarise the each of the following;
   (a) Transmission of *Toxoplasma gondii.*
   (b) Immunity in African trypanosomiasis.
   (c) Complications associated with severe falciparum malaria.
   (d) Prevention and control of leishmaniasis.

4. Illustrate and briefly describe the life cycles of the following organisms;
   (a) *Balantidium coli.*
   (b) *Plasmodium* species.

SECTION B

5. Discuss with examples the general characteristics of helminths.

6. Summarise each of the following with the aid of labelled diagrams:
   (a) The morphology of different eggs of human Schistosoma species
   (b) *Taenia solium* adult worm
   (c) Miracidium larva of *Fasciola hepatica*

7. Describe the life cycle of *Schistosoma haematobium* and indicate the sequences in the life cycle that could easily be broken to prevent and control the disease caused by this parasite.

TURN OVER

8. (a) With the aid of labelled diagrams describe the following stages in the life cycle of *Fasciola hepatica.*
   (i) Reproductive stages
   (ii) Resistant stages

   (b) Describe the transmission of the cysticercus of *Taenia solium* to the primary host.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

INSTITUTE OF DISTANCE EDUCATION

SCHOOL OF NATURAL SCIENCES

2017 ACADEMIC YEAR

FINAL EXAMINATION

BIO 3721: PLANT PHYSIOLOGY
THEORY PAPER

TIME: THREE HOUR

INSTRUCTIONS: ANSWER **FIVE** QUESTIONS.

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1. Compare and contrast $NADP^+$-me and NAD^+- me subtypes of C4 photosynthesis.
2. Summaries adaptations of treachery elements of water conduction in plants.
3. Discuss the principle of the shed avoidance and how it relates to auxin facilitated growth.
4. Summaries the following:
   (b) The role of phytochromes in flowering of short and long day plants.
   (c) Signal transduction events leading to de-etiolation.
5. Summaries the role of auxins:
   (a) In tropisms through the regulation of differential growth patterns;
      - Geotropism using the statoliths hypothesis.
      - Phototropism.
      - Thigmotropism

   (b) Their application in agriculture:
      - Auxins as herbicides.
      - Auxins to control apical dominance.
      - Auxins and gibberellins to stimulate fruit development.

TURN OVER

6. Explain photoperiodic regulation of flowering in angiosperms. In your answer provide a model for the phytochrome pigment (Pr/Pfr) to demonstrate its role in flowering of:
   (a) Long-day plants and Short-day plants.
   (b) Given below are phytochrome data for two experimental plants. Predict and explain if they were grown under red or far red light.

Plant A: Pfr/total phytochrome = 0.03. Total phytochrome = 50 mg/kg dry weight

Plant B: Pfr/total phytochrome = 0.86. Total phytochrome = 1 mg/kg dry weight

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END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2017 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 3841: EVOLUTIONARY BIOLOGY
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 how the Galápagos Islands finches illustrate Charles Darwin's four postulates of biological evolution.

2. Describe the type of selection occurring in the Lake Tanganyika cichlid fish *Perissodus microlepis* with regard to mouth shape polymorphism.

3. With the help of an empirical example, explain the evolutionary significance of inversions.

4. Describe how the incidence of retinitis pigmentosa on Tristan da Cunha Island illustrates the founder effect.

SECTION B

5. Discuss the phenomenon of heterosis, giving at least two applications in which the phenomenon has been utilised.

6. In Labrador dogs (commonly called Labs), black coat colour is dominant to brown. Assume that the skin colour is controlled by two alleles B and b. For a Lab to have brown coat the genotype must be 'b,b' (chocolate labs). For the pigment to be deposited, it is influenced by a dominant allele symbolized by E. If the lab is homozygous recessive for the second locus (e,e) then the coat is yellow regardless of the genotype at the black/ brown locus.
   (a) How would you describe the gene at locus E/e?
   (b) Work out the genotypes of the F2 generation from a heterozygous cross BbEe x BbEe.
   (c) What are the possible phenotypic ratios of the cross?

7. Give a brief description of the prezygotic barriers that may impede members of two species from interbreeding and producing fit off-springs.

8. Explain the differences between allopatric and sympatric speciation.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2017 ACADEMIC YEAR
FINAL EXAMINATIONS

BS 4182: WILDLIFE AND RANGELAND MANAGEMENT
PRACTICAL PAPER

TIME: THREE HOURS

INSTRUCTIONS: ANSWER **ALL** QUESTIONS. ILLUSTRATE YOUR ANSWERS WHERE NECESSARY.

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1. Study specimens labeled **A1** to **A5**. For each specimen:
   (a) State the scientific name.
   (b) Describe the habitat in which the species is co-dominant

2. Examine specimens labeled **B1** to **B10**. For each specimen:
   (a) State the scientific name.
   (b) Describe the habitat in which it is commonly found.
   (c) Describe sex dimorphism of the species.
   (d) Describe breeding habits
   (e) Describe external features

3. An ecologist has carried out an assessment of range condition to determine the grazing capacity of the Lupande Game Management Area. The study shows that the range is suitable for Impala, Zebra, Wildebeest, Kudu and Buffalo. Ten per cent (10 %) of the range is a steep hill and in addition about 40% of the range is within 6.5 km from water. Furthermore, results indicate that the production of key forage species averages about 3,000kg/ha of dry matter biomass per year. The estimated grazing area of the GMA is 10,000 ha in size. Assuming that allowable use is 45% of the total biomass, and that the daily dry matter intake is 2% of the animal body weight,

(a) Calculate the number of 685 Kgs buffaloes you would allow as your base herd in the area.
(b) Calculate the number of hectares you would need to stock 200 zebras of 350 kg weight each per year in this Game Management Area.
(c) Discuss assumptions associated with this method.
(d) Discuss limitations of this method in estimating stocking rate of a wildlife species.

TURN OVER

4. Results of a study of habitat selection in Kafue National Park are presented in Figure1. The study was carried out during the rainy season. Study the figure and answer the following questions:
   (a) Discuss the results of habitat selection in Kafue National Park by the three wildlife species.
   (b) Draw possible conclusions from these results.
   (c) Discuss possible limitations and assumptions in determining wildlife habitat preference.

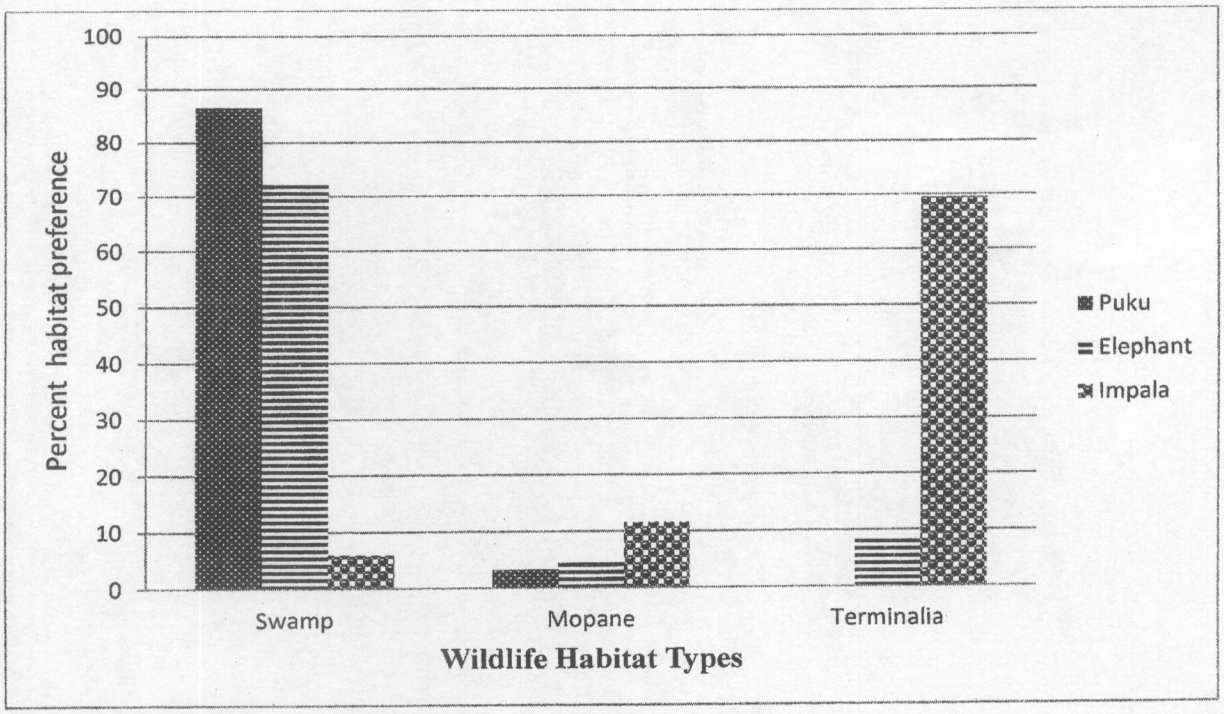

Figure1: Results of wildlife species habitat selection in Kafue National Park.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2017 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 4182: WILDLIFE AND RANGELAND MANAGEMENT
THEORY PAPER

TIME: THREE HOURS

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

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1. Compare and contrast the concepts of carrying capacity and stocking rate in the management of wildlife species.

2. Summarise each of the following:
   (a) Kidney/ Fat ratio.
   (b) King census method.
   (c) Limitations of the Cap-Chur gun.
   (d) Point- intercept method.

3. (a) Describe the appropriate procedure for estimating production of grazing dry matter biomass.
   (b) Discuss the protected area system in Zambia.

4. Discuss the following:
   (a) Threats to wildlife conservation in Zambia.
   (b) Harvesting strategies in wildlife management.

5. (a) Discuss characteristics of a wildlife habitat.
   (c) Describe the *Taurotragus oryx (Pallas, 1767)* in relation to:
      (i) External features.
      (ii) Sex dimorphism.
      (iii)Feeding habits.
      (iv)Distribution in Zambia.

6. (a) Describe methods used to determine $1 - e^{-H}$ for the purpose of exploiting wildlife populations.
   (b) Contrast chemical and mechanical capture methods in wildlife management.

TURN OVER

7. Discuss any **two** of the following:
   (a) Methods used in wildlife habitat improvement in a semi-arid environment.
   (b) Limitations of the Maximum Sustainable Yield concept.
   (c) Describe methods used in the restoration of a *Tragelaphus spekii* habitat.

8. Discuss the following:
   (a) Characteristics and effects of bush fires in a range land ecosystem.
   (b) Difficulties associated with the translocation and restocking operations in a game reserve.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2017 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 4341: INDUSTRIAL MICROBIOLOGY
THEORY PAPER

TIME: THREE HOURS

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

SECTION A

1 (a) Describe growth phases of a microbe growing on a suitable growth medium.
(b) Describe three primary and three secondary metabolites produced during the growth of a microbe in relation to their function.

2. Discuss biopolymer types synthesized by microbes and their uses.

3. Discuss biofertilizers with reference to types and function.

4. Discuss *Phanerochaete chrysosporium* with reference to its industrial application.

SECTION B

5. Discuss filamentous fungi as sources of enzymes and their significance in the production of high quality paper.

6. Discuss the role of four named enzymes of *Bacillus* spp. used in the production of detergents.

7. Explain with examples the significance of microbe-derived pectinases in the production of fruit juices.

8. Explain the importance of starter cultures of named microbes in the production of cheese.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2017 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 4621: ECOLOGY AND EPIDEMIOLOGY OF PARASITIC DISEASES
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. Discuss the roles of various stages of *Fasciola hepatica* in the overall life cycle of the parasite.

2. Explain the release mechanism of *Capillaria hepatica* from the fine structure of the liver of an infected host.

3. Discuss the daily periodicity of *Loa loa* that coincide with the periodic feeding habits of its vector.

4. Discuss the release mechanism employed by the adult female worm *Dracunculus medinensis* as an ecological adaptation for its larvae to gain access to next host without depending on a blood-sucking vector.

SECTION B

5. Explain how microparasite and macroparasite abundance is regulated in nature.

6. Discuss the various ways in which climatic factors influence the epidemiology of most parasitic diseases of humans.

7. Discuss the epidemiology of *Giardia lamblia.*

TURN OVER

8. Summarise each of the following:
   (a) Breakpoints in transmission of parasites
   (b) Factors that generate underdispersion and overdispersion of parasites in host populations.
   (c) Uses, advantages and disadvantages of cohort and case-control study designs.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2017 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 4641: IMMUNOLOGY
THEORY PAPER

TIME: THREE HOURS

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

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1. Compare and contrast each of the following:
   (a) Innate and acquired immunity.
   (b) Humoral and cell-mediated immunity.
   (c) T-cell receptor and B-cell receptor.

2. Explain how lysozyme secretion is able to destroy the cell wall of Gram-positive bacteria.

3. Contrast the properties of the different professional Antigen Presenting Cells (APCs) that affect their abilities to present antigen that induce T-cell activation.

4. Explain the classical pathway of complement activation in killing microbes.

5. Describe the structure, function and classes of antibodies.

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

7. Explain the role of interferons in the prevention of viral replication in a virus infected cell.

8. Explain how hematopoiesis gives rise to the various cells that make the immune system function.

END OF EXAMINATION

UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

FINAL [redacted]D EXAMINATIONS 2017/2018 ACADEMIC YEAR, SEPTEMBER 2016

C2615: BASIC PHYSICAL CHEMISTRY

Duration: Three (3) Hour

Instructions:

Answer any **four (4) questions.**

Answer each question in a **separate answer booklet.**

All questions carry equal marks. **(20 Marks)**

You are reminded to answer questions in a clear and logical manner.

Useful Information and Constants:

R= 8.314 $Jmol^{-1}$ K^{-1}, Molar volume of gas at STP = 22.4 dm^3mol^{-1}, STP = 273 K and 1 atm, 1 atm = 1 bar = 101325 Pa. Avogadro's constant = 6.02 x 10^{23} mol^{-1}, 1 F = 96485 C mol^{-1}

Question 1

(a) (i) Dalton's law of partial pressures states that the total pressure of a mixture of gases is the sum of the partial pressures of the components of the mixture. Which assumption of the kinetic molecular theory justifies this law? Explain in brief.

(ii) 200 mL of oxygen is collected over water at 25 °C and 1 atm. If the oxygen obtained is dried at constant temperature of 25 °C and 1 atm, what volume will it occupy?

(iii) What volume will be occupied by the water removed from the oxygen if maintained at 25 °C and 1 atm? (The equilibrium vapour pressure of water at 25 °C is 0.04 atm)

(b) Ethanol (C_2H_5OH), 0.167 g, was injected into a gas syringe and the syringe placed in a boiling water bath for several minutes. The atmospheric pressure was 101300 Pa and the temperature of the bath was 100 °C.

(i) Calculate the volume, in cm^3, of ethanol vapour that would have been produced under these conditions (use R = 8.314 J $K^{-1}mol^{-1}$.)

(ii) Explain why the gas syringe of 100 cm^3 capacity was found to be unsuitable.

Question 2

The feasibility of a chemical reaction depends on the standard free energy change, $\Delta G°$, which is related to the standard enthalpy and entropy changes by $\Delta G° = \Delta H° - T\Delta S°$. Use this information this information, where relevant, in answering the questions below.

(a) Ice melts at atmospheric pressure only if temperature rises above 0 °C.

(i) State the signs of the enthalpy and entropy changes during melting.

(ii) Explain why ice does not melt at temperatures below 0 °C.

(b) When sodium hydrogen carbonate is added to dilute hydrochloric acid, the temperature drops. Despite this, the reaction is spontaneous. Explain how this can be achieved.

(c) Give the signs of enthalpy, entropy and free energy change for combustion of propane. In ***each*** case give a reason for your answer.

Question 3

(a) What is half-life?

(b) Give equations you will use to calculate half-life for first, second and zero order reaction.

(c) One of the most dangerous radioisotopes in nuclear explosions or accidents is iodine - 131, which concentrates in the thyroid gland. The half - life of radioactive iodine - 131 is 8.0 days. What fraction of the initial iodine - 131 would be present after 24 days if none of it was eliminated though natural body process?

(d) The decomposition of NO_2 according to the equation $2NO_2 \rightarrow N_2 + 2\ O_2$ has a rate constant of 0.225 $M^{-1}\ s^{-1}$.

(i) What is the order of this reaction?

(ii) What is the rate law for the reaction?

(iii) How much (in g) NO_2 remains after 4.00s if the initial concentration of NO_2 is 33M.

(e) Give the integrated rate law equation for a reaction of the type A + B → Product and the reaction is first order with respect to both A and B.

Question 4

a) A 0.002 M $NaNO_3$ solution has a specific conductance 0.0242 Ω^{-1} m^{-1} and its **electric resistance** (R) in conductance cell is 1650 Ω. A solutions 0.002 M HCl measured in the same cell had resistance of 468 Ω.

(i) Calculate the cell constant.
(ii) Determines specific conductance of HCl
(iii) Find the molar conductance of HCl.

b) Consider a cell $Zn(s)|ZnCl_2(0.000772\ M)||\ AgCl(s)|Ag(s)$ at 25°C, with a measured emf 1.2475V.

(i) Write the overall cell reaction
(ii) Calculate the mean activity coefficient and activity of $ZnCl_2$ using the Debye-Huckel limiting law (show your working)
(iii) Calculate the emf of the cell

c) A potential of 12.0 volts was applied to two electrode placed 20 cm apart. A dilute solution of ammonium chloride was placed between the electrodes when NH_4^+ ion was found to cover a distance of 1.60 cm in one hour. What is the mobility of NH_4^+ ion?

Question 5

The following data has been reported for the cell:

$$Ag(s)|AgBr(s)|HBr(aq)|Br_2(g,1\,atm)|Pt(s)$$

The right electrode is the cathode.

t (°C)	442.3	456.0	490.9	521.4	538.3	556.2
E(V)	0.8031	0.7989	0.7887	0.7803	0.7751	0.7702

(a) Perform quadratic regression fitting of the above data.
(b) Calculate the emf of the cell at 500.0 °C.
(c) Find the temperature coefficient for this cell in V K^{-1}.
(d) Determine ΔG, ΔS and ΔH of the cell reaction at 500.0 °C.

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2017/2018 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 THREE 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. **ENSURE** that you have eight (8) printed pages containing questions A1 to A10 and B1 to B5.

ADDITIONAL INFORMATION TO THE CANDIDATES:

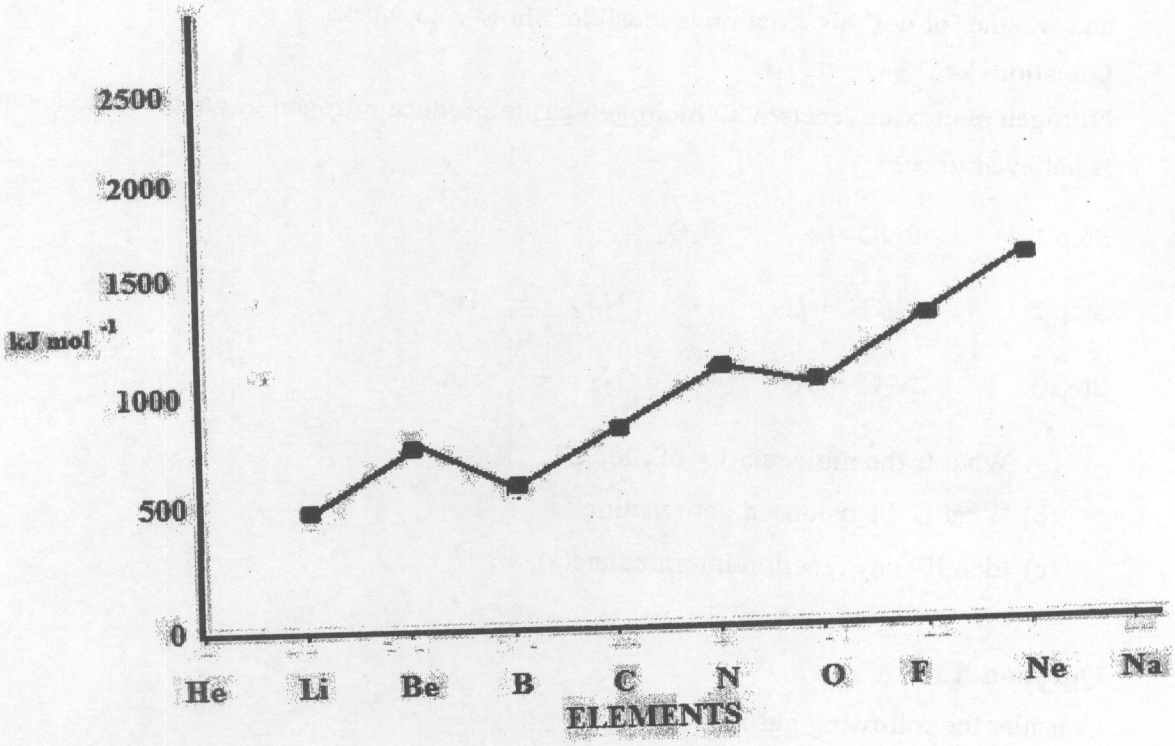
Useful data is provided on page 9.
Periodic Table of Elements is on last page.

SECTION A
ANSWER ALL QUESTIONS IN THE MAIN BOOKLET

Question A1

(a) Differentiate between an orbit and an orbital.

(b) Explain in brief the discontinuities in ionization energy of the elements in the second period as evidenced in the diagram below in going across a period



[4]

Question A2

(a) Define the photoelectric effect and state one condition that must be fulfilled for the photoelectric effect to be observed.

(b) The threshold frequency ν_0 for a metal is $6.0 \times 10^{13}\ s^{-1}$. Calculate the kinetic energy of an electron when the radiation of frequency $\nu = 1.0 \times 10^{14}\ s^{-1}$ hits the metal.

[4]

Question A3

Consider the following data:

Half equation	E /V
$Fe^{3+}(aq) + 3e^- \rightleftharpoons Fe(s)$	− 0.04
$Fe^{2+}(aq) + 2e^- \rightleftharpoons Fe(s)$	− 0.44

Use the data above to construct a redox equation for the reaction between Fe^{3+} (aq) and Fe(s), and whether or not this reaction is feasible. Show your work. **[4]**

Question A4

Nitrogen monoxide reacts with hydrogen gas to produce nitrogen gas and water. The mechanism is believed to be:

Step 1: $2NO \rightarrow N_2O_2$

Step 2: $N_2O_2 + H_2 \rightarrow N_2O + H_2O$

Step 3: $N_2O + H_2 \rightarrow N_2 + H_2O$

(a) What is the molecularity of Step 2?

(b) What is the balanced net reaction?

(c) Identify any reaction intermediate(s).

[4]

Question A5

Consider the following gaseous reaction:

$$SO_2Cl_2(g) \rightarrow SO_2(g) + Cl_2(g)$$

Experiment	Initial Concentration (mol dm^{-3})	Initial rate of formation of SO_2, R_0 (mol $dm^{-3}s^{-1}$)
1	0.100	2.2×10^{-6}
2	0.200	4.4×10^{-6}
3	0.300	6.6×10^{-6}

(a) Determine the rate Law for the reaction

(b) Calculate the rate constant for the reaction solution.

[4]

Question A6

Calculate the enthalpy change, ΔH_R, for the reaction

$$2NH_3(g) + CO_2(g) \rightarrow NH_2CONH_2(s) + H_2O(l)$$

Substance	Enthalpies of formation ΔH_f / kJ mol^{-1}
$NH_3(g)$	−46.2
$CO_2(g)$	−393.5
$NH_2CONH_2(s)$	−632.2
$H_2O(l)$	−285.8

[4]

Question A7

What is the vapour pressure of a solution at 298 K containing 68 g of glucose (M_r 180 g/mol) in 600 g of water? The vapor pressure of pure water at 298 K is 0.03173 bar. [4]

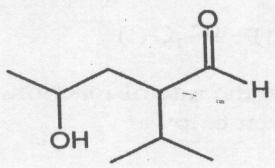
Question A8

Calculate ΔH_{vap} for ethanol, given vapor pressure at 313 K = 0.19999 bar. The normal boiling point for ethanol is 351 K.

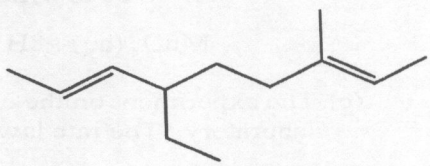
Question A9

Provide the IUPAC name for each of the following compounds:

(a)



(b)



[4]

Question A10

(a) Write the line formula for 4-aminobutanoic acid.

(b) Describe the highlighted carbon oxygen double bond of the ketene, $CH_2 = C = O$.

(c) Provide the stereochemical structure for the C*is*-alkene, C_4H_8, which has two vinylic and six allylic hydrogens.

[4]

SECTION B
ANSWER QUESTION B1 AND ANY THREE QUESTIONS
EACH IN A SEPARATE BOOKLET

Question B1

(a) The reaction of concentrated sulphuric acid with water is highly exothermic. Describe in one sentence how to dilute the acid. [1]

(b) In the laboratory, redox titration was performed involving the following reaction:

$$MnO_4^-(aq) + 5Fe^{2+}(aq) + 8H^+(aq) \rightarrow Mn^{2+}(aq) + 5Fe^{3+}(aq) + 4H_2O(l)$$

The reduction reaction takes place in an acidic medium (H^+). In the experiment sulphuric acid was added to Fe^{2+} solution in the conical flask. At the stoichiometric point or equivalent point, Fe^{2+} completely reacted with potassium permanganate.
The same redox reaction above can be used in a galvanic cell under condition of dynamic equilibrium.

(i) Describe in one sentence, in terms of number of moles, the effect of adding sulphuric acid to Fe^{2+} solution in the conical flask. [2]

(ii) Name the indicator in the titration and how the end-point is detected? [2]

(iii) List three chemicals in the half cell reduction reaction below, required for the half cell to be in dynamic equilibrium. [2]

$$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightleftharpoons Mn^{2+}(aq) + 4H_2O(l)$$

(c) The experiment on the effect of temperature on the rate of reaction was performed in the laboratory. The rate law for the reaction is given below:

$$\frac{\text{constant}}{t} = k[H^+]^m[S_2SO_3^{2-}(aq)]^n$$

(i) In the rate law equation, what is the name of the term on the left hand side of the equation. [1]

(ii) What mathematical rule or manipulation is done on the rate law to obtain a linear equation with $y = -\ln t$ and $x = 1/T$? [2]

(iii) Write the Arrhenius equation. [2]

(iv) Given that $E_a = 3.801 \times 10^4$ Jmol^{-1}
Calculate the slope b in the linear equation. [3]

Question B2

(a) State Grahams Law using the formula format. [4]

(b) Nickel forms a gaseous compound of the formula Ni(CO)x . If methane (CH_4) effuses 3.3 times faster than the compound, under the same conditions of temperature and pressure, calculate the value of x. [5]

(c) A flammable gas made up only of carbon and hydrogen is found to effuse through a porous barrier in 1.50 min. Under the same conditions of temperature and pressure, it takes an equal volume of bromine vapor 4.73 min to effuse through the same barrier.

(i) Calculate the molar mass of the unknown gas. [5]

(ii) Suggest the name of this gas. [1]

Question B3

(a) Write an equilibrium reaction equation for the ionization of acetic acid (CH_3COOH) in water and identify the conjugate acid-base pairs. [2]

(b) Some solid sodium acetate (CH_3COONa) is dissolved in 1 mol dm^{-3} solution of acetic acid.

(i) Write the equilibrium reaction. [1]

(ii) Explain the effect on the pH of the 1 mol dm^{-3} solution of acetic acid when the sodium acetate is dissolved. [4]

(c) Consider the reversible gas phase reaction:

$$SO_2Cl_2(g) \rightarrow SO_2(g) + Cl_2(g)$$

At 380 K, the equilibrium constant $K_p = 2.5$ bar

(i) Write the expression for K_p for the equilibrium. [2]

(ii) A sample of SO_2Cl_2 is introduced in an evacuated reaction vessel and brought to equilibrium at 380 K. If the sample and vessel are of such size that $p_{SO_2Cl_2} = 0.1$ bar at equilibrium; calculate the equilibrium values of p_{SO_2} and p_{Cl_2}. What is total gas pressure in the vessel? [6]

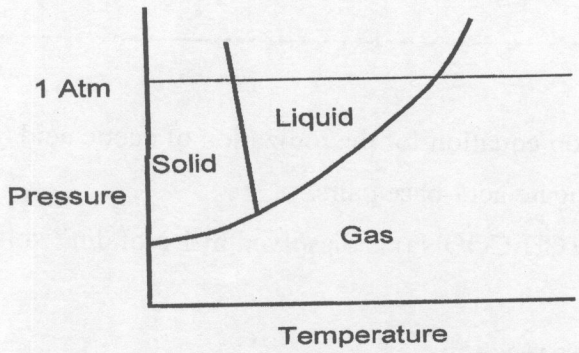
Question B4

(a) Calculate the ionisation energy of a hydrogen atom in its ground state i.e. when the hydrogen's electron is at level 1.

(b) (i) Draw the Lewis structure for the water H_2O molecule and use VSEPR theory to sketch the arrangement of electron pair in space. Name the geometrical shape illustrated.

(ii) For the molecule described in b (i) above show whether the molecule is polar or non-polar. Justify your answer.

(c) The diagram below shows a simplified phase diagram for water. Reproduce the phase diagram for water in your answer booklet and the answer the questions that follow.



(i) Indicate the triple point with the letter **A** and critical temperature **B.**

(ii) On the same diagram show the lines for the phase changes when a solute is added to water. Indicate the triple point for the solution as **C** and critical temperature **D**

Indicate on the diagram the position (temperature axis) ΔT_f and ΔT_b

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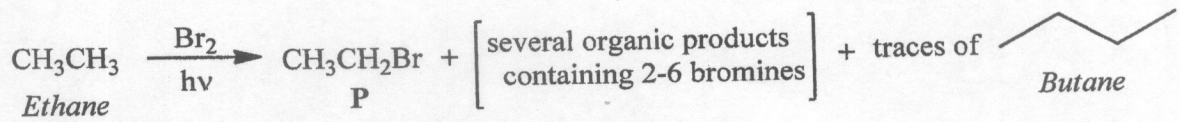
Question B5

(a) Consider the following reaction:



(i) Name the type of reaction. [1]

(ii) Provide detailed reaction mechanisms for formation of **P** from ethane. [6]

(iii) Propose a possible mechanism to account for the traces of butane found in the reaction mixture. [2]

(b) Consider a compound **X**, with molecular formula, C_3H_6O;

(i) Calculate the IHD (also called DBE and DU) of **X** and interpret it. [2]

(ii) Write any two (2) possible structures (line formulae) for **X**. [2]

(iii) Given that compound **X** is a primary alcohol which has 3 vinylic hydrogens, identify **X**, give line formula and IUPAC name. [2]

END OF EXAMINATION

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 $= 1.01325 \times 10^5$ Pa $= 1.01325 \times 10^5$ N m^{-2} = 760 torr = 760 mmHg = 1.01325 bar

1 bar $= 1.00000 \times 10^5$ Pa
$= 1.00000 \times 10^5$ N m^{-2}

Other conversion factors

V= J C^{-1} 1 eV $= 1.602 \times 10^{-19}$ J
1 J = 1 kg m^{2}s^{-2}

PERIODIC TABLE OF THE ELEMENTS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18

KEY

Atomic number
X
Atomic mass
Name of the element X

																1 **H** 1.01 Hydrogen	2 **He** 4.00 Helium
1 **H** 1.01 Hydrogen												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	10 **Ne** 20.18 Neon
3 **Li** 6.94 Lithium	4 **Be** 9.01 Beryllium											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	18 **Ar** 39.95 Argon
11 **Na** 23.00 Sodium	12 **Mg** 24.31 magnesium											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	36 **Kr** 83.80 Krypton
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	49 **In** 114.82 Inidum	50 **Sn** 118.71 Tin	51 **Sb** 121.76 Antimony	52 **Te** 127.60 Telluriu m	53 **I** 126.90 Iodine	54 **Xe** 131.29 Xenon
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	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	86 **Rn** 222.02 Radon
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	113	114 **Fl** 296	115	116 **Lv** **292**	117	118
87 **Fr** (223.02) Francium	88 **Ra** 226.03 Radium	89 - 103	104 **Rf** 261.11	105 **Db** 262.11	106 **Sg** 266	107 **Bh** 264	108 **Hs** 277	109 **Mf** 266	110 **Ds** 271	111 **Rg** 272	112 **Cm** 277						

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 Einstienium	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

2017 ACADEMIC YEAR MID-YEAR EXAMINATIONS

CHE 2001: AGRICULTURAL AND VETINARY CHEMISTRY

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

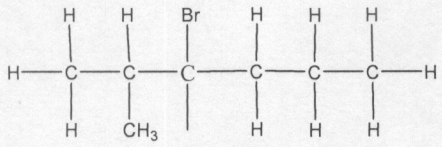
This examination consists of six (6) questions and FOUR (45) printed pages and the DATA sheet

QUESTION 1

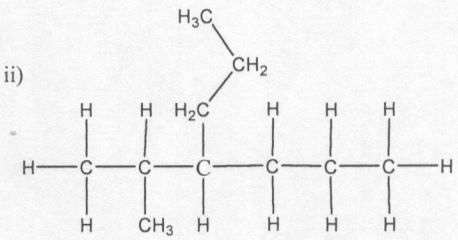
Name the following compounds

a) Provide the IUPAC name for each of the following compounds and draw the bond line structures for each of the two **[4 marks]**

i)



ii)



b) Consider the following reaction:

$$\underset{\textit{methane}}{CH_4} \xrightarrow[h\nu]{Br_2} \underset{\mathbf{P}}{CH_3Br} + \left[\text{several organic products containing 2-4 bromines}\right] + \text{traces of } \textit{ethane}$$

(i) Name the type of reaction. **[1 marks]**

(ii) Provide detailed reaction mechanisms for formation of **P** from methane. **[6 marks]**

(iii) Propose a possible mechanism to account for the traces of ethane found in the reaction mixture. **[2 marks]**

c) Consider a compound **X**, with molecular formula, C_5H_{10}.

(i) Define the term structural isomerism **[2 marks]**

(ii) Define the terms saturated and unsaturated hydrocarbon **[4 marks]**

(iii) Write four (4) possible structural isomers of X and translate them into (line formulae). **[4 marks]**

(iv) What is meant by the term esterification. **[2 marks]**

QUESTION 2

a) Write a note on SN2 reaction. In your discussion include the following aspects of the

I. nature of the substrate **[2 marks]**

II. The rate law **[2 marks]**

III. Give an example of a solvent used in the reaction **[1 marks]**

IV. Give a detailed mechanism of SN2 reaction **[5 marks]**

b) Write a note on the electrophilic addition reaction. In your discussion include the following aspects:

I. Nature of the reactants **[2 marks]**

II. State the Markovinkov rule **[2 marks]**

III. A detailed mechanism of SN1 reaction **[6 marks]**

IV. Give an example of solvent used in the reaction **[1 marks]**

c) Write the chemical reaction equation to represent the esterification reaction **[4 marks]**

QUESTION 3

a) A solution has concentration of hydroxide ions, $[OH^-] = 2.0 \times 10^{-3}$ M at 25^0C. What is the concentration of the hydrogen ion in this solution? Is the solution acidic or basic?

[6 marks]

b) The pH scale is used to determine acidity or alkalinity of a solution.

i. What does it mean for a solution to be acidic or alkaline?

ii. What is the pH of a 0.2 M solution of nitric acid (HNO_3)?

iii. What is the concentration of hydrogen ions $[H^+]$ present in a solution of pH= 14?

iv. A solution has pH=13, what type of solution is this based on this pH value?

[8 marks]

c) Write expressions for the autoionization (autoprotolysis) of the following substances:

i. H_2O

ii. CH_3OH

iii. CH_3NH_2

[6 marks]

QUESTION 4

a) What is the conjugate base of the following?

i. HCl

ii. HNO_3

[6 marks]

b) A solution has concentration of hydroxide ions, $[OH^-] = 3.0 \times 10^{-6}$ M at 25^0C. What is the concentration of the hydrogen ion in this solution? Is the solution acidic or basic?

[6 marks]

c) Write the equilibrium constant expression for the acid dissociation (K_a) for the following reaction:

$$CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$$

[8 marks]

QUESTION 5

a) Classify each of the following processes as endothermic or exothermic. In each case, draw an energy diagram to illustrate the heat content (enthalpy), reactants or products.

I. combustion of natural gas

II. condensation of water vapor

[4 marks]

b) 1674 J of heat are absorbed by 25.0 mL of an aqueous solution of NaOH (ρ = 1.10 g/mL, specific heat = 4.10 J/g °C). The temperature of the solution goes up how many degrees?

[6 marks]

c) 50.0 g of iron that has an initial temperature of 225 °C and 50.0 g of gold that has an initial temperature of 25.0 °C are brought into contact with one another. Assuming no heat is lost to the surroundings, what will be the temperature when the two metals reach thermal equilibrium? The specific heat capacity of iron = 0.449 J/g°C and gold = 0.128 J/g°C.

[10 marks]

QUESTION 6

a) Describe four conditions that affect the rate of a reaction and use the principles of the collision theory to explain why each factor affects the rate as it does.

[4marks]

b) The rate expression for a particular reaction is Rate = [A][B]2. If the initial concentration of B is increased from 0.1 M to 0.3 M, the initial rate will increase by what factor?

[6 marks]

c) A reaction has the experimental rate law of Rate = $k[A]^2$.

I. What happens to the rate if the concentration of A is tripled?

II. What happens to the rate if the concentration if A is reduced to one third the initial concentration?

[10 marks]

END OF EXAMINATION

The Periodic Table of the Elements

1 **H** Hydrogen 1.00794																	2 **He** Helium 4.003
3 **Li** Lithium 6.941	4 **Be** Beryllium 9.012182											5 **B** Boron 10.811	6 **C** Carbon 12.0107	7 **N** Nitrogen 14.00674	8 **O** Oxygen 15.9994	9 **F** Fluorine 18.9984032	10 **Ne** Neon 20.1797
11 **Na** Sodium 22.989770	12 **Mg** Magnesium 24.3050											13 **Al** Aluminum 26.981538	14 **Si** Silicon 28.0855	15 **P** Phosphorus 30.973761	16 **S** Sulfur 32.066	17 **Cl** Chlorine 35.4527	18 **Ar** Argon 39.948
19 **K** Potassium 39.0983	20 **Ca** Calcium 40.078	21 **Sc** Scandium 44.955910	22 **Ti** Titanium 47.867	23 **V** Vanadium 50.9415	24 **Cr** Chromium 51.9961	25 **Mn** Manganese 54.938049	26 **Fe** Iron 55.845	27 **Co** Cobalt 58.933200	28 **Ni** Nickel 58.6934	29 **Cu** Copper 63.546	30 **Zn** Zinc 65.39	31 **Ga** Gallium 69.723	32 **Ge** Germanium 72.61	33 **As** Arsenic 74.92160	34 **Se** Selenium 78.96	35 **Br** Bromine 79.904	36 **Kr** Krypton 83.80
37 **Rb** Rubidium 85.4678	38 **Sr** Strontium 87.62	39 **Y** Yttrium 88.90585	40 **Zr** Zirconium 91.224	41 **Nb** Niobium 92.90638	42 **Mo** Molybdenum 95.94	43 **Tc** Technetium (98)	44 **Ru** Ruthenium 101.07	45 **Rh** Rhodium 102.90550	46 **Pd** Palladium 106.42	47 **Ag** Silver 107.8682	48 **Cd** Cadmium 112.411	49 **In** Indium 114.818	50 **Sn** Tin 118.710	51 **Sb** Antimony 121.760	52 **Te** Tellurium 127.60	53 **I** Iodine 126.90447	54 **Xe** Xenon 131.29
55 **Cs** Cesium 132.90545	56 **Ba** Barium 137.327	57 **La** Lanthanum 138.9055	72 **Hf** Hafnium 178.49	73 **Ta** Tantalum 180.9479	74 **W** Tungsten 183.84	75 **Re** Rhenium 186.207	76 **Os** Osmium 190.23	77 **Ir** Iridium 192.217	78 **Pt** Platinum 195.078	79 **Au** Gold 196.96655	80 **Hg** Mercury 200.59	81 **Tl** Thallium 204.3833	82 **Pb** Lead 207.2	83 **Bi** Bismuth 208.98038	84 **Po** Polonium (209)	85 **At** Astatine (210)	86 **Rn** Radon (222)
87 **Fr** Francium (223)	88 **Ra** Radium (226)	89 **Ac** Actinium (227)	104 **Rf** Rutherfordium (261)	105 **Db** Dubnium (262)	106 **Sg** Seaborgium (263)	107 **Bh** Bohrium (262)	108 **Hs** Hassium (265)	109 **Mt** Meitnerium (266)	110 (269)	111 (272)	112 (277)	113	114				

58 **Ce** Cerium 140.116	59 **Pr** Praseodymium 140.90765	60 **Nd** Neodymium 144.24	61 **Pm** Promethium (145)	62 **Sm** Samarium 150.36	63 **Eu** Europium 151.964	64 **Gd** Gadolinium 157.25	65 **Tb** Terbium 158.92534	66 **Dy** Dysprosium 162.50	67 **Ho** Holmium 164.93032	68 **Er** Erbium 167.26	69 **Tm** Thulium 168.93421	70 **Yb** Ytterbium 173.04	71 **Lu** Lutetium 174.967
90 **Th** Thorium 232.0381	91 **Pa** Protactinium 231.03588	92 **U** Uranium 238.0289	93 **Np** Neptunium (237)	94 **Pu** Plutonium (244)	95 **Am** Americium (243)	96 **Cm** Curium (247)	97 **Bk** Berkelium (247)	98 **Cf** Californium (251)	99 **Es** Einsteinium (252)	100 **Fm** Fermium (257)	101 **Md** Mendelevium (258)	102 **No** Nobelium (259)	103 **Lr** Lawrencium (262)

1995 IUPAC masses and Approved Names from http://www.chem.qmw.ac.uk/iupac/AtWt/
masses for 107-111 from C&EN, March 13, 1995, p. 35
112 from http://www.gsi.de/z112e.html

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
CHEMISTRY DEPARTMENT
2017/2018 ACADEMIC YEAR FIRST HALF FINAL EXAMINATION

CHE 2015: General Analytical and Inorganic Chemistry

TIME: 3 HRS **12th July 2017**

INSTRUCTIONS TO THE CANDIDATES:

1. Indicate your **student ID number** on the provided answer scripts.
2. There are five questions in this paper; **you must answer question one (1) and any other three (3). Answer four in total.**
3. All questions carry equal marks.
4. There are **4 printed papers** for the questions; the periodic table and statistical table data sheet are attached at the end of the exam paper.
5. **YOU ARE REMINDED OF THE NEED TO ORGANISE AND PRESENT YOUR WORK CLEARLY AND LOGICALLY.**

Question 1

(a) What is the Z_{eff} on an extra electron added to nitrogen atom in the formation of anion? Compare this value when the **atom** is ionized.

(b) The magnetic moment, μ_s of $[Fe(H_2O)_6]^{3+}$ is 5.92 BM and that of $[Fe(CN)_6]^{3-}$ is 1.73 BM. Explain this on basis of crystal field theory.

(c) On the basis of Molecular Orbital Theory arrange the following in increasing O-O bond length order:

(i) KO_2 (ii) O_2

Question 2

a. When chlorine is added to drinking water to kill bacteria, some of the chlorine is changed into ions by the following equilibrium:

Cl_2 (aq) + $H_2O \rightarrow H^+$ (aq) + Cl^-(aq) + HOCl (aq). Use the Oxidation Number Method on the forward reaction to determine, which is the reductant in the reverse reaction.

b. A cell is established between two half-reactions:

$H_3AsO_4 + 2H^+ + 2e \rightarrow H_3AsO_3 + H_2O$, ($E^o = +0.559V$) and

$Zn \rightarrow Zn^{2+} + 2e$ ($E^o = -0.763V$). Write a balanced equation for the overall redox reaction; and, calculate the cell voltage.

c. Use the half reaction method to balance the following redox reaction which occur in acidic aqueous medium:

$IO_3^- + I^- \rightarrow I_2$ (for I_2/I^-, $E^o = +0.5345V$ and IO_3^-/I_2, $E^o = +1.20V$).

d. Balance the following equation occurring in basic medium:

$Cr(OH)_3 + Br_2 \longrightarrow CrO_4^{2-} + Br^-$

Question 3

a. The density of toluene (C_7H_8) is 0.867 g/mL, and the density of thiophene (C_4H_4S) is 1.065 g/mL. A solution is made by dissolving 9.660 g of thiophene in 260.0 mL of toluene.

i) Calculate the molality of thiophene in the solution.

ii) Assuming that the volumes of the solute and solvent are additive, determine the molarity of thiophene in the solution.

b. The K_w value that we normally use is for room temperature (25°C). Calculate the equilibrium H^+ concentration and pH of pure, neutral water at 0.0°C (K_w= 1.14 x 10^{-15} at 0.0°C) 0.1148 mol / 0.26907 L = 0.427 M.

c. Oxalic acid is a **diprotic acid**. Calculate the percent of oxalic acid ($H_2C_2O_4$) in a solid given that a 0.7984 g sample of that solid required 37.98 mL of 0.2283 N $Ba(OH)_2$ for neutralization.

d. Soil Sampling can be carried out using three common soil sampling plans. List these three sampling plans.

Question 4

a. By titration, the molarity of acetic acid in vinegar was determined to be 0.870 M. Convert this to %(v/v). (The density of acetic acid is 1.05 g/mL)

b. Calculate the standard deviation and the relative standard deviation for the following data:

Measurement No.	Value (g)
1	16.7724
2	16.7735
3	16.7722
4	16.7756
5	16.7729
6	16.7716
7	16.7720
8	16.7733

c. Define random errors **in brief**, state two sources of random errors and state how they can be minimized.

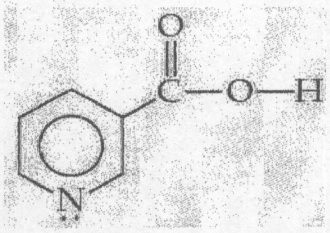
d. A given analytical test was performed five times. The results of the analysis are represented by the following values: 37.23, 32.91, 45.38, 35.22, and 41.81%. Would you say that these results are precise? Can you say that they are accurate? Explain both answers.

Question 5

a. How many grams of H_3PO_4 are in 175 mL of a 3.5 N solution of H_3PO_4?

b. You are developing a new colorimetric procedure for determining the glucose content of blood serum. You have chosen the standard Folin-Wu procedure with which to compare your results. From the following two sets of replicate analyses on the same sample, determine whether the variance of your method differs significantly from that of the standard method.

c. Niacin, one of the B vitamins, has the following molecular structure:



A 0.020 M solution of niacin has a pH of 3.26. What is the acid-dissociation constant, K_a, for niacin?

d. What is a representative sample? Do not use the words "represent" or "representative" in your answer.

>>>>>>>>>>>>>>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%
1	6.314	12.706	63.657
2	2.920	4.303	9.925
3	2.353	3.182	5.841
4	2.132	2.776	4.604
5	2.015	2.571	4.032
6	1.943	2.441	3.707
7	1.895	2.365	3.500
8	1.860	2.306	3.355
9	1.833	2.262	3.250
10	1.812	2.228	3.169
15	1.753	2.131	2.947
20	1.725	2.086	2.845
25	1.708	2.060	2.787
Infinite	1.645	1.960	2.576

3. Values of F at the 95% Confidence Level

v_1 =		2	3	4	5	6	7	8	9	10	15
v_2 =	2	19.0	19.2	19.2	19.3	19.3	19.4	19.4	19.42	19.4	19.4
	3	9.55	9.28	9.12	9.01	8.94	8.89	8.85	8.81	8.79	8.70
	4	6.94	6.59	6.39	6.26	6.16	6.09	6.04	6.00	5.96	5.86
	5	5.79	5.41	5.19	5.05	4.95	4.88	4.82	4.77	4.74	4.62
	6	5.14	4.76	4.53	4.39	4.28	4.21	4.15	4.10	4.06	3.94
	7	4.74	4.35	4.12	3.97	3.87	3.79	3.73	3.68	3.64	3.51
	8	4.46	4.07	3.84	3.69	3.58	3.50	3.44	3.39	3.35	3.22
	9	4.26	3.86	3.63	3.48	3.37	3.29	3.23	3.18	3.14	3.01
	10	4.10	3.71	3.48	3.33	3.22	3.14	3.07	3.02	2.98	2.85
	15	3.68	3.29	3.06	2.90	2.79	2.71	2.64	2.59	2.54	2.40
	20	3.49	3.10	2.87	2.71	2.60	2.51	2.45	2.39	2.35	2.20
	30	3.32	2.92	2.69	2.53	2.42	2.33	2.27	2.21	2.16	2.01

The Periodic Table of Elements

1	2											3	4	5	6	7	0 (8) (18)
							1.0 H hydrogen 1										4.0 He helium 2
(1)	(2)											(13)	(14)	(15)	(16)	(17)	
6.9 Li lithium 3	9.0 Be beryllium 4											10.8 B boron 5	12.0 C carbon 6	14.0 N nitrogen 7	16.0 O oxygen 8	19.0 F fluorine 9	20.2 Ne neon 10
23.0 Na sodium 11	24.3 Mg magnesium 12	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	27.0 Al aluminium 13	28.1 Si silicon 14	31.0 P phosphorus 15	32.1 S sulfur 16	35.5 Cl chlorine 17	39.9 Ar argon 18
39.1 K potassium 19	40.1 Ca calcium 20	45.0 Sc scandium 21	47.9 Ti titanium 22	50.9 V vanadium 23	52.0 Cr chromium 24	54.9 Mn manganese 25	55.8 Fe iron 26	58.9 Co cobalt 27	58.7 Ni nickel 28	63.5 Cu copper 29	65.4 Zn zinc 30	69.7 Ga gallium 31	72.6 Ge germanium 32	74.9 As arsenic 33	79.0 Se selenium 34	79.9 Br bromine 35	83.8 Kr krypton 36
85.5 Rb rubidium 37	87.6 Sr strontium 38	88.9 Y yttrium 39	91.2 Zr zirconium 40	92.9 Nb niobium 41	95.9 Mo molybdenum 42	[98] Tc technetium 43	101.1 Ru ruthenium 44	102.9 Rh rhodium 45	106.4 Pd palladium 46	107.9 Ag silver 47	112.4 Cd cadmium 48	114.8 In indium 49	118.7 Sn tin 50	121.8 Sb antimony 51	127.6 Te tellurium 52	126.9 I iodine 53	131.3 Xe xenon 54
132.9 Cs caesium 55	137.3 Ba barium 56	138.9 La* lanthanum 57	178.5 Hf hafnium 72	180.9 Ta tantalum 73	183.8 W tungsten 74	186.2 Re rhenium 75	190.2 Os osmium 76	192.2 Ir iridium 77	195.1 Pt platinum 78	197.0 Au gold 79	200.6 Hg mercury 80	204.4 Tl thallium 81	207.2 Pb lead 82	209.0 Bi bismuth 83	[209] Po polonium 84	[210] At astatine 85	[222] Rn radon 86
[223] Fr francium 87	[226] Ra radium 88	[227] Ac* actinium 89	[261] Rf rutherfordium 104	[262] Db dubnium 105	[266] Sg seaborgium 106	[264] Bh bohrium 107	[277] Hs hassium 108	[268] Mt meitnerium 109	[271] Ds darmstadtium 110	[272] Rg roentgenium 111							

Key

relative atomic mass
atomic symbol
name
atomic (proton) number

Elements with atomic numbers 112-116 have been reported but not fully authenticated

*Lanthanide series	140 Ce cerium 58	141 Pr praseodymium 59	144 Nd neodymium 60	[147] Pm promethium 61	150 Sm samarium 62	152 Eu europium 63	157 Gd gadolinium 64	159 Tb terbium 65	163 Dy dysprosium 66	165 Ho holmium 67	167 Er erbium 68	169 Tm thulium 69	173 Yb ytterbium 70	175 Lu lutetium 71
*Actinide series	232 Th thorium 90	[231] Pa protactinium 91	238 U uranium 92	[237] Np neptunium 93	[242] Pu plutonium 94	[243] Am americium 95	[247] Cm curium 96	[245] Bk berkelium 97	[251] Cf californium 98	[254] Es einsteinium 99	[253] Fm fermium 100	[256] Md mendelevium 101	[254] No nobelium 102	[257] Lr lawrencium 103

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

2017 ACADEMIC YEAR DEFFERED FINAL EXAMINATIONS

CHE 2112: INTRODUCTORY BIOCHEMISTRY

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) What is the **significance** of hydrogen bonding on the properties of water? **[2 marks]**

b) The K_a of formic acid (HCOOH) is 1.77×10^{-4} at 25 °C. What is the pH of a 0.01 M solution of formic acid in water? **[6 marks]**

c) You were introduced to the acetic acid- acetate buffer as part of the laboratory experiments. Suppose a buffer solution was 0.2 M in acetic acid and acetate. If the buffer species are **equimolar**,

i. **Calculate** the change in pH upon adding 1.0 ml of 0.1 M HCl to 10 ml of this solution. **[8 marks]**

ii. What **assumption did** you make in **part c** (i) to arrive at a mathematically correct estimate? (K_a of acetic acid is 1.75×10^{-5}) **[1 mark]**

Question 2

a) Using a sketch of a graph, **show** what most likely happens to the rate of reaction of a human enzyme when temperature is gradually raised from 15 °C to 90 °C. Briefly **explain** your answer. **[6 marks]**

b) Staring with any four (4) basic assumptions, **derive** the Michaelis-Menten equation. **[12 marks]**

c) The following data was obtained in a study of an enzyme known to follow Michaelis –Menten kinetics:

V_0 (µmol/min)	Substrate added (mmol/L)
215	0.5
320	2.0
430	4.8
490	5.9
650	1,000.0

Without plotting a graph, **calculate** the Km for this enzyme. Show all your steps (reasoning) clearly. **[2 marks]**

Question 3

a) Given the following peptide "LNGRSEAI".

i. **List** the full names of the amino acids in this peptide. **[2 marks]**

ii. **Identify** which are polar or non-polar. **[2 marks]**

iii. **What** is the net charge of this peptides shown above at pH 2.7? **[4 marks]**

b) A particular polypeptide chain containing 105 amino acids residues:

i. **Calculate** its length if It exists entirely in α- helical form. **[3 marks]**

ii. **Calculate** its length if the backbone bonds are fully extended and linear. **[3 marks]**

c) A mixture of amino acids can be separated by paper chromatography and electrophoresis. Ninhydrin is used to locate the position of amino acids on chromatograms. It reacts with ammonia, primary and secondary amine.

i. **Explain** in two to three sentences the principles underlying electrophoresis. **[2 marks]**

ii. **What** is the colour of the complex formed when ninhydrin reacts with proline? **[1 mark]**

iii. **Draw** the chemical structure of D-threonine and **calculate** the number of stereoisomers of threonine. **[3 marks]**

Question 4

The table below refers to some enzymes involved in the digestion of carbohydrates in the human digestive system.

a) **Copy** and **complete** the table by writing the correct word(s) for the site of secretion. For products of reaction, draw the respective chemical structures.

Name of enzyme	Name of substrate	Products of reaction
lactase		
sucrase		
maltase		

[3 marks]

b) **Draw** the Haworth projections of products formed by the action of sucrase in the table above. **[4 marks]**

c) Starch and cellulose are high molecular weight polysaccharides.

i. **Which** hexose sugar forms their basic unit? **[1 mark]**

ii. **What** is the essential structural difference between starch and cellulose? **[2 marks]**

iii. **Describe** mutarotation using glucose as an example **[6 Marks]**

iv. In a **tabular format**, list the reagents, colour produced, and sugars specific for the following reactions:

(a) Barfoeds test **[1 Mark]**
(b) Benedicts test **[1 Mark]**
(c) Molisch test **[1 Mark]**
(d) Seliwanoff test **[1 Mark]**

Question 5

Nucleic acids are macromolecules that are essential for life. The major nucleic acids are deoxyribonucleic acid (DNA) and ribonucleic acid (RNA).

a) List two difference in composition between DNA and RNA **[1 Marks]**

b) A sample of double – stranded DNA was found to have thymidylate as 21% of the nucleotide resides. If its percentage of thymidylate was increased to 33% would you expect the melting temperature of this strand to increase or decrease? Justify your answer. **[5 Marks]**

c) Adenosine triphosphate is a nucleotide.

i. **Draw** the chemical structure of Adenosine triphosphate **[3 Marks]**

ii. **Name** and **label** the chemical linkage joining adenine to ribose, ribose to phosphate, and linkages joining various phosphate in the Adenosine triphosphate. **[4 Marks]**

iii. **Draw** the chemical structure of any Adenosine nucleoside analogue used in treatment of HIV. **[3 Marks]**

iv. **Explain** how such a nucleoside analogue works in the treatment of HIV. **[4 Marks]**

Question 6

a) Lipids are molecules that are generally insoluble in water and soluble in non-polar solvents. Most lipids have fatty acids as their building blocks.

i. **What** is meant by rancidity of lipids? **[2 marks]**

ii. **Write** short notes on polyunsaturated lipids. (Hint: not more than five lines). **[2 marks]**

iii. Give the **systematic name**, **common name** and the **skeletal structure** for the following fatty acid given by the following notations: C18:3 cis $\Delta^{9,12,15}$ **[4 marks]**

b) **What** is the redox potential of the system NAD^+/NADH against hydrogen electrode, if the standard redox potential E_0' is – 0.32 V and ratio NAD^+/NADH is 10:1? (25°C, R = 8.3143 J K^{-1} mol^{-1}, F = 96 487 J V^{-1} mol^{-1})**[12 marks]**

END OF EXAMINATIONS

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
CHEMISTRY DEPARTMENT
2017/2018 ACADEMIC YEAR FIRST HALF FINAL EXAMINATION

CHE2219: CHEMICAL ANALYSIS

TIME: 3 HRS **12th July 2017**

INSTRUCTIONS TO THE CANDIDATES:

1. Indicate your **student ID number** on the provided answer scripts.
2. There are five questions in this paper; **Answer any four.**
3. All questions carry equal marks.
4. There are **4 printed papers** for the questions; the periodic table and statistical table data sheet are attached at the end of the exam paper.
5. **YOU ARE REMINDED OF THE NEED TO ORGANISE AND PRESENT YOUR WORK CLEARLY AND LOGICALLY.**

Question 1

a. When chlorine is added to drinking water to kill bacteria, some of the chlorine is changed into ions by the following equilibrium:

Cl_2 (aq) + $H_2O \rightarrow H^+$ (aq) + Cl^-(aq) + HOCl (aq). Use the Oxidation Number Method on the forward reaction to determine, which is the reductant in the reverse reaction.

b. A cell is established between two half-reactions:

$H_3AsO_4 + 2H^+ + 2e \rightarrow H_3AsO_3 + H_2O$, ($E^o = +0.559V$) and

$Zn \rightarrow Zn^{2+} + 2e$ ($E^o = -0.763V$). Write a balanced equation for the overall redox reaction; and, calculate the cell voltage.

c. Use the half reaction method to balance the following redox reaction which occur in acidic aqueous medium:

$IO_3^- + I^- \rightarrow I_2$ (for I_2/I^-, $E^o = +0.5345V$ and IO_3^-/I_2, $E^o = +1.20V$).

d. Balance the following equation occurring in basic medium:

$Cr(OH)_3 + Br_2 \longrightarrow CrO_4^{2-} + Br^-$

Question 2

The solubility product of $PbSO_4$ in water is 1.6×10^{-8} mol^2/dm^6.

a. Calculate the solubility of $PbSO_4$ in:-

(i) Pure water

(ii) 0.1M $Pb(NO_3)_2$ solution

(iii) 0.01M Na_2SO_4 solution

b. Why is $PbSO_4$ more soluble in water than in any solution containing either Pb^{2+} or SO_4^{2-}?

Question 3

a. The density of toluene (C_7H_8) is 0.867 g/mL, and the density of thiophene (C_4H_4S) is 1.065 g/mL. A solution is made by dissolving 9.660 g of thiophene in 260.0 mL of toluene.

i) Calculate the molality of thiophene in the solution.

ii) Assuming that the volumes of the solute and solvent are additive, determine the molarity of thiophene in the solution.

b. The K_w value that we normally use is for room temperature (25°C). Calculate the equilibrium H^+ concentration and pH of pure, neutral water at 0.0°C (K_w= 1.14 x 10^{-15} at 0.0°C) 0.1148 mol / 0.26907 L = 0.427 M.

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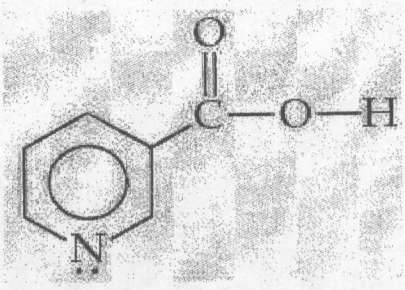

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20	1.725	2.086	2.845
25	1.708	2.060	2.787
Infinite	1.645	1.960	2.576

3. Values of F at the 95% Confidence Level

v_1 =		2	3	4	5	6	7	8	9	10	15
v_2 =	2	19.0	19.2	19.2	19.3	19.3	19.4	19.4	19.42.	19.4	19.4
	3	9.55	9.28	9.12	9.01	8.94	8.89	8.85	8.81	8.79	8.70
	4	6.94	6.59	6.39	6.26	6.16	6.09	6.04	6.00	5.96	5.86
	5	5.79	5.41	5.19	5.05	4.95	4.88	4.82	4.77	4.74	4.62
	6	5.14	4.76	4.53	4.39	4.28	4.21	4.15	4.10	4.06	3.94
	7	4.74	4.35	4.12	3.97	3.87	3.79	3.73	3.68	3.64	3.51
	8	4.46	4.07	3.84	3.69	3.58	3.50	3.44	3.39	3.35	3.22
	9	4.26	3.86	3.63	3.48	3.37	3.29	3.23	3.18	3.14	3.01
	10	4.10	3.71	3.48	3.33	3.22	3.14	3.07	3.02	2.98	2.85
	15	3.68	3.29	3.06	2.90	2.79	2.71	2.64	2.59	2.54	2.40
	20	3.49	3.10	2.87	2.71	2.60	2.51	2.45	2.39	2.35	2.20
	30	3.32	2.92	2.69	2.53	2.42	2.33	2.27	2.21	2.16	2.01

The Periodic Table of Elements

1	2											3	4	5	6	7	0 (8)
							1.0 H hydrogen 1										4.0 He helium 2
(1)	(2)											(13)	(14)	(15)	(16)	(17)	(18)
6.9 Li lithium 3	9.0 Be beryllium 4											10.8 B boron 5	12.0 C carbon 6	14.0 N nitrogen 7	16.0 O oxygen 8	19.0 F fluorine 9	20.2 Ne neon 10
23.0 Na sodium 11	24.3 Mg magnesium 12	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	27.0 Al aluminium 13	28.1 Si silicon 14	31.0 P phosphorus 15	32.1 S sulfur 16	35.5 Cl chlorine 17	39.9 Ar argon 18
39.1 K potassium 19	40.1 Ca calcium 20	45.0 Sc scandium 21	47.9 Ti titanium 22	50.9 V vanadium 23	52.0 Cr chromium 24	54.9 Mn manganese 25	55.8 Fe iron 26	58.9 Co cobalt 27	58.7 Ni nickel 28	63.5 Cu copper 29	65.4 Zn zinc 30	69.7 Ga gallium 31	72.6 Ge germanium 32	74.9 As arsenic 33	79.0 Se selenium 34	79.9 Br bromine 35	83.8 Kr krypton 36
85.5 Rb rubidium 37	87.6 Sr strontium 38	88.9 Y yttrium 39	91.2 Zr zirconium 40	92.9 Nb niobium 41	95.9 Mo molybdenum 42	[98] Tc technetium 43	101.1 Ru ruthenium 44	102.9 Rh rhodium 45	106.4 Pd palladium 46	107.9 Ag silver 47	112.4 Cd cadmium 48	114.8 In indium 49	118.7 Sn tin 50	121.8 Sb antimony 51	127.6 Te tellurium 52	126.9 I iodine 53	131.3 Xe xenon 54
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*actinide series	232 Th thorium 90	[231] Pa protactinium 91	238 U uranium 92	[237] Np neptunium 93	[242] Pu plutonium 94	[243] Am americium 95	[247] Cm curium 96	[245] Bk berkelium 97	[251] Cf californium 98	[254] Es einsteinium 99	[253] Fm fermium 100	[256] Md mendelevium 101	[254] No nobelium 102	[257] Lr lawrencium 103

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2017 ACADEMIC YEAR
MID YEAR EXAMINATIONS

CHE 2511: BASIC ORGANIC CHEMISTRY

INSTRUCTIONS TO CANDIDATES:

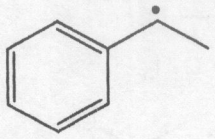
TIME ALLOWED: THREE (3) HOURS

1. This paper contains **five questions** and has six (6) printed pages. Please ensure that you have all printed pages.
2. **Answer any four (4) questions.**
3. Questions carry equal marks, **twenty five (25)**.
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 **neat** and **logical manner**, try to be to the point.

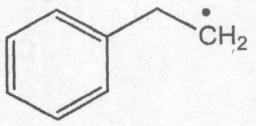
QUESTION 1

(a) Draw the possible stereochemical structures for the saturated chiral carboxylic acid, containing five carbon atoms and give the IUPAC name for *any one* of them. **(4 marks)**

(b) The radical **A** is more stable than radical **B**. State why? **(1 mark)**

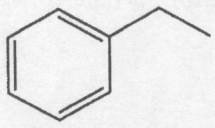


A

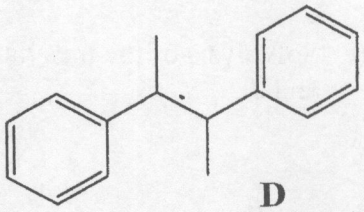


B

(c) Ethylbenzene was reacted with NBS in carbon tetrachloride in presence of the UV light at room temperature. The major organic product, **C**, isolated from the reaction mixture was found to be optically inactive. Traces of compound **D**, shown below, were also detected in the reaction mixture.



Ethylbenzene



D

(i) Identify the product **C** and give reaction mechanism. **(7 marks)**

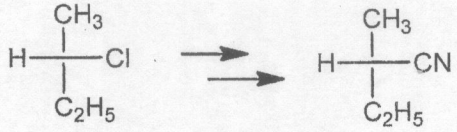
(ii) Provide a mechanistic explanation to account for the optical inactivity of the isolated product **C**. **(5 marks)**

(iii) Suggest a plausible mechanism for formation of the trace amount of **D** in this reaction. **(2 marks)**

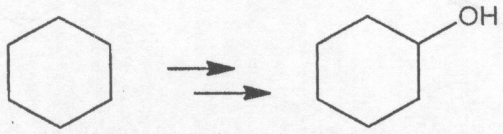
(d) A hydrocarbon **E** reacts with hydrogen iodide to form **F** which reacts with aqueous potassium hydroxide to give compound **G**. Oxidation of **G** with Jones reagent gives propanone. What are the structural formulas of **E**, **F**, and **G**? Show your reasoning. **(6 marks)**

QUESTION 2

(a) Suggest the shortest synthetic schemes for each of the following transformations. More than one step is required in each case. Show the reagents, solvents, reaction conditions, and intermediates for each step clearly. Please *do not* write reaction mechanisms.

(i) 

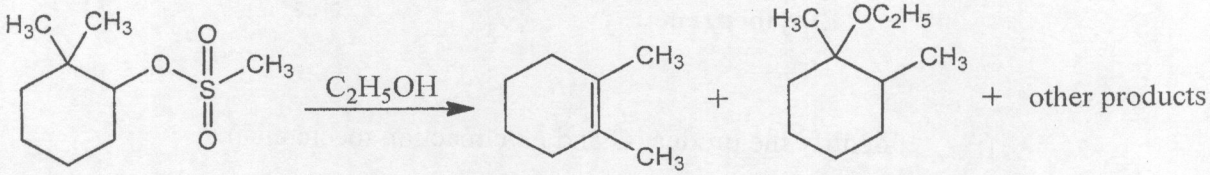
(4 marks)

(ii) 

(4 marks)

(b) Propose the stereochemical structure of the alkyl halide that gives only *E*-3-methyl-2-phenyl-2-pentene by E2 elimination. **(3 marks)**

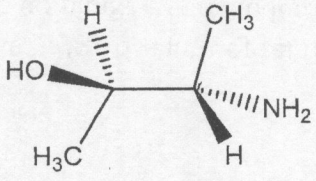
(c) Solvolysis of the mesylate **H** in aqueous ethanol gives a mixture of products, including **I** and **J**.



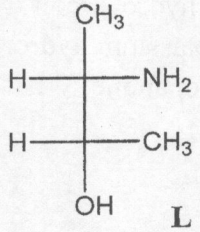
H **I** **J** (racemic)

Propose plausible reaction mechanisms to account for the products **I** and **J**. **(8 marks)**

(d) State the relationship between the compounds **K** and **L** as either identical, structural isomers, enantiomer, diastereomers or meso compound. Show your reasoning clearly. **(6 marks)**



K



L

QUESTION 3

(a) Sighting the (R)-2-methylbutane molecule along the C2-C3 bond:

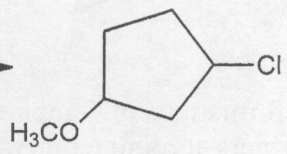
(i) Draw the Newman projections for all possible conformers. **(4 marks)**

(ii) Draw a qualitative graph of potential energy versus angle of rotation about the C2-C3 bond. **(4 marks)**

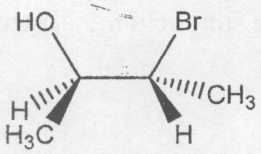
(iii) Given the "energy costs" in the table below, calculate and assign the quantitative energy values to your graph. **(6 marks)**

Interaction	**Energy Cost kJ.mol^{-1}**	**Interaction**	**Energy Cost kJ.mol^{-1}**
CH_3-CH_3 gauche	3.8	H-CH_3 eclipsed	6.0
H-H eclipsed	4.0	CH_3-CH_3 eclipsed	11.0

(b) Provide the structures, including stereochemistry, where pertinent, of the compounds **M** and **N**.

(i) **M** $\xrightarrow{HCl}$ 

(2 marks)

(ii) 

$\xrightarrow{Na}$ **N** (C_4H_8O)

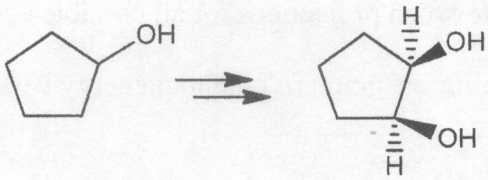
(3 marks)

(c) Identify the product and give mechanism of the reaction of (S)-2-butanol with thionyl chloride in presence of pyridine. **(6 marks)**

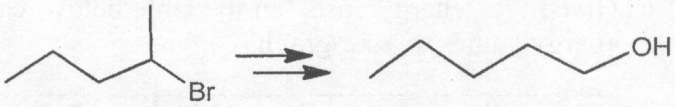
QUESTION 4

(a) Outline how you would make the following transformations. Show all steps clearly. Please *do not* write reaction mechanisms. **(8 marks)**

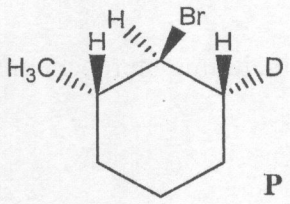
(i)



(ii)



(b) Upon heating with sodium ethoxide in ethanol, the compound **P** gave the product **Q**.



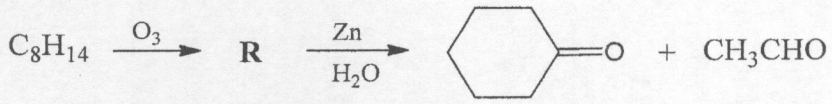
P

(i) Draw two chair conformations of compound **P** and show the equilibrium between the two chair conformers at room temperature. **(3 marks)**

(ii) Using appropriate conformational structure of **P**, provide the reaction mechanism, including the transition state, and the stereochemical structure of **Q**. **(5 marks)**

(c) Explain why 1-alkynes are acidic in nature. **(2 marks)**

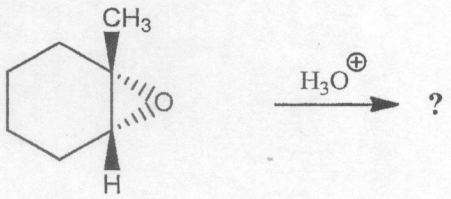
(d) (i) Determine the structure of the unknown compound, C_8H_{14}, from the following reaction. **(2 marks)**



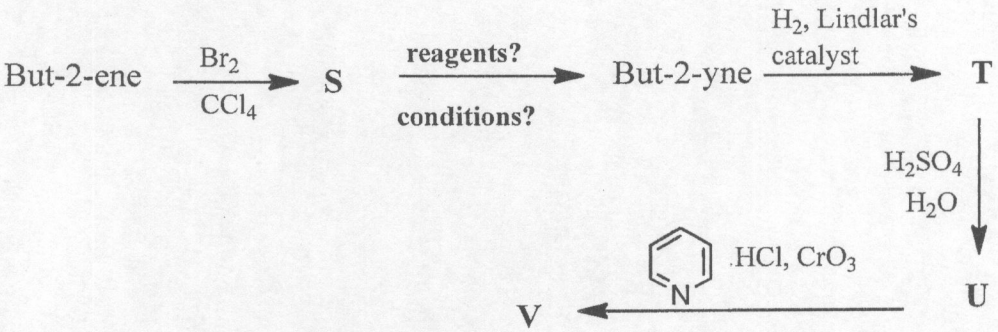
(ii) Provide the structure of **R** and the mechanism of its formation. **(5 marks)**

QUESTION 5

(a) Identify the product of the following reaction, showing the pertinent stereochemistry. **(3 marks)**

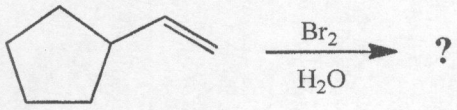


(b) (i) Provide the missing intermediates **S**, **T**, **U**, the product **V**, reaction conditions and reagents for the following synthesis. **(8 marks)**

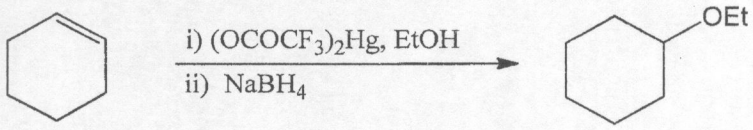


(ii) Give the composition of Lindlar's catalyst. **(2 marks)**

(c) Predict the major product and give a mechanism for the following reaction. **(7 marks)**



(d) Suggest a mechanism to account for the following ether synthesis. **(5 marks)**



END OF EXAMINATION
GOOD LUCK!

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2017 ACADEMIC YEAR
DEFERRED FINAL EXAMINATIONS

CHE 2511: BASIC ORGANIC CHEMISTRY

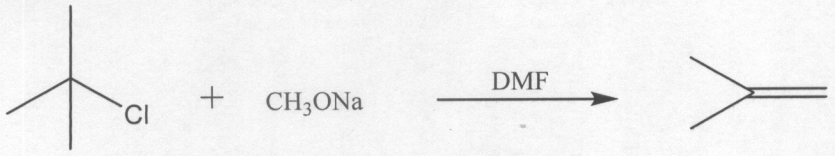
TIME ALLOWED: THREE (3) HOURS

INSTRUCTIONS:

1. Answer any four (4) questions.
2. Each question carries 25 marks.
3. Write your TG number (example: TG 9) on the cover page of each answer booklet.
4. Present your answers in a logical manner.
5. Begin each question on a new page.
6. Ensure that you have 5 printed pages and five (5) questions in this question paper.

QUESTION 1

(a) A CHE 2511 student attempted to prepare *tert*-butyl methyl ether, $(CH_3)_3COCH_3$, by Williamson ether synthesis by reacting *tert*-butyl chloride with sodium methoxide, but instead of the ether, she obtained an alkene, 2-methylpropene.



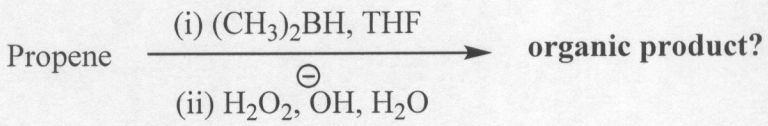
***tert*-Butyl chloride** **2-Methylpropene**

(i) Briefly explain why *tert*-butyl methyl ether was not obtained. **(2 marks)**

(ii) Give a mechanism to account for the 2-methylpropene product. **(2 marks)**

(iii) Show how you would prepare *tert*-butyl methyl ether by Williamson ether synthesis. **(3 marks)**

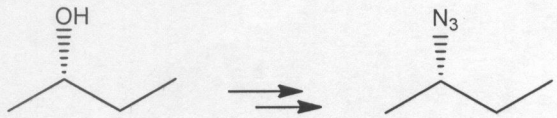
(b) Predict the major organic product and give the mechanism of the following reaction:



(8 marks)

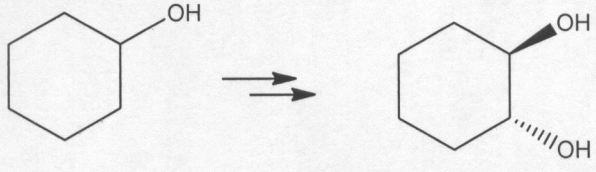
(c) Suggest how the following transformations can be achieved. More than one step are required, show all steps clearly. *Reaction mechanisms are NOT required*.

(i)



(5 marks)

(ii)



(5 marks)

QUESTION 2

(a) Use Fischer projections to draw all the stereoisomers of 3-amino-2-butanol. Give the complete names for **any two** of the stereoisomers. **(9 marks)**

(b) Predict the product and give the mechanism of the reaction of propene with NBS in presence of sunlight. **(6 marks)**

(c) Draw the following: **(2 marks each)**

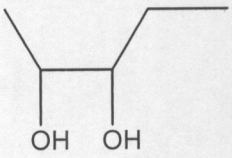
(i) A stable butterfly conformer for methylcyclobutane.
(ii) A stable envelope conformer for ethylcyclopentane.
(iii) A stable chair conformer for cis-1,3-diisopropylcyclohexane.

(d) Give the structures of the products from the following reactions. Reaction mechanisms are **not** required to be shown. **(2 marks each)**

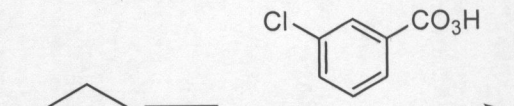
(i) Treatment of 1-methylcyclohexene with cold alkaline potassium permanganate.
(ii) Treatment of methylcyclopentene with hydrogen chloride.

QUESTION 3

(a) Provide the missing starting materials/reagents/solvents/conditions/products of the following reactions. Show the stereochemistry of reactants/products, where required.

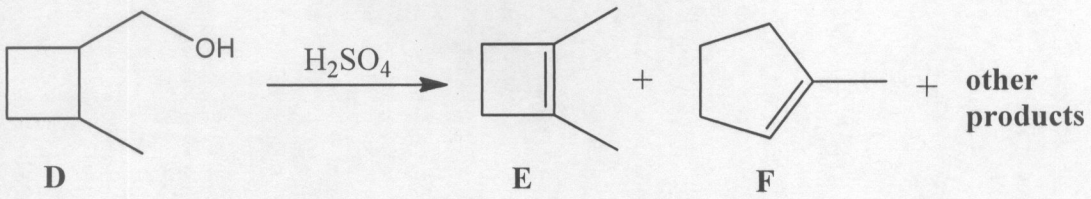
(i) *Cis*-2-pentene $\xrightarrow{OsO_4}$ **A** $\xrightarrow{\textbf{reagent?}}$ 

(2 marks)

(ii) **B** $\xrightarrow[\textbf{conditions?}]{\textbf{reagent?}}$ 

C **(4 marks)**

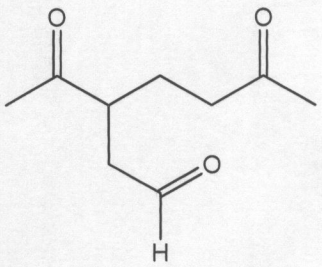
(b) Treatment of the alcohol **D** with sulphuric acid gives a complex mixture of products, including **E** and **F**. Propose a plausible mechanistic explanation to account for the products **E** and **F**. **(9 marks)**



D **E** **F**

(c) Limonene, $C_{10}H_{16}$, is a terpene found in lemon and orange oils. Upon treatment with excess hydrogen over a platinum catalyst, limonene gives 1-isopropyl-4-methyl-cyclohexane. Upon treatment with ozone and then with zinc and acetic acid, limonene gives methanal and a compound **G**:

Compound G:



(i) Calculate IHD of limonene and interpret it. **(2 marks)**

(ii) Propose a structure for limonene that is consistent with these experimental results. Justify your answer. **(7 marks)**

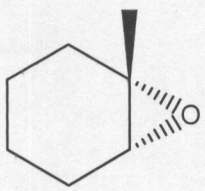
(iii) Provide the IUPAC name for compound **G**. **(1 mark)**

QUESTION 4

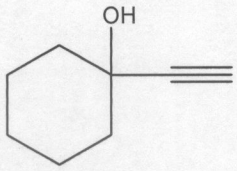
(a) Suggest the structure of an alkyl halide that gives only *E*-3-methyl-2-phenyl-2-pentene and none of the *Z*-isomer upon E2 elimination. Show the reaction. **(4 marks)**

(b) Identify the organic product(s), including pertinent stereochemistry, and give mechanisms of the following reactions:

(i) (R)- 2-Butanol $\xrightarrow[\text{Pyridine}]{\text{TsCl}}$ **P** $\xrightarrow[\text{THF}]{\text{KSH}}$ **Q** **(6 marks)**

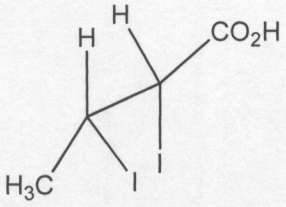
(ii)  $\xrightarrow[\text{(ii) } H_3O^{\oplus}]{\text{(i) } CH_3ONa}$ **R** **(4 marks)**

(c) Suggest a synthesis for compound **S** from any alcohol containing not more than six carbons and a hydrocarbon with two carbon atoms. Show all steps clearly. *Do not write reaction mechanisms.* **(5 marks)**

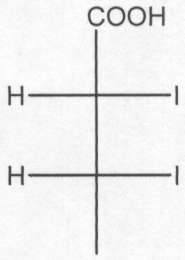


S

(d) State the isomeric relationship between the following pair of compounds. **(6 marks)**



and



QUESTION 5

(a) Draw the Newman projections for staggered and eclipsed conformers of butane along the C2-C3 bond and arrange them in increasing order of energy. **(6 marks)**

(b) Predict the organic product of the following reactions. Do not write reaction mechanisms. **(2 marks each)**

(i) Reaction of 1-butyne with aqueous sulphuric acid in presence of mercuric ions.
(ii) Reaction of cyclohexene with CH_2N_2 in presence of uv radiation.

(c) Propose a Grignard synthesis of 3-hexanol from 1-propanol as the only source of carbon atoms and any needed reagents. Show all steps clearly, including the reagents, solvents, conditions and intermediates for each step. *DO NOT write reaction mechanisms*. **(8 marks)**

(d) Write the mechanism for the reaction of (*S*)-2-pentanol with phosphorous tribromide. **(7 marks)**

END OF EXAMINATION
GOOD LUCK!

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2017 ACADEMIC YEAR
FINAL EXAMINATIONS

CHE 2522: FUNCTIONAL GROUP AND ARENE CHEMISTRY

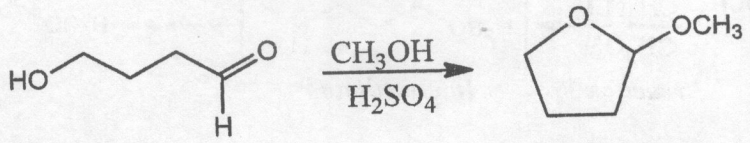
TIME ALLOWED: THREE (3) HOURS

INSTRUCTIONS:

1. Answer any FOUR (4) questions.
2. Present your answers in a logical manner.
3. Write your TG number (example: TG 9) on the cover page of each answer booklet.
4. Begin each new question on a new page.
5. Ensure you have six (6) printed pages containing five (5) questions.

QUESTION ONE

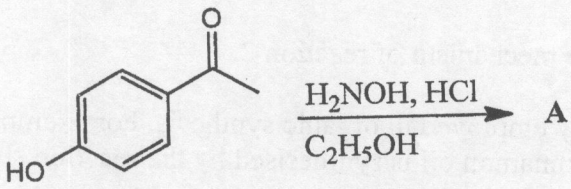
(a) Upon treatment with methanol in the presence of a strong proton acid, 4-hydroxybutanal gives 2-methoxytetrahydrofuran. Propose a plausible mechanism for the transformation. **(6 marks)**



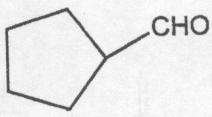
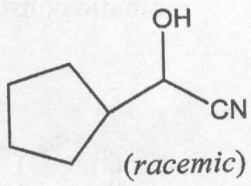
4-Hydroxybutanal *2-Methoxytetrahydrofuran*

(b) Provide the missing starting materials/products/reagents/conditions for the following reactions. *Do not write* reaction equations or mechanisms. **(13 marks)**

(i)



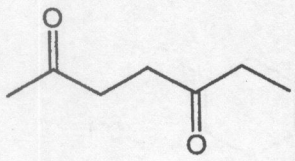
(2 marks)

(ii) **B** (an alcohol) $\xrightarrow[\textit{reaction 1}]{\text{reagents?}}$  $\xrightarrow[\textit{reaction 2}]{\text{reagents?}}$  *(racemic)*

reaction 3 (hydrolysis) $\xrightarrow[C_2H_5OH,\Delta]{H_2SO_4}$ **C**, $C_9H_{16}O_3$

(6 marks)

(iii)



intramolecular aldol

D, $C_7H_{10}O$ + **E**, $C_7H_{10}O$

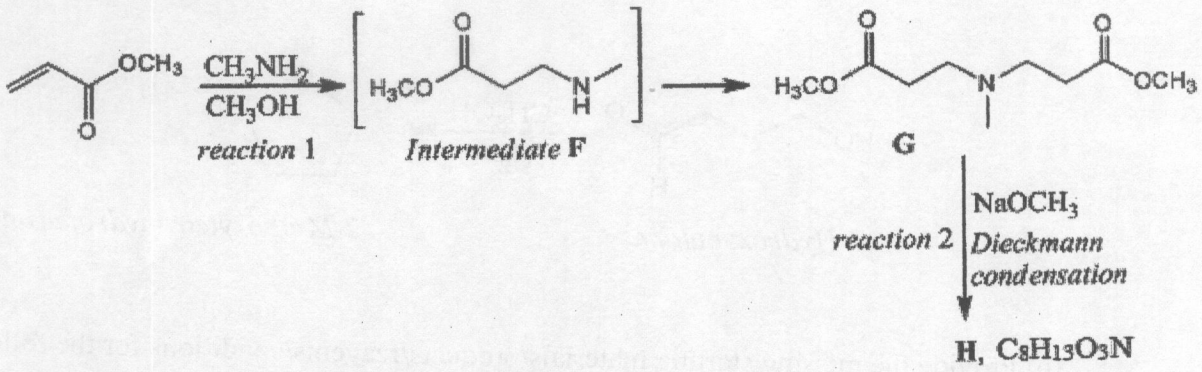
(major) *(minor)*

(5 marks)

(c) Suggest a synthesis of butanoic acid ($CH_3CH_2CH_2COOH$) from propanoic acid (CH_3CH_2COOH). Show all steps clearly, including the reagents, conditions and intermediates for each step. *Do not write reaction mechanisms*. **(6 marks)**

QUESTION TWO

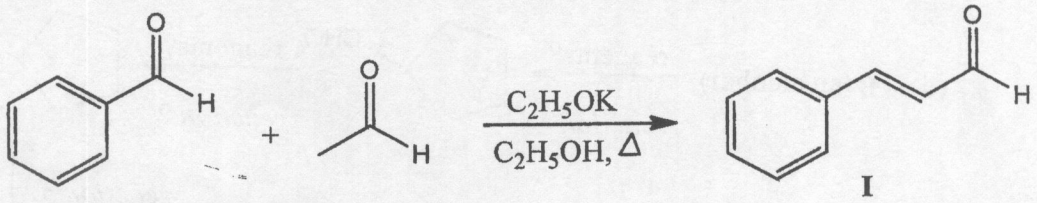
(a) Two steps of a procedure for the synthesis of 4-oxopiperidones are shown below:



(i) Provide a plausible mechanism to account for the formation of the intermediate **F** in reaction 1. **(4 marks)**

(ii) Identify **H** and give the mechanism of reaction 2. **(4 marks)**

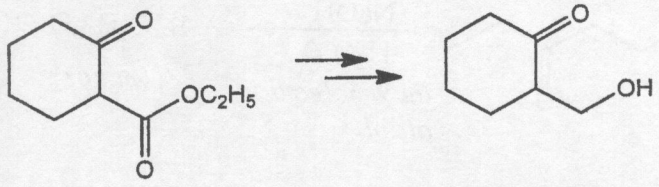
(b) Aldol condensations are widely employed in organic synthesis. For example, the aromatic constituent **I** of the cinnamon oil is synthesised by the reaction shown below:



Provide a detailed mechanism for the reaction. **(7 marks)**

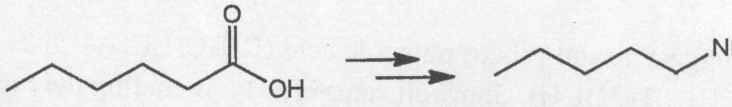
(c) Suggest efficient synthetic routes to the following transformations. More than one step is required. Show all steps, including the intermediates clearly. **(10 marks)**

(i)



(6 marks)

(ii)



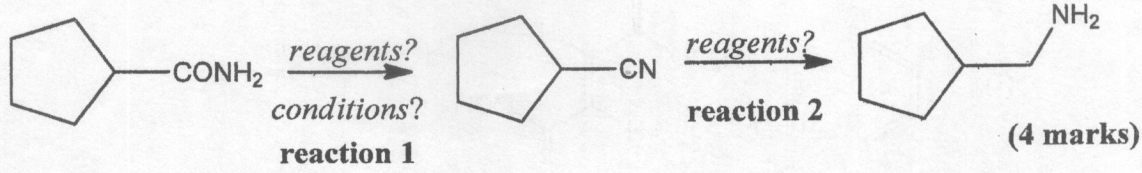
via Hofmann rearrangement

(4 marks)

QUESTION THREE

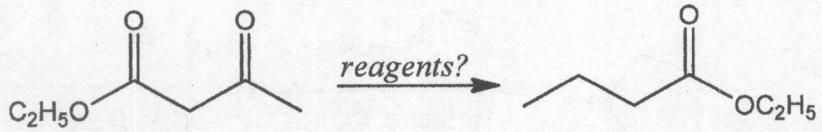
(a) Provide the reagents and conditions for the following transformations. *Please do not write reaction equations*. **(6 marks)**

(i)



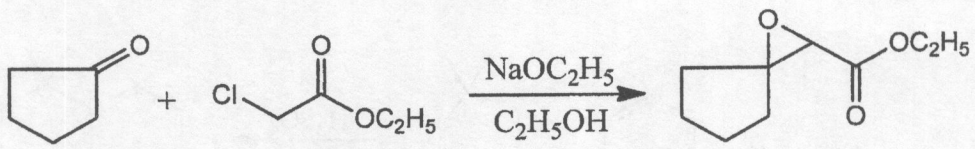
(4 marks)

(ii)



(2 marks)

(b) Base catalyzed condensation of ethyl chloroacetate **K** with a ketone gives an epoxy ester. The reaction is called Darzens condensation, an example is shown below:



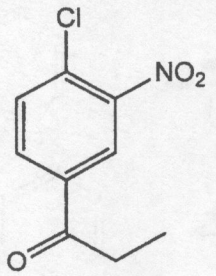
J **K**

(i) The α-hydrogens of compound **K** are more acidic than those of compound **J**. Explain why. **(2 marks)**

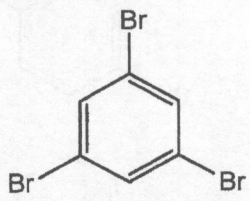
(ii) Darzens condensation involves two steps, the first step is a nucleophilic addition reaction and the second step is an intramolecular S_N2 reaction. On this basis, provide the mechanism of the Darzens condensation shown above. **(5 marks)**

(c) Propose the most efficient route for the synthesis of the following compounds starting from benzene. Show all steps clearly. *Do not write mechanisms*. **(12 marks)**

(i)



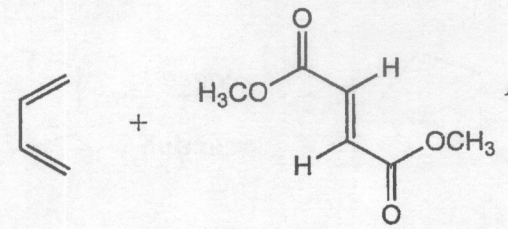
(ii)



QUESTION FOUR

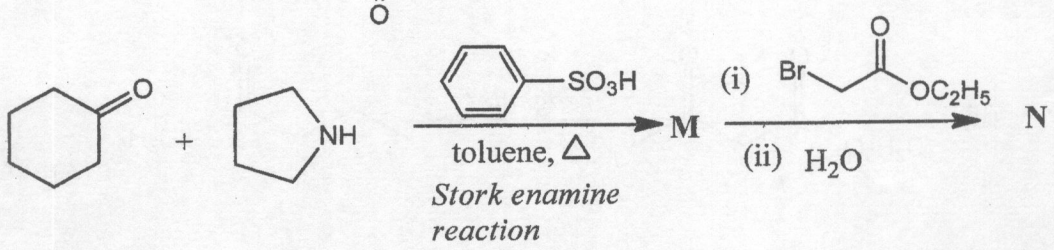
(a) Provide the structures, including the stereochemistry, where relevant, of the products **L-N** of the following reactions. *Do not write mechanisms*. **(6 marks)**

(i)



L

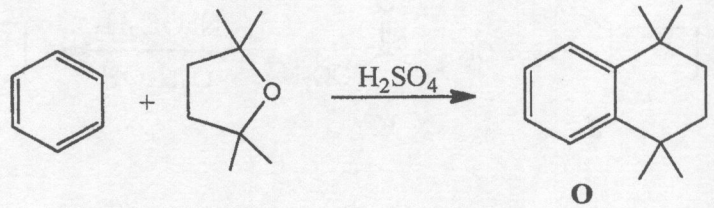
(ii)



M **N**

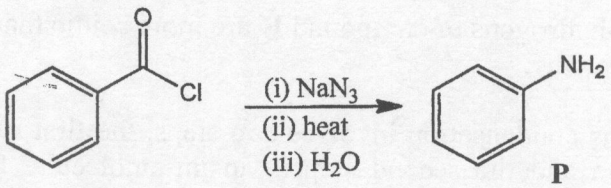
(b) Provide plausible mechanisms to account for the products of the following reactions: **(12 marks)**

(i)



O

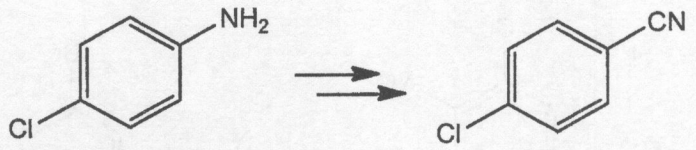
(ii)



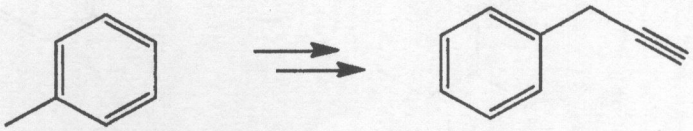
P

(c) Suggest the shortest synthesis for each of the following transformations. Show all steps, including the intermediates clearly. *Do not write reaction mechanisms*. **(7 marks)**

(i)

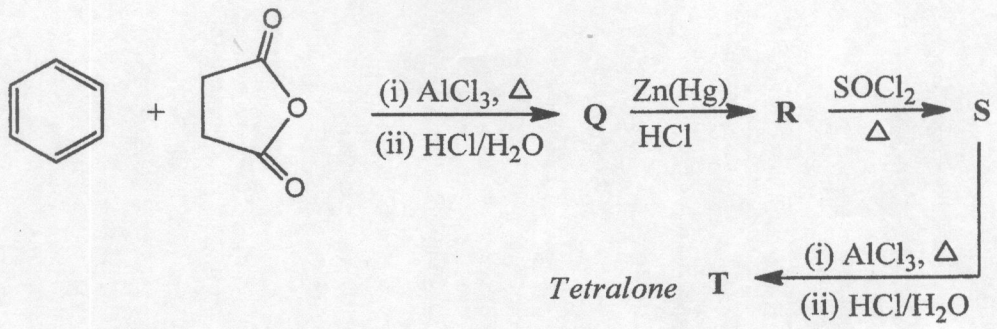


(ii)



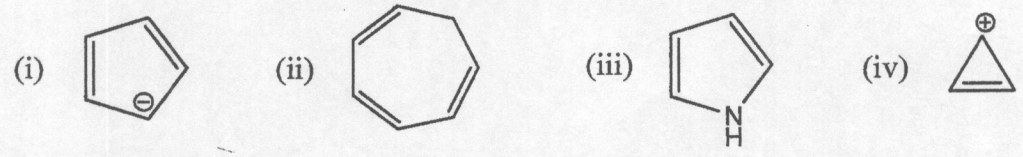
QUESTION 5

(a) Benzene is a starting point in the synthesis of many aromatic compounds. Tetralone can be synthesized using the following schemes of reactions. Provide the structures for the products, **Q-T**, of the following reactions. **(5 marks)**

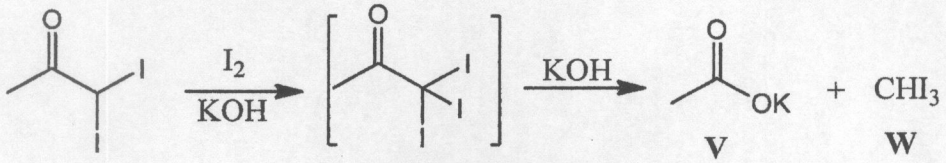


(b) Draw the π-molecular orbitals of the 1,3-pentadienyl anion and label the HOMO and LUMO **(7 marks)**

(c) Consider the following molecules and state, with a reason, which ones are aromatic, non-aromatic, or antiaromatic. **(6 marks)**



(d) Provide a mechanistic explanation to account for the intermediate **U** and the products **V** and **W** of the iodoform reaction shown below. **(7 marks)**



Intermediate **U**

END OF EXAMINATION
GOOD LUCK!

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2017 ACADEMIC YEAR
UNIVERSITY DEFERRED EXAMINATIONS

CHE 2522: FUNCTIONAL GROUP AND ARENE CHEMISTRY

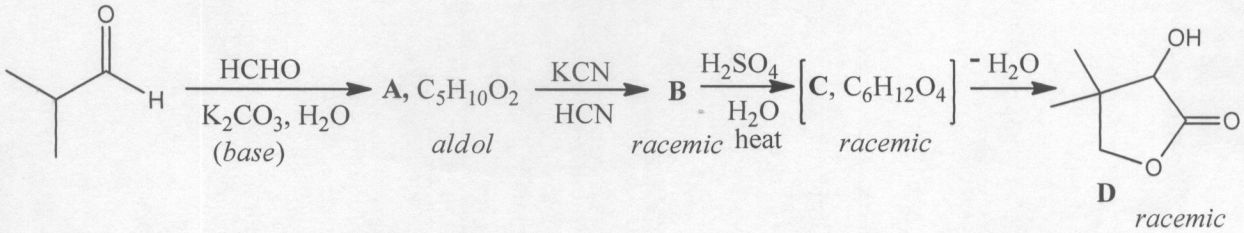
TIME ALLOWED: THREE (3) HOURS

INSTRUCTIONS:

1. Answer any FOUR (4) questions.
2. Present your answers in a logical manner.
3. Write your TG number (example: TG 9) on the cover page of each answer booklet.
4. Begin each new question on a new page.
5. Ensure you have 7 printed pages containing five (5) questions.

QUESTION ONE

(a) The compound **D**, an important intermediate in the synthesis of pantothenic acid, vitamin B5, was prepared by the route shown below:

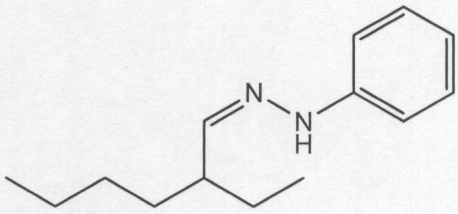


(i) Identify the intermediates **A-C** in the above synthesis. **(4 marks)**

(ii) Give the mechanism for the formation of **D** from **C**. **(5 marks)**

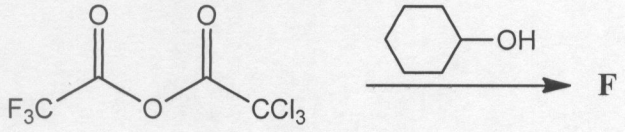
(b) Propose a synthesis of the compound **E** shown below, from any alcohols via an aldol condensation. Show all steps, including the intermediates clearly. *Do not write reaction mechanisms*. **(6 marks)**

E:

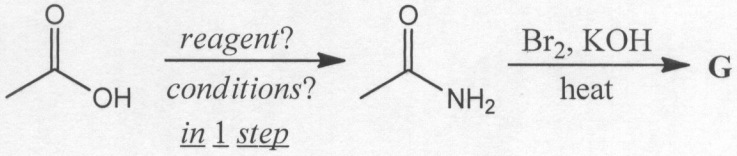


(c) Provide the missing reagents, conditions and the products **F** and **G** of the following reactions: **(4 marks)**

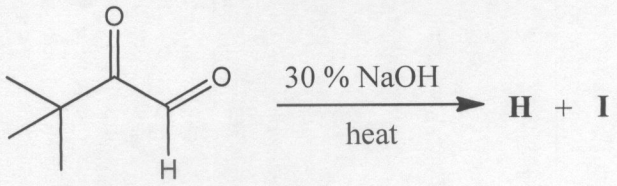
(i)



(ii)

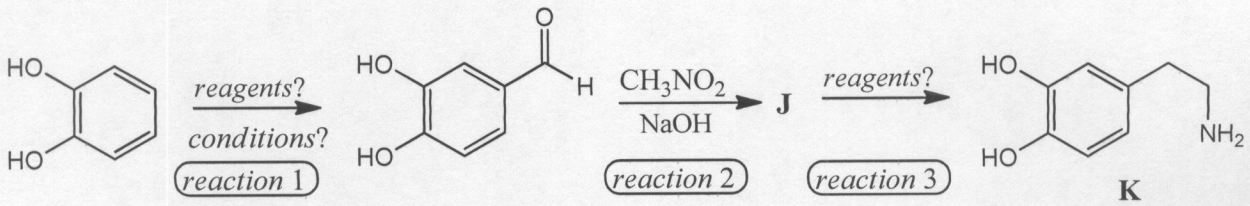


(d) Predict the products and give mechanism of the following reaction: **(6 marks)**



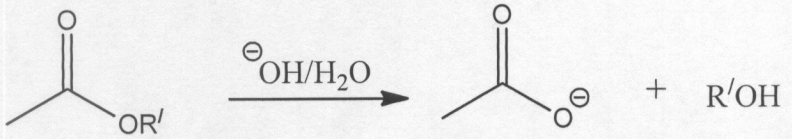
QUESTION TWO

(a) Consider the following synthesis of the neurotransmitter **K**.



(i) Provide the reagents and conditions for reaction 1. **(2 marks)**
(ii) Identify the intermediate **J** and give the mechanism of the reaction 2. **(7 marks)**
(iii) Give the reagents for reaction 3. **(1 mark)**

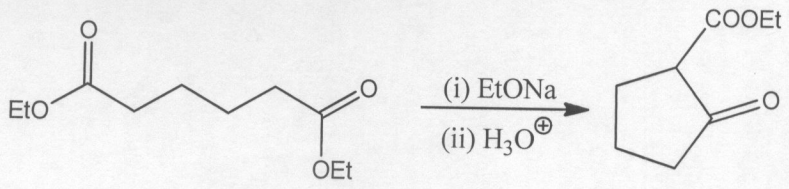
(b) The carboxylic acid group is often protected as a *tert*-butyl ester in organic synthesis. Unlike methyl and ethyl esters, which are easily hydrolysed by aqueous bases, *tert*-butyl esters, $RCOOC(CH_3)_3$, are resistant to alkaline hydrolysis.



(i) Write the mechanism of alkaline hydrolysis of esters, $RCOOR'$, indicating the rate determining step. **(4 marks)**

(ii) Based on the hydrolysis mechanism you wrote, briefly explain why *tert*-butyl esters are resistant to alkaline hydrolysis. **(2 marks)**

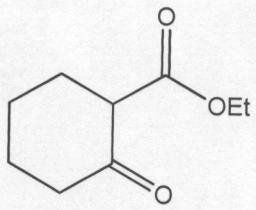
(c) (i) Dieckmann condensation is used for synthesis of a variety of cyclopentanone and cyclohexanone derivatives. An example is shown below:



Provide a detailed mechanism for the reaction, including the resonance stabilisation of the anion intermediates. **(8 marks)**

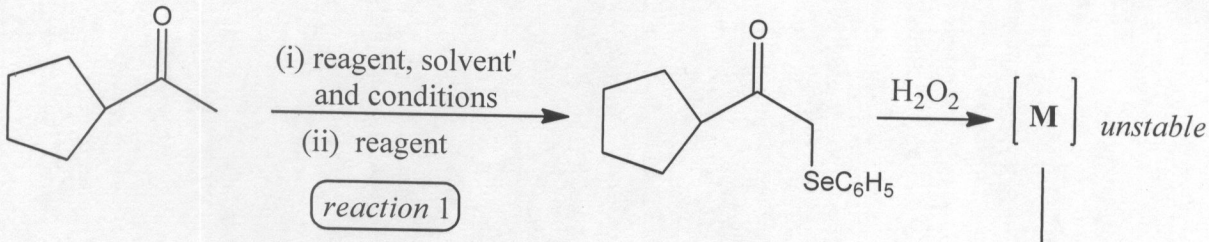
(ii) What starting material would you use to prepare **L** by Dieckmann condensation? **(1 mark)**

L:



QUESTION THREE

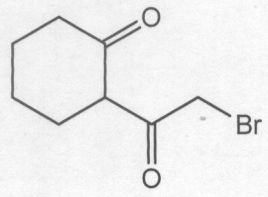
(a) α-Selenylation is frequently used for the synthesis of the α,β-unsaturated carbonyl compounds. An example is shown below:



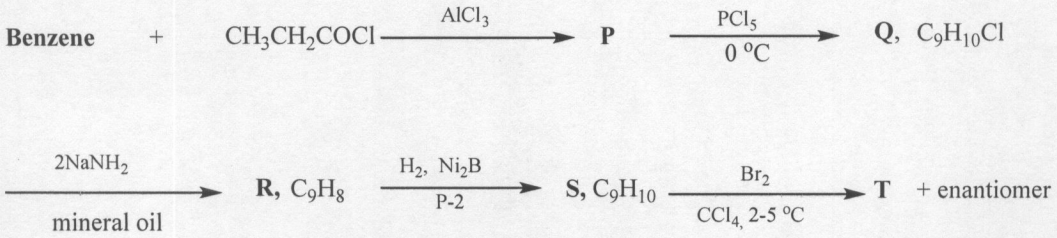
(i) Provide the reagents and conditions for the reaction 1. **(3 marks)**
(ii) Identify the intermediate **M** and the final product **N**. **(2 marks)**
(iii) Show the mechanism of the reaction for the transformation of **M** into **N**. **(2 marks)**

(b) Suggest a synthesis of the compound **O**, shown below, starting from any alcohols as the only source of carbons via Stork enamine reaction. Show all steps, including the intermediates clearly. *Please do not write reaction mechanisms.* **(7 marks)**

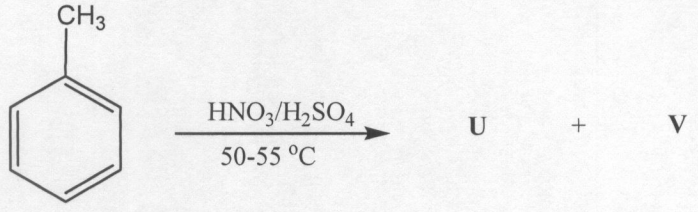
O:



(d) Give the structures, including stereochemistry where appropriate for the Compounds; **P-T.** **(5 marks)**



(e) Write the mechanism of the following reaction which proceeds by electrophilic aromatic substitution mechanism. Identify the products **U** and **V**. **(6 marks)**

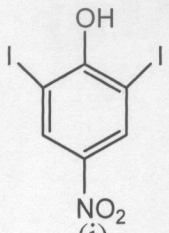


QUESTION FOUR

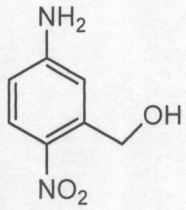
(a) Draw the structures of the following compounds: **(4 marks)**

(i) 1-(4-Bromo-3-nitro-phenyl) ethanoate
(ii) 2,4-Difluoro-3-propylphenol

(b) Provide the systematic name for the following compounds: **(4 marks)**

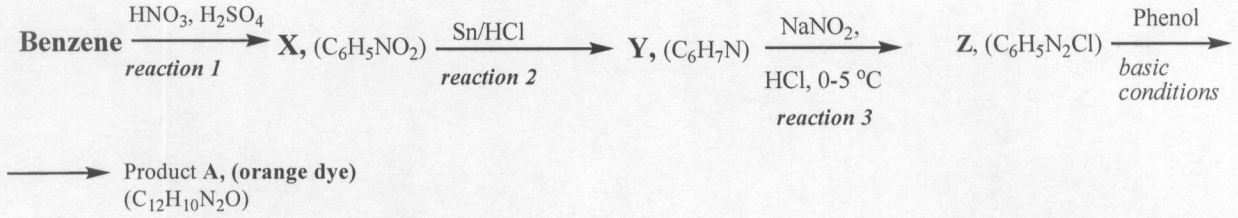


(i)



(ii)

(c) The following reaction sequence is of valuable synthetic utility. Consider the chemistry, starting with benzene and ending with an azo compound **A.**



(i) Provide the structures **X**, **Y**, **Z** and **A** **(4 marks)**

(ii) Write the reaction mechanism for reaction 3, the formation of diazonium salt. **(7 marks)**

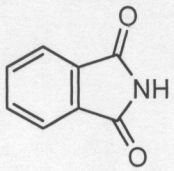
(d) Define the following terms

(i) Aromaticity **(4 marks)**

(ii) Huckel's (4n+2) rule **(2 marks)**

QUESTION FIVE

(a) Phthalimide, structure shown below, used in the Gabriel synthesis, is prepared by the reaction of ammonia with phthalic acid.

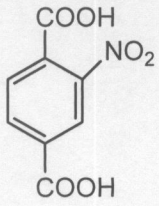


Phthalimide

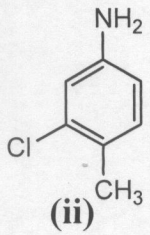
(i) Propose a reaction mechanism for the synthesis. **(8 marks)**

(ii) When phthalimide obtained in (a)(i) above is treated with isopropyl iodide in the presence of aqueous potassium hydroxide, what products would you expect to obtain? Suggest the mechanism for this reaction. **(7 marks)**

(b) Outline the methods for the preparation of the following compounds in a reasonably pure state and good yield from benzene by electrophilic aromatic substitution. **(10 marks)**



(i)



(ii)

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

2017 ACADEMIC YEAR FINAL DEFERRED EXAMINATIONS

CHE 3111: CELLULAR BIOCHEMISTRY

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 on **FIVE (5)** printed pages

QUESTION 1

i. Quite often in biochemistry, we use spectrophotometry (optical density or absorbance) to measure amount of protein in a sample. **What** molecular feature(s) in protein are responsible for absorbance measurements?
[5 marks]

ii. The absorbance of a protein solution containing 1 mg/ml albumin was measured using a 1 cm light path and was found to be 0.550 and 0.199 absorbance units at 279 nm and 290 nm respectively. Assuming that tyrosine and tryptophan are the only amino acids that absorb appreciably at these wavelengths, **calculate** the number of these two amino acids in a molecule of the protein given that:

a) MW of albumin is 65 000 dalton.
b) The molar extinction coefficient of tyrosine is 1.1×10^3 l/mol.cm at 279 nm and 0.28×10^3 l/mol.cm at 290 nm.
c) The molar extinction coefficient of tryptophan is 5.2×10^3 l/mol.cm at 279 nm and 4.3×10^3 l/mol.cm at 290 nm.

[15 marks]

Question 2

a) Using a neat table, **compare** and **contrast** myoglobin and haemoglobin.
[10 marks]

b) Using a neat diagram, briefly **discuss** the probable molecular mechanism for the sigmoidal oxygen dissociation curve of haemoglobin.
[10 marks]

PLEASE TURNOVER THE PAGE

Question 3

a) With a neat diagram, **explain** the whole process of metabolism.
[8 marks]

b) **True of False. If False, write the correct statement.** There are 2 major types of non-linear metabolic pathways.
[4 marks]

c) Using chemical structures, explain the process of glycogen synthesis starting from glucose-6-phosphate, naming all enzymes involved in the linking of the first six residues.
[8 marks]

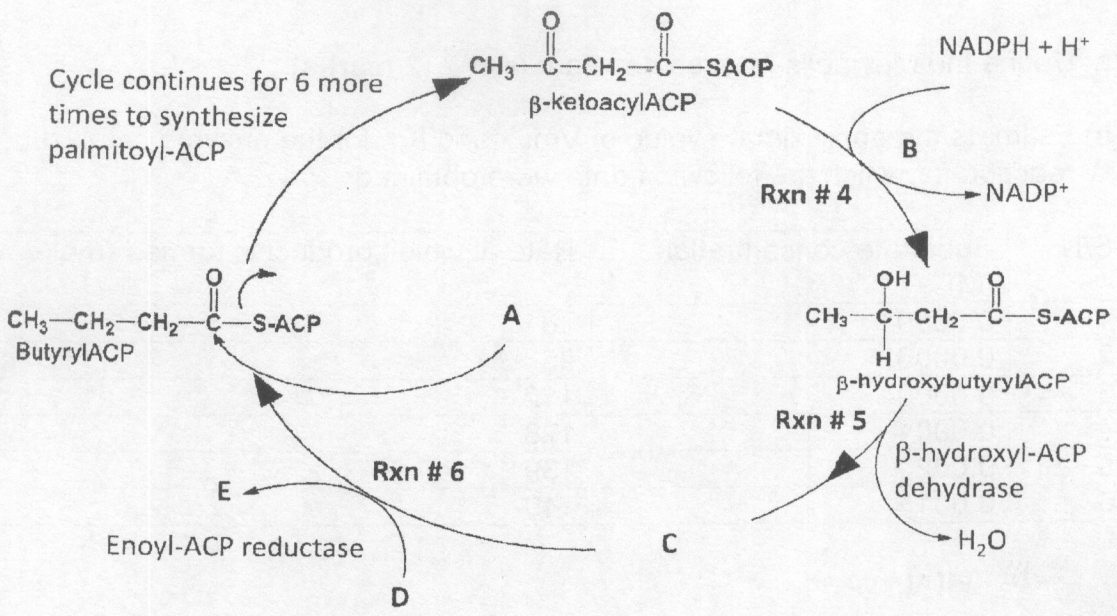
Question 4

a) **Which** of the two under aerobic conditions, yields more ATP per gram, Hexanoic acid or glucose? Prove your answer by biochemically by applying mathematical reasoning. *(Hint: molecular masses are 116 and 180 respectively)*
[12 marks]

PLEASE TURNOVER THE PAGE

b) **Copy and complete** the following diagram clearly providing structures and names from A to E.

[8 marks]



Question 5

a) **What** is the source of atoms in urea formed by the urea cycle?

[4 marks]

b) With the help of biochemical reactions, **explain** the mitochondrial part of the urea cycle.

[12 marks]

c) **What** is the difference between CPS I and CPS II?

[4 marks]

Question 6

There are various mechanisms of action used by enzymes. Michaelis-Menten's equation tries to characterize the kinetic features of enzyme catalysis. Chymotrypsin and some antiretroviral drugs such as saquinavir are protease inhibitors

(a) Define the Michaelis-Menten constant (Km)? **[2 marks]**

(b) Estimate the approximate value of Vmax and Km for the enzyme catalyzed reaction for which the following data were obtained

S/N	Substrate concentration {M}	Rate at which product is formed {mole/min}
1	0.00001	70
2	0.00002	95
3	0.00004	112
4	0.0001	128
5	0.002	139
6	0.001	140

[9 mark]

(c) Outline the detailed mechanism of action chymotrypsin. **[8 marks]**
(d) Name the mechanism of action used by saquinavir **(1marks)**

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

2017 ACADEMIC YEAR FINAL EXAMINATIONS

CHE 3122: ENERGY TRANSDUCTION SYSTEMS

INSTRUCTIONS TO CANDIDATES:

Time: **THREE (3)** hours

All questions carry **equal marks** (20 marks each)

Answer any **FIVE (5)** questions

Write your student identification number (ID) on **ALL** answer booklets

This examination consists of **SIX (6)** questions on **FIVE (5)** printed pages

Question1

a) **Copy and complete** the following table: **[10 marks]**

Component/molecule/ion:	**Role/function:**
Creatine	
Troponin	
Ca^{2+} ions	
Myosin	
Actin	

b) Briefly **discuss** the statement: "Muscle contraction does not mean shortening of muscle proteins". **Include** a neat diagram **[10 marks]**

QUESTION 2

a) **Write** briefly about any three (3) ways how ATP can be generated in a muscle fibre? **[6 marks]**

b) **What** is muscle fatigue? **[2 marks]**

c) **Name** any three (3) causes of muscle fatigue. **[6 marks]**

d) **Give** any two (2) characteristics of the 3 kinds of muscle fibres. **[6 marks]**

Question 3

a) **How** do the following alterations in the structures of fatty acids affect the membrane physical properties? **[3 marks]**

i) Increasing the chain lengths of saturated fatty acids.

ii) Increasing the number of double bonds in unsaturated fatty acids.

iii) Changing a cis double bond in a fatty acid to a trans double bond.

b) Consider the following information about a giant squid neuron.

Ion	Axoplasmic side	Exoplasmic side
Potassium	400 mM	12 mM
Sodium	55 mM	450 mM
Calcium	0.0001 mM	10 mM
Chloride	56 mM	550 mM



i) Assuming a temperature of 20 ^{o}C, R= 8.314 $JK^{-1}mol^{-1}$ and F=96,485 $JV^{-1}mol^{-1}$, **calculate** the Nernst equilibrium potential for **each** of the above ions. **[8 marks]**

ii) **State** the Goldman equation and hence **calculate** the membrane potential (V_m) for the giant squid neuron, using the above ion concentrations and the following ion permeabilities: $P(K^+) = 1.0$; $P(Na^+) = 0.05$ and $P(Cl^-) = 0.55$ **[8 marks]**

iii) Calcium is totally ignored in the Goldman equation which was designed to calculate the resting membrane potential. **Explain** why, this is so. **[1 mark]**

Question 4

a) **What** key observations support the chemiosmotic hypothesis? **[3 marks]**

b) **Explain** using a neat diagram the F-type ATPase **[12 marks]**

c) **Show** with a clear arrow the direction of flow of protons if the pump in part (b) works as a synthase **[1 mark]**

d) In bullet form, **give** an account of the physiologic changes that occur in the pump during ATP synthesis **[4 marks]**

Question 5

a) **Explain** in less than 100 words and with the **help** of a neat diagram the FRAP experiment. **[6 marks]**

b) Transport across membranes is broadly divided into two classes; passive and active transport. Give one example and function of any of the passive transporters and one example and function of any of the active transporters. **[2 marks]**

c) With reference to the erythrocyte, **explain** membrane asymmetry with respect to phosphatidyl choline, phosphatidyl serine, phosphatidyl inositol and sphingomyelin. **[2 marks]**

d) The membrane composition of *E.coli* is 25% phospholipid and 75 % protein while the human myelin sheath is 30% phospholipid and 30% protein (all percentages are mass by mass). **Explain** using biochemical and evolutional knowledge why such a differential distribution of membrane components occur in these two organisms. **[4 marks]**

e) **Explain** (less than 150 words) the molecular basis of the onset of cystic fibrosis. **[6 marks]**

Question 6

a) Compare and contrast the mitochondrial and nuclear genetic code. **[5 marks]**

b) Illustrate using a diagram that the mitochondrial genome is degenerate. **[6 marks]**

c) In not more than five sentences Illustrate that the Mitochondrial genome is diverse **[3 marks]**

d) In the mitochondria, gamma DNA polymerase is selectively affected by Emtricitabine a drug used in HIV treatment

i. List three side effects arising as a result of the aforementioned fact. **[3 marks]**

ii. Explain how these side effects are biochemically caused. **[3 marks]**

END OF EXAMINATION

Universal to
non ambiguous ✓
non punctuation ✓
~~no comma~~ non overlapp
degeneracy ✓

myopathy
lipodystrophy

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

2017 ACADEMIC YEAR DEFERRED FINAL EXAMINATIONS

CHE 3122: ENERGY TRANSDUCTION SYSTEMS

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 on **FOUR (4)** printed pages

QUESTION 1

Using a neat diagram, **explain** skeletal muscle contraction. In what sense do muscles proteins actually contract i.e., do muscle proteins actually shorten? **Explain**. **[20 marks]**

QUESTION 2

a) The Ca^{2+} ion is one of the main players in skeletal muscle contraction. Using a neat diagram, **explain** in detail its role in muscle contraction. **[15 marks]**

b) **What** is the source of Ca^{2+} ions in skeletal muscles? **Mention** any two. **[5 marks]**

QUESTION 3

a) When an *E. coli* cell is cultured at 10 ^{0}C, 20 ^{0}C, 30 ^{0}C and 40 ^{0}C, respectively, what is the general trend in fatty acid composition of the cell membrane with respect to myristic acid and palmitoleic acid? **[4 marks]**

b) Explain with the help of a neat diagram, the major types of integral membrane protein classes. **[6 marks]**

c) Calculate the free energy needed to move 1 mol of Na^+ ions from outside the cell (where $[Na^+]$ = 150 mM) to the inside (where $[Na^+]$ = 5 mM) when the membrane potential is 70 mV and the temperature is 37°C. R= 8.314 $JK^{-1}mol^{-1}$ and F = 96,485 $JV^{-1}mol^{-1}$ **[10 marks]**

PLEASE TURNOVER THE PAGE

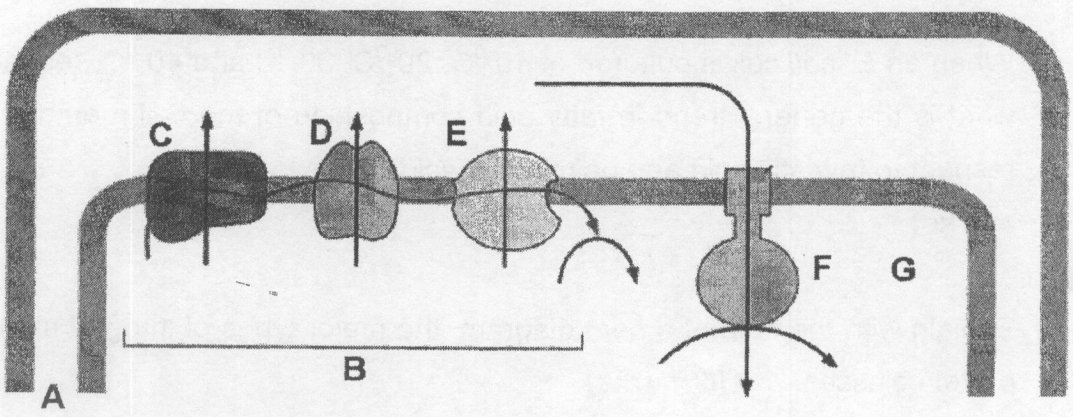
QUESTION 4

a) **Explain** detail how ions and glucose move with respect to the Na^+/K^+ ATPase and the Na^+/Glucose transporter in the intestinal epithelial cells. **[15 marks]**

b) **How** is carbon dioxide effectively removed from respiring tissue? **Explain** with the help of an appropriate diagram. **[5 marks]**

QUESTION 5

a) **Copy** and fill in the missing details of the diagram below. **[15 marks]**



b) For each of the following, **state** the part of the electron transport chain inhibited.

i) Rotenone ii) Azide iii) Oligomycin **[3 marks]**

c) **How** many ATP molecules will be synthesized if only 7 protons are translocated from the intermembrane space? **[2 marks]**

PLEASE TURNOVER THE PAGE

QUESTION 6

a) Compare and contrast the mitochondrial and nuclear genome. **[10 marks.]**

b) In not more than five sentences Illustrate that the Mitochondrial genome is diverse **[4marks]**

c) In the mitochondria, gamma DNA polymerase is selectively affected by Emtricitabine and not Abacavir. Both drugs are used in HIV treatment

i. List three side effects caused by Emtricitabine arising as a result of the aforementioned fac and explain how these side effects are biochemically caused. **[3 marks].**

ii. Explain why Emtricitabine affect gamma DNA polymerase but Abacavir does not. **[3 marks].**

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

Department of Chemistry

2017 Academic year Term 2 Final Exam

CHE3422

Organometallics and Inorganic Reaction Mechanism

Instructions: Answer any four questions

All questions carry equal marks **Duration: 3 hours**

QUESTION 1.

(a) From the knowledge of chemical properties, speculate on why cerium and Europium were the easiest lanthanides to be isolated before the development of ion-exchange chromatography?

(b) Actinides form oxocations but lanthanides don't. Explain

(c) Account for the electrolytic conductivity of a solution of alkali metal in liquid ammonia.

QUESTION 2.

(a) What is the principle behind atom bomb? How does it differ from hydrogen bomb?

(b) What is meant by critical mass in relation with nuclear reactor. Why does it vary?

(c) Draw a diagram to illustrate how binding energy per nucleon varies with mass number. Comment on the shape of the curve.

QUESTION 3.

(a) Extraction of Uranium involves both chemical and physical separation techniques.Briefly outline the steps involved in the separation of nuclear grade uranium from its ore.

(b) Compare and contrast the electronic spectra of lanthanide ions with those of transition metal ions.

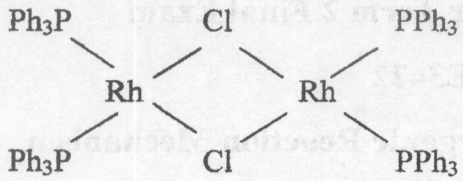
(c) Comment on the behaviour of HNO_3 in solvents:

(i) liquid ammonia
(ii) acetic acid
(iii) H_2SO_4

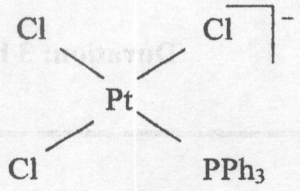
QUESTION 4.

For each organometallic complex below, determine the oxidation state of the metal, d-electron count of the metal, total number of metal electrons and justify any unsaturation or saturation.

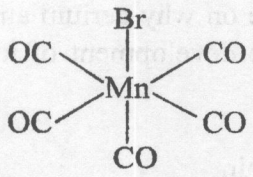
(a)



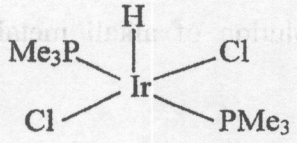
(b)



(c)



(d)



QUESTION 5.

(a) $V(CO)_6$ and $[V(CO)_6]^-$ are both octahedral organometallic complexes. Which of the two should have the shorter C- O bond? Briefly explain

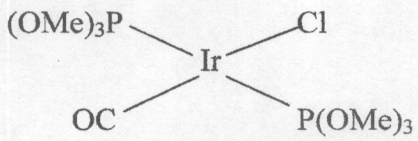
(b) Which of the two should have the shorter V- C bond? Briefly explain

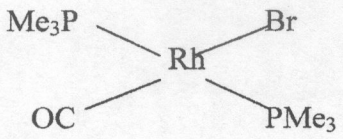
(c) Which organo complex, $(CH_3)Tc(CO)_5$ or $(F)Re(CO)_5$, will have the weakest M-CO bonding? Explicitly explain your answer.

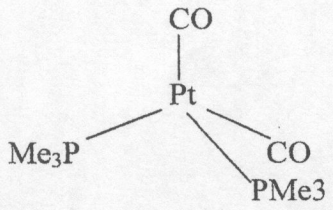
QUESTION 6.

(a) (i). What does an oxidative addition reaction involve?
(ii). State THREE general features of an oxidative addition reaction.

(b) To which of the following organo complexes will H_2 most readily undergo oxidative addition and Why?

(i) 

(ii) 

(iii) 

(c) (i) Stability/Formation constants for the reactions of $[Cd(H_2O)_6]^{2+}$ with NH_2CH_3 and en,

(a) $[Cd(H_2O)_6]^{2+} + 4NH_2CH_3 \rightleftharpoons [Cd(H_2O)_2(NH_2CH_3)_4]^{2+} + 4H_2O$

(b) $[Cd(H_2O)_6]^{2+} + 2en \rightleftharpoons [Cd(H_2O)_2(en)_2]^{2+} + 4H_2O$ are $\log \beta_4 = 6.6$ and $\log \beta_2 = 10.6$ respectively. Explain why we have $\log\beta_4$ in (C) (i) a and $\log\beta_2$ in (C) (i) b.

(ii) Why is $\log\beta_2$ higher than $\log\beta_4$?

(iii) Tetra ammine Platinum(II) complex ion reacts with chloride ions as follows:

$[Pt(NH_3)_4]^{2+} \xrightarrow{2Cl^-}$ trans $[Pt(NH_3)_2Cl_2]$ while

Tetrachloride Platinum(II) complex ion reacts with ammonia as follows:

$[Pt(Cl)_4]^{2-} \xrightarrow{2NH_3}$ cis $[Pt(NH_3)_2Cl_2]$

Why do different isomers form?

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	18

KEY

Atomic number
X
Atomic mass
Name of the element X

1 **H** 1.01 Hydrogen																1 **H** 1.01 Hydrogen	2 **He** 4.00 Helium
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	10 **Ne** 20.18 Neon
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	18 **Ar** 39.95 Argon
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	36 **Kr** 83.80 Krypton
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	54 **Xe** 131.29 Xenon
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	86 **Rn** 222.02 Radon
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

Department of Chemistry

2017 Academic Year Final Examination

CHE3422: Organometallics and Reaction Mechanisms

Instructions:

Answer any four (4) questions

All questions carry equal marks **Time: Three (3) hours**

QUESTION 1

(a) Lanthanides exhibit +3 oxidation state whereas actinides exhibit +2 to +7 oxidation states. Why is this so?

(b) Lanthanide contraction is the steady decrease in size by lanthanides from La (atomic radius r = 188pm) to Lu (atomic radius r = 173pm). Deduce why this happens.

(c) Spectroscopy of d-block metals is governed by crystal field splitting whereas crystal field splitting is insignificant in lanthanides. State what governs lanthanide spectroscopy and why spectra of Ln^{3+} ions contain large number of absorptions.

(d) Compare and differentiate between absorption bands of d-d transitions and 4f-5d transitions. Explain the differences.

(e) Determine the ground state term symbols for Ce^{3+} and Er^{3+}.

QUESTION 2

(a) Briefly discuss how lanthanide metals are extracted from monazite and bastanite ores and how they are separated into from each other.

(b) (i) Define alpha - decay.

(ii) Describe how α-decay is used in smoke detectors.

(c) Define β^- -decay and β^+-decay with examples.

(d) (i) What is fission?

(ii) How is fission used to generate power?

(iii) State common problems and solutions for using nuclear power.

(e) After 500 years, a sample of radium-226 decayed to 80.4% of its original mass. Find the half life of radium-226.

QUESTION 3

(a) (i) What sub atomic particles are present in nuclei?
(ii) What are their charges?
(iii) Are these sub particles naturally attracted to each other?
(iv) What holds nuclei together?
(v) What is mass defect?

(b) The mass of ^{19}F is 18.9984 amu. Given that the mass of a hydrogen atom (1 proton and 1 electron) is 1.007825 amu and a neutron is 1.008665 amu, find the mass defect in ^{19}F.

(c) State and describe the self ionization of liquid SO_2, liquid H_2SO_4 and liquid NH_3. State a neutralization reaction in liquid ammonia.

(d) Liquid H_2SO_4 has a very long liquid range making for wide use as a non aqueous solvent but its use is limited. Explain why.

(e) Solutions of ammonium halides in ammonia are used as acids in preparation of silane and arsane. Give equations by which silane and arsane are produced.

QUESTION 4

(a) All organometallic complexes are diamagnetic except Vanadium hexacarbonyl which is paramagnetic. Explain

(b) Calculate the EAN for $V(CO)_6$.

(c) How is the C-O bond order related to the C-O stretching frequencies in metal carbonyls?

(d) Discuss the preparation, properties and structure of dicobalt octacarbonyl.

QUESTION 5

(a) Explain the applications of "trans-effect" using synthesis of Pt (II) complexes.

(b) Describe the SN_1CB mechanism involved in base hydrolysis of Co(III) ammine complexes.

(c) Give the steps involved in the formation of cis & trans isomers by treating $[PtCl_4]^{2-}$ ion with NH_3.

(d) Compare and contrast the mechanism of S_N1 and S_N2 reactions in octahedral complexes.

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	18
																1 H 1.01 Hydrogen	2 He 4.00 Helium
1 H 1.01 Hydrogen												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	10 Ne 20.18 Neon
3 Li 6.94 Lithium	4 Be 9.01 Beryllium											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	18 Ar 39.95 Argon
11 Na 23.00 Sodium	12 Mg 24.31 magnesium																
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 Seleniu m	35 Br 79.90 Bromine	36 Kr 83.80 Krypton
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 Telluriu m	53 I 126.90 Iodine	54 Xe 131.29 Xenon
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	86 Rn 222.02 Radon
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 Gadoliniu m	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 Plutoniun	95 Am 243.06 Americium	96 Cm 247.07 Curium	97 Bk 247.07 Berkelium	98 Cf 251.08 Californium	99 Es 252.08 Einstienium	100 Fm 257.10 Fermium	101 Md 260 Mendelevium	102 No 259.10 Nobelium	103 Lr 262.11 Lawrenciu m

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

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}

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2017 ACADEMIC YEAR
FINAL EXAMINATIONS

CHE 3522
POLYFUNCTIONAL COMPOUNDS, MOLECULAR REARRANGEMENTS AND ORGANIC SYNTHESIS

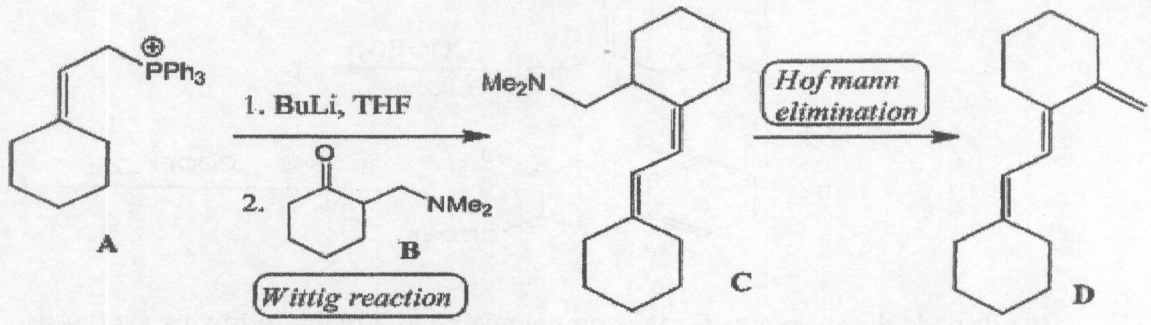
TIME ALLOWED: THREE (3) HOURS

INSTRUCTIONS:

1. Answer any four (4) questions.
2. Each question carries 25 marks.
3. Please present your answers in a neat and logical manner.
4. Ensure you have six (6) printed pages containing five (5) questions.

QUESTION ONE

(a) Consider the following synthesis of the triene, **D**, which was designed as a model for synthesis of vitamin D.

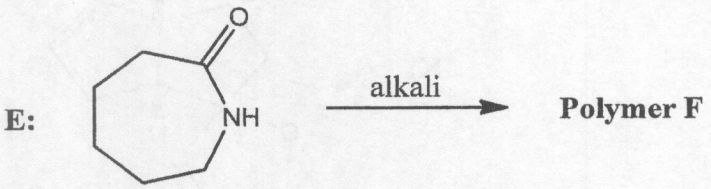


(i) Provide the reagents and conditions for the Hofmann elimination step. **(2 marks)**

(ii) Suggest a synthesis of the Wittig reagent **A** from acetylene, cyclohexanone and triphenyl phosphine (PPh_3) and any needed reagents. **(5 marks)**

(iii) Give the reaction equation for preparing **B** from cyclohexanone by Mannich reaction and provide a detailed mechanism of the reaction. Assume that all needed reagents are available. **(7 marks)**

(b) The polymer **F** (fibers), required by textile industry, is made by alkaline polymerization of the lactam **E**.



(i) What is the structure of the polymer **F**? **(2 marks)**

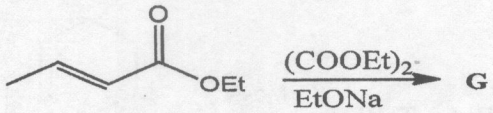
(ii) Explain the reactions underlying the polymerization and give reaction mechanisms. **(6 marks)**

(c) Would you expect D-glucaric acid to be optically active? Briefly explain. **(3 marks)**

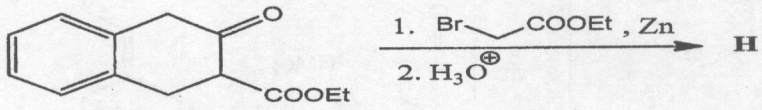
QUESTION TWO

(a) Identify the major organic products **G** and **H**, including pertinent stereochemistry, where relevant, of the following reactions: **(4 marks)**

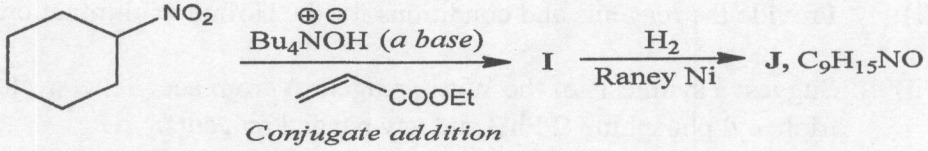
(i)



(ii)



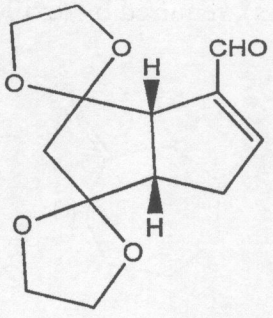
(b) Provide the structures for the compounds **I** and **J** in the following synthesis. **(5 marks)**



Conjugate addition

(c) Applying the disconnection approach, propose a synthesis for the key intermediate in prostaglandin synthesis, **K**, shown below, from readily available starting materials. Show clearly the retrosynthetic analysis, and all steps of the proposed synthesis, stating the reagents, conditions and intermediates for each step. Please <u>*do not*</u> write reaction mechanisms. **(12 marks)**

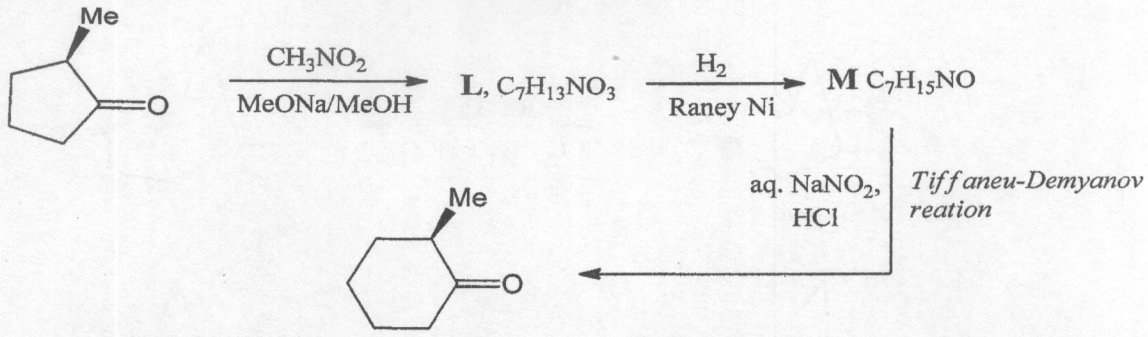
K:



(d) Two of the four aldopentoses yield D-threose on Ruff degradation. What are their structures? **(4 marks)**

QUESTION THREE

(a) A general method for homologation of cyclic ketones is shown below. The last step of the reaction sequence is known as Tiffaneu-Demyanov reaction, a variant of Pinacol rearrangement.



(i) Identify the intermediates **L** and **M** **(2 marks)**

(ii) Suggest the most likely mechanism for the Tiffaneau-Demyanov reaction. shown above. **(8 marks)**

(iii) Give the structure of one other possible product that could be formed in the last step of the above reaction sequence **(2 marks)**

(b) Propose a malonic ester synthesis of cyclobutanecarboxylic acid. Show the reagents, conditions and intermediates for each step of your proposed synthesis. **(5 marks)**

(c) The synthetic polymer polytetrafluoroethylene (PTFE) has many applications.

(i) Provide the structures of PTFE and the monomer required to make it. **(3 marks)**

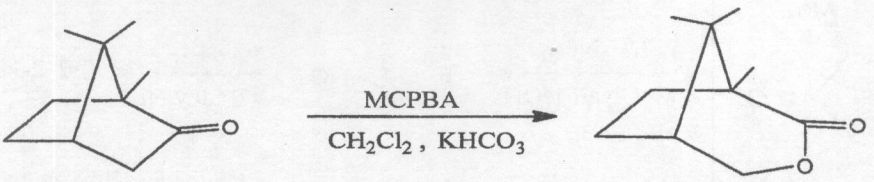
(ii) What type of polymer is PTFE? **(1 mark)**

(iii) PTFE is used as non-stick coating for cookware. Provide a scientific rationale for this use. **(2 marks)**

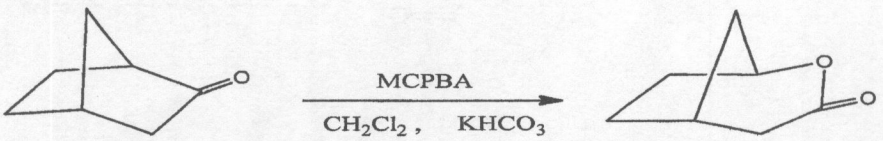
(iv) Neither water nor water-containing substances wet PTFE. Briefly explain why. **(2 marks)**

QUESTION FOUR

(a) Baeyer Villiger oxidation of camphor gave an unexpected product, **N** in 30 % yield; whereas norcamphor gives the expected product **O** as shown below. Provide a mechanistic explanation for these experimental results. **(10 marks)**

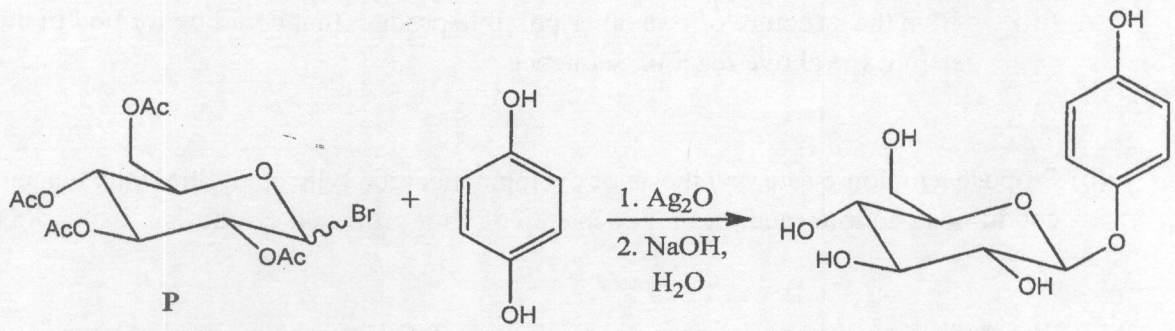


Camphor **N**



Nor-Camphor **O**

(b) Bearberry leaf extract is used in skin lightening treatments designed for long term and regular use. The active ingredient of the extract, *arbutin*, is commercially prepared by Koenigs-Knorr reaction:



P **Arbutin**

(i) What classes of compounds are **P** and *arbutin*? **(2 marks)**

(ii) Identify the aglycon in *arbutin*. **(1 mark)**

(iii) Both α- and β- anomers of **P** yield *arbutin* in good yield. Propose a mechanistic explanation to account for these results. **(6 marks)**

(c) **α**-Amino acids, are synthesised in many ways. Describe the synthesis of Leucine using the Strecker method. **(6 marks)**

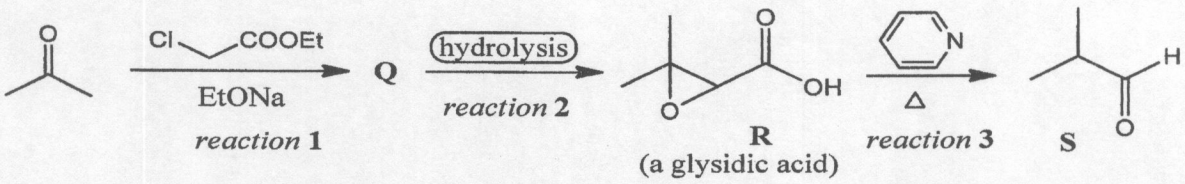
QUESTION FIVE

(a) Show how you would carry out the following transformations, **(12 marks)**

(i) D-glucose ⟶ D-fructose

(ii) D-glucose ⟶ D-mannose

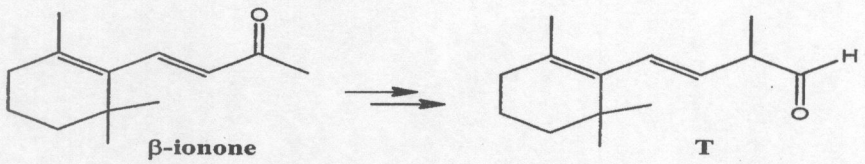
(b) A general method for conversion of a ketone to an aldehyde with one carbon more is outlined below.



(i) Identify the glycidic ester **Q** and suggest a plausible mechanism for the reaction **1** (Darzens condensation). **(5 marks)**

(ii) Propose the most likely mechanism for the decarboxylation reaction **3**. **(4 marks)**

(iii) Using this method, propose a synthesis of the aldehyde **T**, a key intermediate in an industrial synthesis of vitamin A. **(4 marks)**



END OF EXAMINATION
GOOD LUCK!

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

2017 ACADEMIC YEAR FINAL EXAMINATIONS

CHE 4102: BIOCHEMICAL RESEARCH TECHNIQUES

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 on FOUR (4) printed pages

Question 1

The human liver hosts two types of reactions that deal with foreign chemicals that come into the body.

a) **Give** the general expressions for these two types reactions in the liver and provide specific examples. **[10 marks]**

b) **What** is the ultimate aim of these two reactions? **[5 marks]**

c) **Do** these reactions always result in desirable results? Explain. **[5 marks]**

Question 2

Consider the human kidney:

i) Using a neat diagram, **describe** the anatomy of the human kidney. **[10 marks]**

ii) **Discuss** in detail the role of the human kidney in dealing with xenobiotics. **[10 marks]**

Question 3

Write short notes (maximum 4 sentences) on: **[10 marks]**

a) Agonist vs antagonist

b) Innate immunity vs adaptive immunity

c) Biochemical explanation for the development of cholera

d) Natural killer cell cells vs phagocytic cells

e) Interferons vs complement system

Question 4

a) Explain the following terms: **[4 marks]**

i) Primary cell culture

ii) Senescence

iii) Cell viability (using a formula)

iv) EMEM

b) What are the sources of the following cell lines? **[2 marks]**

i) HeLa cells

ii) Sf9

iii) MCF-7

iv) Cos-7

c) i) Using mouse B cells producing anti-insulin antibody and HeLa cells, **explain** how hybridomas are formed. **[7 marks]**

ii) How can **select** the positive hybrid cells in part c) i)? **[7 marks]**

Question 5

Regulation of metabolic pathways could be effected by phosphorylation and dephosphorylation of enzymes. The levels of glucose in the human blood is usually maintained at a near constant level.

a) One-way glucose levels are maintained at this near constant level is through glycogenolysis and glycogenogenesis. **State** the normal level of glucose in human blood **[1 mark]**

b) **What** is meant by the term glycogenolysis? **[1 mark]**

c) **Explain** in detail how glycogenolysis and glycogenogenesis is regulated (*Hint: include both positive and negative regulation*). **[18 marks]**

Question 6

a) **Compare** and **contrast** in the table form catabolism and anabolism **[5 marks]**

b) Using a diagram, **illustrate** that catabolism of carbohydrate, protein and lipids is **convergent** in character. **[5 marks]**

c) **Explain** the gene regulation of lactose metabolism *E.coli*. **[10 marks]**

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

2017 ACADEMIC YEAR MID-YEAR DEFERRED EXAMINATIONS

CHE 4111: INFORMATION STORAGE AND BIOCHEMICAL GENETICS

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 THREE (3) printed pages

QUESTION 1

Write a critical essay on:

"Dangers (and precautions against) of recombinant DNA technology – facts versus myths" **[20 marks]**

QUESTION 2

a) Why do restriction enzymes not hydrolyze the DNA of the organism that produces it? **[5 marks]**

b) What are the key differences between a DNA library and cDNA library? **[10 marks]**

c) Why is it a large undertaking to construct a DNA library? **[5 marks]**

QUESTION 3

a) **Describe** the general composition of eukaryotic nucleosomes **[8 marks]**

b) Write a note on the various levels of DNA packaging from the double strand duplex to the chromosome. (*Hint: use a diagram to help you explain*) **[12 marks]**

QUESTION 4

1 bp of DNA is approximately 0.34 nm in length. A bacterial chromosome is about 4 million bp in length and is organized into about 100 loops that are about 40,000 bp in length each.

a) If it was stretched out linearly, **how** long (in micrometers) would one loop be? **[5 marks]**

b) If a bacterial chromosomal loop is circular, what would be its diameter? (Note: Circumference = πD, where D is the diameter of the circle.) **[5 marks]**

c) **Explain** the complementation test experiment in detail using appropriate examples **[10 marks]**

QUESTION 5

a) The survival of the human race partly depends prevention and minimising mutations. **Explain** briefly how DNA polymerase participates in the prevention and minimising of mutations. **[10 marks]**

b) Humans carry out transcription in three stages, initiation elongation and termination. **Describe** the detailed the process of initiation of transcription. **[10 marks]**

QUESTION 6

Reverse transcription is observed in HIV particles and is catalysed by reverse transcriptase.

a) **Outline** the enzymatic activities of HIV reverse transcriptase. **[8 marks]**

b) **Name** one nucleotide analogue that can inhibit the above process. **[2 marks]**

c) **Discuss** how the nucleotide analogue named in part (b) can inhibit the reverse transcription ***(Hint use biochemical reactions to discuss with chemical structures)*** **[5 marks]**

d) **Explain** the biochemical advantage of nucleotide analogue over most nucleoside analogue when used as antiretroviral drugs **[5 marks]**

END OF EXAMINATION.

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

2017 ACADEMIC YEAR FIRST TERM FINAL EXAMINATIONS

CHE4211 ANALYSIS OF INORGANIC COMPOUNDS

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) There are generally two methods on which air sampling is based. **State** these two general methods employed in the sampling of air for analysis of contaminants and describe air sampling protocol using an impinger.

(b) Mention seven (7) organoleptic and physical parameters determined during water analysis.

(c) (i) Define what is meant by Dissolved Oxygen and state two methods that may be employed for its determination.

(ii) Mention two main sources of dissolved oxygen and two main processes that use it up in natural water bodies.

(d) (i) Most labs use the **Hach Method** to measure chemical oxygen demand (COD). Define chemical oxygen demand and State the conditions employed in the **Hach** method for determination of COD.

(ii) In this method, the catalyst use can form a precipitate with chloride ions if present. How would this interference prevented?

Question 2

(a) Compare and contrast the methods of Hutchinson and MacLennan to that of Tinsley, Taylor and Moore with respect to sample digestion and final limestone content.

(b) Dissolution for the analysis of rocks and minerals may be achieved using fusion. What is fusion technique in mineral analysis? Give two examples each, of acidic and basic fluxes used; and name one disadvantage of fusion.

(c) A sample of potassium is analyzed by FES using the standard addition method. Two 0.5 mL aliquots are added to 5.0 mL portions of water. To one portion is added 10 µL 0.05 M KCl solution. The net emission signals in arbitrary units are 32.1 and 58.6. What is the concentration of potassium?

(d) Phosphorus content of soils was determined by gravimetry using quinolinium phosphomolybdate agent. A 3.1 g precipitate of quinolinium phosphomolybdate $(C_9H_7N)_3PMo_{12}O_{40}$ was obtained from a 1.0 g sample. Using atomic weights P = 31; O = 16; N= 14 and Mo = 96, calculate:

(i) %P

(ii) % P_2O_5

Question 3

(a) Define the following terms **in brief.**

(i) Quick-release fertilizers
(ii) Slow-release fertilizers
(iii) Biochemical oxygen demand
(iv) Hard water
(v) Soft water
(vi) Aerosols
(vii) Dusts
(viii) Fumes
(ix) Smokes

(b) State two physical parameters used to assess quality of fertilizer

(c) The Karl Fischer is one analytical technique used to measure the moisture (water) content in solids, liquids or gases. Mention three advantages and three disadvantages associated with this analytical technique.

(d) Mention four possible points where and when water samples should be collected to assess domestic water quality. For each, state the reason for the stated assessment.

Question 4

(a) Define the terms TEB and CEC; and name three components of TEB, and two components of CEC as the terms are used in soil analysis. On which part of the sample are TEB and CEC determined?

(b) Chromic oxide,(Cr_2O_3), a green pigment is often produced by the reaction between sodium dichromate and ammonium chloride to yield chromic oxide, nitrogen gas, and other products. What type of reaction is this? Calculate how much pigment (in mg) can be produced from 0.010 kg of sodium dichromate.

(c) (i) Malachite, $CuCO_3.Cu(OH)_2$, is used as a decorative stone when cut and polished. Use malachite to define what is meant by the term 'mineral'.

(ii) Determine the carbon content in 1.00 g of a copper ore that contains 10% malachite, giving your answer in milligramme, correct to two significant figures.

(d) Describe briefly how you would analyze the different components in an ordinary Portland cement (OPC).

Question 5

(a) Iron is found in ores such as haematite (Fe_2O_3); limonite ($Fe_2O_3.3H_2O$); and, magnetite (Fe_3O_4), which is the most magnetic of all the naturally occurring minerals on Earth. Most of these ores are acid soluble. Give a brief description of an appropriate method for:

(i) Sample digestion using aqua regia

(ii) If you are to determine iron content by redox method, how would you prepare the sample aliquot from the digestate?

(b) Some minerals like NaCl, $MgSO_4$ and $FeSO_4.2H_2SO_4$ may be water soluble.However, to achieve complete dissolution it is necessary to add another solvent. Suggest, giving reasons which mineral acid you would choose.

(c) A 0.5 g soil sample was intimately mixed with 0.6 g potassium dichromate in order to analyse for its carbon content using the chromic acid oxidation method. The mixture was heated with concentrated sulphuric acid; then the excess chromate was titrated against a solution of iron (II) sulphate requiring 12.5 mL. The iron (II) sulphate was standardised against 0.4 g potassium dichromate requiring 20.0 mL. Calculate the carbon content (%) of the soil sample.

(d) Major mineral groups in the earth's crust include silicates which occur widely in nature. This phenomenon can be explained by the fact that the earth's crust contains approximately 50% (46.6%) oxygen and almost 30% (27.7%) silicon. Define the following terms which are used in the analysis of silicates. Give an example of each one.

(i). Major constituents

(ii). Minor constituents

(iii). Traces

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

Department of Chemistry

2017 Academic year Term 2 Final Exam

CHE4422

Metal Chemistry and its application to Organometallics and Catalysis

Duration: 3 hours

Instructions: 1. This exam paper consists of **five (5)** questions

2. Attempt **any four (4)** questions

3. All questions carry **equal marks**

4. Answer each question in a **separate** answer booklet

5. You are reminded of the necessity for **tidy and orderly presentation** of your work.

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 One

Many organometallic compounds function as "homogeneous catalysts" for significant chemical transformations. An understanding of these catalysts depends upon concepts such as

(a) ligand association and/or dissociation,
(b) oxidative-addition,
(c) reductive-elimination, and
(d) migratory-insertion reaction.

Briefly explain, with examples, each one of those processes and, then explain **in detail** (using labelled catalytic cycles), the roles of homogeneous catalysts in **TWO** of the following processes:

(i) the Monsanto acetic acid synthesis from methanol.

(ii) the rhodium-catalyzed hydroformylation of propene.

(iii) The Wacker olefin oxidation process (ethylene to ethanal).

In your catalytic cycles, clear indicate the name of each step, and the electron count of each species postulated to be involved.

Question Two

Write brief, but concise notes, on **any four (4)** of the following:

(a) Asymmetric synthesis using homogeneous catalysis.

(b) Tennessee–Eastman acetic anhydride process using homogeneous catalysis.

(c) BASF and Cativa processes for the manufacture of acetic acid.

(d) Comparison of conditions and selectivities of the BASF, Monsanto and Cativa processes for the manufacture of acetic acid

(e) Tennessee–Eastman acetic anhydride process

Question Three

(a) Discuss the *isolobal concept* as enunciated by the 1981 Chemistry Nobel Laureate **Roald Hofmann**.

(b) "The isolobal analogy can be extended to any molecular fragment having frontier orbitals of suitable size, shape, symmetry, and energy. The realization of these analogies inspired research by suggesting target molecules that can appear unorthodox on first inspection."

In the light of that statement, and limiting yourself to the ligand CO and first-row transition metals, state at least one organometallic fragment that is isolobal with each of the following hydrocarbon fragments:
CH_3, CH_2, CH, CH_3^-, CH_2^-, CH^-, CH_3^+, CH_2^+, and CH^+.

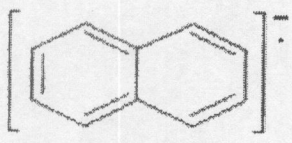
(c) Isolobal analogies find tremendous utility in suggesting new compounds. Formation of metal–metal bonds differ from others in the use of *d* orbitals on both atoms, in addition to the usual *s*- and *p*- bonds.

For the species, $[Re_2Cl_8]^{2-}$,
(i) State the bond order
(ii) Show the bonding Interactions between metal *d orbitals*, and hence
(iii) Show the relative energies of orbitals formed from *d*-orbital interactions

Question Four

(a) What are metastable ion peaks? Calculate the metastable peak for $Ni(CO)_4^+$ and represent it in a diagram.

(b) Predict the ESR spectrum of Naphthalene radical anion.



Represent the hyperfine splitting using a stick diagram and predict the intensities using Pascals triangle.

(c) 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.

Question Five

(a) N_2 gas molecule at 298 K, molar magnetic susceptibility, χm being $^{-}1.24 \times 10^{-5}$ cm^3/mol, calculate μ_M, magnetic moment and its number of unpaired electrons.

(b) Calculate the spin only moment, μ_s, and μ_{S+L} of Lanthanide ion, Pm^{3+} and compare with the experimental moment, μ_{exp} 3.6 Bohr Magnetons. Justify your answer.

(c) Predict the mass spectrum of CH_2Br_2, given that Br^{79} =50% and Br^{81} = 50%

END OF CHE4422 EXAMINATION for 2017/2018 ACADEMIC YEAR

The Periodic Table of Elements

1	2											3	4	5	6	7	0 (8)
																	(18)
							1.0 H hydrogen 1										4.0 He helium 2
(1)	(2)											(13)	(14)	(15)	(16)	(17)	
6.9 Li lithium 3	9.0 Be beryllium 4											10.8 B boron 5	12.0 C carbon 6	14.0 N nitrogen 7	16.0 O oxygen 8	19.0 F fluorine 9	20.2 Ne neon 10
23.0 Na sodium 11	24.3 Mg magnesium 12	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	27.0 Al aluminium 13	28.1 Si silicon 14	31.0 P phosphorus 15	32.1 S sulfur 16	35.5 Cl chlorine 17	39.9 Ar argon 18
39.1 K potassium 19	40.1 Ca calcium 20	45.0 Sc scandium 21	47.9 Ti titanium 22	50.9 V vanadium 23	52.0 Cr chromium 24	54.9 Mn manganese 25	55.8 Fe iron 26	58.9 Co cobalt 27	58.7 Ni nickel 28	63.5 Cu copper 29	65.4 Zn zinc 30	69.7 Ga gallium 31	72.6 Ge germanium 32	74.9 As arsenic 33	79.0 Se selenium 34	79.9 Br bromine 35	83.8 Kr krypton 36
85.5 Rb rubidium 37	87.6 Sr strontium 38	88.9 Y yttrium 39	91.2 Zr zirconium 40	92.9 Nb niobium 41	95.9 Mo molybdenum 42	[98] Tc technetium 43	101.1 Ru ruthenium 44	102.9 Rh rhodium 45	106.4 Pd palladium 46	107.9 Ag silver 47	112.4 Cd cadmium 48	114.8 In indium 49	118.7 Sn tin 50	121.8 Sb antimony 51	127.6 Te tellurium 52	126.9 I iodine 53	131.3 Xe xenon 54
132.9 Cs caesium 55	137.3 Ba barium 56	138.9 La* lanthanum 57	178.5 Hf hafnium 72	180.9 Ta tantalum 73	183.8 W tungsten 74	186.2 Re rhenium 75	190.2 Os osmium 76	192.2 Ir iridium 77	195.1 Pt platinum 78	197.0 Au gold 79	200.6 Hg mercury 80	204.4 Tl thallium 81	207.2 Pb lead 82	209.0 Bi bismuth 83	[209] Po polonium 84	[210] At astatine 85	[222] Rn radon 86
[223] Fr francium 87	[226] Ra radium 88	[227] Ac* actinium 89	[261] Rf rutherfordium 104	[262] Db dubnium 105	[266] Sg seaborgium 106	[264] Bh bohrium 107	[277] Hs hassium 108	[268] Mt meitnerium 109	[271] Ds darmstadtium 110	[272] Rg roentgenium 111							

Key

relative atomic mass
atomic symbol
name
atomic (proton) number

Elements with atomic numbers 112-116 have been reported but not fully authenticated

140 Ce cerium 58	141 Pr praseodymium 59	144 Nd neodymium 60	[147] Pm promethium 61	150 Sm samarium 62	152 Eu europium 63	157 Gd gadolinium 64	159 Tb terbium 65	163 Dy dysprosium 66	165 Ho holmium 67	167 Er erbium 68	169 Tm thulium 69	173 Yb ytterbium 70	175 Lu lutetium 71
232 Th thorium 90	[231] Pa protactinium 91	238 U uranium 92	[237] Np neptunium 93	[242] Pu plutonium 94	[243] Am americium 95	[247] Cm curium 96	[245] Bk berkelium 97	[251] Cf californium 98	[254] Es einsteinium 99	[253] Fm fermium 100	[256] Md mendelevium 101	[254] No nobelium 102	[257] Lr lawrencium 103

* Lanthanide series

* Actinide series

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2017 ACADEMIC YEAR
MID YEAR EXAMINATIONS

CHE 4511: SYNTHETIC REACTIONS, NEIGHBOURING GROPUPS AND CHEMOTHERAPEUTIC AGENTS

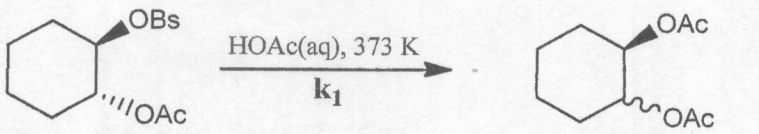
INSTRUCTIONS TO CANDIDATES:

TIME: THREE (3) HOURS

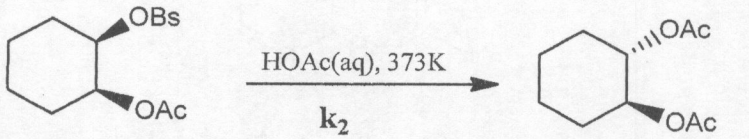
1. THIS PAPER HAS FIVE (5) QUESTIONS.
2. ANSWER **ANY FOUR (4)** QUESTIONS.
3. EACH QUESTION CARRIES **25 MARKS.**
4. PLEASE PRESENT YOUR ANSWERS IN A **LOGICAL** MANNER.
6. ENSURE THERE ARE **FIVE (5)** PRINTED PAGES.

QUESTION 1

(a) Acetolysis of *syn*- and *anti*-brosylates **A** and **B** at 373 K, structures shown below, was found to proceed as follows:



A (*Optically active*) *Racemic mixture*



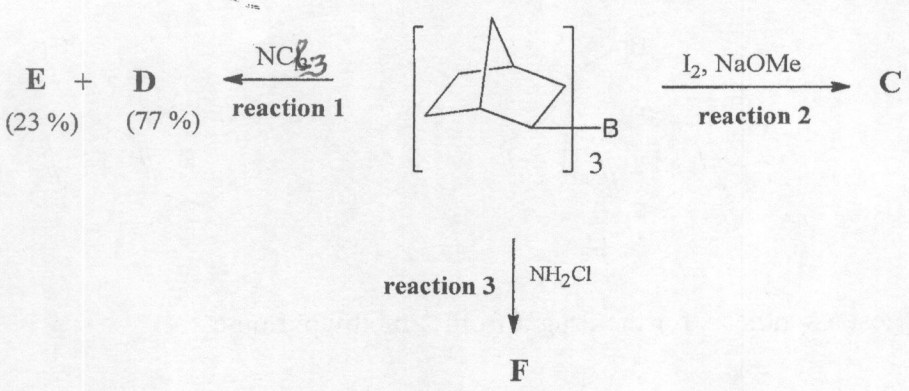
B (Optically active) Optically active

Kinetics data: $k_1 = 1.9 \times 10^{-4}$ $k_2 = 2.9 \times 10^{-7}$

(i) Give a mechanistic explanation for the above experimental results. **(8 marks)**

(ii) What product or products could be isolated that would support your explanation if the above reactions were run in aqueous ethanol. **(3 marks)**

(b) Consider the following reaction scheme:



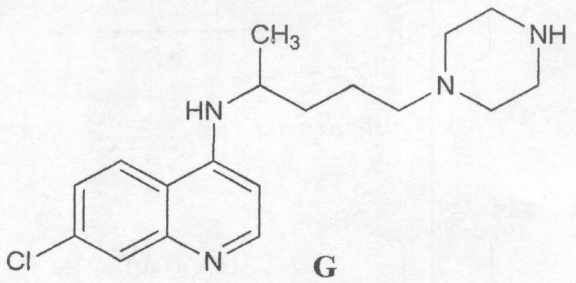
(i) Provide the stereochemical structures of the products **C-F**. **(7 marks)**

(ii) Give mechanism for the reaction 3. **(5 marks)**

(c) Define the terms 'bacteriostatic' and 'bactericidal' drugs. **(2 marks)**

QUESTION 2

(a) Suggest a synthesis of the antimalarial drug, **G**, from readily available non-heterocyclic starting materials and reagents. Show all steps of your proposed synthesis clearly, stating the reagents, solvents, special conditions if any, and intermediates. **(14 marks)**



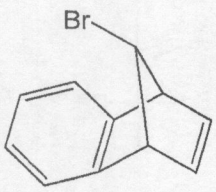
G

(b) Explain the mode of action of the following drugs: **(11 marks)**

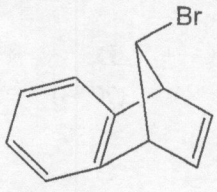
(i) Trimethoprim
(ii) Artemisinin

QUESTION 3

(a) Although there is a substantial difference in the rate at which **H** and **I** solvolyze (**H** reacts 4.4×10^4 times faster than **I** in acetic acid), both compounds give products of completely retained configuration. Briefly explain the difference in reaction rate and mechanistically account for the observed stereochemistry. **(6 marks)**

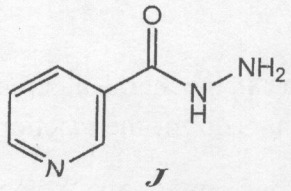


H



I

(b) Suggest a synthesis for the drug **J** from 2-methylpyridine. **(5 marks)**



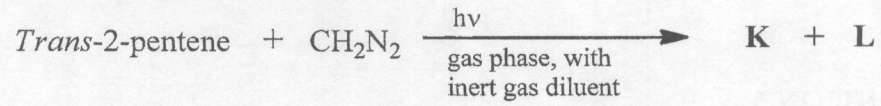
J

(c) (i) What are carbenes? **(2 marks)**

(ii) Give classification for carbenes. **(2 marks)**

(iii) Provide three methods for generation of carbenes. **(6 marks)**

(d) Identify the products of the following reaction and show their stereochemistry. **(4 marks)**



QUESTION 4

(a) Provide one example (structures and name) of each of the following drugs. **(8 marks)**

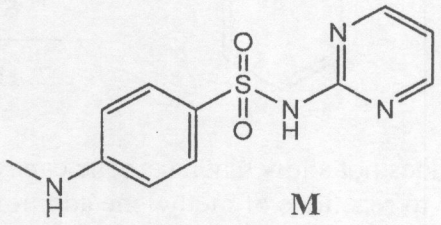
(i) Anti-fungal drug

(ii) Fluoroquinolone antibacterial drug

(iii) Non-nitrogenous antimalarial drug

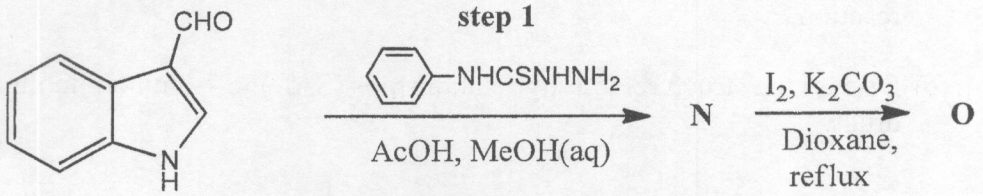
(iv) Antimicrobial cephalosporin

(b) Propose a synthesis of the drug **M** from 4-acetamidobenzenesulfonyl chloride and any needed non-heterocyclic reagents. Show all steps, including the intermediates clearly. **(6 marks)**



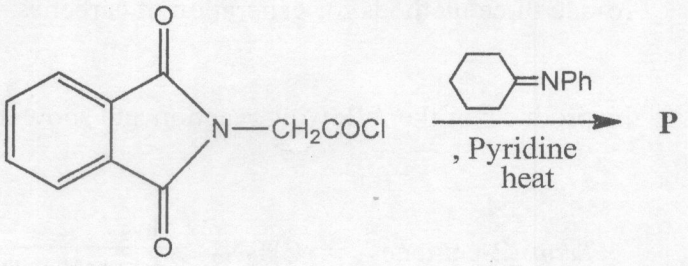
M

(c) (i) Deduce the structure of the biologically active molecule **O** from the following synthesis and state its principal biological action. **(4 marks)**



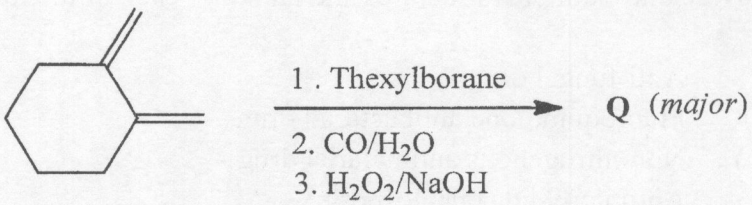
(ii) How would you make the thiosemicarbazide used in step 1? **(3 marks)**

(d) Identify the antimicrobial agent **P** and give mechanism of the following reaction.
(4 marks)

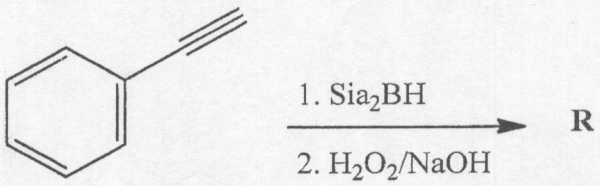


QUESTION 5

(a) Predict the major product and give the mechanism of the following reaction. **(8 marks)**



(b) Provide the stereochemical structure of the product of the following reaction. **(2 marks)**



(c) Spectroscopy does not show that a carbene can react either as a single or a triplet. With reference to reactions of methylene addition across a double bond, show how you would differentiate a carbene that reacts as a singlet from a carbene that reacts as a triplet.
(6 marks)

(d) The carbene generated from dichloromethane and methyl lithium were reacted with 3-methylindole, what product would you expect to obtain? Show the mechanism for the reaction. **(5 marks)**

(e) Discuss the structure-activity relationships (SAR) in 4-aminoquinoline antimalarial drugs. **(4 marks)**

END OF EXAMINATION
GOOD LUCK!

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2017 ACADEMIC YEAR
FINAL EXAMINATIONS

CHE 4522
PHYSICAL ORGANIC CHEMISTRY AND NATURAL PRODUCTS CHEMISTRY

TIME ALLOWED: THREE (3) HOURS

INSTRUCTIONS:

1. Answer any FOUR (4) questions.

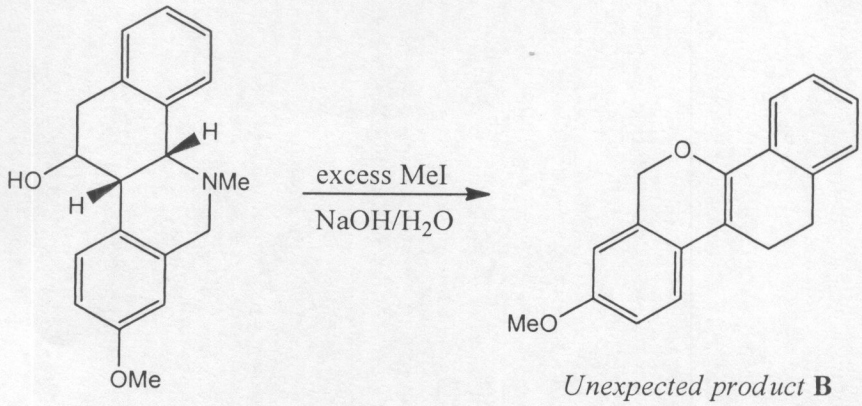
3. Each question carries 25 marks.

3. Present your answers in a concise and logical manner

4. Ensure you have seven (7) printed pages and five questions.

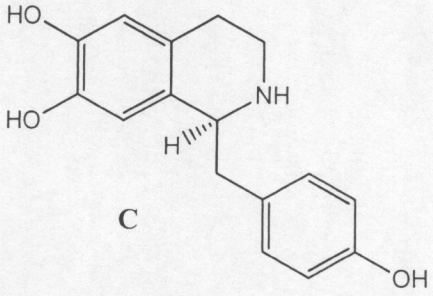
QUESTION ONE

(a) Hofmann degradation of the alkaloid **A** with excess methyl iodide and aqueous sodium hydroxide unexpectedly gave a compound **B** in good yield. Propose a plausible mechanistic explanation to account for the unexpected product **B.** **(8 marks)**



Alkaloid **A** *Unexpected product* **B**

(b) Isotopic labeling experiments have shown that the alkaloid **C**, an intermediate in the biosynthesis of the protoberberine alkaloids in plants, is derived from the amino acid *L*-tyrosine. On this basis suggest the most likely biosynthetic pathway for **C**, showing all steps clearly. **(8 marks)**

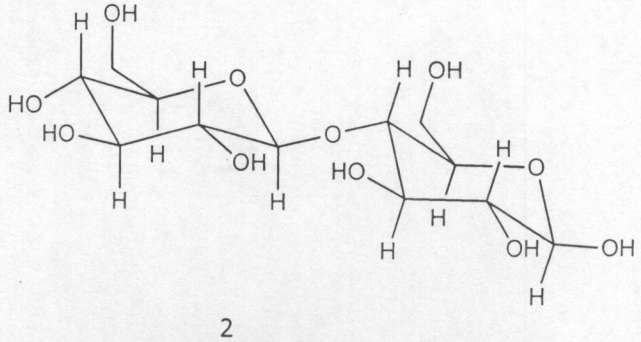


C

(c) Propose a scheme for the synthesis of the disaccharide **D**, from D-glucose and methyl 2,3,6-tri-O-acetyl-β-D-glucopyranoside and provide a systematic name for it.

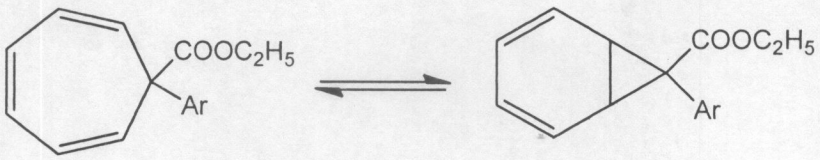
(9 marks)

D:



QUESTION TWO

(a) Cycloheptatriene are often in rapid equilibrium with an isomeric bicyclo[4.1.0]hepta-diene.



The thermodynamics of the isomerization has been studied and some of the data are given below.

Ar	**ΔH** **(kJ/mol)**	**ΔS** **$kJK^{-1}mol^{-1}$**
Phenyl	-22.60	-0.160
p-Nitrophenyl	-14.23	-0.110
p-Methoxyphenyl	-9.62	-0.074

(i) Calculate the equilibrium constant for each case at 298 °K. **(3 marks)**

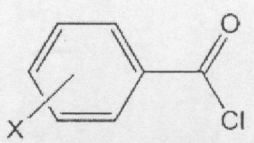
(ii) Calculate the temperature at which K=1 for each system. **(3 marks)**

(iii) Are the signs of enthalpy and entropy as you would expect them to be? Briefly explain. **(4 marks)**

(iv) Explain the pattern of substituent effects that emerge from the above data. **(5 marks)**

(b) Experimental studies on the hydrolysis of substituted benzoyl chlorides, **E**, in moist acetonitrile (a neutral nucleophilic reagent) gave a ρ of 1.20 from the Hammett σ plot. When the same studies were conducted in the presence of perchloric acid (an acid and a highly polar reagent), a correlation with σ^+ was obtained with a ρ of -3.90. Explain these observations. **(10 marks)**

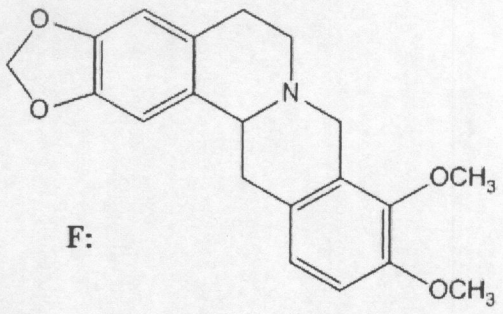
E :



QUESTION THREE

(a) Using the disconnection approach, propose an efficient synthesis for the alkaloid **F** shown below. Show all steps clearly, including the reagents, conditions and the intermediates for each step. *Please do not write any reaction mechanism.* Assume that 1,2-dihydroxy- and 1,2-dimethoxy benzenes are available. **(14 marks)**

F:



(b) Interpret the data on the rare disaccharide **G**, $C_{12}H_{22}O_{11}$, isolated from saffron and deduce its structure.

(i) The disaccharide **G** gives positive Tollens test, undergoes mutarotation and forms a phenylosazone.

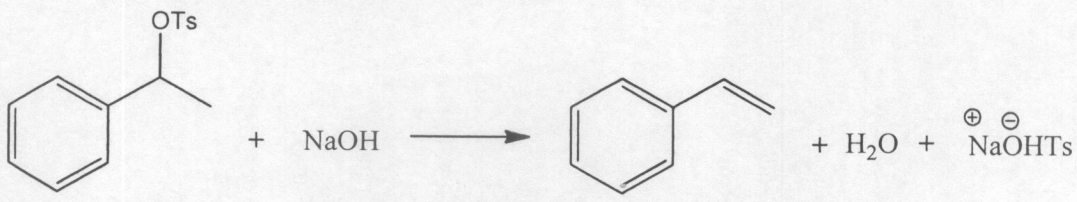
(ii) Reaction of **G** with a largeexcess of iodomethane and silver iodide gives an octamethyl derivative, which upon acidic hydrolysis gives 1 equivalent of 2,3,4,6-tetra-*O*-methyl-D-glucose and 1 equivalent of 2,3,4-tri-O-methyl-D-glucose.

(iii) The coupling constant, $^{3}J_{H1,H2}$ for the hydrogen at the anomeric carbon of the glycosidic linkage in **G** was found to be 4.1 Hz.

(11 marks)

QUESTION FOUR

(a) Consider the elimination reaction shown below:



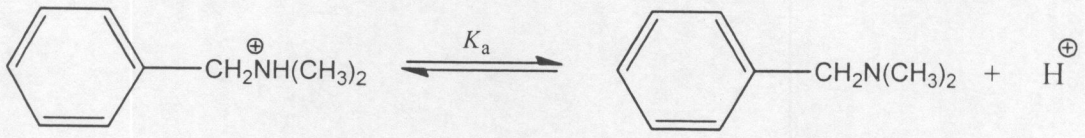
You are required to confirm whether it is an E1 or E2 reaction using the kinetic isotope effect methods.

(i) Briefly describe what is meant by 'kinetic isotope effect'. **(2 marks)**

(ii) Design an experiment describing how you could go about testing the proposed mechanism. **(4 marks)**

(iii) Briefly discuss how your results could answer the question under investigation. **(7 marks)**

(b) The basicity of a series of substituted benzyldimethylamines was studied and the data is given in the table below:



X	pKa	X	pKa
p-CH_3O	9.32	m-NO_2	8.19
p-CH_3	9.22	p-NO_2	8.14
p-F	8.94	p-Cl	8.83
H	9.03	m-Cl	8.67

(i) Determine graphically whether the data correlates with the Hammett equation. **(5 marks).**

(ii) What is the value of ρ? **(2 marks)**

(iii) Interpret the observed ρ value obtained from the graph. **(5 marks)**

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2017 ACADEMIC YEAR
FINAL EXAMINATIONS

CHE4522: PHYSICAL ORGANIC AND NATURAL PRODUCTS CHEMISTRY

SOME USEFUL PHYSICAL CONSTANTS

Substituent	σ	σ^-	σ^+
H	0.00	0.00	0.00
p-NO_2	0.78	1.23	0.79
m-NO_2	0.71		0.67
m-CH_3	-0.07		-0.07
p-CH_3	-0.17		-0.31
m-Br	0.39		
p-Br	0.23		0.15
m-Cl	0.37		
m-COOEt	0.37		
p-OCH_3	-0.27	-0.27	
p-COOEt	-0.45	0.68	0.48
m-OCH_3	0.10		0.05
p-CN	-		0.66
m-CN	-		0.56

THE UNIVERSITY OF ZMBIA

SCHOOL OF NATURAL SCIENCES

DEPARTMENT OF CHEMISTRY

2017-2018 ACADEMIC YEAR SESSIONAL EXAMINATIONS TERM II

CHE 4622: THERMODYNAMICS AND INTRODUCTION TO STATISTICAL MECHANICS.

09:00 HOURS, WEDNESDAY 28 NOVEMBER 2018.

TIME: THREE HOURS

INSTRUCTIONS: ANSWER *ANY FOUR* OF SIX QUESTIONS.

ALL QUESTIONS CARRY EQUAL TWENTY FIVE MARKS EACH.

DATA

PHYSICAL CONSTANTS AND ANY OTHER DATA YOU MAY WISH TO USE ARE GIVEN ON THE ATTACHMENT TO THIS QUESTION PAPER.

QUESTION 1

a).

A given change in state can be carried out in two ways: *reversibly* with an accompanying entropy change in the system, ΔS_{rev} or *irreversibly* with an entropy change, $\Delta S_{irrev.}$ Which of the following statements is correct?

(i) $\Delta S_{irrev.} < \Delta S_{rev}$; (ii) $\Delta S_{irrev.} > \Delta S_{rev}$; (iii) $\Delta S_{irrev.} = \Delta S_{rev}$

Explain your answer.

b).

The enthalpy of a system cannot change during:

(i) an adiabatic constant pressure process
(ii) an isothermal process
(iii) a reversible isobaric process

providing no non-pV work is done by the system in any of these processes. Which of the above statements is correct? Explain your answer.

c).

Derive a general equation for the change in enthalpy, ΔH, for a change in state of a gas *A*:

$$A(\mathrm{g}, \mathrm{p}_1, \mathrm{T}_1) \quad \rightarrow \quad A(\mathrm{g}, \mathrm{p}_2, \mathrm{T}_2)$$

The equation of state for the gas is: $V = \frac{\alpha T}{p}$, where α is a constant independent of temperature, volume and pressure.

d).

Calculate the entropy change when two moles of acetylene are heated at constant pressure from 400 to 900 K. $\mathrm{C}_p(\mathrm{C}_2\mathrm{H}_2) = 51.0 + 16.2\,x\,10^{-3}\mathrm{T}$.

e)

Consider the equation: $dE + p_{ext}dV - \mathrm{T}_{surr}dS \leq 0$. Identify the equation and briefly explain its importance in thermodynamics.

QUESTION 2

a) Write a general expression for a partition function of an ensemble of independent and indistinguishable particles.
b) For a gas of N independent and indistinguishable atoms, show that the entropy S is given in terms of the molecular partition function, q, by:

$$\frac{S}{Nk_B} = \mathrm{T}\left(\frac{\partial ln q}{\partial \mathrm{T}}\right)_{\mathrm{V}} + ln\left(\frac{qe}{N}\right)$$

c) Now consider an atomic gas at 300 K and p = 1 bar. If the vibrational, rotational, electronic and nuclear contributions to the macroscopic thermodynamic properties of the gas can be ignored, then the entropy of such a gas is given by the Sackur-Tetrode equation.
   (i) Show that the translational contribution to the entropy S of the gas may be written in the form: $\frac{S}{Nk_B} = \mathrm{C} + \frac{3}{2}\ln m$; where m is the relative atomic mass (g) and C is independent of the chemical identity of the gas.
   (ii) The standard molar entropy of neon at 300 K is $S_M = 146.2\ \mathrm{J\ K^{-1}mol^{-1}}$. Calculate S_M for argon at 300 K.

QUESTION 3

The van der Waals equation of a gas can be expanded in the form:

$$\frac{pV}{RT} = 1 + \left(b - \frac{a}{RT}\right)\frac{1}{V} + \frac{b^2}{V^2} + \ldots$$

At low pressures the equation of state for the gas can be accurately approximated by the virial equation:

$$pV = RT + Bp$$

a) . Explain the constants a and b in the van der Waals equation

b). Express the virial coefficient B in terms of the van der Waals' constants, a and b.

c). Sketch a graph of B as a function of temperature T for the gas. On your labeled sketch clearly indicate the:

(i) Boyle temperature, T_B;

(ii) region of the graph in which the ideal gas equation is valid;

(iii) regions of the graph that are associated with the van der Waals' constants, a and b.

d). Calculate the Boyle temperature of nitrogen gas whose constants are $a = 1.408$ bar L^2 mol^{-2} and $b = 0.03913$ L mol^{-1}.

QUESTION 4

The oxygen (Z = 8) atom has three closely lying electronic energy levels. The ground state $^3P_2$, has J = 2. The first excited state, $^3P_1$ has J = 1 and its energy level is 0.02 eV above the ground state while the second excited state, $^3P_0$ is at energy level 0.03 eV above the ground state. The degeneracy of an electronic state is 2J + 1. Therefore the electronic contribution of atomic oxygen gas to its thermodynamic properties cannot be neglected.

a) Write the general electronic partition function q_{el} of atomic oxygen.
b) Calculate the electronic partition function q_{el} of atomic oxygen at 300 K.
c) Calculate the probability of occupation of each of the electronic excited states of atomic oxygen.
d) Calculate the Helmholtz free energy for 1 mole of atomic hydrogen at 300 K.
e) Calculate the electronic contribution to the molar heat capacity of oxygen at constant volume at 300 K.

QUESTION 5

a)

Calculate the change in entropy when 46.08 g of ethanol undergoes the following irreversible change in state:

$$CH_3CH_2OH(l, 346.7\ K, 1.00\ bar) \rightarrow CH_3CH_2OH(g, 346.7\ K, 1.00\ bar)$$

The enthalpy of vaporization, $\Delta_{vap}H$, of liquid ethanol is 43.5 $kJ\ mol^{-1}$ at its normal boiling temperature 351.7 K. The molar heat capacity of liquid ethanol is 111.5 $JK^{-1}mol^{-1}$ and that of gaseous ethanol is 65.4 $JK^{-1}mol^{-1}$.

b)

Calculate ΔG for the change in state in part a) above.

c)

Calculate ΔG and the work done, *w*, when liquid ethanol is irreversibly evaporated at 351.7 K into an evacuated vessel of such size that the final pressure is 1.00 bar.

QUESTION 6

a)

At 273 K measurements on argon gave B = -21.7 $cm^3\ mol^{-1}$ and C = 1200 $cm^6\ mol^{-2}$, where B and C are the second and third virial coefficients in the expansion of the compression factor, Z, in the powers of $\frac{1}{V}$. Assuming that the perfect gas law holds sufficiently well for the estimation of the second and third terms of expansion, calculate the compression factor of argon at 100 atm. and 273 K. From your result, estimate the molar volume of argon under these conditions.

b)

One mole of an ideal gas initially at 50°C and 10 bar is expanded isothermally and reversibly to a final volume of 300 L. Calculate the final pressure, *p*, the heat, *q*, and the work, *w* in the change of state.

END OF CHE 4622 SESSIONAL EXAMINATION

THE UNIVERSITY OF ZMBIA

SCHOOL OF NATURAL SCIENCES

DEPARTMENT OF CHEMISTRY

2017-2018 ACADEMIC YEAR SESSIONAL EXAMINATIONS TERM II

CHE 4622: THERMODYNAMICS AND INTRODUCTION TO STATISTICAL MECHANICS

09:00 HOURS, WEDNESDAY 28 NOVEMBER 2018.

ATTACHMENT

DATA SHEET

$R = 8.314\ J\ K^{-1}mol^{-1} = 0.08314\ L\ bar\ K^{-1}mol^{-1} = 0.08206\ L\ atm.K^{-1}mol^{-1}$;

$h = 6.63 \times 10^{-34}\ J\ s$; $c = 3.00 \times 10^{8}\ m\ s^{-1}$; $N_A = 6.02 \times 10^{23} mol^{-1}$, $k_B = 1.38 \times 10^{-23} J\ K^{-1}$;

$1\ eV = 1.602 \times 10^{-19}\ J$;

$\left(p + \frac{a}{V^2}\right)(V - b) = RT$; $dE = TdS - pdV$; $dH = TdS + Vdp$; $dA = -SdT - pdV$;

$dG = -SdT + Vdp$; $dS_p = C_p \frac{dT}{T}$

$S = k_B ln\Omega$; $A = -k_B T lnq$; $E = k_B T^2 \left(\frac{lnQ}{\partial T}\right)_{V,N}$; $C_v = \left(\frac{\partial E}{\partial T}\right)_V$; $lnN! = NlnN - N$

$O = 16.00$; $Ne = 20.18$; $Ar = 39.95$; $C = 12.01$; $H = 1.01$; $1\ amu = 1.6601 \times 10^{-27}\ kg$

$P_i = \frac{g_i e^{-\varepsilon_i / k_B T}}{\sum_i g_i e^{-\varepsilon_i / k_B T}}$; $q_{trans} = \left(\frac{2\pi m k_B T}{h^2}\right)^{3/2} V$; $\frac{S_{trans}}{R} = \frac{5}{2} lnT + \frac{3}{2} lnm + lnp - 1.15, p(bar)$

$\frac{\partial lnf(x)}{\partial x} = \frac{1}{f(x)} \frac{\partial f(x)}{\partial x}$; $\frac{d(e^{f(x)})}{dx} = e^{f(x)} \frac{df(x)}{dx}$; $\frac{dln(x)}{dx} = \frac{1}{x}$; $ln\, e = 1$

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

Department of Chemistry

2017 Academic year Term 2 Final Exam

CHE4822

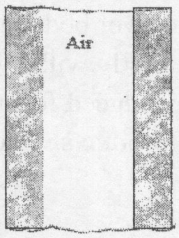
Inorganic Industrial Chemistry II

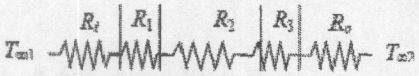
Instructions: Answer any four questions
Question 1 carries 20 marks **Duration: 3 hours**
Questions 2 to 5 carry 15 marks each

QUESTION 1.

a) List the three basic mechanisms of heat transfer and explain the mode of heat transfer in each of the three cases and State Fourier's Law of heat for each case.

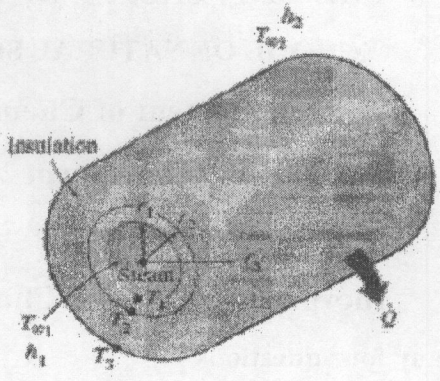
b) Consider a 0.8 m high and 1.5 m wide double- pane window consisting of two 4mm thick layers of glass(k = 0.78 w/mk) separated by a 10 mm wide stagnant air space (k = 0.026 W/m.k). Determine the steady rate of heat transfer through this double plane window and the temperature of its inner surface for a day during which the room is maintained at 20°C while the temperature of the outdoors is 10°C. Given that the Convection heat transfer coefficients on the inner and outer surface of the window is





$h_1 = 10$ W/m^{2}K and $h_2 = 40$ W/m^{2}k. Use a sketch to illustrate your answer.

c) Steam at T∞1 = 320°C flows in a cast Iron pipe K = 80 W/mk whose inner and outer diameters are D1 = % cm and D2 = 5.5 cm, respectively. The pipe is covered with 3 cm thick glass wool insulation with k = 0.05 W/mk. Heat is lost to the surroundings at T∞2 = 5°C by natural convection and radiation, with a combined heat transfer coefficient of h2 = 18 W/m2k. Given that the heat transfer coefficient inside the pipe to be h1 = 60 W/m2k. Determine the rate of heat loss from the steam per unit length of the pipe and calculate the temperature drops across the pipe shell and the insulator.



QUESTION 2

(a) The CONTACT PROCESS for the manufacture of sulfuric acid did not come into widespread use until the importance of the following points was realised:

- There must be excess air in the air/SO_2 mixture.
- The temperature of the reacting gases must be kept as low as is practical.

(i) Why is excess oxygen used and where in the process units is it added?
(ii) State the conditions that will favour a high yield of SO_3.

(b) (i) Even though high pressures will improve the yield of product, why do industries carry out the Contact Process at normal atmospheric conditions?
(ii) Why is it important to ensure complete conversion of SO_2 to SO_3?

(c) (i) Why is the catalyst spread over beds in the converter?
(ii) Why isn't SO_3 reacted directly with H_2O to produce H_2SO_4?
(iii) How then is H_2SO_4 produced form SO_3 in the Contact Process?
(iv) Name two industrial products which are produced using sulfuric acid?

QUESTION 3

(a) The HABER PROCESS combines nitrogen from the air with hydrogen derived mainly from natural gas (methane) into ammonia. The reaction is reversible and the production of ammonia is exothermic. State the following conditions for the reaction:
(i) proportion of nitrogen to hydrogen;
(ii) temperature;
(iii) pressure;
(iv) catalyst;
(v) how the ammonia is removed from the equilibrium mixture.

(b) The choice of conditions you gave the question 2 (a) above affects the process in a number of ways. These conditions have an effect on:
- the position of equilibrium,
- on the rate of the reaction,
- the economics of the process.

Explain how each of the conditions you gave in question 2(a), i.e. temperature, pressure and the catalyst affects:
(i) the position of equilibrium,
(ii) the rate of the reaction,
(iii)the economics of the process.

QUESTION 4

(a) With the help of a process diagram, describe the production of weak nitric acid.
(b) With the help of a process diagram, describe the production of high strength nitric acid.
(c) Discuss emissions from nitric acid production and how to control them.

QUESTION 5

(a) Describe how you would make 1 ton of hydrochloric acid by synthesis from molecular hydrogen (H_2) and molecular chlorine (Cl_2).
(b) State the necessary conditions for the reaction between H_2 and Cl_2 to proceed. Explain with the help of a process diagram.
(c) The reaction that produces HCl from H_2 and Cl_2 in Q. 1 above is highly exorthermic and this heat energy would set off the reverse reaction thus breaking up HCl back into H_2 and Cl_2. This is undesirable because it would lead to low HCl yields. How are high yields of HCl assured?

END OF EXAMINATION

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}

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2017/18 ACADEMIC YEAR FINAL EXAMINATIONS

GES 1310: INTRODUCTION TO GEOGRAPHY

TIME: Three Hours
INSTRUCTIONS: Answer **any three questions.** Use of an approved calculator is allowed. Candidates are encouraged to use illustrations wherever appropriate.

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1. Discuss the assertion that 'industry location decisions need detailed analyses'.

2. Describe the theory of plate tectonics and the physical features resulting from tectonic movements.

3. The biogeographical taxonomical classification of organisms involves a standardized ranking of living organisms into a hierarchical system that proceeds from the general to the specific. Explain the eight biogeographical categories of classification of living organisms proceeding from the general to the specific.

4. Soil properties are categorized into three major groups, namely; physical, chemical and biological. Answer the following questions on the soil physical properties:

   (i) Given that the mass of the core ring (diameter = 5cm and height = 5cm) is 70.0g, mass of core ring plus the wet soil is 278.5g and the mass of the core ring plus oven dry soil is 230.0g. Calculate the bulk density, volumetric water content and porosity.
   (ii) Discuss the importance of soil colour.

5. Outline the Central Place Theory and state its relevance in our world today.

END OF EXAMINATION

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2017/2018 ACADEMIC YEAR FINAL EXAMINATIONS

GES 2130 : THE GEOGRAPHY OF AFRICA WITH SPECIAL REFERENCE TO ZAMBIA

TIME : Three Hours

INSTRUCTIONS: Answer any three questions. All questions carry equal marks. Candidates are advised to make use of illustrations and examples wherever appropriate. Use of the Phillips University Atlas is allowed.

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1. Explain the relationship between relief and population distribution.

2. 'The Great Lakes of Africa are socio-economically and environmentally important to Africa' Discuss.

3. Describe the space-economy of Ghana, showing the environmental basis for regional socio-economic disparity, and how to mitigate it.

4. Explain the changes that Zambia made in her journey to achieve socio-economic development during and after Dr. Kaunda's rule up to 2011.

5. Describe the achievements, and challenges that the successive administrations in Zambia have experienced in the quest to develop the country, from 1991 to date.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

2017/18 ACADEMIC YEAR FINAL EXAMINATIONS

GES 2322: FUNDAMENTALS OF NATURAL RESOURCES ECONOMICS

TIME: Three Hours

INSTRUCTIONS: Answer question 1 and any other two. All questions carry equal marks. Candidates are encouraged to use illustrations wherever appropriate. Use of an approved calculator is allowed.

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1. Answer **ALL** of the following:

a) State two negative effects of inflation.

b) What is the difference between market and administered prices?

c) List any two types of economic actors.

d) Define structural unemployment.

e) Outline any two determinants of the quantity of a good or service that suppliers are willing to supply at a given price.

f) What is the difference between nominal and real Gross Domestic Product?

g) In which two (2) ways do monopolies create barriers to entry into their industries?

h) Mention one (1) positive effect of inflation.

i) What are the four factors of production?

j) Give two examples of administered prices.

k) In 1998, Zambia hypothetically had a nominal GDP of K100 million and a real GDP of K120 million. Calculate the GDP deflator for Zambia in 1998.

l) Outline any two (2) factors that are important for economic growth.

m) Study Table 1 and answer the questions that follow.

Table 1: Data on a firm's short-run costs of producing different levels of output

Output (dresses)	Short-run fixed cost (SFC)	Short-run variable cost (SVC)	Short-run total cost (STC)	Short-run marginal cost (SMC)
0	30	0	30	
1	30	22	52	
2	30	38	68	
3	30	48	78	
4	30	61	91	
5	30	79		

i. Calculate the Short run marginal cost when output goes up from 3 to 4 dresses.

ii. Calculate the short run total cost when output is 5 dresses

n) Study Table 2 and answer the questions that follow.

Table 2: An economy's total expenditure

Item	Amount(ZMW)
Transfer Payments	54
Interest Income (i)	150
Depreciation	36
Wages (W)	67
Gross Private Investment (I)	124
Business Profits (PR)	200
Indirect Business Taxes	74
Rental Income (R)	75
Net exports (X-M)	18
Net Foreign Factor Income	12
Government Purchases (G)	156
Household Consumption (C)	304

i. Calculate GDP using the expenditure approach.

ii. Calculate GDP using the income approach.

2. Study Table 3 and answer the questions that follow:

Table 3: Quantity demanded of good a good at different prices

Periods	Quantity demanded	Price (ZMW)
(a)	200	2
(b)	100	4
(c)	70	6
(d)	50	8
(e)	25	10
(f)	10	12

Source: Hypothetical data

(a) On the graph paper provided, plot quantity demanded against price
(b) Why is the demand curve downward sloping?
(c) On the same graph in (a), show the difference between a shift in demand and a change in quantity demanded due to price changes.
(d) Briefly explain how any two factors affect the demand for a normal good.
(e) What is the price elasticity of demand when;
    i. When there is a change from (a) to (b)
    ii. When there is a change from (b) to (c)
    iii. Describe the elasticity in i and ii

(f) Briefly explain three factors that influence the elasticity of demand of a good.

3. Explain how having natural resources can either enhance or hinder the development of a country.

4. With the aid of examples, explain how the following factors have impeded economic growth in developing countries:
   a) Economic inefficiency
   b) Rapid population growth
   c) Cultural barriers and
   d) Inadequate human resources.

5. Explain five major similarities and five differences between monopoly and monopolistic competition markets.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2017/18 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 an approved calculator is allowed

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1. Write shorty explanatory notes on **ALL** of the following

    a) Scales of measuring geographical data
    b) Type I and type II errors in hypotheses testing
    c) Extraneous variables
    d) Inductive analysis
    e) Normal and skewed distributions

2. The data presented in Table 1 shows the distance from the central business district (CBD) of a hypothetical city and the price of a 250 milliliters bottle of water. What conclusion can you make at $\alpha = 0.05$ and assuming that the data is highly skewed?

Table 1: Distance from the CBD and the price of a bottle of water

Convenience store	Distance from the CBD (meters)	Price of 250ml bottle of water (Kwacha)
1	50	1.80
2	175	1.20
3	270	2.00
4	375	1.00
5	425	1.00
6	580	1.20
7	710	0.80
8	790	0.60
9	890	1.00
10	980	0.85

Source: *Hypothetical*

3. It is assumed that the application of fertilizer to certain crops results in high yields. But it is also true to say that some crops do not do well when fertilizer is applied to them. A soil scientist planted some beans in a number of fields where he applied fertilizer as shown in Table 2. Answer all the questions below this table.

Table 2: Relationship between amount of fertilizer and Yields of beans

Field	Amount of fertilizer (kg)	Yield in tonnes/ha
A	3.4	26.2
B	1.8	17.8
C	4.6	31.3
D	2.3	23.1
E	3.1	27.5
F	5.5	36.0
G	0.7	14.1
H	3.0	22.3
I	2.6	19.6
J	4.3	31.3
K	2.1	24.0
L	1.1	17.3
M	6.1	43.2
N	4.7	36.4
O	3.8	26.1

Source: *Hypothetical*

a) Plot the data
b) Conduct a regression analysis so as to come up with a regression equation
c) Draw a line of best fit in your scatter diagram
d) Define your Regression Equation
e) How much yield of beans in tonnes/ha would you expect if the amount of fertilizer was 9.0kg?

4. Professor Mwenzi conducted a study on 'FGE 2405 students' awareness of the degradation of the environment and their perceived capacity to take action to improve the environment'. Quantitative data was collected using a questionnaire while qualitative data was collected through interviews and observation. A week later, Dr. Nchimunya conducted the same research whose sample was collected from the same population as Professor Mwenzi's. Surprisingly the results of the two researchers were significantly different.

   Explain what could have led to the differences in the research findings of the two researchers.

5. 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 α = 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*

6. What do grades 4 to 6 pupils consider to be the most important characteristic that defines who they are between good grades (performance in class), athletic ability, or popularity? What conclusion can you make from the data presented in Table 4 at α = 0.05?

Table 4: Grade 4-6 pupils and characteristic preferences

	Grades		
Characteristic	4	5	6
Grades	49	50	69
Popular	24	36	38
Sports	19	22	28

Source: *Hypothetical*

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

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2017/2018 ACADEMIC YEAR FINAL EXAMINATIONS

GES 3151: REGIONAL PLANNING AND DEVELOPMENT

TIME: Three hours

INSTRUCTIONS: Answer question **1** and any other **two**. All questions carry equal marks. Candidates are encouraged to use illustrations wherever possible.

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1. Write short explanatory notes on ALL of the following:
   a) The Brandt Map
   b) Leakage as a transaction in a regional economy
   c) Occupational structure as a measure of regional economic development status
   d) Endogenous regional development
   e) Competitive advantage of regions.
2. 'Regional Economic Theory suggests that economic growth is a result of the processes of efficient capital accumulation'. Discuss.
3. Explain how Income Transfers can influence regional and employment growth.
4. With reference to Growth Poles Theory, discuss any three types of polarisation.
5. The Zambia Multi- Facility Economic Zone (MFEZ) programme was introduced to Zambia in 2005. The Programme seeks to create a platform for Zambia to achieve economic development by attracting both Domestic Direct Investment (DDI) and Foreign Direct Investment (FDI) through a strengthened policy and legislative environment. It is envisaged that the implementation of MFEZs in Zambia will lead to increased activity in the trade and manufacturing sectors, which have numerous positive spill over effects in other sectors such as utilities, transport, housing, agriculture and services among others. The concept of the MFEZs seeks to create an efficient and effective administrative infrastructure that configures an ideal investment environment for attracting major world class investors.

With reference to the Lusaka South Multi-Facility Economic Zone (LS-MFEZ), briefly answer the following questions:

a) Explain the concept of forward and backward linkages in regional development.
b) Outline investment and trade instruments that are being deployed in the LS-MFEZ to avert the negative externalities of globalisation.
c) How is the implementation of the LS-MFEZ a threat to environmental sustainability of Lusaka city-region and a factor in intra-regional socio-economic polarisation?

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

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2017/2018 ACADEMIC YEAR FINAL EXAMINATIONS

GES 3321: ENVIRONMENT AND NATURAL RESOURCES ECONOMICS

TIME: Three hours

INSTRUCTIONS: Answer the two questions in Section A and any question from Section B. Use of an approved calculator is allowed. Discounting Factor Tables are provided. All questions carry equal marks.

SECTION A

1. Write short explanatory notes on **all** of the following:
   a) Standards as instruments for pollution control
   b) Travel Cost valuation method
   c) Effects of discounting on the environment
   d) How price changes affect demand for and supply of natural resources
   e) Use of Ecolabels to influence sustainable natural resources management

2. The government wants to set up a nuclear power plant in Chongwe district to generate 10 000 KW of electricity annually for a period of 30 years. The residents of Chongwe are opposed to the project on grounds that other than the risk of radiation, nuclear power generation will be more expensive than hydroelectric power generation in the long run. The nuclear power plant will have initial costs of USD 10 million. Electricity generation will start in year 5 and continue undisturbed for 30 years. Labour to operate and maintain the plant will cost USD 20 000 annually. Each Kilowatt of electricity will be sold for USD 2 during the first 15years. The price will then be raised to USD 5 for the remaining project period.

   ZESCO currently generates 4000 KW of electricity which it sells at USD 3 per kilowatt. Its annual maintenance costs are USD 8000. It would need to replace its equipment in 20 years at a cost of USD 20 million.

   (a) Use cost benefit analysis to assess the claim by the residents of Chongwe. Assume a discount rate of 10%
   (b) If the government goes ahead to build the nuclear power plant, the value of residential properties in Chongwe would go down. In addition, crop and livestock productivity would reduce due to the resulting air and water pollution. What two indirect valuation methods could be used to estimate the costs of these developments?

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2017/18 ACADEMIC YEAR FINAL EXAMINATIONS

GES 3262: BIOGEOGRAPHY

TIME: Three Hours

INSTRUCTIONS: Answer any three questions. Candidates are encouraged to make use of illustrations wherever appropriate.

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1. Write short explanatory notes on **ALL** of the following:

   (a) Characteristics of *Chipya* woodland

   (b) Criticisms of the 'Pleistocene Overkill Hypothesis'

   (c) Historical biogeography

   (d) Abiotic processes

   (e) Ecological niche and habitat

   (f) Climatic relicts

   (g) Natural selection

   (h) Evidence in support of Continental Drift.

2. Discuss the use of fire by pre-agricultural people and outline its effects on local vegetation.

3. Explain the two alternative approaches that have been used to understand the disjunct distribution patterns of plants and animals.

4. The Linnaean System of classification is described as being "generic, hierarchical, comprehensive, and binomial," (McKnight, 1984:194). Explain the terminology binomial in relation to the scientific name of organisms.

5. It has generally been observed that pressures reduce the number of organisms but rarely eliminate the last surviving individual. Explain how species finally become extinct.

END OF EXAMINATION

SECTION B

3. Discuss the use of any two economic instruments for fisheries management.

4. Using an example, explain the use of the contingent valuation method.

5. Explain the principles of Cost Benefit Analysis.

END OF EXAMINATION

Table 3.3 Sample Compounding and Discounting Table

RATE 10%

Year	COMPOUNDING FACTOR FOR 1 What an initial amount becomes when growing at compound interest	COMPOUNDING FACTOR FOR 1 PER ANNUM Growth of equal year-end deposits all growing at compound interest	SINKING FUND FACTOR Level deposit required each year to reach 1 by a given year	DISCOUNT FACTOR How much 1 at a future date is worth today	PRESENT WORTH OF AN ANNUITY FACTOR How much 1 received or paid annually for X years is worth today	CAPITAL RECOVERY FACTOR Annual payment that will repay a $1 loan in X years with compound interest on the unpaid balance	Year
1	1.100 000	1.000 000	1.000 000	.909 091	.909 091	1.100 000	1
2	1.210 000	2.100 000	.476 190	.826 446	1.735 537	.576 190	2
3	1.331 000	3.310 000	.302 115	.751 315	2.486 852	.402 115	3
4	1.464 100	4.641 000	.215 471	.683 013	3.169 865	.315 471	4
5	1 610 510	6.105 100	.163 797	.620 921	3.790 787	.263 797	5
6	1.771 561	7.715 610	.129 607	.564 474	4.355 261	.229 607	6
7	1.948 717	9.487 171	.105 405	.513 158	4.868 419	.205 405	7
8	2.143 589	11.435 888	.087 444	.466 507	5.334 926	.187 444	8
9	2.357 948	13.579 477	.073 641	.424 098	5.759 024	.173 641	9
10	2.593 742	15.937 425	.062 745	.385 543	6.144 567	.162 745	10
11	2.853 117	18.531 167	.053 963	.350 494	6.495 061	.153 963	11
12	3.138 428	21.384 284	.046 763	.318 631	6.813 692	.146 763	12
13	3.452 271	24.522 712	.040 779	.289 664	7.103 356	.140 779	13
14	3.797 498	27.974 983	.035 746	.263 331	7.366 687	.135 746	14
15	4.177 248	31.772 482	.031 474	.239 392	7.606 080	.131 474	15
16	4.594 973	35.949 730	.027 817	.217 629	7.823 709	.127 817	16
17	5.054 470	40.544 703	.024 664	.197 845	8.021 553	.124 664	17
18	5.559 917	45.599 173	.021 930	.179 859	8.201 412	.121 930	18
19	6.115 909	51.159 090	.019 547	.163 508	8.364 920	.119 547	19
20	6.727 500	57.274 999	.017 460	.148 644	8.513 564	.117 460	20
21	7.400 250	64.002 499	.015 624	.135 131	8.648 694	.115 624	21
22	8.140 275	71.402 749	.014 005	.122 846	8.771 540	.114 005	22
23	8.954 302	79.543 024	.012 572	.111 678	8.883 218	.112 572	23
24	9.849 733	88.497 327	.011 300	.101 526	8.984 744	.111 300	24
25	10.834 706	98.347 059	.010 168	.092 296	9.077 040	.110 168	25
26	11.918 177	109.181 765	.009 159	.083 905	9.160 945	.109 159	26
27	13.109 994	121.099 942	.008 258	.076 278	9.237 223	.108 258	27
28	14.420 994	134.209 936	.007 451	.069 343	9.306 567	.107 451	28
29	15.863 093	148.630 930	.006 728	.063 039	9.369 606	.106 728	29
30	17.449 402	164.494 023	.006 079	.057 309	9.426 914	.106 079	30
31	19.194 342	181.943 425	.005 496	.052 099	9.479 013	.105 496	31
32	21.113 777	201.137 767	.004 972	.047 362	9.526 376	.104 972	32
33	23.225 154	222.251 544	.004 499	.043 057	9.569 432	.104 499	33
34	25.547 670	245.476 699	.004 074	.039 143	9.608 575	.104 074	34
35	28.102 437	271.024 368	.003 690	.035 584	9.644 159	.103 690	35
36	30.912 681	299.126 805	.003 343	.032 349	9.676 508	.103 343	36
37	34.003 949	330.039 486	.003 030	.029 408	9.705 917	.103 030	37
38	37.404 343	364.043 434	.002 747	.026 735	9.732 651	.102 747	38
39	41.144 778	401.447 778	.002 491	.024 304	9.756 956	.102 491	39
40	45.259 256	442.592 556	.002 259	.022 095	9.779 051	.102 259	40
41	49.785 181	487.851 811	.002 050	.020 086	9.799 137	.102 050	41
42	54.763 699	537.636 992	.001 860	.018 260	9.817 397	.101 860	42
43	60.240 069	592.400 692	.001 688	.016 600	9.833 998	.101 688	43
44	66.264 076	652.640 761	.001 532	.015 091	9.849 089	.101 532	44
45	72.890 484	718.904 837	.001 391	.013 719	9.862 808	.101 391	45
46	80.179 532	791.795 321	.001 263	.012 472	9.875 280	.101 263	46
47	88.197 485	871.974 853	.001 147	.011 338	9.886 618	.101 147	47
48	97.017 234	960.172 338	.001 041	.010 307	9.896 926	.101 041	48
49	106.718 957	1.057.189 572	.000 946	.009 370	9.906 296	.100 946	49
50	117.390 853	1.163.908 529	.000 859	.008 519	9.914 814	.100 859	50

Source: Gittinger (1973:20-21). Reprinted by permission of The World Bank and The Johns Hopkins University Press.

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2017/2018 ACADEMIC YEAR FINAL EXAMINATIONS

GES 3330: ENVIRONMENT AND DEVELOPMENT

TIME: Three hours

INSTRUCTIONS: Answer any **THREE** questions

All questions carry equal marks

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1. Explain how climate change might affect Zambia's physical environment.

2. Discuss the scientific and societal responses to the challenges of the Anthropocene.

3. 'Zambia has abundant natural resources yet remains very poor'. Discuss.

4. 'According to the ecological economics perspective, the economy is a growing dependent sub-system of the non-growing environment. Hence, unsustainability becomes a state of the economy being incompatible with a non-growing environment' (Rees 2003). Elaborate.

5. Explain any five Sustainable Development Goals (SDGs) that are related to the environment.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

INSTITUTE OF DISTANCE EDUCATION

2017/2018 ACADEMIC YEAR FINAL EXAMINATIONS

GES 3330: ENVIRONMENT AND DEVELOPMENT

TIME: Three Hours

INSTRUCTIONS: Answer question **1**and any other **two**. All questions carry equal marks. Candidates are encouraged to make use of illustrations wherever appropriate.

---

1. Write short explanatory notes on **ALL** of the following:

   a) Obstacles to sustainable development

   b) Characteristics of modern day environmental problems.

   c) Types of natural resources

   d) Economic Instruments for environmental policy and management.

   e) Climate change adaptation

2. Explain the necessary conditions required for sustainable development to be a reality in the next 50years.

3. Outline any four of the six 'criteria pollutants' of air.

4. Explain the assertion that 'climate change affects all dimensions of food security in Southern Africa'.

5. a) With the aid of a diagram, describe the steps of an environmental management process in a chronological order.
   b) Explain the relevance of each step.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

2017/2018 ACADEMIC YEAR FINAL EXAMINATIONS

GES 3342: ENVIRONMENTAL PLANNING AND MANAGEMENT

TIME: Three Hours

INSTRUCTIONS: Answer question **1** and any other **two**. All questions carry equal marks. Candidates are encouraged to use illustrations wherever appropriate.

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1. Write short explanatory notes on **ALL** of the following:

   a) Polluter Pays Principle (PPP)
   b) Pattern matching
   c) Weak sustainability
   d) Clustering as a tool in Strategic Environmental Assessment (SEA)
   e) Property rights

2. Discuss the assertion that 'decentralization is a better way of managing natural resources'.

3. Equity is the ultimate anchor of sustainability'. Elucidate

4. a) State the significance of an Environmental Impact Statement (EIS)
   b) Briefly describe the contents of an EIS report
   c) Explain why an Environmental Impact Assessment (EIA) should always take a participatory approach.

5. With the aid of examples, discuss the 'tragedy of the commons'.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

INSTITUTE OF DISTANCE EDUCATION

2017/2018 ACADEMIC YEAR FINAL EXAMINATIONS

GES 4172: RURAL LAND USE AND LANDSCAPES

TIME: Three hours

INSTRUCTIONS: Answer question **1** and any other **two**. Question 1 carries 40 marks while the rest carry 30 marks each. Candidates are advised to make use of illustrations and examples wherever appropriate.

1.

a. Figure 1 illustrates some economic concepts. Identify curve A and curve B

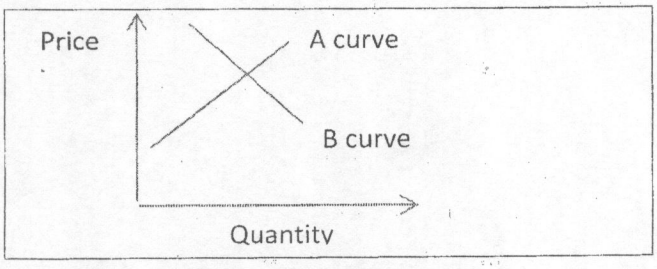

Figure 1: Some economic concepts

b. Identify five types of actors in rural development in Zambia
c. State four types of property regimes
d. Name four dimensions of food security
e. State the triple role of women
f. Identify four factors that influence location of settlements in rural Zambia
g. A landscape can be defined as 'patterns and trends of imprinted aspects associated with a particular area'. State two key attributes of the concept of landscape.
h. State one advantage and one disadvantage of the following in understanding rural landscapes:
    i. Perceptual approach,
    ii. Interdisciplinary approach,
    iii. Participatory approaches.
i. State four reasons why rural industrialization is important for rural development.
j. State two strengths and two weaknesses of Community Based Natural Resources Management in Zambia.

2. Explain the importance of transport infrastructure in the development of rural Africa

3. How do physical, economic and policy environments influence rural livelihoods

4. 'Women hold fifty percent of the sky'. Explain this adage with respect to the role that women play in contributing to household food security and nutrition in Africa.

5. Outline any five principles of community based natural resources management

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END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL STUDIES

2017/18 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.

Candidates are encouraged to make use of illustrations wherever possible.

---

1. Write short explanatory notes on ALL of the following:
    a) Consequences of segregation in the city
    b) Levels of culture in the city
    c) Characteristics of strategic planning
    d) Urbanization without industrialization in sub saharan africa
    e) Local Environmental Area Planning (LEAP).
2. Describe four characteristics of the squatter settlement and suggest four ways in which Zambia can deal with the problem.
3. In Zambia and other parts of Africa ,colonial urbanization created urban areas that manifest characteristics not seen in cities of the global north. Elaborate
4. Using a city of your choice, give three examples of an urban public space and explain how it works well.
5. Describe the impacts of industrialization on the urban environment using the Environmental Kuznets Curve Hypothesis.

End of Examination

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2017/2018 ACADEMIC YEAR DEFERRED EXAMINATIONS

GES 4285: GEOGRAPHICAL HYDROLOGY

TIME: Three Hours

INSTRUCTIONS: Answer all questions in section A and any other **two** in section B. All questions carry equal marks. Candidates are advised to make use of illustrations and examples wherever appropriate.

Section A

1. How does precipitation type influence interception? [3 mars]
2. Give at least five methods used for determining soil moisture [5 marks]
3. In a given month, precipitation into a lake was 30 mm, the inflow to the lake from a stream was 70mm and the outflow from the lake through another stream was 35 mm. The groundwater inflow was 6 mm and Ground water outflow was 4 mm. Given that that water level in the lake increased by 50 mm:
   a) What was the lake's rate of Evaporation during that month? [5 marks]
   b) What assumption is important for your answer in a)? [3 marks]
4. Study figure 1 and answer the questions that follow.
   a) If a contaminant was discharged into borehole B, how long will it take the contaminant to reach borehole C which is 1,564 meters away if the hydraulic conductivity of this aquifer is 0.0028 m/s? [5 marks]
   b) What will be the groundwater discharge at Borehole C from Borehole B, if the cross section area of the aquifer is $1000m^2$? [3 marks]
   c) Will the contaminant reach well A? Explain. [3 marks]
5. Diagrammatically show and explain three methods used for separating base flow from storm runoff. [9 marks]
6. Name any six factors that influence the amount of runoff in a catchment. [6 marks]
7. State four ways used for measuring floods. [8 marks]

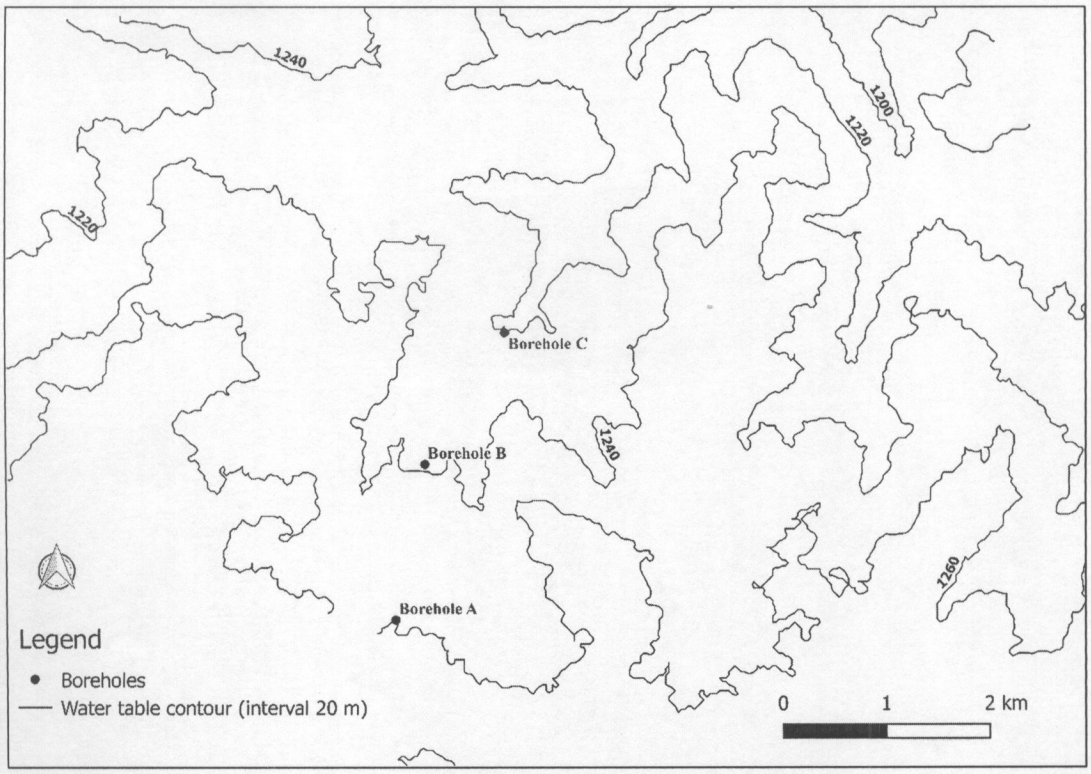

Figure 1: Groundwater table for Lusaka (*Source: Hypothetical*)

Section B: Answer any **two** questions

8. Explain the hydrological impacts of river basin development and show why river basin development planning is important.
9. Show why infiltration is important and outline at least five (5) factors that influence the infiltration rate
10. Describe three methods for river discharge measurement and justify water resources monitoring to Zambia's national development.
11. 'Floods are both a menace and a blessing'. Discuss.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

2017/2018 ACADEMIC YEAR DEFFERRED FINAL EXAMINATIONS

GES 4342: ENVIRONMENT AND NATURAL RESOURCE MANAGEMENT

TIME: Three hours

INSTRUCTION: Answer question 1 and any other **two**. Candidates are encouraged to make illustrations wherever possible.

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1. Write short explanatory notes on all of the following:
    a) Common ways that wetlands form – and remain waterlogged
    b) Unsustainable off -take
    c) Pollution as an external cost that should not be completely eliminated
    d) Policy framework for wildlife
    e) Composting
    f) Importance of water resource management and conservation
2. Discuss the institutional arrangements that govern property regime.
3. Explain why the Zambezi wetland is important in hydrological and chemical cycles.
4. Hazardous wastes are substances unsafe to use commercially, industrially, agriculturally or economically. Explain how these wastes can be properly handled in order to reduce air and water contaminations.
5. Using specific examples, explain the differences between a positive and a negative externality

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END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

2017/2018 ACADEMIC YEAR FINAL EXAMINATIONS

GES 4342: ENVIRONMENT AND NATURAL RESOURCE MANAGEMENT

TIME: Three hours

INSTRUCTION: Answer question 1 and any other **two**. Candidates are encouraged to make illustrations wherever possible.

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1. Write short explanatory notes on all of the following:
    a) Non- consumptive utilization of wildlife
    b) Survival value of wildlife
    c) Stock and fund pollutants
    d) Values and functions of wetlands
    e) Groundwater conservation
    f) Integrated waste management
2. Wildlife plays a critical role in the healthy functioning of ecosystems. Discuss the ways in which wildlife ecosystems are conserved and managed in Zambia.
3. Explain any four policy instruments the government may use to control pollution.
4. Why are Wetlands referred to as 'biological supermarkets'.
5. Burying in landfills is one of the most common methods of waste management in Zambia and it involves either open dumps or sanitary landfills. Explain why sanitary landfills are a better mode of waste management compared to open dumps.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2017/18 ACADEMIC YEAR FINAL EXAMINATIONS

GES 4451: CARTOGRAPHY

TIME: Three Hours

INSTRUCTIONS: Answer questions 1 and any other **two**. All questions carry equal marks. Candidates are advised to make use of illustrations and examples wherever appropriate.

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1. Write short explanatory notes on ALL of the following:

   a) Computer Aided Design (CAD)

   b) Plainimetric maps

   c) Relevance of the Global Positioning System (GPS) in Cartography

   d) Characteristics of traditional cartography up to the 1950s

   e) Differential elements of symbolisation

   f) Universal Transverse Mercator (UTM) Grid System.

2. You have been asked to generate an up-to-date topographic map for the City of Lusaka. Explain:

   a) The major types of information that your map will contain

   b) The sources of data for your topographic mapping exercise

   c) Major colour considerations when representing features

   d) Any two ways you would use to represent relief.

3. 'Today, far more maps are made using the computer than by hand and this has had far-ranging impacts in cartography'. Discuss.

4. 'Cartography is set in the context of progress through time'. Explain this statement in relation to its development.

5. With the help of three examples of each of the three classes of map symbols, explain how they can be used to portray nominal, ordinal and interval data on a map.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

2017/2018 ACADEMIC YEAR FINAL EXAMINATIONS

GES 4461: LAND RESOURCES SURVEY

TIME: Three Hours

INSTRUCTIONS: Answer question **1** and any other **two**. All questions carry equal marks. Candidates are encouraged to make use of illustrations wherever appropriate.

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1. Write short explanatory notes on **ALL** of the following:

   (a) Social Approach to Land-use planning
   (b) Role of aerial photos in land resources survey
   (c) Incremental planning
   (d) Any five principles of Land-use planning
   (e) Suitability orders
   (f) Integrated surveys.

2. 'the utilization and management of land resources is influenced by socio-economic and institutional complexities'. Discuss

3. 'environmental impacts of land-use development are pervasive in almost all forms of economic activities'. Elucidate.

4. Land Evaluation (LE) is the process of assessment of land performance when a parcel of land is used for specified purposes. LE is very important as it aids land use planning. With respect to Land Evaluation, answer the following questions:

   (a) Account for the main stages in the process of land evaluation.
   (b) Explain the criteria used to select land use requirements.
   (c) Describe the various land capability classes.

5. Luapula Province is one of the 10 provinces in Zambia and is located in agro- ecological region III (receiving more than 1000 mm of rainfall per year). The Province is endowed with several natural resources such as plateaus, lakes, rivers, mountains, and waterfalls among others. As a surveyor at the Ministry of Lands and Natural Resources, you have been tasked to conduct a natural resource survey of Luapula province. The information extracted from the survey will later be used for land use planning in this region. Based on the description of the study area i.e. Luapula Province, answer the following questions:

i. Explain the type of survey you would use in this study and justify your answer. [7]

ii. State the type of base materials you would use, and where necessary, give the scale of the base materials to be used. [3]

iii. Describe the method of survey would you employ and justify your answer. [5]

iv. What type of data would you collect when conducting your field survey? [7]

v. State the various personnel that would be involved in this survey? [3]

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

2017/2018 ACADEMIC YEAR FINAL DEFERRED EXAMINATIONS

GES 4461: LAND RESOURCES SURVEY

TIME: Three Hours

INSTRUCTIONS: Answer question **1** and any other **two**. All questions carry equal marks. Candidates are encouraged to make use of illustrations wherever appropriate.

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1. Write short explanatory notes on **ALL** of the following:

   (a) Sustainable land management (SLM)

   (b) Limitations of Land-use planning

   (c) Any five classes of Land Capability Classification

   (d) Detailed surveys

   (e) Status of Land Use Planning in Southern Africa

2. Account for the process that you would follow when conducting a soil survey for a 10 hectares farm. In your answer, also state the appropriate method of survey and the level of detail.

3. Land evaluation is the process of assessment of land performance when a parcel of land is used for specified purposes and it is based on various principles. Explain the various principles of land evaluation.

4 'Land use planning can only be achieved successfully through a sequence of steps based on certain principles '. Elucidate.

5. Luapula Province is one of the 10 provinces in Zambia and is located in agro- ecological region III (receiving more than 1000 mm of rainfall per year). The Province is endowed with several natural resources such as plateaus, lakes, rivers, mountains, and waterfalls among others. As a surveyor at the Ministry of Lands and Natural Resources, you have been tasked to conduct a natural resource survey of Luapula province. The information extracted from the survey will later be used for land use planning in this region. Based on the description of the study area i.e. Luapula Province, answer the following questions:

i. Explain the type of survey you would use in this study [7]

ii. State the type of base materials you would use, and where necessary, give the scale of the base materials to be used. [3]

iii. Describe the method of survey would you employ and justify your answer. [5]

iv. What type of data would you collect when conducting your field survey? [7]

v. State the various personnel that would be involved in this survey? [3]

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2017/2018 ACADEMIC YEAR FINAL EXAMINATIONS

GES 4472: FUNDAMENTALS OF GEOGRAPHICAL INFORMATION SYSTEMS

TIME: Three Hours

INSTRUCTIONS: Answer question **1** and any other **two**. All questions carry equal marks. Candidates are advised to make use of illustrations and examples wherever appropriate.

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1. Write short explanatory notes on all of the following
   a) Forward and inverse mapping equations
   b) Local versus international datum
   c) Mapping socio-economic data
   d) Diffusion modeling
   e) Modelling data using vector and raster
   f) Direct spatial data capturing

2. 'The application of GIS is limited only by the imagination of those who use it'. Discuss.

3. Explain fundamental cases to be considered when integrating data from different sources.

4. Identify an environmental problem and discuss how GIS can be used to address it.

5. Demonstrate the significance of the GIS process in solving spatial challenges.

END OF EXAMINATION

The University of Zambia

End of Year Examinations: November/December 2018

ICT 1110: Computer Systems and Architecture

Marks: 100
Time: Three (3) hours
Instructions:

a) This examination consists of a total of six (6) questions and seven (7) pages.
b) Answer all questions from **Section A** and any two (2) questions from **Section B**.
b) Show all calculations were applicable.
c) You are allowed to use a certified scientific calculator if you wish to do so.
d) Page seven (7) has reference tables for MIPS instructions and system calls.

Section A [Answer questions 1 and 2 – both compulsory]

Question 1 – Computer Systems [25]

a) Computer systems can be broadly viewed as being composed of computer system hardware and software.
   i) For each of the classical five (5) computer generations, list the major technological innovation associated with them. **[5]**
   ii) Computers systems can, in part, be broadly classified based on their relative size; cost; power consumption; efficiency and reliability. Arrange the following broad computer system categories in order of increasing size; cost; power consumption; efficiency and reliability: Supercomputers; Microcomputers; Embedded systems; Servers; and Mainframes. **[5]**
   iii) State two differences between hardware and software. **[2]**
   iv) State one core difference between system software and application software. **[1]**
   v) List two types of language translators and for each, briefly explain how they function. **[4]**
b) Computer systems accept input and present processed input as output, using input/output interfaces.
   i) List four (4) broad types of peripheral devices and for each, give a specific example. **[4]**
   ii) Briefly explain the role of computer hardware ports. **[2]**
   iii) Briefly state two (2) core functionalities of a computer system input/output module. **[2]**

Question 2 – Computer Architecture [35]

a) Convert the following binary numbers into decimal:
   i) **11110000_2** when interpreted as a one's complement binary number representation. **[2]**
   ii) **11101011_2** when interpreted as a two's complement binary number representation. **[2]**

b) Consider the expression $-101_{10} + -19_{10}$. Using two's complement and, assuming 8-bit representation:
   i) Convert **-101_{10}** from decimal to hexadecimal. **[2]**
   ii) Convert **-19_{10}** from decimal to hexadecimal. **[2]**
   iii) Evaluate the expression **$-101_{10} + -19_{10}$** using Two's complement. **[4]**

c) Write MIPS assembly language instructions for implementing the following:
   i) Load the value 1110 into register 11. **[2]**
   ii) Subtract the value in register 13 from the value in register 14 and store the result into register 15. **[2]**
   iii) Branch to the label **ict1110Label** when the value in register 9 is greater than the value in register 10.
   iv) Print an integer value currently in register 8. **[2]**
   v) Read an integer value and store it in register 8. **[2]**

d) MIPS instructions come in three main types—R, I and J-format—and are encoded using 32-bits.

   i) For each of the three MIPS instruction formats, outline the instruction format, specifying the operator and operands. **[3]**

Table 1: MIPS Instruction Formats

	31	0
R		
I		
J		

   ii) For each of the three MIPS instruction formats and, using an illustration similar to Table 1, indicate the number of bits used to represent each instruction component—operators, operands. **[3]**
   iii) For each of the three MIPS instruction formats and, using an illustration similar to Table 1, indicate the bit segment ranges of the 32-bits used to represent instructions, that are used to represent the instruction's components. **[3]**

e) Complete the Truth Table in Table 2. **[4]**

Table 2: Random Truth Table

A	B	C	A+B	$\overline{C}$	A+B.$\overline{C}$

Section B [Answer any two questions ONLY]

Question 3 – Logic Gates [20]

The full-subtractor is a combinational circuit that is used to perform subtraction of three input bits—the minuend X, Y, and borrow in B_{in}. Effectively, the full-subtractor outputs two bits—the difference D and borrow out B_{out}. Bin is set when the previous bit is borrowed from X. As such, Bin is also subtracted from X as well as the subtrahend Y.

Table 3: Full-subtractor Truth Table

X	Y	B_{in}	D	B_{out}
0	0	0	0	0
0	0	1	1	1
0	1	0	1	1
0	1	1	0	1
1	0	0	1	0
1	0	1	0	0
1	1	0	0	0
1	1	1	1	1

a) There are three basic operations that are fundamentally used to construct complex circuits—AND (conjunction), OR (disjunction) and NOT (negation).
   i) Using input variables A and B and C as the output variable, provide a boolean algebra expression representing conjunction. **[2]**
   ii) Using input variables A and B and C as the output variable, provide a boolean algebra expression representing disjunction. **[2]**
   iii) Using input variable A and C as the output variable, provide a boolean algebra expression representing negation. **[2]**

b) Using the Truth Table presented in in Table 2 and the specification provided for the full-subtractor:
   i) Derive the boolean algebra equation for D, using appropriate logical operators. **[2]**

ii) Derive the boolean algebra equation for B_{out}, using appropriate logical operators. **[2]**

iii) Draw the full-subtractor circuit diagram, which will result in the Truth Table above, using appropriate logic gates. **[10]**

Question 4 – MIPS Instruction Formats and Datapath [20]

Consider the following the MIPS datapath and control representation in Figure 1 and answer the questions below:

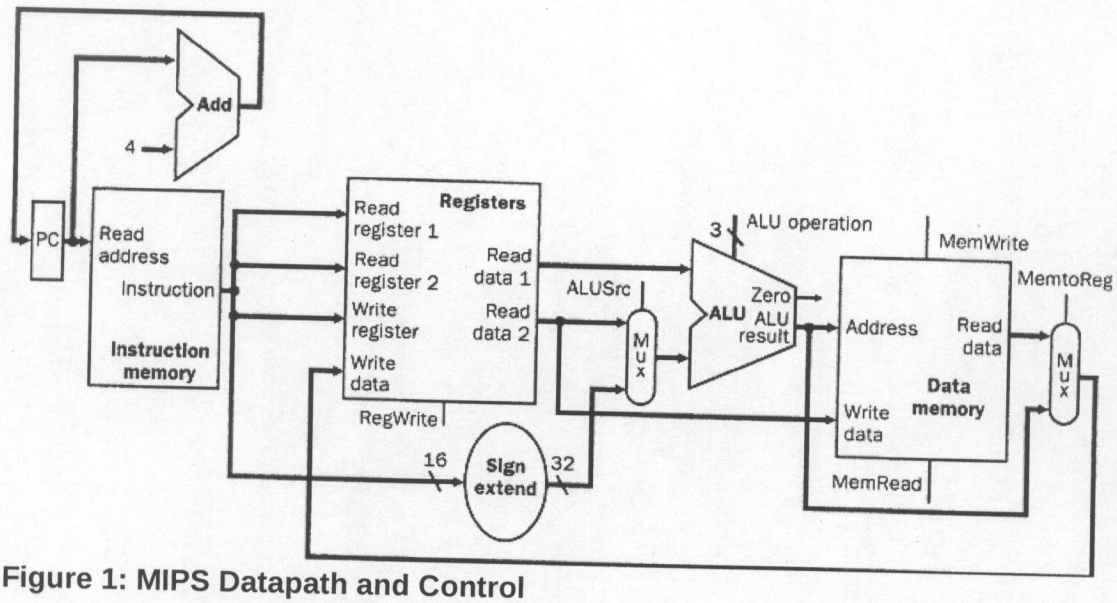

Figure 1: MIPS Datapath and Control

a) State the role of each of the following datapath components play during an instruction cycle.

i) Program Counter (PC) **[1]**

ii) Register File **[1]**

iii) Multiplexer **[1]**

iv) Arithmetic Logic Unit (ALU) **[1]**

b) Consider the MIPS code snippet below:

addi $12, $0, 2017
addi $13, $0, 2021
sub $16, $13, $12

Consider the MIPS instruction **sub $16, $13, $12**. Compute the binary representation of the values of the following:

i) Read Register 1 **[2]**

ii) Read Data 1 **[2]**

iii) Read Register 2 **[2]**

iv) Read Data 2 [2]
v) Write Register [2]
vi) Write Data [2]

c) Consider the MIPS instruction **addi $14, $0, -1110**. Clearly, the Sign Extend hardware component is involved in processing the instruction at some point.
   i) State the role of the Sign Extend component. [1]
   ii) Compute the binary representation of the value held by register $14, once the instruction is executed. [3]

Question 5 – Von Neumann Architecture and Machine Cycle [20]

The Von Neumann model is perhaps the most widely used model for designing contemporary computer systems.

a) The "Stored Program Concept" forms the basis of the Von Neumann architecture. Briefly explain the "Stored Program Concept". [2]
b) Explain and illustrate/draw the Von Neumann model
   i) Illustrate/draw the high-level components of the Von Neumann model clearly illustrating how the components interact. [6]
   ii) Briefly outline how the high-level components of the Von Neumann architecture interact with each other. [2]
   iii) By making reference to the Von Neumann model and any other relevant details that might be necessary, briefly outline when happens when a user of a computer system presses the letter "A" on the keyboard, when typing using a Word Processor. [3]
c) The typical instruction cycle is represented by the FETCH, DECODE, EXECUTE and STORE phases.
   i) Briefly explain the four stages of the instruction cycle, indicating the CPU sub-components responsible. [4]
d) Registers play a crucial role during instruction execution. For each of the following registers, briefly explain their role.
   i) Current Instruction Register (CIR) [1]
   ii) Memory Address Register (MAR) [1]
   iii) Memory Buffer Register (MBR) [1]

Question 6 – Computer Memory [20]

a) Primary memory comes in various forms. For each of the following forms of primary memory, outline how it works.
   i) Random Access Memory (RAM) [1]
   ii) Read Only Memory (ROM) [1]
   iii) Virtual Memory [1]

b) CPU Cache is located on the CPU chip and is crucial to ensuring the efficient execution of program instructions. Explain how CPU Cache works, using the concepts of Cache HIT and Cache MISS. **[2]**

c) Quizzes #18, #19 and #20 of the 2018 ICT 1110 were tagged as 'take-home quizzes' and, submitted electronically. The average scanned document was 400KB.

   i) Compute the total space used, in megabytes (MB), for each student submission (READ: all three submissions). **[2]**

   ii) A total of 90 students submitted their solutions. Assuming each of the students submitted solutions for all three quizzes, compute the total space used, in gigabytes (GB), used all students' submissions. **[2]**

d) In recent times, cloud-based secondary storage has become popular.

   i) Give one specific example of a cloud-based storage service, briefly explaining how it works. **[1]**

   ii) State two advantages of cloud-based storage. **[2]**

   iii) State two disadvantages of cloud-based storage. **[2]**

   iv) Explain a core difference between cloud-based storage and network storage. **[1]**

e) Regular, consistent and reliable data backups are often stored on secondary memory and, additionally, are crucial for critical systems.

   i) State two reasons why data backups are often stored on secondary storage. **[2]**

   ii) Briefly explain the difference between full backups, differential backups and incremental backups. **[3]**

Table 4: MIPS System Calls

Code	Service	Argument	Result
1	Print Integer	$a0=Integer Value	—
4	Print String	$a0=String Address	—
5	Read Integer	—	$v0=Integer Value
8	Read String	$a0=String Address $a1=length	—

Table 5: MIPS Instructions

Instruction	Description
add <Rdes>, <Rsrc1>, <Rsrc2>	Addition
addi <Rdes>, <Rsrc1>, <Rsrc2>	Addition
sub <Rdes>, <Rsrc1>, <Rsrc2>	Subtraction
b <label>	Unconditional branching
beq <Rsrc1>, <Rsrc2>, <label>	Branch if equal
bne <Rsrc1>, <Rsrc2>, <label>	Branch if not equal
blt <Rsrc1>, <Rsrc2>, <label>	Branch if less than
bgt <Rsrc1>, <Rsrc2>, <label>	Branch if greater than

—End of Examination—

The University of Zambia

End of Year Deferred Examinations: November/December 2018

ICT 1110: Computer Systems and Architecture

Marks: 100
Time: Three (3) hours
Instructions:

a) This examination consists of a total of six (6) questions and six (6) pages.
b) Answer all questions from **Section A** and any two (2) questions from **Section B**.
b) Show all calculations were applicable.
c) You are allowed to use a certified scientific calculator if you wish to do so.
d) Page six (6) has reference tables for MIPS instructions and system calls.

Section A [Answer questions 1 and 2 – both compulsory]

Question 1 – Computer Systems [25]

a) Computer systems can be broadly viewed as being composed of computer system hardware and software.
   i) Microcomputers and Supercomputers fall in different categories of computer systems. State two advantages of Microcomputers, when compared with Supercomputers. **[3]**
   ii) State the three (3) broad categories of system software, and for each, provide an example. **[6]**
   iii) State and explain at least three (3) Operating System functions. **[6]**
b) Computer systems process data, primarily using the CPU.
   i) List four broad types of input devices that are used to provide input to the CPU. **[4]**
   ii) List the three (3) CPU sub-components that are crucial in facilitating processing of input data and, additionally, explain their role. **[6]**

Question 2 – Computer Architecture [35]

a) Convert -1110_{10} into decimal format, using the following methods, assuming 16-bit representation:
   i) Signed magnitude. **[2]**
   ii) One's complement. **[2]**
   iii) Two's complement. **[2]**

b) Data represented by computer systems is classified into three broad categories: sound, text and images.
   i) Explain how text is represented by computers. **[1]**
   ii) Explain how audio input is converted into a form that computer systems are able to interpret. **[2]**
   iii) Explain how video footage is represented by computer systems. **[2]**

c) Write MIPS assembly language for implementing the following:
   i) A program that prompts a user to enter two numbers and prints out the largest of the two entered numbers. **[6]**
   ii) A program that prompts a user to enter a natural number and then prints the square of all natural numbers less than or equal to the entered number. The program should be implemented using loops. **[6]**

d) Illustrate and provide the Truth Tables for the following logic gates.
   i) AND **[3]**
   ii) OR **[3]**
   iii) NOT **[3]**
   iv) XOR **[3]**

Section B [Answer any two questions ONLY]

Question 3 – Logic Gates [20]

Consider the the schematic diagram of an 8-bit Full Adder, shown in Figure 1.

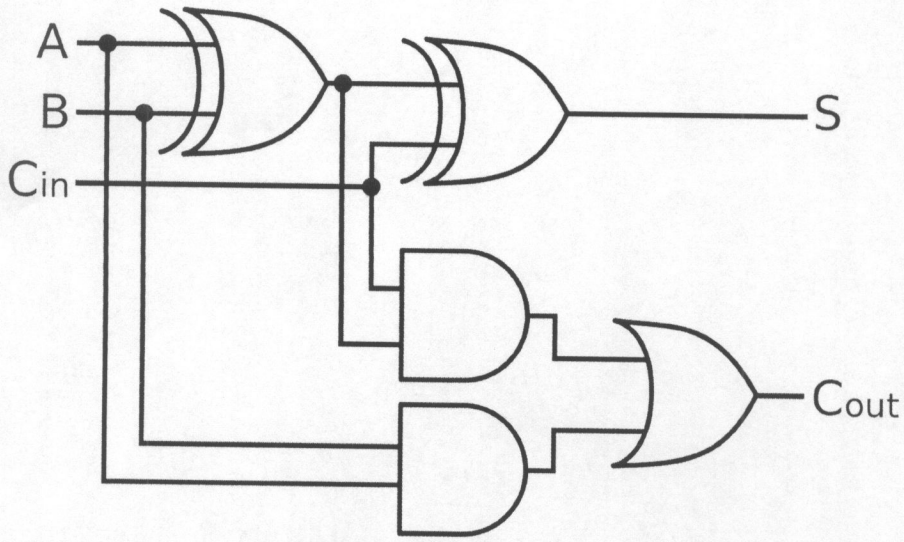

Figure 1: 8-bit Full Adder

a) For each of the three (3) distinct logic gates in Figure 1:
   i) State the name of the logic gate. **[3]**
   ii) Provide the boolean algebra expression using A and B as input variables, and C as the output variable. **[6]**
   iii) Provide the Truth Table, with appropriate input and output values. **[6]**

b) Provide the Truth Table for the Full Adder in Figure 1. **[5]**

Question 4 – MIPS Instruction Formats and Datapath [20]

The MIPS datapath and control specifies the hardware required to perform operations and the data movement between the various components.

a) The different MIPS instructions require specific components for their respective datapaths. For each of the following, state the hardware elements needed to implement the datapath. In addition, illustrate the datapath.
   i) R-format instructions **[2]**
   ii) I-format instructions **[4]**

iii) J-format instructions [4]

b) Consider the MIPS code snippet below:

addi $12, $0, 2017
addi $13, $0, 2021
sub $16, $13, $12

Illustrate and describe the path followed for each of the following MIP instructions, specifying the inputs and outputs in binary format.

i) addi $12, $0, 2017 [4]
ii) sub $16, $13, $12 [6]

Question 5 – Von Neumann Architecture and I/O Subsystem [20]

The Von Neumann model is one of the most influential models for designing contemporary computer systems.

a) Explain why the Input/Output module of the Von Neumann model cannot interact directly with the memory module. [2]

b) The Input/Output module connects devices with varying capabilities, characteristics and data rates.

i) Distinguish between block devices and character devices. [2]
ii) Explain why data rates for storage and communications devices are normally faster than input devices. [2]
iii) Distinguish between latency and throughput. [2]
iv) Provide an example of a hardware port used to connect devices to a computer system and, additionally, explain how that specific example port works. [2]

c) The Input/Output module is composed of I/O controllers, specific for each peripheral device, which connect to an I/O bus.

i) Explain the significance of having dedicated I/O controllers for different peripheral devices. [2]
ii) Illustrate, using an appropriate diagram, the interaction between peripherals, I/O controllers and the I/O bus. [2]
iii) State and described the three (3) main techniques used for performing I/O operations. [6]

Question 6 – Computer Memory [20]

Computer memory comes in various forms, however, it is fundamentally used to store data and program instructions.

a) The classic memory hierarchy is used to classify memory based on response time.
   i) List the four (4) broad categories of the classic memory hierarchy, and for each, provide an example. **[8]**
   ii) State three (3) factors that affect the response time of memory. **[3]**
   iii) Explain how the capacity, efficiency and cost of memory is affected relative to its location from the CPU. **[3]**

b) CPU Cache is located on the CPU chip and is crucial to ensuring the efficient execution of program instructions.
   i) Explain why CPU Cache is usually small in size. **[1]**
   ii) Explain why CPU Cache is implemented using multiple levels, e.g. L1, L2 and L3. **[1]**

c) Secondary memory is responsible for persistent storage of both program instructions and data. Data and instructions are generally organised as files.
   i) List four (4) operations that can be performed on a file. **[2]**
   ii) Distinguish between disk partitioning and disk formatting. **[2]**

Table 4: MIPS System Calls

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Table 5: MIPS Instructions

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—End of Examination—

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2017 ACADEMIC YEAR
FINAL EXAMINATIONS

MAT2602 INTRODUCTION TO STATISTICS

Time Allowed: Three (3) Hours

Instructions:
1. Answer any **Five (5)** Questions
2. Show All Essential Working
3. Statistical Tables are provided
4. Calculators are Allowed

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1. (a) Define the following:
   (i) sample of convenience.
   (ii) response bias.

   (b) A study was conducted to compare the failure rates for maths and history students. Out of a sample of 150 history students, 18 students failed to complete their programme on time while a sample of 250 maths students showed that 50 failed to complete on time.
   (i) Test whether the proportion of history students who fail to complete their studies on time is higher than 0.08. Use $\alpha = 0.02$.
   (ii) Construct a 99% confidence interval for the proportion of maths students not completing on time.
   (iii) Is the failure rate higher among maths students compared to history students? Test at the 5% level of significance.

   (c) A company claims there is no difference in the mean lifespans of the two brands of bulbs it produces. A random sample of 22 brand A bulbs had a mean lifespan of 1.8 years while a sample of 15 brand B bulbs had a mean lifespan of 1.3 years. The lifespans for the bulbs are normally distributed with standard deviations 0.54 years and 0.82 years for brands A and B respectively.
   (i) Test whether the company's claim is valid at the 5% level of significance.
   (ii) How large a sample is required if we want to to be 90% confident that our estimate of the brand B mean lifespan is within 0.16 years of the true value?

2. (a) Define the following:
   (i) stratified sample.
   (ii) descriptive statistics.

   (b) The following data represent marks of 30 students in a mathematics entry examination at a certain university:

60	42	71	23	11	55	20	53	81	14
63	9	33	98	57	13	77	86	31	28
66	72	5	62	51	25	54	43	40	20

   (i) Construct an ordered stem and leaf plot for the marks.
   (ii) Describe the distribution of the marks.
   (iii) Find the percentile rank of 62.
   (iv) Construct a boxplot for the marks and identify outliers if any.

   (c) Weights of Grade 5 pupils at a certain school are normally distributed with a mean of 45kg and a standard deviation of 5kg.
   (i) Find the probability that a randomly chosen pupil weighs more than 42kg.
   (ii) Find the probability that the mean weight of 24 randomly chosen pupils lies between 42.2kg and 44.8kg.
   (iii) If probability that the total weight of 9 randomly chosen pupils exceeds k is 0.0082, find the value of k.

3. (a) (i) State the central limit theorem.
   (ii) Define a statistical hypothesis.

   (b) A school principal claims that more than 30% of the pupils in the school are left handed. To test the claim, a sample of 200 pupils is taken and the claim is accepted if more than 70 pupils are found to be left handed.
   (i) Explain how one can commit a type II error in this context.
   (ii) Find the probability of committing a type I error.
   (iii) Find the probability of committing a type II error assuming that the proportion of left handed pupils is 0.4.

   (c) Speeds of 10 cars (in km/h) passing through a residential area are captured as follows:

   28 45 15 32 33 20 42 25 35 40

   (i) Determine whether the mean speed is significantly lower than the speed limit of 40km/h. Use $\alpha = 0.05$.
   (ii) Construct a 98% confidence interval for the standard deviation of the speeds of the cars.
   (iii) Is the standard deviation of the cars significantly different from 6km/h? Explain.
   (iv) State the assumption(s) required for (i), (ii) and (iii) to be valid.

4. (a) State two properties of the
   (i) linear correlation coefficient.
   (ii) normal curve.

(b) A director at the Ministry of Tourism claims that 32% of the visitors to the Victoria Falls are Europeans, 24% are Americans, 15% are Asians, 10% are Africans and the rest are from other parts of the world. The following distribution was obtained from a sample of 250 visitors:

European	75
American	50
Asian	42
African	36
Others	47

Test whether the director's claim is valid at the 5% level of significance.

(c) An experiment was conducted to compare the number of bags of maize obtained per acre for different varieties of maize. The experiment compared 4 varieties of maize in 5 different locations. The following results were obtained:

		Location					
		1	2	3	4	5	Total
Variety	1	34	41	26	50	38	189
	2	40	44	28	46	42	200
	3	62	48	44	50	52	256
	4	58	46	42	48	54	248
	Total	194	179	140	194	186	893

(Additionally $\sum_i \sum_j y_{ij}^2 = 41409$)

(i) Explain why a randomized block design is suitable for this study.
(ii) Taking varieties to be treatments and locations to be blocks, write down a model for the experiment. Explain the meaning of all the terms in the model and state all the assumption(s).
(iii) Prepare an ANOVA table for the experiment.
(iv) Is there a significant difference among the maize varieties? Test at the 5% level of significance.
(v) Does location have an effect on the yield? Use a 5% level of significance.

5. (a) Define the following:
(i) simple random sample.
(ii) sampling distribution.

(b) To study the effect of speed (in km/h) on the number of kilometres covered per litre of petrol, an investigation involving 9 hybrid cars was carried out and the following results were obtained:

Speed (x)	126	121	116	118	114	118	132	141	108
Number of km per litre (y)	4.3	4.5	5.9	5.6	6.1	5.2	3.8	2.1	7.5

(You may use the following: $\sum_{i=1}^{9} x_i = 1094$, $\sum_{i=1}^{9} y_i = 45$
$\sum_{i=1}^{9} x_i^2 = 133786$, $\sum_{i=1}^{9} y_i^2 = 244.26$, $\sum_{i=1}^{9} x_i y_i = 5348.2$)
(i) Estimate the simple linear regression line.
(ii) Explain the meaning of the estimated slope parameter in (i).
(iii) Estimate the number of kilometres covered per litre at the speed of 110 km/h.
(iv) Copy and complete the following ANOVA table:

Source	SS	df	MS	F*
Regression				
Error			0.116189	
Total				

(v) Test whether there is a significant negative linear relationship between speed and fuel consumption. Use $\alpha = 0.05$.
(vi) Compute the coefficient of determination.
(vii) Explain the meaning of the coefficient in (vi).
(viii) Compute the correlation coefficient.

6. (a) Define the following:
(i) type II error.
(ii) parameter.

(b) A study was conducted to determine whether level of education and economic status are related. The following results were obtained from a survey of 250 people.

		Education level			
		None	Primary	Secondary	College
Economic Status	Rich	14	29	41	51
	Poor	21	26	27	41

Test at the 10% level of significance whether level of education and economic status are independent.

(c) A worker has two possible routes she can use to get to work. A sample of 13 times she used route 1 had a mean time of 32 minutes with a standard deviation of 5.4 minutes and a sample of 10 trips on route 2 had a mean of 40 minutes with a standard deviation of 7.2 minutes. Assume that the times it takes to drive to work are normally distributed.

(i) Is there sufficient evidence to indicate that route 1 is faster than route 2? Test at the 1% level of significance assuming equal variances.

(ii) Construct a 95% confidence interval for the ratio of the two population standard deviations.

(iii) Is the assumption of equal variances made in (i) valid? Explain.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
DEPARTMENT OF MATHEMATICS AND STATISTICS
2018/2019 ACADEMIC YEAR MID YEAR EXAMINATION
MAT3011 – PRINCIPLES OF FINANCE AND FINANCIAL REPORTING
12TH JULY 2019

Time Allowed: THREE (3) hours
INSTRUCTIONS

1. Answer ALL Questions from both Section A and B
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. Which of the following is legally responsible for the commitment owed by a limited company to the company's lenders?

A The company's directors.
B The company's external auditor.
C The company's shareholders.
D The company's treasurer, who negotiated the terms of the loan with the lenders.

2. Which of the following best explains the problems arising from information asymmetry?

A Directors do not always have sufficient information with which to reach sound managerial decisions.
B Shareholders cannot process all of the information that is available to them.
C Shareholders feel that they do not have sufficient information to evaluate the behaviour of the directors.
D Some shareholders are better informed than others.

3. Which of the following is most likely to explain a company's decision to issue subordinated debt?

A A lower rate of interest will be available.
B Existing lenders may have the right to prevent the issue of further senior debt.
C Subordinated debt may offer tax advantages.
D The shareholders will feel more secure if the company issues subordinated debt rather than senior debt.

4. A company wishes to issue convertible stock with a conversion date in five years' time.

Which of the following proposals for the conversion terms is likely to be the most attractive to investors?

A Compulsory conversion to equity shares at the end of year five.
B Investors can choose to convert to equity shares at the end of year five. If they do not convert then their securities will continue as loan stock indefinitely.

C Investors can choose to convert to equity shares at the end of year five. If they do not convert then their securities will continue as loan stock that will be redeemable after a further five years.
D Investors can choose to convert to equity shares at the end of year five. If they do not convert then their securities will be converted to preference shares.

5. A quoted company's statement of financial position shows equity shares worth K10m, retained earnings of K20m and non-current liabilities in the form of a K15m nominal loan paying 7% pa interest.

The shares have a total market value of K48m and the non-current liabilities have a market value of K18m.

The company's cost of equity has been determined as 17% and the cost of debt as 8%.

What is the company's weighted average cost of capital?

A 11.60%
B 14.00%
C 14.27%
D 14.55%

6. A speculator has a policy of investing all of his cash in a single company for a short period in the hope of achieving a capital gain. The speculator is presently looking for a company whose shares have a high beta coefficient.

Which of the following is the most rational explanation for the speculator's desire to identify a high beta security?

A High beta securities tend to increase in value.
B Specific risks can be diversified away and only systematic risks matter.
C The speculator expects stock market prices to strengthen.
D The speculator expects stock market prices to weaken.

7. A company's earnings before interest and tax is K400,000. It has one million K1 shares in issue, fully paid, and retained earnings of K800,000. Long term liabilities are K500,000.

What is the entity's return on capital employed?

A 17.4%
B 22.2%
C 26.7%
D 30.8%

8. How will the components of the return on capital employed ratio be affected if a company charges depreciation too slowly?

A Return will be understated and capital employed will be overstated.
B Return will be overstated and capital employed will be overstated.
C Return will be overstated and capital employed will be understated.

D Return will be understated and capital employed will be understated.

9. Which of the following best explains why liquidity ratios based on a company's published accounts are unlikely to be useful for credit control purposes?

A The figures are likely to be based on historical costs.
B The figures are likely to be inaccurate.
C The figures are likely to be manipulated by creative accounting.
D The figures are likely to be out of date.

10. Which of the following best describes the need for the consistency concept in financial reporting?

A All similar transactions should input into the bookkeeping records in the same way throughout the accounting period.
B Financial statements prepared by an entity should be comparable from year to year.
C Financial statements prepared by different entities should be comparable.
D The users of financial statements should use consistent criteria for interpreting accounting information.

Question Two **[Total 20 Marks]**

(a) Brighton works in a factory owned by Global Manufacturing ("Global"), a quoted company. Global grants employees who have been employed by the company for more than five years the right to purchase up to 1,000 shares every year at a 5% discount to the share price at the date of purchase. Global's current share price is K4.70 per share.

Discuss the advantages and disadvantages to Brighton of taking up the right to purchase shares under this scheme. [5 marks]

(b) A quoted company is planning to make a rights issue on the basis of one new share for every seven shares currently held. The present share price is K5.20. The rights issue will be priced at K4.50. The directors intend to use the funds raised to fund a project that they are confident will increase the company's present market capitalisation by 20%.

(i) Calculate the expected price per share after the rights issue. [3 marks]

(ii) Comment on whether the stock will trade above or below the price in (i) [2 marks]

(c) National tax systems often have the objectives that the tax burden is fair and reasonable. Explain how these objectives are achieved. [5 marks]

(d) Define the term Eurobonds and give two advantages and two disadvantages of this form of government borrowing. [5 marks]

Question Three **[Total 20 Marks]**

The following information has been extracted from the books of Tubombe, a limited liability company, as at 31 October 2018.

	Dr *K'000*	*Cr* *K'000*
Cash	15	
Insurance	75	
Inventory at 1 November 2017	350	
General expenses	60	
Energy expenses	66	
Marketing expenses	50	
Wages and salaries	675	
Discounts received		50
Share premium account		200
Retained earnings at 1 November 2017		315
Allowance for receivables at 1 November 2017		40
Sales revenue		5,780
Telephone expenses	80	
Property expenses	100	
Bank		94
Returns inward	95	
Trade payables		290
Loan note interest	33	
Trade receivables	900	
Purchases	3,570	
7% loan notes		470
Irrecoverable debts	150	
K1 ordinary shares		1,800
Accumulated depreciation at 1 November 2017		
Buildings		360
Motor Vehicles		80
Furniture and equipment		420
Land at cost	740	
Buildings at cost	1,500	
Motor vehicles at cost	240	
Furniture and equipment at cost	1,200	
	9,899	9,899

You have also been provided with the following information:

a) Inventory at 31 October 2018 was valued at K275,000 based on its original cost. However, K45,000 of this inventory has been in the warehouse for over two years and the directors have agreed to sell it in November 2018 for a cash price of K20,000.
b) The marketing expenses include K5,000 which relates to November 2018.
c) Based on past experience the allowance for receivables is to be increased to 5% of trade receivables.
d) There are wages and salaries outstanding of K40,000 for the year ended 31 October 2018.
e) Buildings are depreciated at 5% of cost. At 31 October 2018 the buildings were professionally valued at K1,800,000 and the directors wish this valuation to be incorporated into the accounts.
f) Depreciation is to be charged as follows:

(i) Motor vehicles at 20% of written down value
(ii) Furniture and equipment at 20% of cost

g) No dividends have been paid or declared.
h) Tax of K150,000 is to be provided for the year.
i) During October 2018 a bonus issue of one for ten shares was made to ordinary shareholders. This has not been entered into the books. The share premium account was used for this purpose.

Required

Prepare the following statements, for internal use:

A. The statement of profit or loss for the year ended 31 October 2018. [10 marks]
B. The statement of financial position as at 31 October 2018. [10 marks]

Question Four **[Total 20 Marks]**

Agness Hotels is a family-owned company that is in the process of recovering from a major corporate scandal. Agness Hotels is a substantial business that is not quoted. None of its shareholders owns more than 5% of the equity shares. None of the shareholders is able to take an active role in the company's management.

Agness Hotels' directors were all forced to step down because of the discovery that the directors had been overstating reported profits, which had the effect of inflating their profit-related bonuses. The directors also provided themselves with lavish lifestyles at the company's expense. For example, the company provided chauffeur-driven limousines to transport the directors on both business and personal travel.

The entire board of Agness Hotels has resigned. The shareholders have met and have appointed a new chairman and a chief executive. Neither of these appointees have had anything to do with Agness Hotels in the past. They have both agreed that their first priority is to appoint a new board and to structure the management arrangements so that the shareholders' confidence is restored.

The chairman has suggested that the new board should be structured as follows:

- The chairman will work on a part-time basis and will be responsible for the management of the board, including chairing board meetings. The chairman will be paid a fixed annual salary that offers an appropriate rate for the time that he is expected to commit to the company.

- The chief executive will be employed on a full-time basis to manage the company itself and will receive both a substantial salary and a profit-related bonus.

- Four additional full-time directors will be appointed to take charge of particular areas such as marketing and finance. Each will receive a similar package to the chief executive.

- Two part-time directors will be appointed to participate in board meetings and to review corporate strategy. They will be paid a fixed salary.

- The chief executive and each of the full-time directors will receive a 5% shareholding after satisfactorily completing three years on Agness Hotels' board.

- The chairman and the two part-time directors will appoint a new larger and more reputable external audit firm to replace outgoing auditor and will pay a larger fee for the new auditor's services.

(a) Discuss the suitability of each of the proposals above from the perspective of maintaining shareholder confidence. [10 marks]

An advisor has recommended that the new team of executives seek a stock exchange quotation and commit in their prospectus to have a specific dividend pay-out ratio.

(b) Evaluate the decision to list the company at this particular moment. [4 marks]

(c) Outline the various factors to be considered in deciding on the dividend policy for Agness Hotels post listing. [6 marks]

Question Five **[Total 20 Marks]**

(a) Didier plc is a quoted company. Its directors are reviewing the company's long term financial strategy. The company has been criticised for being financed largely by equity. It has no significant long term borrowings. The board has asked for some calculations to enable them to decide whether the company should consider borrowing in the future. The next phase of expansion will require the company to raise K200m and will involve a general expansion of the existing lines of business.

The following information has been obtained:

Current cost of Equity	11%
Current corporation tax rate	30%
Equity capital	K1,000m
Probable gross interest rate on debt	7%

(i) Calculate Didier plc's expected WACC AFTER the new finance has been raised assuming that the finance is raised by borrowing. Comment on your result. [3 marks]

(ii) Use capital structure theories to explain the relevance of the WACC figure to the decision to use equity or debt for the new finance. [7 marks]

(b) Pentact is an actuarial consultancy. Pentact has owned a two floor office block for the past 20 years.

Improvements in technology mean that Pentact has reached the point where the whole of the upper floor is left unoccupied.

Pentact's directors are considering using the free space in the building to launch a new consultancy venture. This would involve taking on new consultants with relevant expertise, as well as equipping the floor with suitable IT equipment.

The initial investment in the IT equipment will be K15 million.

Over the next five years, Pentact predicts that the fees earned from the new consultancy venture, minus the cash outflows associated with wages and other running costs, will have a net present value of K40 million.

Pentact's directors believe that they should allow something for the building in deciding whether to proceed with this venture. Four possible arguments have been put forward by four members of the board:

1. The building cost K20 million when it was acquired and it has been depreciated by K8 million since. That leaves a net book value of K12 million, of which K6 million could be attributed to the upper floor.

2. The cost of the building is a sunk cost and it should not be incorporated into the project appraisal.

3. The upper floor could be sold to a third party for K27 million.

4. The upper floor could be rented out over the next five years, with rental income yielding a net present value of K9 million.

The debate over the building has been heated because it could affect the decision to go ahead with the project.

(i) Outline the logic of each of the four arguments concerning the building. [4 marks]

Critics of the net present value (NPV) technique state that it has a fundamental flaw in that it is possible to justify either the acceptance or rejection of almost any project by manipulating estimates and assumptions in the evaluation of NPV.

(ii) Evaluate the assertion that this project illustrates this fundamental flaw in the net present value criterion. [6 marks]

..... END OF EXAMINATION.....

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
DEPARTMENT OF MATHEMATICS & STATISTICS
2017/2018 ACADEMIC YEAR FINAL EXAMINATION
MAT3022 – INVESTMENT ANALYSIS AND PORTFOLIO MANAGEMENT

Time Allowed: THREE (3) hours

INSTRUCTIONS

1. Answer ALL FIVE (5) questions
2. Show all your workings to earn full credit
3. Indicate your computer number on ALL answer booklets

Question One [Total 20 Marks]

(a) Describe 'informational efficiency' under the efficient market hypothesis (EMH) and give examples of tests that have been used to test each level of EMH. [6 marks]

(b) Discuss the philosophy and analysis tools employed by the following approaches to security analysis.

(i) Fundamental analysis [7 marks]

(ii) Technical analysis [5 marks]

(c) Within the context of the capital asset pricing model, give a formula and explain what is meant by the "market price of risk". [2 marks]

Question Two [Total 20 Marks]

(a) Describe any two of the following themes of Behavioural Finance, provide a practical scenarios applicable to each.

- Myopic loss aversion
- Prospect theory
- Anchoring and adjustment

- Estimating probabilities [6 marks]

(b) The marketing team of a unit trust management company are updating the promotional literature for their actively managed UK Equity trust. The trust produced a return of 5% over the last calendar year, compared to 4% for the FTSE 100 index. Explain how the marketing team could present the past performance of the fund favourably to prospective investors. [3 marks]

(c) Suppose that Robert and Mahundo each have a log utility function and an initial wealth of K100m and K200m respectively. Both are offered a gamble such that they will receive a sum equal to 30% of their wealth should they win, whereas they will lose 10% of their wealth should they lose. The probability of winning is ¼.

(i) Calculate Robert's certainty equivalent for the gamble alone and comment briefly on your answer. [2 marks]

(ii) Repeat part (i) in respect of Mahundo and compare your answer with that in part (i). [2 marks]

(iii) Use the relative risk aversion for $U(w) = log(w)$ to confirm that your comments in parts (i) and (ii) apply irrespective of the individual's wealth. [2 marks]

(d) Consider the two risky assets, A and B, with cumulative probability distribution functions:

$$F_A(w) = w$$

$$F_B(w) = w^{½}$$

In both cases, $0 \leq w \leq 1$.

(i) Show that A is preferred to B on the basis of first-order stochastic dominance. [3 marks]

(ii) Verify explicitly using either graphical or algebraic procedures that A also dominates B on the basis of second-order stochastic dominance. [3 marks]

Question Three **[Total 20 Marks]**

(a) In the context of mean-variance portfolio theory:

(i) Describe the validity of any two assumptions of mean-variance portfolio theory. [3 marks]

(ii) Define the words in **bold** font and use a well annotated diagram to show an **optimal**, **efficient** and **inefficient** portfolio. [5 mark]

(b) Assume that, there are only three assets available on a stock exchange:

Asset 1, expected return 2%, standard deviation 4%
Asset 2, expected return 4%, standard deviation 12%
Asset 3, expected return 3%, standard deviation 8%

The correlation between the returns on assets 1 and 3 is 0.75. The return on asset 2 is uncorrelated with the returns on the other two assets.

Let x_i denote the weight of asset i (i = 1, 2, 3) in the minimum variance portfolio with an expected return of 4%.

An investor in this market wants to minimise the variance of his portfolio.

(i) Determine the Lagrangian function that can be used to find the minimum variance portfolio for a given expected return. [4 marks]

(ii) Show, by taking partial derivatives of the Lagrangian function in part (i) and solving the resulting equations, that:

$x_1 = -0.45, x_2 = 0.55, x_3 = 0.9.$ [7 marks]

(iii) Comment on how the portfolio would change if short-selling was not allowed. [1 mark]

Question Four **[Total 20 Marks]**

(a) An investor is contemplating an investment with a return of KR , where:

$R = 250{,}000 - 100{,}000N$

and N is a Normal [1,1] random variable.

Calculate each of the following measures of risk:

(i) variance of return [2 marks]
(ii) shortfall probability, where the shortfall level is K50,000 [2 marks]
(iii) Value at Risk at the 5% level [2 marks]

(b)

(i) State the equation of the single-index model of asset returns. Define all terms used. [2 marks]

You are given the following results and data for Securities 1, 2 and 3 in Table 1 for the single index model.

$$E_i = \alpha_i + \beta_i E_M$$
$$V_i = \beta_i^2 V_M + V_{\varepsilon i}$$
and $$C_{ij} = \beta_i \beta_j V_M$$

Security	1	2	3
α_i	0.0	2.0	-2.2
β_i	1.1	0.6	2.0
$V_{\varepsilon i}$	2.2	1.3	1.2

You are given that:

- the expected return and standard deviation of the market return are 10 and 5 respectively
- the returns of each security can be modelled using an appropriate single-index model.

(i) Calculate the expected return and standard deviation of return for each security. [2 marks]
(ii) calculate the covariance of returns between each pair of securities. [2 marks]

(c)

(i) Describe any two categories of multifactor models and examples of the variables that could be used under each model [4 marks]

(ii) A modeller has developed a two-factor model to explain the returns obtained from security *i*.

It has the form:

$R_i = 2 + 1.3I_1 + 0.8I_2 + c_i$

However, he is concerned that the two indices 1 and 2 may be correlated and so decides to re-express the model in terms of orthogonal factors. He therefore regresses Index 1 on Index 2 and obtains the following equation for the line of best fit:

$I_1 = 0.8 + 0.3I_2$

Use this information to re-express the two-factor model in terms of two orthogonal factors I_1^* and I_2^* [4 marks]

Question Five [Total 10 Marks]

(a) Highlight the key differences between the following terms used in portfolio management.

(i) Top-down and bottom up [2 marks]

(ii) Active and passive [2 marks]

(b) Define an index tracker fund and describe how you could create such a portfolio on the Lusaka Stock Exchange (LuSE). [4 marks]

(c) You have been asked to evaluate the investment performance of three different professional asset managers relative to each other and to the LuSE index. After gathering quarterly return data over the past five years, you compute the following statistics:

Portfolio	Average Annual Return (%)	Standard Deviation (%)	Beta	Standard error (%)
A	12	20	0.82	0.5
B	13	21	1.36	2.8
C	15	22	2.00	1.1
Benchmark	12	8	1.00	
Risk free Asset	8.0			

You are given the following

Treynor (T) Sharpe (S) Information Ratio (IR)

$T_i = \frac{\bar{R}_i - \overline{RFR}}{\beta_i}$ $S_i = \frac{\bar{R}_i - \overline{RFR}}{\sigma_i}$ $IR_j = \frac{\bar{R}_j - \bar{R}_b}{\sigma_{ER}} = \frac{\overline{ER}_j}{\sigma_{ER}}$

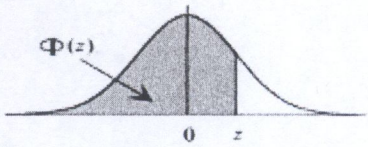
(i) Use the above data to compute any two risk adjusted performance measures and evaluate the performances of the given fund managers. Interpret your results. [5 marks]

(ii) Comment on which performance measure is most sited for a portfolio of four most traded counters on the Lusaka stock Exchange (LuSE). [2 marks]

(iii) Define the term 'diversification' and show explicitly using either graphical or algebraic procedures its effect on the risk of a portfolio of two or more (say N) assets. [5 marks]

**********END OF EXAMINATION**********

TABLE 1: AREAS UNDER THE NORMAL CURVE



z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
-3.4	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0002
-3.3	0.0005	0.0005	0.0005	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0003
-3.2	0.0007	0.0007	0.0006	0.0006	0.0006	0.0006	0.0006	0.0005	0.0005	0.0005
-3.1	0.0010	0.0009	0.0009	0.0009	0.0008	0.0008	0.0008	0.0008	0.0007	0.0007
-3.0	0.0013	0.0013	0.0013	0.0012	0.0012	0.0011	0.0011	0.0011	0.0010	0.0010
-2.9	0.0019	0.0018	0.0018	0.0017	0.0016	0.0016	0.0015	0.0015	0.0014	0.0014
-2.8	0.0026	0.0025	0.0024	0.0023	0.0023	0.0022	0.0021	0.0021	0.0020	0.0019
-2.7	0.0035	0.0034	0.0033	0.0032	0.0031	0.0030	0.0029	0.0028	0.0027	0.0026
-2.6	0.0047	0.0045	0.0044	0.0043	0.0041	0.0040	0.0039	0.0038	0.0037	0.0036
-2.5	0.0062	0.0060	0.0059	0.0057	0.0055	0.0054	0.0052	0.0051	0.0049	0.0048
-2.4	0.0082	0.0080	0.0078	0.0075	0.0073	0.0071	0.0069	0.0068	0.0066	0.0064
-2.3	0.0107	0.0104	0.0102	0.0099	0.0096	0.0094	0.0091	0.0089	0.0087	0.0084
-2.2	0.0139	0.0136	0.0132	0.0129	0.0125	0.0122	0.0119	0.0116	0.0113	0.0110
-2.1	0.0179	0.0174	0.0170	0.0166	0.0162	0.0158	0.0154	0.0150	0.0146	0.0143
-2.0	0.0228	0.0222	0.0217	0.0212	0.0207	0.0202	0.0197	0.0192	0.0188	0.0183
-1.9	0.0287	0.0281	0.0274	0.0268	0.0262	0.0256	0.0250	0.0244	0.0239	0.0233
-1.8	0.0359	0.0351	0.0344	0.0336	0.0329	0.0322	0.0314	0.0307	0.0301	0.0294
-1.7	0.0446	0.0436	0.0427	0.0418	0.0409	0.0401	0.0392	0.0384	0.0375	0.0367
-1.6	0.0548	0.0537	0.0526	0.0516	0.0505	0.0495	0.0485	0.0475	0.0465	0.0455
-1.5	0.0668	0.0655	0.0643	0.0630	0.0618	0.0606	0.0594	0.0582	0.0571	0.0559
-1.4	0.0808	0.0793	0.0778	0.0764	0.0749	0.0735	0.0721	0.0708	0.0694	0.0681
-1.3	0.0968	0.0951	0.0934	0.0918	0.0901	0.0885	0.0869	0.0853	0.0838	0.0823
-1.2	0.1151	0.1131	0.1112	0.1093	0.1075	0.1056	0.1038	0.1020	0.1003	0.0985
-1.1	0.1357	0.1335	0.1314	0.1292	0.1271	0.1251	0.1230	0.1210	0.1190	0.1170
-1.0	0.1587	0.1562	0.1539	0.1515	0.1492	0.1469	0.1446	0.1423	0.1401	0.1379
-0.9	0.1841	0.1814	0.1788	0.1762	0.1736	0.1711	0.1685	0.1660	0.1635	0.1611
-0.8	0.2119	0.2090	0.2061	0.2033	0.2005	0.1977	0.1949	0.1922	0.1894	0.1867
-0.7	0.2420	0.2389	0.2358	0.2327	0.2296	0.2266	0.2236	0.2206	0.2177	0.2148
-0.6	0.2743	0.2709	0.2676	0.2643	0.2611	0.2578	0.2546	0.2514	0.2483	0.2451
-0.5	0.3085	0.3050	0.3015	0.2981	0.2946	0.2912	0.2877	0.2843	0.2810	0.2776
-0.4	0.3446	0.3409	0.3372	0.3336	0.3300	0.3264	0.3228	0.3192	0.3156	0.3121
-0.3	0.3821	0.3783	0.3745	0.3707	0.3669	0.3632	0.3594	0.3557	0.3520	0.3483
-0.2	0.4207	0.4168	0.4129	0.4090	0.4052	0.4013	0.3974	0.3936	0.3897	0.3859
-0.1	0.4602	0.4562	0.4522	0.4483	0.4443	0.4404	0.4364	0.4325	0.4286	0.4247
0.0	0.5000	0.5040	0.5080	0.5120	0.5160	0.5199	0.5239	0.5279	0.5319	0.5359
0.1	0.5398	0.5438	0.5478	0.5517	0.5557	0.5596	0.5636	0.5675	0.5714	0.5753
0.2	0.5793	0.5832	0.5871	0.5910	0.5948	0.5987	0.6026	0.6064	0.6103	0.6141
0.3	0.6179	0.6217	0.6255	0.6293	0.6331	0.6368	0.6406	0.6443	0.6480	0.6517
0.4	0.6554	0.6591	0.6628	0.6664	0.6700	0.6736	0.6772	0.6808	0.6844	0.6879
0.5	0.6915	0.6950	0.6985	0.7019	0.7054	0.7088	0.7123	0.7157	0.7190	0.7224
0.6	0.7257	0.7291	0.7324	0.7357	0.7389	0.7422	0.7454	0.7486	0.7517	0.7549
0.7	0.7580	0.7611	0.7642	0.7673	0.7704	0.7734	0.7764	0.7794	0.7823	0.7852
0.8	0.7881	0.7910	0.7939	0.7967	0.7995	0.8023	0.8051	0.8078	0.8106	0.8133
0.9	0.8159	0.8186	0.8212	0.8238	0.8264	0.8289	0.8315	0.8340	0.8365	0.8389
1.0	0.8413	0.8438	0.8461	0.8485	0.8508	0.8531	0.8554	0.8577	0.8599	0.8621
1.1	0.8643	0.8665	0.8686	0.8708	0.8729	0.8749	0.8770	0.8790	0.8810	0.8830
1.2	0.8849	0.8869	0.8888	0.8907	0.8925	0.8944	0.8962	0.8980	0.8997	0.9015
1.3	0.9032	0.9049	0.9066	0.9082	0.9099	0.9115	0.9131	0.9147	0.9162	0.9177
1.4	0.9192	0.9207	0.9222	0.9236	0.9251	0.9265	0.9279	0.9292	0.9306	0.9319
1.5	0.9332	0.9345	0.9357	0.9370	0.9382	0.9394	0.9406	0.9418	0.9429	0.9441
1.6	0.9452	0.9463	0.9474	0.9484	0.9495	0.9505	0.9515	0.9525	0.9535	0.9545
1.7	0.9554	0.9564	0.9573	0.9582	0.9591	0.9599	0.9608	0.9616	0.9625	0.9633
1.8	0.9641	0.9649	0.9656	0.9664	0.9671	0.9678	0.9686	0.9693	0.9699	0.9706
1.9	0.9713	0.9719	0.9726	0.9732	0.9738	0.9744	0.9750	0.9756	0.9761	0.9767
2.0	0.9772	0.9778	0.9783	0.9788	0.9793	0.9798	0.9803	0.9808	0.9812	0.9817
2.1	0.9821	0.9826	0.9830	0.9834	0.9838	0.9842	0.9846	0.9850	0.9854	0.9857
2.2	0.9861	0.9864	0.9868	0.9871	0.9875	0.9878	0.9881	0.9884	0.9887	0.9890
2.3	0.9893	0.9896	0.9898	0.9901	0.9904	0.9906	0.9909	0.9911	0.9913	0.9916
2.4	0.9918	0.9920	0.9922	0.9925	0.9927	0.9929	0.9931	0.9932	0.9934	0.9936
2.5	0.9938	0.9940	0.9941	0.9943	0.9945	0.9946	0.9948	0.9949	0.9951	0.9952
2.6	0.9953	0.9955	0.9956	0.9957	0.9959	0.9960	0.9961	0.9962	0.9963	0.9964
2.7	0.9965	0.9966	0.9967	0.9968	0.9969	0.9970	0.9971	0.9972	0.9973	0.9974
2.8	0.9974	0.9975	0.9976	0.9977	0.9977	0.9978	0.9979	0.9979	0.9980	0.9981
2.9	0.9981	0.9982	0.9982	0.9983	0.9984	0.9984	0.9985	0.9985	0.9986	0.9986
3.0	0.9987	0.9987	0.9987	0.9988	0.9988	0.9989	0.9989	0.9989	0.9990	0.9990
3.1	0.9990	0.9991	0.9991	0.9991	0.9992	0.9992	0.9992	0.9992	0.9993	0.9993
3.2	0.9993	0.9993	0.9994	0.9994	0.9994	0.9994	0.9994	0.9995	0.9995	0.9995
3.3	0.9995	0.9995	0.9995	0.9996	0.9996	0.9996	0.9996	0.9996	0.9996	0.9997
3.4	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9998

$\alpha = 1 - \phi(z_\alpha)$

α	z_α
0.10	1.2816
0.05	1.6449
0.025	1.9600
0.010	2.3263
0.005	2.5758
0.001	3.0902
0.0005	3.2905
0.0001	3.7190
0.00005	3.8906
0.00001	4.2649

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
DEPARTMENT OF MATHEMATICS & STATISTICS

2017/2018 Academic Year Final Examinations DECEMBER, 2018
MAT 3100 ADVANCED CALCULUS

Total time allowed: Three (3) hours
Instructions:

- Answer any five (5) questions.
- Show detailed working to earn full marks.
- Each question carries 20 marks.
- The total marks for this paper is 100.

---

1. (*a*) (*i*) Sketch the graph of the surface $z - x^2 - y^2 - 8x + 4y = 25$.
[4 Marks]

(*ii*) Assuming that the equation

$$z^2 - x^2 - y^2 - 8x + 4y - 25 = 0$$

defines z implicitly as a function of x and y, say $z = f(x, y)$, find $\dfrac{\partial f}{\partial x}$.

[3 Marks]

(*b*) Obtain the odd periodic extension of the given function and give a sketch of the extension for $-3\pi < x < 3\pi$,

$$f(x) = \begin{cases} x & \text{if } 0 < x < \frac{\pi}{8}, \\ \frac{\pi}{4} - x & \text{if } \frac{\pi}{8} < x < \frac{\pi}{4}. \end{cases}$$

[9 Marks]

(c) A region R_{xy} in the xy plane is bounded by $x + y = 6$, $x - y = 2$, and $y = 0$. Sketch the region R_{uv} in the uv plane into which R_{xy} is mapped under the transformation $x = u + v$, $y = u - v$. Compute $\dfrac{\partial(x, y)}{\partial(u, v)}$. By finding the ratio of the areas of R_{xy} and R_{uv}, compare with $\dfrac{\partial(x, y)}{\partial(u, v)}$.

[4 Marks]

2. (a) (i) State Stokes's theorem without proof.

[4 Marks]

(ii) Evaluate $\int\int_S \text{curl}\boldsymbol{F} \cdot d\boldsymbol{S}$ given that $\boldsymbol{F}(x, y, z) = yz\boldsymbol{i} + xz\boldsymbol{j} + xy\boldsymbol{k}$ and S is the part of the surface $z + x^2 + y^2 = 9$ that lies above the plane $z = 5$, with upward orientation.

[6 Marks]

(b) The plane $x + y + 2z = 2$ intersects the paraboloid $z = x^2 + y^2$ in an ellipse. Find the points on this ellipse that are nearest to and furthest from the origin.

[6 Marks]

(c) Let $\boldsymbol{F}(x, y, z) = 3x^2y\boldsymbol{i} + y^2z\boldsymbol{j} + 4xz^2\boldsymbol{k}$. Find

(i) $\text{div}\boldsymbol{F}$,

[2 Marks]

(ii) Laplacian$(\boldsymbol{F})$.

[2 Marks]

3. (a) Find the volume of the solid enclosed by the parabolic cylinder $y = x^2$ and the planes $z = 2y$, $z = 3 + y$.

[8 Marks]

(b) Solve the ODE by converting to a system of first-order ODEs

$$y'' + 2y' + 0.75 = 0.$$

[6 Marks]

(c) Solve the equation by the Laplace transform method

$$y(t) + 4e^{2t} \int_0^t y(\tau) e^{-2\tau} d\tau = te^t.$$

[6 Marks]

4. (a) (i) State Green's theorem without proof.

[4 Marks]

(ii) Apply Green's theorem in finding the area bounded by one arc of a cycloid and the positive $x-$ axis. (The cycloid is given by $a(t - \sin t)\boldsymbol{i} + a(1 - \cos t)\boldsymbol{j}$, $0 \leq t \leq 2\pi$).

[6 Marks]

(b) Sketch the region given by the integral

$$\int_0^2 \int_{2-x}^{2+x} dy dx$$

and interchange the order of integration.

[6 Marks]

(c) Given that

$$f(x, y) = \int_{y^2+1}^{x^2+2} \ln t^2 dt,$$

find

(i) $\dfrac{\partial f}{\partial x}$,

[2 Marks]

(ii) $\dfrac{\partial f}{\partial y}$.

[2 Marks]

5. (*a*) Solve the following initial value problem by the Laplace transform

$$y'' - 2y' - 3y = 0,\ y(4) = -3,\ y'(4) = -17.$$

[7 Marks]

(*b*) Represent the function using unit step functions and find its Laplace transform

$$f(t) = \begin{cases} 4 \text{ if } 0 < t < 1, \\ \frac{1}{4}t^2 \text{ if } 1 < t < \frac{\pi}{2}, \\ \cos t \text{ if } t > \frac{\pi}{2}. \end{cases}$$

[8 Marks]

(*c*) Obtain the complex form of the Fourier series of the function $f(t) = t$, $-\pi \leq t \leq \pi$ given that $f(t + 2\pi) = f(t)$.

[5 Marks]

6. (*a*) (i) State the Divergence theorem without proof.

[4 Marks]

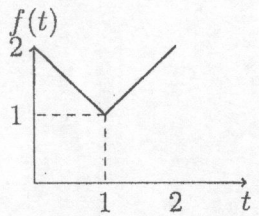
(ii) Find the flux of $\boldsymbol{F}$ across S where

$$\boldsymbol{F}(x, y, z) = e^x \sin y\boldsymbol{i} + e^x \cos y\boldsymbol{j} + yz^2\boldsymbol{k},$$

and S is the surface of the tetrahedron with vertices $(0, 0, 2)$, $(0, 2, 0)$ and $(1, 0, 0)$ and $(0, 0, 0)$.

[6 Marks]

(*b*) Find the Laplace transform of the following function



[5 Marks]

(*c*) If $z = f(x, y)$ has continuous second-order partial derivatives and $x = r^2 + s^2$, $y = 2rs$, find

(*i*) $\dfrac{\partial z}{\partial r}$,

[1 Mark]

(*ii*) $\dfrac{\partial^2 z}{\partial r^2}$.

[4 Marks]

7. (*a*) (*i*) Find the Fourier integral representation of the following function $f(x) = \begin{cases} 0 & \text{if } x < 0, \\ e^{-x} & \text{if } x \geq 0, \end{cases}$

[5 Marks]

(*ii*) hence or otherwise show that

$$\int_0^\infty \frac{\cos wx + w \sin wx}{1 + w^2} dw = \begin{cases} 0 & \text{when } x < 0, \\ \frac{\pi}{2} & \text{when } x = 0, \\ \pi e^{-x} & \text{when } x > 0. \end{cases}$$

[3 Marks]

(*b*) Apply the power series method to find the general solution of $(1 - x^2)y'' - 2xy' + 2y = 0$.

[7 Marks]

(*c*) Find a function f such that $\nabla f = \boldsymbol{F}$, hence or otherwise evaluate the line integral $\displaystyle\int_C \boldsymbol{F} \cdot d\boldsymbol{r}$ given that $\boldsymbol{F}(x, y, z) = -ye^{-x}\boldsymbol{i} + e^{-x}\boldsymbol{j} + 2z\boldsymbol{k}$ and $\boldsymbol{r}(t) = t^2\boldsymbol{i} + \sin t\boldsymbol{j} + t\boldsymbol{j}$, $0 \leq t \leq \pi$.

[5 Marks]

-END OF EXAM-

The University of Zambia
School of Natural Sciences
Department of Mathematics and Statistics

2017/18 Academic Year Examinations

MAT 3110 Engineering Mathematics II

December 3, 2018.

Duration: THREE Hours

Instructions:

- Do not open this booklet until you are told to do so.
- This paper consists of two sections, section A and section B. Attempt FIVE questions, choosing atleast one question from each section. All questions carry equal marks(20).
- Each question carries 20 marks. Candidates must answer 5 questions, answering at least one question from each section. Total marks is 100.
- Please indicate the five questions you attempt on the main answer booklet. For example, if you attempt questions 1, 3,4,6 and 7 write

FOR USE BY EXAMINER

1	
3	
4	
6	
7	

- Use the main answer booklet for your answers to questions in section A and continuation answer booklet for the questions in section B.
- Non programmable calculators are allowed.
- A standard normal table is attached at the end of this booklet.

Section A

Question 1

(a) Apply the power series method to solve the following ordinary differential equation. (10

$$y'' - y = x$$

(b) i. Solve the initial value problem (5

$$x^2y'' - 4xy' + 4y = 0.$$

ii. Find the general solution of the following system of first order linear differential equations (5

$$\begin{aligned} x_1' &= 2x_1 + 7x_2 \\ x_2' &= -5x_1 - 10x_2 \end{aligned}$$

Question 2

(a) Use Laplace transforms to solve the following initial value problem. (10

$$y'' + y' = \cos 2t, \quad y(0) = 2,\ y'(0) = 1.$$

(b) i. Find the Laplace transform of the function (5

$$f(t) = \begin{cases} 0 & ,0 \le t < 1 \\ t^2 & ,1 \le t < 2 \\ 0 & ,2 \le t \end{cases}$$

ii. Find the inverse Laplace transform of the function (5

$$F(s) = \frac{2\pi s}{(s^2 + \pi^2)^2}$$

Question 3

(a) i. Write down the equation of the plane containing the point $(3, 0, -4)$ and orthogonal to the line given by (5

$$r(t) = (12 - t)\,\mathbf{i} + 8t\,\mathbf{j} + (4 + 6t)\,\mathbf{k}.$$

ii. Evaluate the double integral (5

$$\int_{-1}^{0} \int_{-\sqrt{1-y^2}}^{\sqrt{1-y^2}} x^2 \; dxdy$$

(b) Use a triple integral to find the volume of the solid enclose by the surfaces $y = x^2 + z^2$ and $y = \sqrt{x^2 + z^2}$ (10

Question 4

(a) Let

$$F(x, y, z) = (2z^4 - 2y - y^3)\,\mathbf{i} + (z - 2x - 3xy^2)\,\mathbf{j} + (6 + y + 8xz^3)\,\mathbf{k}.$$

i. Show that the given vector field is conservative.

ii. Find the potential function of the vector field F.

iii. Evaluate the line integral

$$\int_C F \cdot \mathrm{d}r$$

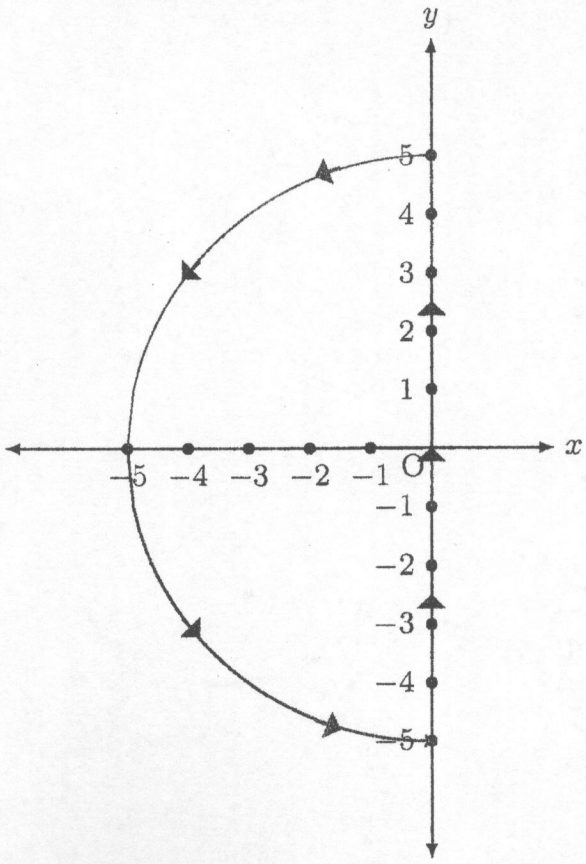
where C is the helix given by

$$r(t) = \cos t\,\mathbf{i} + \sin t\,\mathbf{j} + \frac{2t}{5\pi}\,\mathbf{k}, \quad 0 \le t \le \frac{5\pi}{2}.$$

(b) Verify Green's theorem for the integral

$$\int_C F \cdot \mathrm{d}r$$

where $F(x, y) = yx^2\,\mathbf{i} + x^2\,\mathbf{j}$ and C is shown below.



Question 5

(a) Evaluate the surface integral (10

$$\int\int_S F \cdot \mathrm{d}S$$

where $F(x, y, z) = yx^2\,\mathbf{i} + (xy^2 - 3z^4)\,\mathbf{j} + (x^3 + y^2)\,\mathbf{k}$ and S is the surface of the solid $x^2 + y^2 + z^2 \leq 4$, $z \geq 0$ and $y \geq 0$.

(b) Use Stoke's theorem the line integral (10

$$\int_C \mathbf{F} \cdot \mathrm{d}r$$

where $\mathbf{F}(x, y, z) = (zx^3 - 2z)\,\mathbf{i} + xz\,\mathbf{j} + xy\,\mathbf{k}$ and C is the triangle with vertices $(0, 0, 4)$, $(0, 2, 0)$ and $(2, 0, 0)$. Direction is $(2, 0, 0)$ to $(0, 0, 4)$ to $0, 2, 0$ to $(2, 0, 0)$.

Section B

Question 6

(a) i. Let X be the number of cars per minute passing a certain point of some road between 8.00hrs and 10.00hrs on a Sunday. Assume that X has a Poisson distribution with mean 5. Find the probability of observing 3 or fewer cars during any given minute.

ii. In an experiment, two bags A and B, consisting red and green marble are used. Bag A contains four red marble and one green marble and bag B contains two red marble and seven green marbles. An unbiased coin is tossed. If a head turns up, a marble is drawn at random from bag A while if a tail turns up, a marble is drawn at random from bag B. Given that a red marble is selected, calculate the probability that when the coin was tossed a head was obtained.

(b) Three screws are drawn at random from a lot of 50 screws, 2 of which are defective. Find the probability of the event that exactly two are non-defective , assuming that we draw

i. with replacement

ii. without replacement

Question 7

(a) i. In how many different ways can we select a committee consisting of 4 engineers, 2 chemists, and 2 mathematicians from 10 engineers, 5 chemists, and 7 mathematicians?

ii. The random variable X has probability density function given by

$$f(x) = \begin{cases} kx(1-x^2), & 0 \leq x \leq 1 \\ 0 & \text{otherwise} \end{cases}$$

Find the value of K and the mean of this distribution.

(b) i. A manufacturer knows from experience that the resistance of resistors he produces is normal with mean 150 ohms and standard deviation 5 ohms. What is the percentage of the resistors will have resistance between 148 ohms and 152 ohms.

ii. The breaking strength X of a certain type of plastic block is normally distributed with a mean of 1250 kg and a standard deviation of 55 kg. What is the maximum load such that we can expect no more than 5% of the blocks to break?

End of Examination

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
INSTITUTE OF DISTANCE EDUCATION

2017/2018 Academic Year Final Examinations AUGUST, 2018
MAT 3200 ABSTRACT ALGEBRA

Total time allowed: Three (3) hours
Instructions:

- Answer any five (5) questions.
- Show detailed working to earn full marks.

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1. (*a*) (*i*) Let X be a non-empty finite set. Define the symmetric group denoted by S_X.
   (*ii*) Compute the Cayley table for A_3, the alternating group of order 3.
   (*b*) (*i*) Prove that an $r-$cycle in S_n has order r.
   (*ii*) Compute the order and inverse of the following permutation $((1345)(46))^{2018}$.
   (*c*) (*i*) Let x and y be two arbitrary permutations in S_3. Use the fact that x is conjugate to y if and only if they have the same cycle structure to compute the conjugacy classes of S_3.
   (*ii*) Compute the size of the centralizer of a representative of each conjugacy class of S_3.

2. (*a*) (i) Let $\{f_1, f_2, f_3, f_4, f_5, f_6\}$ be a set of functions

$$\mathbb{R} - \{0,1\} \to \mathbb{R} - \{0,1\}$$

under composition. Where

$$f_1(x) = x,\ f_2(x) = 1 - x,\ f_3(x) = \frac{1}{x},\ f_4(x) = 1 - \frac{1}{x},$$
$$f_5(x) = \frac{1}{1-x},\ f_6(x) = \frac{x}{x-1}.$$

Prove that this set forms a group,

(ii) show that it is isomorphic to S_3.

(b) Let H be any subgroup of a group G. Prove that there is a one-to-one correspodence between the set of right cosets of H in G and the set of left cosets of H in G.

(c) (i) Find all the left and right cosets of $H = \{(1), (13)\}$ in S_3.

(ii) Prove that if H is the only subgroup of a given order in a group G, then H is normal in G.

3. (a) (i) Let $G = S_3$ and $H =< (123) >$. Prove that H is a normal subgroup of G.

(ii) Define a quotient group G/N of a group G mod a normal subgroup N. Justify why this is indeed a group.

(b) Let $\rho : G \to H$ be a homomorphism. Prove that $\mathrm{Ker}(\rho)$ is a normal subgroup of G and that $\mathrm{Im}(\rho)$ is a subgroup of H.

(c) (i) Find all group homomorphisms from $\mathbb{Z}$ to $\mathbb{Z}_4$.

(ii) State without proof the first isormophism theorem.

4. (a) (i) Define a commutative ring.

(ii) Prove that the set $(\mathbb{Q}(\sqrt{5}), +, .)$ forms a commutative ring.

(b) (i) Suppose that $0 = 1$ in the ring R. Prove that R is simply the trivial ring.

(ii) Construct the addition and multiplication tables for the ring $(\mathbb{Z}_4, +, .)$.

(c) (i) Define an integral domain.

(ii) Give an example of a ring which is not an integral domain.

5. (a) (i) Define a ring homomorphism.

(ii) Justify whether or not the map given by $f : (\mathbb{Z}_6, +, .) \to (\mathbb{Z}_3, +, .)$ such that $f([x]_6) = [x]_3$ forms a ring homomorphism.

(b) (i) Denote by $(R[x], +, .)$ the polynomial ring with coefficients in R. Prove that if R is an integral domain and $p(x)$, $r(x)$ are non zero polynomials in $(R[x], +, .)$, then $\deg(p(x) \cdot q(x)) = \deg(p(x)) + \deg(r(x))$.

(ii) Compute $(2x^5 + x^2 + 1) \cdot (2x^2)$ in $\mathbb{Z}_4[x]$, what conclusion could you make from the result in $b(i)$?.

(c) Prove that every proper ideal I is the kernel of a ring homomorphism.

6. (a) (i) Define a faithful action of a group G acting on a finite set X. Why is this action important?

(ii) Let G act on a finite set X. Let $y = x^g$ for some $x, y \in X$ and $g \in G$. Show that $g^{-1}G_x g = Gx^g = G_y$.

(b) (i) Define transitive action of a group G on a finite set X.

(ii) Show that the action of a group G on the set of right cosets of a subgroup H in G is transitive.

(c) Let G act on a finite set X. Show that the relation $x \sim y$ given by $y = x^h$ for some $h \in G$ defines an equivalence relation.

7. (a) Define the following terms

(i) Unique factorization domain.

(ii) Principal ideal domain.

(b) (*i*) Prove that every principal ideal domain is a unique factorization domain.

(*ii*) Factor the polynomial into irreducible factors in the given polynomial ring $x^4 + 1$ in $\mathbb{Z}_5[x]$.

(c) (i) Find a splitting field K for $f(X) = X^2 - 4$ over $\mathbb{Q}$. Hence or otherwise find $[K : \mathbb{Q}]$.

(ii) Characterize all irreducible polynomials of degree 5 over $\mathbb{Z}_2$.

END OF EXAM

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
DEPARTMENT OF MATHEMATICS & STATISTICS

2017 Academic Year Final Examinations — 7th December, 2018
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.
- Marks are indicated in square brackets at the end of each part of the question.

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1. (a) (i) Define the order of an element a in a group G. [3]
   (ii) State Sylow's First Theorem. [3]

   (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 distinct conjugacy classes for this group. [5]

   (c) (i) List all the distinct left cosets of the cyclic subgroup $K = \langle 6\rangle = \{0,\ 6,\ 12,\ 18\}$ in the group $\mathbb{Z}_{24}$. [2]
   (ii) Find the order of the elements $14+K$ and $15+K$ in the factor group $\mathbb{Z}_{24}/K$. [2]
   (iii) Find the inverse of the element $8+K$ and the inverse of the element $9+K$ in the factor group $\mathbb{Z}_{24}/K$. [2]

   (d) Let $\delta = (1243)(24567)$ be a permutation in the symmetric group S_7. Find the order of δ and determine whether δ is even or odd. [4]

2. (a) (i) Define an even permutation. [2]
   (ii) State The Fundamental Theorem of Cyclic Groups. [2]

(b) Find $\gcd(253, 189)$ and then find integers m and n such that the equation $253m + 189n = \gcd(253, 189)$ is satisfied. [5]

(c) (i) List the elements of $U(15)$, the group of units modulo 15. [2]

(ii) Given that $H = U_5(15)$, list all the elements of the factor group $U(15)/H$. [2]

(iii) Construct the Cayley table for the factor group $U(15)/H$. [2]

(d) State and prove Lagrange's Theorem. [5]

3. (a) (i) Let G be a group of permutations of a set S. Then define the stabilizer of an element a in S. [2]

(ii) State Cauchy's Theorem For Abelian Groups. [3]

(b) Use the Division Algorithm to find the quotient and remainder when -369 is divided by 8 and hence express -369 in the form $-369 = 8q + r$, where q is the quotient and r is the remainder. [4]

(c) Let $A = \{a,\ b,\ c,\ d,\ e,\ f,\ g\}$ and consider the permutation $\beta = (a\ b\ c\ e)(f\ g)$ in the symmetric group S_A. By writing your final answer in array notation find β^{-6}. [5]

(d) Let ϕ be the group homomorphism from $\mathbb{Z}_{16}$ to $\mathbb{Z}_{12}$ defined by $\phi(x) = 3x$. Then find the following:

(i) the image of ϕ, [2]

(ii) the kernel of ϕ, [2]

(iii) $\phi^{-1}(K)$, given that $K = \{0,\ 6\}$. [2]

4. a) Let D be an integral domain. What does it mean that

(i) $x \in D$ is unit? [2]

(ii) a polynomial $f(x) \in D[x]$ is irreducible? [2]

b) (i) Let R be a commutative ring with unity and let I be an ideal of R. Prove that $I = R$ if and only if I contains a unit. [3]

(ii) Show that $2 + 3i$ is a unit in $\mathbb{Z}[i]$. [3]

c) Let $\phi : R \to S$ be a ring isomorphism. Show that

(i) if $r \in R$ is a unit, then $\phi(r)$ is a unit is S. [2]

(ii) if R is a field, then S is also a field. [2]

d) i) Let F be a field. Prove that if $f(x) \in F[x]$ has degree 2 or 3, then $f(x)$ is reducible if and only if $f(x)$ has a zero in F. [4]

ii) Hence or otherwise, determine whether or not $f(x) = x^3 + 2x^2 + x + 2$ is reducible over $\mathbb{Q}$. [2]

5. a) Define the following
   (i) a Euclidean domain, [2]
   (ii) a unique factorization domain (UFD). [2]
   b) Show that $\mathbb{Z}$ with norm $N(x) = |x|, x \in \mathbb{Z}$ is a Euclidean domain. [4]
   c) i) Show that $\mathbb{Z}[\sqrt{-3}]$ is not a UFD. [2]
   ii) Prove that any two elements in a UFD have a greatest common divisor (gcd). [5]
   d) Find the greatest common divisor of $-4 + 7i$ and $1 + 7i$ in $\mathbb{Z}[i]$. [4]

6. a) Define the following
   (i) a field extension, [2]
   (ii) the minimum polynomial of linear operator T. [2]
   b) i) Let F be a field and $f(x)$ be a non-constant polynomial in $F[x]$. Prove that F has an extension field E in which $f(x)$ has a zero. [6]
   ii) Find the splitting field over $\mathbb{Q}$ of $x^4 - x^2 - 2$ [3]
   c) Prove that the minimum polynomial of T is unique. [3]
   d) Let $T : \mathbb{R}^4 \to \mathbb{R}^4$ be a linear operator defined by $T(x_1, x_2, x_3, x_4) = (x_1 - x_2, 2x_2, x_3, 2x_4)$. Find the minimum polynomial of T. [4]

7. a) Define
   (i) a linear operator T, [2]
   (ii) an adjoint T^* of a linear operator T on an inner product space V. [2]
   b) i) State the Caylay-Hamilton Theorem. [2]
   ii) Verify the Caylay-Hamilton Theorem for $T : \mathbb{R}^3 \to \mathbb{R}^3$ defined by $T(x, y, z) = (x - y, y, 2z)$. [4]
   c) i) Show that Kernel of T is T-invariant. [2]
   ii) Show that the image of T is T-invariant. [2]
   d) Let T_1 and T_2 be linear operators on an inner product space V. Show that
   i) $(T_1 + T_2)^* = T_1^* + T_2^*$. [3]
   ii) $(T_1 T_2)^* = T_2^* T_1^*$. [3]

END OF EXAM

THE UNIVERSITY OF ZAMBIA

DEPARTMENT OF MATHEMATICS AND STATISTICS

END OF YEAR EXAMINATIONS - 2017/18 ACADEMIC YEAR

MAT3300 REAL ANALYSIS

Duration: Three (3) Hours

Instructions:

- There are six (6) questions in this paper. Answer any five (5).
- All questions carry equal marks.
- Show all necessary work to earn full marks.

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1. (a) Define the following terms:
   i. A compact subset of $\mathbb{R}$.
   ii. A connected subset of $\mathbb{R}$.

   (b) i. Prove that every compact subset of $\mathbb{R}$ is closed and bounded.
   ii. State and prove the intermediate value theorem.

   (c) i. Show that the collection $C = \{A_i : i = 0, 1, 2, ..., n\}$, where $A = \left(\frac{1}{2^i} - \frac{1}{2^{i+1}}, \frac{1}{2^i} + \frac{1}{2^{i+1}}\right)$, is an open covering of the open interval $A = (0, 1)$ and there is no finite subcovering $C' \subset C$ of A.
   ii. Show that the set $A = \{x \in \mathbb{R} : x^2 < 3\}$ is disconnected.

2. (a) Define the following:
   i. A relative neighbourhood of a point $x_0 \in A \subset \mathbb{R}$.
   ii. An accumulation point of a set $A \subset \mathbb{R}$.

   (b) Prove the following:
   i. A set $F \subset \mathbb{R}$ is closed if and only if the limit of any convergent sequence of points in F is in F.
   ii. A subset $B \subset A \subset \mathbb{R}$ is relatively open in A if and only if every $x \in B$ has a relative neighbourhood V in A such that $V \subset B$.

   (c) Let $A = \{(x, y) : 0 < x \leq 1; 0 \leq y < 1\}$. Determine
   i. $\mathbf{iso}(A)$

ii. $\mathbf{bd}(A)$

iii. $\mathbf{acc}(A)$

iv. $\mathbf{int}(A)$

3. (a) Define the following terms:

   i. A pointwise convergent sequence (f_n) of real-valued functions.

   ii. A uniformly convergent sequence (f_n) of real-valued functions.

   (b) i. State and prove the extreme value theorem.

   ii. State and prove the Weierstrass M-test.

   (c) If $\sum_{n=1}^{\infty} a_n$ is absolutely convergent, prove that $\sum_{n=1}^{\infty} \frac{a_n x^n}{1+x^{2n}}$ converges uniformly for all x.

4. (a) What is meant by the following:

   i. A function of bounded variation.

   ii. An absolutely continuous function.

   (b) Prove the following:

   i. If f, g are absolutely continuous on $I = [a, b]$, then fg is absolutely continuous on $[a, b]$.

   ii. If f is absolutely continuous on $[a, b]$, then it is of bounded variation on $[a, b]$.

   (c) Show that the function $g(x) = \sqrt{x}$ is absolutely continuous on $[0, 1]$.

5. (a) Define the following:

   i. The left hand derivative of a function f at x_0.

   ii. A relative minimum of a function f.

   (b) Prove the following:

   i. If $f(x_0)$ is a local extremum, then $f'(x_0) = 0$ or else $f'(x_0)$ does not exist.

   ii. If a function f is continuous at every point in $[a, b]$, with $f(a) = f(b)$, and if f is differentiable at every point of (a, b), then there exists at least one point $c \in (a, b)$ such that $f'(c) = 0$.

   (c) Show that there is no value of α such that the equation $x^3 - 3x + \alpha = 0$ has two distinct roots in $[0, 1]$.

6. (a) Define the following terms:

   i. The upper Riemann sum of a function f on $[a, b]$.

   ii. The lower integral of a function f on $[a, b]$.

   (b) Let f be a real-valued function defined on $[a, b]$. Prove the following:

i. If f is continuous on $[a, b]$ then it is Riemann integrable on $[a, b]$.

ii. If f is monotone on $[a, b]$, then it is Riemann integrable on $[a, b]$.

(c) Let $f(x) = x^2$. For each $n \in \mathbb{N}$, let σ_n be the partition $\{0, \frac{1}{n}, \frac{2}{n}, ..., \frac{n}{n}\}$ of $[0, 1]$. Compute $\lim_{n\to\infty} U[f; \sigma_n]$ and $\lim_{n\to\infty} L[f; \sigma_n]$.

The University of Zambia
School of Natural Sciences
Department of Mathematics & Statistics

2017/2018 ACADEMIC YEAR

MID-YEAR EXAMINATIONS

MAT3601 : Mathematical Statistics

Time Allowed: Three (3) Hours

Instructions:

- There are Five (5) questions in this paper, Attempt any **Four (4)** questions.
- Full credit will only be given where all the necessary work is shown
- Some formulae on the last page
- You must write your **Computer Number** on each answer booklet used.

---

1 a) Define each of the following:
(i) Chi-square distribution (no pdf).
(ii) An F- distribution (no pdf).
(iii) j^{th} –order statistics

b) Let X be a random variable with probability density function

$f(x,\theta) = 3\theta x^2 e^{-\theta x^3}$, $x > 0$, $\theta > 0$. Find the following:

(i) Cumulative distribution function (cdf) of X.
(ii) Probability density function of the 2nd –order statistics.
(iii) Probability function of $Y = \theta X^3$
(iv) Cramer-Rao lower bound for θ.

c) Let X and Y have a joint probability function

$f(x,y) = 4x(1-y)$, $x \in (0,1)$ *and* $y \in (0,1)$. Find the following:

(i) $P(2X - Y > 1)$
(ii) Conditional probability density function of Y given X = $\frac{1}{3}$
(iii) E(Y/ X=$\frac{1}{3}$).

2 a) Define the following:
(i) Mean-squared error of an estimator T of θ.
(ii) Consistent estimator for θ.
(iii) Sufficient statistics for θ

b)(i) State the Neyman - Pearson lemma.
(ii) Prove the Neyman - Pearson lemma.
(iii) Let $X_1, X_2, \ldots. X_n$ be a random sample of size n from

$f(x,\theta) = \frac{\theta}{(x+1)^{\theta+1}}$, $x > 0$, $\theta > 0$

Construct a most powerful test of size α for testing H_0 θ = 2 vs H_a θ = 4.

c) Let $X_1, X_2, \ldots. X_n$ be a random sample of size n from

$f(x,\theta) = \theta(1-\theta)^x$, $0 < \theta < 1$, $x = 0,1,2,3, \ldots \ldots \ldots \ldots \ldots \ldots \ldots$

(i) Find the maximum likelihood estimator for θ.
(ii) Find the maximum likelihood estimator for $\tau(\theta) = \frac{1-\theta}{\theta}$
(iii) Find the Cramer-Rao lower bound for θ
(iv) Is the MLE for θ in (i) above UMVUE? Justify your answer

3 a) Define the following:
(i) Relative efficient of T_2 with respect to T_1.
(ii) Power function of a test γ.
(iii) Size of a test γ

b)(i) Define a t-distribution without specifying its pdf.
(ii) Derive the probability density function for a t-distribution with m-degrees of freedom.

c) Prove each of the following:
(i) If the random variables $X_1, X_2, X_3, \ldots\ldots, X_k$ are independent and $X_j \sim N(\mu_j, \sigma_j^2)$ then the random variable $Y = \sum_{j=1}^{k} \left(\frac{X_j - \mu_j}{\sigma_j}\right)^2$ has a Chi-square distribution with k-degrees of freedom.
(ii) If X and Y are independent gamma random variables with $X \sim g(\alpha, \lambda)$ and $Y \sim g(\beta, \lambda)$ then the random variable $X + Y \sim g(\alpha + \beta, \lambda)$

4. a) Define each of the following:
(i) Most powerful test of size α
(ii) Uniformly most powerful test of size α
(iii) Monotone likelihood ratio.

b) Let $X_1, X_2, \ldots\ldots X_n$ be a random sample of size n from uniform on the interval $(\theta-1, \theta+1)$

$f(x,\theta) = \frac{1}{2}$, $\theta - 1 < x < \theta + 1$, $\theta > 0$ Find the following:
(i) Method of moments estimator for θ
(ii) Maximum likelihood estimator for θ
(iii) Sufficient statistics for θ

c)(i)Let $X_1, X_2, \ldots\ldots X_n$ be a random sample of size n from exponential with pdf

$$f(x,\theta) = \theta e^{-\theta x}, \quad x > 0, \quad \theta > 0$$

Construct a generalized likelihood ratio test of size α for testing
$H_0: \theta = 2$ vs $H_a: \theta \neq 2$
(ii) Let $X_1, X_2, \ldots\ldots X_n$ be a random sample of size n from Poisson with parameter μ. Construct a uniformly most powerful test of size α for testing
$H_0 : \mu = \mu_0$ vs $H_a : \mu > \mu_0$.

5. a) Define each of the following:
   (i) Simple likelihood ratio test.
   (ii) Generalized likelihood ratio
   (iii) Generalized likelihood ratio test of size α

b) Let X and Y be independent random variables each having a standard normal distribution, i.e means 0 and variances 1.

Let $Z = X^2 + Y^2 \quad and\ U = \frac{X}{Y}$

   (i) Find the joint probability function of Z and U.
   (ii) Find the marginal probability density function of Z and U
   (iii) Are Z and U independent? Justify your answer

c) Let X_1, X_2 be a random sample of size two from $f(x,\theta) = \theta x^{\theta-1}$, $0 < x < 1$, $\theta > 0$
Consider the hypotheses H_0 : $\theta = 1$ and H_a $\theta = 2$, find the following
   (i) A most powerful test of size α
   (ii) Size of the test γ : reject H_0 if $X_1 + X_2 > \frac{3}{2}$
   (iii) The power of the test γ in (ii) above

$$If\ Y \sim \chi^2_V, then \quad f(y) = \frac{y^{\alpha-1}e^{-\frac{y}{2}}}{2^{\alpha}\Gamma(\alpha)}, where\ \alpha = \frac{V}{2}, \quad y > 0, \quad V > 0$$

$$If\ Z \sim N(0,1), then\ f(z) = \frac{e^{-\frac{z^2}{2}}}{\sqrt{2\pi}}, \quad z \in (-\infty, \infty)$$

$$If\ X \sim g(\alpha,\lambda), then \quad f(x) = \frac{x^{\alpha-1}e^{-\frac{x}{\lambda}}}{\lambda^{\alpha}\Gamma(\alpha)}, \quad \lambda > 0, \quad x > 0, \quad \alpha > 0$$

END OF EXAM GOOD LUCK

The University of Zambia
School of Natural Sciences
Department of Mathematics and Statistics
2017 Academic Year Exams - November, 2018
MAT3622 - Linear Regression

Time allowed : 3 Hours

Instructions:

- There are **five (5)** questions in this examination. 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 5 pages of questions.

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1. (a) Suppose the experimenter postulates a zero intercept model $y_i = \beta x_i + \varepsilon_i \quad (i = 1, 2, \ldots, n)$, with $E[\varepsilon] = 0$ and $\text{Var}[\varepsilon] = \sigma^2$.
   (i) Find the least squares estimator of β.
   (ii) Find the variance of the slope $(\hat{\beta})$ for the least-squares estimator found in part (i).
   (iii) Find a $100(1-\alpha)\%$ confidence interval for β. Compare this interval to the interval for the case where both the slope and intercept are unknown? Justify your answer.
   (iv) Prove that $E(Y_i - \hat{\beta}x_i)^2 = \sigma^2\left(1 - \frac{x_i^2}{\sum_{i=1}^{n} x_i^2}\right)$.
   (v) Prove that $S^2 = \frac{1}{n-1}\sum_{i=1}^{n}(Y_i - \hat{\beta}x_i)^2$ is an unbiased estimator of σ^2.

(b) Consider the multiple linear regression model $Y = X\beta + \varepsilon$.

(i) Show that the residuals from a linear regression model can be expressed as $e = (I - H)\varepsilon$.

(ii) find Var[e]

2. (a) Suppose the experimenter postulates a model $y_i = \beta_0 + \beta_1 x_i + \varepsilon_i \quad (i = 1, 2, \ldots, n)$ and $\varepsilon_i \sim N(0, \sigma^2)$.

(i) Write the model in matrix form.

(ii) Use the matrix form of the simple linear regression model to find the least squares estimation of β_0 and β_1.

(iii) Show whether or not the estimators found in part (ii) are unbiased.

(iv) Find the variances of the estimators of β_0 and β_1.

(v) Find the covariance of the estimators β_0 and β_1.

(b) Suppose that we want to fit the model $y_i = \beta(x_i - \bar{x}) + \varepsilon_i$ using weighted least squares. Assume that the observations 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 $Var(\varepsilon_i) = k(x_i - \bar{x})^2$, that is, the variance of ε_i is proportional to the corresponding $(x_i - \bar{x})^2$. Using the results of parts (i) and (ii), find the weighted least-squares estimator of β and the variance of this estimators.

3. (a) Consider the multiple regression model:
$Y_i = \beta_1 X_{i1} + \beta_2 X_{i2} + \varepsilon_i, \quad i = 1, 2, \ldots, n$
where the ε_i are uncorrelated, with $E(\varepsilon_i) = 0$ and $\text{Var}(\varepsilon_i) = \sigma^2$.

(i) Derive the least squares estimators of β_1 and β_2.

(ii) Assuming that the ε_i, are independent normal random variables, state the likelihood function and obtain the normal equations for the maximum likelihood estimators of β_1 and β_2. Are these the same as the normal equations for the least squares estimators?

(b) The data below show seasonally adjusted quarterly sales for the McGill Company (Y, in million kwacha) and for the entire industry (X, in million kwacha), for the most recent 20 quarters.

t	x_t	y_t	Residuals
1	127.3	20.96	-0.026052
2	130.0	21.40	-0.062015
3	132.7	21.96	0.022021
4	129.4	21.52	0.163754
5	135.0	22.39	0.046570
6	137.1	22.76	0.046377
7	141.2	23.48	0.043617
8	142.8	23.66	-0.058435
9	145.5	24.10	-0.094399
10	145.3	24.01	-0.149142
11	148.3	24.54	-0.147991
12	146.4	24.30	-0.053054
13	150.2	25.00	-0.022928
14	153.1	25.64	0.105852
15	157.3	26.36	0.085464
16	160.7	26.98	0.106102
17	164.2	27.52	0.029112
18	165.6	27.78	0.042316
19	168.7	28.24	-0.044160
20	171.7	28.78	-0.033009

(i) Fit a simple linear regression model to these data.

(ii) Plot residuals versus time and explain whether you find any evidence of positive autocorrelation.

(iii) Conduct a formal test for positive autocorrelation using a significance level of 0.05. Clearly stating the alternatives, decision rule, and conclusion.

(iv) Is the residual analysis in part (ii) in accord with the test result in (iii)?

4. (a) Consider a simple linear regression model with first-order autoregressive errors $y_t = \beta_0 + \beta_1 x_t + \varepsilon_t$ where $\varepsilon_t = \rho\varepsilon_{t-1} + u_t$.

(i) Define autocorrelation.

(ii) Show that $\varepsilon_t = \sum_{j=0}^{\infty} \rho^j u_{t-j}$.

(iii) Find $Cov(\varepsilon_t, \varepsilon_{t+j})$.

(iv) Find an estimate of ρ using the least squares method.

(b) The data in the accompanying table relate grams plant dry weight Y to percent soil organic matter X_1, and kilograms of supplemental soil nitrogen added per 1,000 square meters X_2:

Y	X_1	X_2
78.5	7	2.6
74.3	1	2.9
104.3	11	5.6
87.6	11	3.1
95.9	7	5.2
109.2	11	5.5
102.7	3	7.1
Sums: 652.5	51	32.0
Means: 93.21	7.29	4.57

(i) Define $\mathbf{Y}, \mathbf{X}, \beta$, and ε for a model involving both independent variables and an intercept.

(ii) Compute $\mathbf{X}'\mathbf{X}$ and $\mathbf{X}'\mathbf{Y}$.

(iii) $(\mathbf{X}'\mathbf{X})^{-1}$ for this problem is

$$(\mathbf{X}'\mathbf{X})^{-1} = \begin{bmatrix} 1.7995972 & -0.0685472 & -0.2531648 \\ -0.0685472 & 0.0100774 & -0.0010661 \\ -0.2531648 & -0.0010661 & 0.0570789 \end{bmatrix}.$$

Compute $\hat{\beta}$ and write the regression equation.

(iv) Test the significance of the regression at $\alpha = 0.05$.

(v) Construct a 95% confidence interval for each of the parameters in the model.

5. (a) Twelve batches of the plastic were made, and from each batch one test item was molded and the hardness measured at some specific point in time. The results are shown below; X is elapsed time in hours, and Y is hardness in Brinell units. Assume that the first-order regression model is appropriate.

Observation	Elapsed time (x)	Hardness (y)
1	32	230
2	48	262
3	72	323
4	64	298
5	48	255
6	16	199
7	40	248
8	48	279
9	48	267
10	24	214
11	80	359
12	56	305

(i) Plot the scatter diagram and the regression line. Does the regression function appear to have a good fit here?

(ii) Compute $\hat{\beta}_0$ and $\hat{\beta}_1$ for the linear regression of Hardness on time and write the regression equation.

(iii) Interpret the meaning of the values of $\hat{\beta}_0$ and $\hat{\beta}_1$ calculated in part (ii).

(iv) Construct 95% confidence intervals on β_1 and β_0. Interpret the intervals.

(v) Test the hypothesis $H_0 : \beta_1 = 0$ versus $H_a : \beta_1 \neq 0$ using an F-test with $\alpha = 0.01$.

(vi) Use a t-test to test $H_0 : \beta_0 = 150$ against $H_a : \beta_0 \neq 150$ with $\alpha = 0.01$. Interpret the results.

(vii) Compute the 95% confidence interval estimates of the mean hardness when $x = 50$ hours.

(b) Suppose that we have fit the straight line regression model $\hat{y} = \hat{\beta}_0 + \hat{\beta}_1 x_1$ but the response is affected by a second variable x_2 such that the true regression function is

$$E(y) = \beta_0 + \beta_1 x_1 + \beta_2 x_2$$

(i) Determine whether or not the least-squares estimator of the slope in the original simple linear regression model unbiased.

END OF EXAM

The University of Zambia

School of Natural Sciences

Department of Mathematics and Statistics

2017/18 Academic Year Examinations - December 2018

MAT3632 - Fundamentals of Survival Models

Time allowed : 3hrs Total marks : 150

Instructions:

- Attempt **all five (5)** questions.
- Marks available per question are indicated in [ ] at the end of each question. Each questions carries 30 marks.
- Indicate your **Computer Number** on all your booklets.
- **Full credit** will only be given when **necessary work** is shown.
- You may find the **formulae** on the last page useful.

*This paper consists of **5** pages.*

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1. a) Derive the expression

$$ {}_tq_x = \int_0^t {}_sp_x\mu_{x+s}\,ds $$

defining all notation used. Give an intuitive justification of the expression.

b) (i) State the probability density function for the future lifetime of a person aged x exact, defining all notation used.

(ii) Derive an expression for the survival probability in terms of the force of mortality.

c) (i) If the mortality of a particular population follows Gompertz' law with $\mu_{40} = 0.0004$ and $\mu_{50} = 0.001$, calculate the probability that an individual aged 60 exact reaches age 70 exact and dies within 10 years.

(ii) How would the calculation be different if Makeham's law was assumed? No further calculation is required.

[8, 10, 12]

2. A Scientist is investigating the average lifetime of certain type of battery using the Kaplan-Meier method. He has placed ten batteries into similar torches and has observed the number of hours until each battery failed. The experiment is stopped at the end of 16 hours.

   a) (i) Calculate the $\hat{\lambda}_j$'s, the estimates of the hazard rate in discrete time for this type of battery, given the following data:

Battery	Lifetime (hours)
1	14
2	8
3	12
4	battery did not fail, but bulb failed after 11
5	10
6	battery did not fail, but bulb failed after 13
7	9
8	7
9	14
10	did not fail by end of experiment

   (ii) Calculate the Kaplan-Meier estimate of $\hat{F}(t)$ of the distribution function $F(t)$.

   b) Estimate the probability that a new battery fails before the end of 11 hours.

   c) Calculate the variance of $F(t)$ at each time t when a failure occurs.

[10, 6, 4, 10]

3. You are studying the mortality differences between males and females using a proportional hazards regression model with a single covariate representing sex.

   a) If the baseline hazard function represents females, state the appropriate mathematical form of your model defining all quantities used.

   b) You observe two men and one woman to die from a population with equal proportions of males and females at all ages.

      (i) Calculate the regression parameter that maximises the partial likelihood function and write down the asymptotic distribution of the corresponding maximum likelihood estimator. Hint: Assume N females and N males.

      (ii) Calculate the ratio of hazard functions for males and females according to the fitted model obtained in (i). Comment on the result.

   c) Without further calculation, explain what the estimate of the regression parameter in b) would have been if the same three deaths had occurred but there were twice as many men as women at all ages.

[5, 15, 6, 4]

4. a) (i) What is a Markov chain?

(ii) State and derive Chapman-Kolmogorov equations.

(iii) Prove that if state i is recurrent and state i communicates with state j, then state j is recurrent.

b) Consider a Markov chain having probability transition matrix

$$P = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ \frac{1}{4} & \frac{1}{2} & \frac{1}{4} & 0 & 0 & 0 \\ 0 & \frac{1}{5} & \frac{2}{5} & \frac{1}{5} & 0 & \frac{1}{5} \\ 0 & 0 & 0 & \frac{1}{6} & \frac{1}{3} & \frac{1}{2} \\ 0 & 0 & 0 & \frac{1}{2} & 0 & \frac{1}{2} \\ 1 & 0 & 0 & \frac{1}{4} & 0 & \frac{3}{4} \end{pmatrix},$$

with state space $\{E_0, E_1, E_2, E_3, E_4, E_5\}$.

(i) Draw the transition diagram for the Markov chain.

(ii) How many classes are there?

(iii) Determine which states are recurrent and which states are transient.

c) Consider a Markov chain with state space $\{E_0, E_1, E_2, E_3, E_4\}$ having probability transition matrix

$$P = \begin{pmatrix} 0 & \frac{1}{3} & \frac{2}{3} & 0 & 0 \\ 0 & 0 & 0 & \frac{1}{4} & \frac{3}{4} \\ 0 & 0 & 0 & \frac{1}{4} & \frac{3}{4} \\ 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \end{pmatrix}.$$

(i) Show that the markov chain is irreducible.

(ii) Find the period of the Markov chain.

(iii) Compute P^6 and P^7.

(iv) Find the limiting (stationary) distribution of the Markov chain.

[10, 10, 10]

5. a) List the benefits and limitations of modelling in actuarial work.

b) (i) Define the standard quantities T_x, ${}_tp_x$ and ${}_tq_x$ in words and give mathematical definitions of ${}_tp_x$ and ${}_tq_x$ in terms of T_x.

(ii) Define, in terms of probabilities involving T_x, the force of mortality, μ_{x+t}. Define all quantities used. Hence or otherwise show that

$$\lim_{h \to 0} \frac{{}_hq_{x+t}}{h} = \mu_{x+t}.$$

c) An investigation took place into the mortality of persons between exact ages 70 and 71 years. The table below gives an extract from the results. For each person it gives the age at which they were first observed, the age at which they ceased to be observed, and whether their departure from observation was because of their death or withdrawal from the investigation.

Person	Entry age	Exit age	Reason
1	70 0/12	70 06/12	Withdrew
2	70 1/12	70 05/12	Withdrew
3	70 1/12	70 03/12	Died
4	70 2/12	70 03/12	Withdrew
5	70 3/12	70 09/12	Died
6	70 4/12	70 05/12	Withdrew
7	70 5/12	70 11/12	Died
8	70 7/12	70 09/12	Withdrew
9	70 8/12	70 10/12	Died
10	70 9/12	70 11/12	Withdrew

(i) Describe how the central exposed to risk differs from the initial exposed to risk.

(ii) Write down the likelihood for the Binomial model in terms of q-type probabilities.

(iii) Define the actuarial estimate of q_{70} for the Binomial model and calculate this, stating any assumptions that you make.

[5, 8, 17]

END!

Survival Models

Survival probabilities

$${}_tp_x = \exp\Big(-\int_0^t \mu_{x+s}\, ds \Big)$$

Gompertz' Law

$$\mu_x = Bc^x, \quad {}_tp_x = g^{c^x(c^t-1)} \qquad \text{where } g = e^{-B/\log c}$$

Makeham's Law

$$\mu_x = A + Bc^x, \quad {}_tp_x = s^t g^{c^x(c^t-1)} \qquad \text{where } g = e^{-A}$$

Empirical Estimation

Greenwood's formula for the variance of the Kaplan-Meier estimator

$$\text{var}[\tilde{F}(t)] = [1-\hat{F}(t)]^2 \sum_{t_j \le t} \frac{d_j}{n_j(n_j-d_j)}$$

Variance of the Nelson-Aalen estimate of the integrated hazard

$$\text{var}[\tilde{\Lambda}(t)] = \sum_{t_j \le t} \frac{d_j(n_j-d_j)}{n_j^3}$$

Mortality Assumptions

Balducci Assumption

$${}_{1-t}q_{x+t} = (1-t)q_x, \quad x \in \mathbb{Z}, \quad 0 \le t \le 1$$

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
DEPARTMENT OF MATHEMATICS & STATISTICS

2017/2018 ACADEMIC YEAR
FINAL EXAMINATIONS

MAT3902 PROBABILITY THEORY

Time Allowed: Three (3) Hours

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. Show all the necessary working to get full credit
4. All questions carry equal marks

---

1. a) Given X is the number of defects per plate of a metal sheet which has a Poisson distribution with mean 10. There is a constant probability of 0.9 of finding each defect during the inspection process and successes are independent, that is if Y represents the number of defects found then,

$$P(Y = y/\ X = x) = \binom{x}{y}(0.9)^y(0.1)^{x-y} \quad , \quad y = 0,1,2,3 \ldots \ldots \ldots x$$

Find the following:

(i) Marginal probability mass function of Y

(ii) Conditional probability mass function of X given Y=y

b) The joint probability density function (pdf) of X and Y is given by

$$f(x,y) = 3e^{-x-3y} \quad , \quad 0 < x < \infty, \quad 0 < y < \infty$$

Compute the following:

(i) P(X < Y) (ii) P(X – Y > 1)

c) Let X_1 and X_2 be independent gamma random variables with joint pdf

$$f(x_1, x_2) = \frac{{x_1}^{\alpha-1} {x_2}^{\beta-1} e^{-x_1-x_2}}{\Gamma(\alpha)\Gamma(\beta)} \quad , \quad 0 < x_1 < \infty, \quad 0 < x_2 < \infty$$

Given that $Y_1 = X_1 + X_2$ and $Y_2 = \frac{X_1}{X_1 + X_2}$ find the following:

(i) Joint pdf of Y_1 and Y_2

(ii) Marginal pdf of Y_2

2 a) Define the following:

(i) Probability generating function

(ii) Conditional expectation of X given Y

(iii) Variance of Y given X

b) Let X be a discrete random variable with probability mass function.

$$P(X = x) = \frac{1}{2^{x+1}} , \quad x = 0,1,2,3, \ldots \ldots \ldots \ldots \ldots$$ Find the following:

(i) Probability generating function of X

(ii) The mean and variance of X

c) A hen lays X number of eggs, where X has a Binomial distribution with parameters M and, each egg hatches with probability 0.9 independently of the other eggs. Let Y be the number of hatched chicks, find the following:

(i) Conditional expectation of Y given X

(ii) Expectation of Y.

3. a) Define the following:

(i) Convergence in distribution

(ii) Asymptotic normal distribution

(iii) Convergence in probability

b) (i) State and prove the weak law of large numbers

(ii) State and prove the one-sided Chebyshev's inequality.

c) (i) Suppose X_1 and X_2 are survival times (in hours) of two white rats that were subjected to different levels of radiation. Assume that X_1 and X_2 are independent with respective pdfs

$$f(x_1) = \frac{1}{(1+x_1)^2}, \quad x_1 > 0 \quad and \quad f(x_2) = \frac{2}{(1+x_2)^3}, \quad x_2 > 0$$

Find the probability that the second rat out lives the first rat.

(ii) Let $X_1, X_2, X_3, \ldots\ldots\ldots\ldots X_n$ be a random sample of size n from a

Distribution with CDF given by $F(y) = 1 - \frac{1}{y}, \quad y > 1$ Find the limiting distribution of $Y_n = nln(X_1'),$ where X_1' is the first order statistics.

4. **a)** Define the following:

(i) Counting process

(ii) Poisson Process

(iii) A markov Chain

b) In a certain region, the weather patterns have the following sequence. A day is described as Sunny(S) if the sun shines for at least 60% of the day light hours and Cloudy(C), if the sun shines for less than 60% of the day light hours. Data indicates that if it is Sunny one day then the probability that it will be Cloudy the next day is $\frac{1}{4}$. If it is Cloudy there is a probability of $\frac{1}{3}$ that it will be Sunny the next day.

(i) Construct the probability transition matrix P for this process.

(ii) Display the transition paths/diagram for this markov chain

(iii) If it is Sunny today, what is the probability that it will be Sunny in three days

c) Events occur according to a Poison process with λ=5 per day. Find the following probabilities :

(i) Two or more events occur in two days

(ii) Two or more events occur between 09.30 hrs and 19.30 hrs

(iii) No event occurs between 10.00hrs and 18.30 hrs

5. **a)** Define the following for a counting process:

(i) Independent increments

(ii) Stationary increments

(iii) Waiting time

b) (i) State and derive the Chapman-Kolmogorov equations

(ii) Events occur according to a Poisson process. Derive the distribution of the waiting time using the fact that the $\mathbf{k}^{\text{th}}$ event will occur prior to or at time t if and only if the number of events occurring by time t is at least **k.**

c) (i) Let $\{X_k\}$ denote a sequence of independent and identically distributed random variables and let N be a non-negative integer valued random variable that is independent of the sequence $\{X_k\}$. If $Y = \sum_{k=1}^{N} X_k$. Prove that

$$Var(Y) = Var(X)E(N) + Var(N)(E(X))^2$$

(ii) Prove that if X and Y are random variables having joint distribution, then

$$Var(X) = E(Var(X/_Y)) + Var(E(X/_Y))$$

----------GOOD LUCK END OF EXAM ----------

The University of Zambia

School of Natural Sciences

Department of Mathematics and Statistics

University Examinations for 2017/2018 Academic Year

MAT4119-ENGINEERING MATHEMATICS III

Maximum Time Allowed: Three Hours

INSTRUCTIONS: There are six questions in this examination paper. You are required to answer any five questions. Your answers should be reasonably detailed and presented in a logical sequence.

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1. a. Given $f(x) = \sqrt{x}$

   (i) Find the third Taylor polynomial of $f(x)$ at $x = 1$.

   (ii) Estimate $\sqrt{1.001}$ using the polynomial of part (i).

   (iii) Find a bound on the associated error of estimation.

   (iv) Write the true value of $\sqrt{1.001}$ using your calculator and hence find the true error.

   b. The true atomic weight of oxygen is 15.9994 amu. Determine based on % relative error, which is a better estimate of the atomic weight if it is chopped to 15.9 or rounded to 16.

   c. Suppose an initial estimate of a root of the equation

$$x^3 - x^2 - 10x - 8 = 0 \quad is \quad x_0 = 6$$

Perform four iterations of the Newton Raphson method to locate the root.

2. a. The equation $x^3 - x^2 - x + 1 = 0$ has a double root. Apply three iterations of appropriate Newton Raphson method with $x_0 = 0.8$ to estimate that root.

b. The current flows I_1, I_2, I_3 in an electric circuit are described by the following equations.

$4I_1 + I_2 + I_3 = 4$, $I_1 + 4I_2 - 2I_3 = 4$, $3I_1 + 2I_2 - 4I_3 = 6$

Solve the system of equations by the Gauss elimination method.

c. Evaluate the integral $\int_0^{\frac{\pi}{2}} \frac{d\theta}{\sqrt{1-\frac{1}{2}sin^2\theta}}$ to four decimal places using Simpson's rule with four sub intervals.

3. a. The percentage of light (L), passing through the sea surface, that penetrates to specific depth (D) in clear ocean water is as follows:

D(m)	0	1	2	10
L(%)	100	45	39	22

Estimate L at a depth of 1.6 m.

b. Given the system of equations

$4x + y + 2z = 4$, $3x + 5y + z = 7$, $x + y + 3z = 3$,

apply three iterations of Gauss Seidel method with the initial solution $X_0 = (0,0,0)$ to estimate the solution of the system.

c. Given the initial value problem $\frac{dy}{dt} = \sqrt{t+y}$, $y(0.4) = 0.41$,

use Runge Kutta method with step size h = 0.2 to estimate y(0.8). You may keep all your calculations to four places of decimal.

The difference equations associated with Runge Kutta method in the usual notations are :

$$k_1 = hf(t_i, w_i),\ k_2 = hf\left(t_i + \frac{h}{2}, w_i + \frac{k_1}{2}\right),\ k_3 = hf\left(t_i + \frac{h}{2}, w_i + \frac{k_2}{2}\right),$$
$$k_4 = hf(t_{i+1}, w_i + k_3), \qquad w_{i+1} = w_i + \frac{1}{6}(k_1 + 2k_2 + 2k_3 + k_4)$$

4. a. The following table gives the water vapor capacity of air (v_c) in grains per cubic foot for selected temperatures (T) in degrees Fahrenheit.

T	50	54	58	62
v_c	4.108	4.725	5.420	6.203

(i) Find the forward difference Newton's interpolating polynomial

(ii) Estimate the vapor capacity at 52^oF temperature.

(iii) Find the slope of the water vapor capacity curve at a temperature of 52^oF.

b. The equation $x^3 - x - 4 = 0$ has only one real root and that root lies in the interval (1,2). Apply six iterations of the Bisection method to estimate this root.

c. The system of equations $log_e(x^2 + y^2) - 1 + y = 0$; $\sqrt{x} + xy = 0$ has an approximate solution (x_0, y_0)=(2.4 , -0.6). Apply one iteration of Newton Raphson method to improve this approximation.

5. a. Consider the function $f(z) = z\bar{z} + \bar{z}^2, where\ \bar{z}$ is the complex conjugate of Z. Apply Cauchy Reimann equations to show that $f(z)$ is nowhere analytic.

b. Solve the following equations for z:

(i) $sinz = 0$ (ii) $e^z = 0$ (iii) $lnz = -\frac{\pi}{2}i$

c. Express the following in the form $a + ib$:

(i) 3^{4-i} (ii) $(i)^{-1+i}$ (iii) $sini$

6. a. Evaluate $\oint_C \frac{z+4}{z^2+2z+5} dz$, where C is a unit circle centered at z = -1.

b. Let C be a unit circle centered at z = i . Write the equation of C in the parametric form. Hence evaluate $\oint_C \frac{1}{z-i} dz$ where n is an integer.

c. Evaluate $\oint_C \frac{1}{z} \cos z \, dz$, where C is the ellipse $9x^2 + 4y^2 = 1$.

The University of Zambia
School of Natural Sciences
Department of Mathematics & Statistics
2017/2018 Sessional Examinations - November 23, 2018
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 5 pages of questions.

---

1. **(a)** State, without proof, the following inequalities in L^p spaces:
   - (i) Young's Inequality
   - (ii) Cauchy-Schwarz Inequality

   (b) State and prove the Hölder's Inequality in L^p spaces.

   (c) State and prove the Minkowski's Inequality for L^p spaces.

[4,8,8]

[Turn Over.....]

2. **(a)** **(i)** Define a metric function on a nonempty set X.

(ii) Let d be a metric on a nonempty set X. Show that the function $e : X \times X \longrightarrow \mathbb{R}$, defined by

$$e(a,b) = \frac{d(a,b)}{1+d(a,b)}$$

is also a metric on X.

(b) **(i)** When is a metric space said to be complete?

(ii) Show that the space $\mathbb{R}^n$ is complete with respect to the Euclidean metric.

(c) Using the triangle inequality, show that

$$|d(x,z) - d(y,z)| \leq d(x,y)$$

[8,7,5]

3. **(a)** **(i)** When is a map $f : (X,\rho) \longrightarrow (Y,\sigma)$, between two metric spaces (X,ρ) and (Y,σ), said to be continuous?

(ii) When is a metric space (X,ρ) said to be compact?

(iii) Let f be a continuous mapping from a compact metric space X to a metric space Y. Show that its image $f(X)$ is also a compact space.

(b) **(i)** When is a map $f : (X,\rho) \longrightarrow (Y,\sigma)$, between two metric spaces (X,ρ) and (Y,σ), said to be uniformly continuous?

(ii) Prove that a continuous mapping from a compact metric space (X,ρ) into a metric space (Y,σ) is uniformly continuous.

[Turn Over.....]

(c) (i) Define a Baire space.

(ii) State, without proof, the Cantor Intersection Theorem.

(iii) Show that a complete metric space is a Baire space.

[7,6,7]

4. (a) Let (X, d) be a metric space and $T : X \longrightarrow X$ be a self map.

(i) Define a fixed point of T.

(ii) When is T said to be a contraction map.

(b) Suppose (X, d) is a complete metric space and $T : X \longrightarrow X$ is a contraction map. Show that T has a unique fixed point.

(c) Show that if the map $T : X \longrightarrow X$ has a fixed point and satisfies $d(T(x), T(y)) < d(x, y)$ if $x \neq y$, then the fixed point of T is unique.

[2,12,6]

5. (a) (i) When are two norms $||\cdot||$ and $||\cdot||_0$ said to be equivalent on a vector space X?

(ii) Show that the norms $||f||_1$ and $||f||_\infty$ are not equivalent in $C[0, 1]$.

(b) Let X, Y be vector spaces, both real or both complex. Let

$$T : \mathcal{D}(T) \longrightarrow Y$$

be a linear operator with domain $\mathcal{D}(T) \subset X$ and range $\mathcal{R}(T) \subset Y$. Show that

[Turn Over.....]

(i) the inverse $T^{-1} : \mathcal{R}(T) \longrightarrow \mathcal{D}(T)$ exists if and only if

$$Tx = 0 \implies x = 0.$$

(ii) if T^{-1} exists, then it is linear operator.

(c) Let $T : X \longrightarrow Y$ and $S : Y \longrightarrow Z$ be bijective linear operations, where X, Y, Z are vector spaces. Show that the inverse $(ST)^{-1} : Z \longrightarrow X$ of the composite ST exists and

$$(ST)^{-1} = T^{-1}S^{-1}.$$

[7,7,6]

6. **(a)** **(i)** Define a bounded linear functional.

(ii) Define the norm of a linear functional.

(iii) Give an alternative formula for the norm of a linear functional.

(iv) Compute the norm of the linear functional $f : \mathbb{R}^3 \longrightarrow \mathbb{R}$ defined by

$$f(x) = x \cdot a = x_1a_1 + x_2a_2 + x_3a_3,$$

where $a = (a_1, a_2, a_3) \in \mathbb{R}^3$ is fixed.

(b) **(i)** Define a sublinear functional on a vector space X.

(ii) State, without proof, the Hahn-Banach Theorem.

(c) **(i)** Define a convex subset of a vector space X.

(ii) If p is a sublinear functional on a vector space X, show that

$$M = \{x : p(x) \leq \lambda,\ \lambda > 0 \text{ fixed }\},$$

is a convex set.

[7,5,8]

[Turn Over.....]

7. **(a)** **(i)** Define an inner product space.

(ii) Define a Hilbert space.

(iii) Show that a norm on an inner product space satisfies the parallelogram equality

$$||x+y||^2 + ||x-y||^2 = 2(||x||^2 + ||y||^2).$$

(b) Show that the space $C[a,b]$ is not an inner product space, hence not a Hilbert space.

(c) If Y is a closed subspace of a Hilbert space H, show that

$$Y = Y^{\perp\perp}.$$

[6,7,7]

END!

THE UNIVERSITY OF ZAMBIA

2017/18 ACADEMIC YEAR UNIVERSITY EXAMINATIONS

MSE9040: Advanced Biology Teaching Methods

Time: Three hours **Marks: 100**

Information:

1. There are **seven** questions in this paper.
2. Each question has a maximum possible mark of 20.
3. The intended marks for part of the question are shown in brackets [ ].

Instructions:

1. Attempt question **one** and
2. Any other **four** questions.

.....

1. Practical activities such as experiments and the practical examination are vital in the teaching and learning of Biology at senior secondary school level.
    a) Discuss three roles played by practical work during biology lessons. [06]
    b) The biology practical examination requires candidates to make drawings of specimens provided during the examination.
        i. Describe four qualities of a drawing they are expected to make. [04]
        ii. Explain how the drawing is expected to be labeled. [03]
    c) Indication of magnification in any biological drawing is important.
        i. Describe clearly how you would go about to determine the magnification of a drawing including how to indicate it. [05]
        ii. What unit is used for magnification? Why? [05]

.....

2. You have been appointed a head of science department at St. Christopher Secondary in one of the districts in Zambia.

   a) Give three duties you are expected to perform as a head of the science department. [03]

   b) Discuss six good practices that will enable you to run your science department effectively. [12]

   c) Describe three issues that you need to take into consideration when assigning responsibilities to other teachers in your department. [03]

   d) Explain one benefit and one weakness of decentralized system of managing a science department. [02]

.....

3. Biology teachers need support within and outside the school to enable them teach effectively.

   a) Give an account of how the Examination Council of Zambia provides support to teachers of biology in secondary schools. [06]

   b) Teachers of biology are encouraged to be members of the Zambia Association of Science Education. Justify the value of this. [06]

   c) Engaging in continuing professional development (CPD) by teachers of biology is important.

      i. Why should a graduate biology teacher engage in CPD? [02]

      ii. Identify three avenues for CPD available to a teacher of biology within a school. [03]

   d) Explain three ways pupils can provide support to a biology teacher. [03]

.....

4. It is claimed that "the success of biology can be achieved by maximum participation of the learners" (CDC, 2013: ix).

   a) Explain what is meant by *active learning*? [02]
   b) Why should pupils be involved during biology lessons? [03]
   c) Discuss six strategies you can employ to ensure that pupils participate actively during your biology lessons. [12]
   d) Describe three challenges you may encounter in encouraging pupil participation during biology lessons. [03]

.....

5. The biology examination at the end of senior secondary school have been described as " *a necessary-evil*".

   a) Justify why it is said to be necessary. [05]
   b) Justify why it is considered to be evil. [05]
   c) The performance of pupils in biology examinations at the end of grade 12 has **not been** good in some schools. Discuss five issues which may have contributed to the situation described above. [05]
   d) Discuss five steps you can take to reverse the situation described in (c) above. [05]

.....

6. Pupils in a particular biology class vary in the way they learn. Discuss strategies you can use to ensure that your biology lessons appeal or capture the wide range of individual learning styles . [20]

.....

7. Both boys and girls should be given an opportunity to learn biology at senior secondary school level.

   a) Give three justifications as to why girls should be encouraged to learn biology. [03]

   b) It has been claimed that some teachers of biology contribute to none or low participation of girls during their lessons. Discuss ways they contribute to this situation. [10]

   c) Given a chance to teach biology to mixed sex class grade 11 class, discuss steps you will take to ensure that girls participate as boys do during your biology lessons. [07]

END OF THE EXAMINATION

The University of Zambia
Physics Department
University Examinations 2017-18
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. Some useful equations are given at the back of the question paper.

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:

$g = 9.8 m/s^2$

$P_A = 1.01 \times 10^5$ N/m²

1 cal. = 4.18 J

C_{water} = 4184 J/kg.°C

$R = 8314$ J/kmol.K

$k = 1.381 \times 10^{-23}$ J/K (Bolzmann's constant)

$\varepsilon_0 = 8.85 \times 10^{-12}$ C²/Nm²

$c = 3 \times 10^8$ m/s

$h = 6.63 \times 10^{-34}$ J-s

1 pascal =1 N/m²

1eV = 1.6×10^{-19} J

$e = 1.6 \times 10^{-19}$ C

$m_e = 9.11 \times 10^{-31}$ kg

$k = 9 \times 10^9$ Nm²/C²

$\mu_0 = 4\pi \times 10^{-7}$ N/A²

ρ_{water} = 1000 kg/m³

$G = 6.67 \times 10^{-11}$ Nm²/kg²

1 metric ton = 1000 kg

H_f = 80 cal/g-water

H_v = 539 cal/g-steam

1 litre = 1×10^{-3} m³

Vol. sphere = $\frac{4}{3}\pi r^3$

(F) An object has a positive electric charge whenever:

a) it has excess of electrons
b) the nuclei of its atoms are positively charged
c) the electrons of its atoms are positively charged
d) It has a deficiency of electrons

(G) The specific heat of a substance is:

a) The temperature change per unit mass of substance per unit heat input
b) The rate of change of the temperature of a substance
c) The amount of heat that must be added or removed from a unit mass of substance to change its temperature by a unit temperature
d) The mass of the substance which undergoes a unit temperature rise for a unit heat input

(H) In rotational motion, the equivalent of force is:

a) Angular velocity
b) Moment of inertia
c) Torque
d) Rotational inertia

(I) In a convection process, a portion of the fluid rises because it:

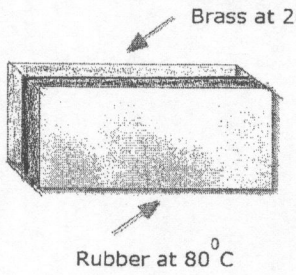
a) is more dense
b) has higher a temperature
c) is in motion
d) is lighter

(J) Two boys are standing at the edge of a vertical cliff. One boy fires an air-gun pellet horizontally at the same time the second boy drops a pellet at the edge of the cliff. The shot pellet and the dropped pellet start at the same height from the top of the cliff. The time taken for the pellets to reach the ground:

a) Is greater for the one shot off the cliff horizontally
b) Is the same for both
c) Is shorter for the one shot off the cliff horizontally
d) Depends on the initial velocity of the one shot off the cliff

Attempt any four questions from the following:

Q 2 (a) A 0.50 cm thick sheet of brass is stuck to 0.50 cm thick sheet of rubber, both sheets have the same area. The outer face of the brass sheet is at 20 ^{0}C and the outer side of the rubber sheet is at 80 ^{0}C. Find the temperature of the rubber-brass junction, given that k_{brass} is 490 times k_{rubber}. [8]



(b) A sample of air is compressed isothermally from a pressure of 2 atmospheres To a pressure of 5 atmospheres. The original volume and temperature are 20 litres and 17 ^{0}C respectively. Next the air is expanded back adiabatically back to its original pressure of 2 atmospheres.

Find:

i) the final volume (in litres);

ii) the temperature of the gas; and

iii) sketch the *PV*- diagram of the two processes. [12]

Q.3 (a) In summer a person wants to cool 250 g of Coca-Cola (essentially water) in an insulated cup (i.e. cup absorbs no heat at all), initially at 25 °C by adding ice whose temperatre at -20 °C. How much ice should he add so that the final temperature will be 0 °C with all the ice melted?

(c_{ice} = 2.1 x 10^3 J/kg.K, c_{water} = 4184 J/kg.K) [10]

(b) A Carnot engine is operated at temperatures of 400 K and 350 K. If the engine consumes 20 x 10^5 J per cycle, find:

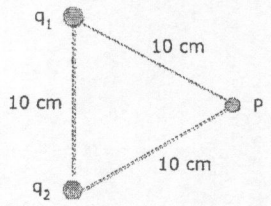
i) the efficiency of the engine;

ii) the work done per cycle, and

iii) the heat rejected to the cold reservoir [10]

Q.4 (a) A speaker emits 0.8 W of acoustic power. Assume that it behaves as a point source which emits uniformly in all directions. At what distance will the intensity level be 85 dB? [10]

(b) Two equal positive charges q_1 and q_2 of 4 x 10^{-10}C each are separated by 10 cm. A unit test charge is placed at a point P, 10 cm from each charge, as shown. Calculate the magnitude of the total electric field at point P. [10]

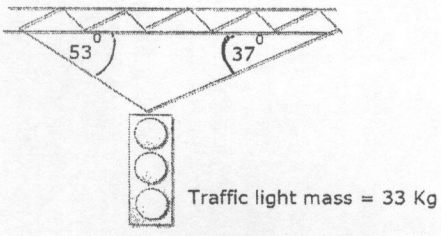


Q.5 (a) A stone is shot from a catapult with a speed of 40 m/s at a certain angle θ with the horizontal.

i) What is the maximum horizontal distance it goes if it reaches a maximum height of 30 m?

ii) Find the angle θ. [12]

(b) Find the tension in each of the two wires supporting the traffic light shown below. Take the left side wire as T_2 and the right side as T_1. [8]



Q.6 (a) A billiard ball A of mass m_A = 0.400 kg moving with a speed v_A = 1.80 ms^{-1} along the positive x-axis strikes another ball B of mass m_B = 0.500 kg initially at rest. As a result of the collision, ball A is deflected off at an angle of 30° with respect to the x-axis at a speed of v_A' = 1.10 ms^{-1}.

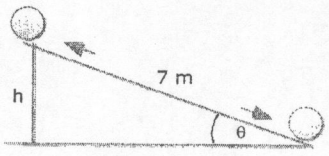
i) Write down the equations expressing the conservation of momentum in the *x* and *y* directions separately.

ii) Solve these equations for the speed v_B' and angle θ_B of ball B. Do not assume the collision is elastic. [10]

(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 sideways a distance of 2 cm from its equilibrium position and released. Calculate the:

i) frequency of oscillation;
ii) maximum speed and maximum acceleration;
iii) speed of the mass when the spring is compressed by 1 cm; and
iv) Potential energy when the spring is at its maximum compression. [10]

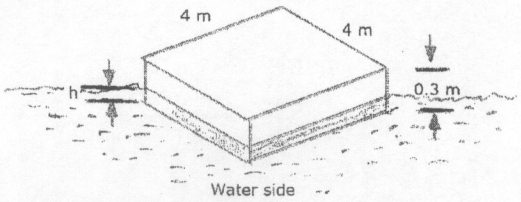
Q.7 (a) A solid ball starting from rest rolls without slipping down an inclined plane 7 m long and reaches the bottom 4.5 s later. What angle does the plane make with the horizontal? [$I_{sphere}=(2/5)MR^2$] [12]



(b) The density of lead is 11.3 g/cm^3 and its specific heat capacity is 0.0306 cal/g^{0}C. A lead ball with diameter of 1 cm is dropped onto a concrete surface from a height of 4 m. If on impact 80% of its kinetic energy is transformed into thermal energy in the lead ball, calculate temperature increase of the ball. [8]

Q.8 (a) A solid square pinewood raft measures 4.0 m on a side and is 0.3 m thick. Given the density of pinewood as 550 kg/m^3 and that of water is 1000 kg/m^3.

i) Determine whether the raft floats in water; and
ii) If so, how much of the raft is beneath the surface [7]



(b) What should be the length of a steel rod and the length of a copper rod so that the length of the steel rod is 5 cm longer than the length of the copper rod at all temperatures? Given, $\alpha_{copper} = 1.7 \times 10^{-5}\ per\ ^0C$ and $\alpha_{steel} = 1.1 \times 10^{-5}\ per\ ^0C$ [8]

(c) A listener moves towards a wall with a velocity of 2 m/s. A stationary source behind him emits sound of frequency 680 Hz and velocity of 340 m/s. Calculate the number of beats heard by him. [5]

END OF EXAMINATION

Some Useful Equations

Uniformly accelerated motion:

$x = \bar{v}t \qquad \bar{v} = \frac{1}{2}(v_f + v_i) \qquad v_f = v_i + at \qquad v_f^2 = v_i^2 + 2ax \qquad x = v_i t + \frac{1}{2}at^2$

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:

$T = \frac{2\pi r}{v} \qquad a_c = \frac{v^2}{r} \qquad F_c = \frac{mv^2}{r} \qquad F_{grav} = -G\frac{m_a m_b}{r^2} \qquad 1rev = 360^0 = 2\pi\, rad$

$v_T = \frac{(2\pi r)}{T} : \quad \tan\theta = \frac{v^2}{rg} :$

Rotational motion and angular momentum:

$\theta = \frac{s}{r} = \left(\frac{\omega_i + \omega_f}{2}\right)t \qquad \omega = \frac{\theta}{t} \qquad \theta = \omega_i t + \frac{1}{2}\alpha t^2 \qquad \omega_f = \omega_i + \alpha t \qquad v = \omega r$

$I = mk^2 \qquad \omega_f^2 = \omega_i^2 + 2\alpha\theta \qquad \alpha = \frac{\Delta\omega}{\Delta t} = \frac{a_T}{r} \qquad I = \sum mr^2 \qquad KE_{rot} = \frac{1}{2}I\omega^2$

$\tau = FL = I\alpha \qquad W = \tau\theta \qquad P = \tau\omega \qquad L = I\omega \qquad KE_{total} = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$

Properties of matter:

$\rho = \frac{m}{V} \qquad F = -kx \qquad \frac{\Delta L}{L_i} = \frac{1}{Y}\frac{F}{A} \qquad \phi = \frac{s}{d} = \frac{1}{s}\frac{F}{A} \qquad B = -\frac{\Delta P}{\Delta V / V_0}$

$W_{app} = W\left(1 - \frac{\rho_{fluid}}{\rho}\right) \qquad F_B = \rho V g$, (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 $\frac{I}{I_0}$

$\tau = \frac{2\pi x_0}{v_0} = 2\pi\left(\frac{x_0}{v_0}\right) = \frac{2\pi}{\omega}$ $f = \frac{1}{2L}\sqrt{\frac{T}{m}}$ $x = x_0\cos(\omega t)$ $I_0 = 10^{-12}\ W/m^2$

Electric Field:

$\boldsymbol{F} \propto \frac{q_1 q_2}{r^2}$ *or* $F = k.\frac{q_1 q_2}{r^2}$; k = 8.9874 × 10^9 N.m^2.C^{-2} or $k = (1/(4\pi\varepsilon_0)$ where ε_0 is the permittivity constant = 8.85 × 10^{-12} C^2.(N.m^2)$^{-1}$.

The University of Zambia
Department of Physics
Final Examination August 2018
PHY1010: Introductory Physics
Distance Education

All questions carry equal marks. The marks are shown in square brackets. Attempt any five questions. Clearly indicate on the answer script cover page which questions you have attempted.

Time: Three hours. **Maximum marks = 100.**

Write clearly your name and computer number on the cover page.

==========

Wherever necessary use:

$g = 9.8 m/s^2$: $P_A = 1.013 \times 10^5 N/m^2$: 1 Pascal $= 1 N/m^2$: $\rho_{water} = 1000 kg/m^3$

1 hp = 746 W : 1 ton = 1000 kg

Clearly indicate the number of the question answered, noting that each question has more than one part:

Example:

Question 2(b)

DO NOT write the question number in the top left corner of the page, and then staple over it!! Preferably indicate it at the center of the page.

Q1(a). When vector **B** is added to vector **A**, the resultant vector has x-component equal to 6 and y-component equal to 1. When vector **B** is subtracted from vector **A**, the resultant vector has x-component equal to -4 and y-component equal to 7. Find the magnitude of vector **A**. [11]

(b) Find the maximum load in kg which may be placed on a steel wire of diameter 1mm if the permitted strain may not exceed 1/1000 and Young's modulus for steel is 2.00 $\times 10^{11}$ N/m^2. [9]

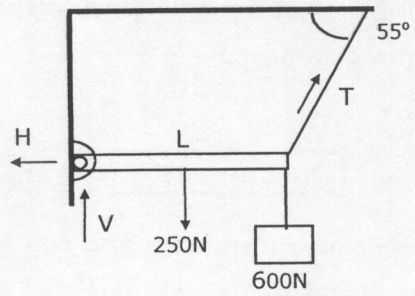
Q2(a). A rock is thrown vertically upwards with a velocity of 6 m/s from a point situated 12 m above the ground.

(i) What is the velocity of the rock when it hits the ground?

(ii) What is the time taken for the journey?

(iii) Calculate the average velocity and the acceleration for the journey. [11]

(b) A uniform bar weighing 200 N and of length L is at equilibrium as shown. The bar is hinged at one end. Find the values of T, H, and V. [9]



Q3(a). A cart with small wheels and well-lubricated bearings is released from rest on an inclined plane which makes an angle of 35^0 with the horizontal. The mass of the cart is 1.2 kg.

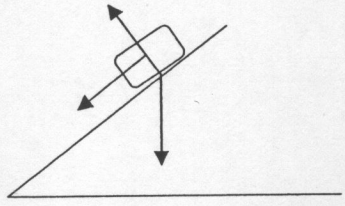
Determine:

(i) The magnitude of the force exerted by the surface on the cart,

(ii) The acceleration of the cart,

(iii) The speed of the cart after a time of 1.5 s

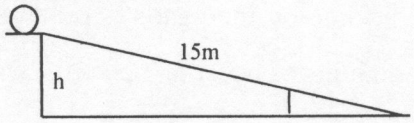
(iv) The distance the cart travels in this time. [11]



(b) A hollow ball of mass m and radius r starts rolling from rest down an inclined plane 15 m long and reaches the bottom 10 seconds later.

What angle does the plane make with the horizontal?

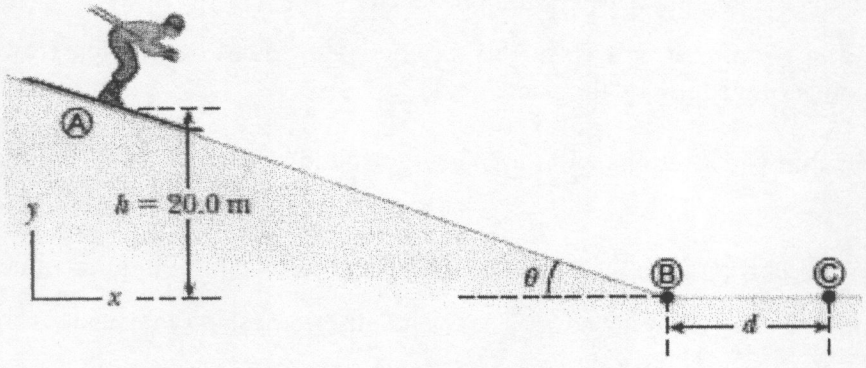
[Moment of inertia of a hollow sphere = $(2/3)mr^2$] [9]



Q4(a). A skier starts from rest at the top of a frictionless incline of height 20.0 m. At the bottom of the incline at B, the skier encounters a horizontal surface where the coefficient of kinetic friction between skis and snow is 0.210.

(i) Find the skier's speed at the bottom.

(ii) How far does the skier travel on the horizontal surface before coming to rest at C? Neglect air resistance. [Use the energy conservation principle]. [10]



(b) (i) Find the centripetal force needed by a 1500 kg car to make a turn of radius 40 m at a speed of 30 km/hour.

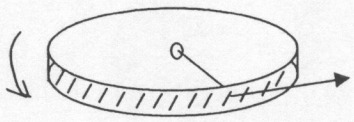
(ii) Assuming the road is level, find the minimum coefficient of static friction between the car's tires and the road that will permit the turn to be made.

(iii) If the friction between the car's tires and the road is zero, at what angle relative to the horizontal does the road need to be banked? [10]

Q5(a). A 3 g bullet is fired into a 1.997 kg block suspended by a long cord. The bullet remains in the block which swings until its centre of gravity is raised by 1.6 cm.
Find the speed of the block and the bullet as they leave the equilibrium position of the block. What was the initial speed of the bullet? [10]

(b) Water is confined in a strong container by means of a piston with a cross sectional area of 0.50 cm^2. How large a force on the piston is required to increase the density of water by 0.01 percent? Bulk modulus of water is 2.2×10^9 N/m^2. [10]

Q6.(a) A merry-go-round has a mass of 100 kg and a radius of 1.6 m. Consider it as a uniform disk of moment of inertia $\frac{1}{2}mr^2$. A man pushes with a horizontal force of 80 N tangential to the merry-go-round. [10]

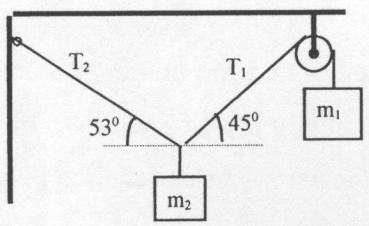


(i) What is the angular acceleration produced?

(ii) Starting from rest, how fast will the merry-go-round be moving (rev/s) after 12 seconds of pushing by the man? and

(iii) How many revolutions will the merry-go-round have made in 12 seconds?

(b) The system in the figure is at equilibrium when $m_1 = 10$ kg. Find the values of m_2, T_1 and T_2. Assume the pulley to be massless and frictionless so that it does not alter the tension in the cord. [10]



Q7(a). A 2 kg grindstone 20 cm in diameter is turning at 120 rad/s. The motor is switched off and a chisel is pressed against the grindstone with a force whose tangential component is 2 N.

How long will it take for the grindstone to come to a halt?

How many revolutions has the grindstone made during this period? [$I = (1/2) MR^2$]

[10]

(b) A 2.5 g lead bullet is moving at 210 m/s when it strikes a bag of sand and is brought to rest.

(i) Assuming that all the friction work with the sand is converted to heat energy of the bullet, what is the rise in temperature of the bullet as it is brought to rest?

(ii) Answer the same question if the bullet lodges in a 90 g block of wood that is free to move when hit. [10]

END OF PHY1010 FINAL EXAM-2018 Distance

Some Useful Equations

Uniformly accelerated motion:

$$x = \bar{v}t \qquad \bar{v} = \tfrac{1}{2}\left(v_f + v_i\right) \qquad v_f = v_i + at \qquad v_f^2 = v_i^2 + 2ax \qquad x = v_i t + \tfrac{1}{2}at^2$$

Projectile motion:

$$v_x = v_i \cos\theta_i = \text{constant} \qquad v_y = v_i \sin\theta_i - gt \qquad y = \left(v_i \sin\theta_i\right)t - \tfrac{1}{2}gt^2$$

$$y = \left(\tan\theta_i\right)x - \left[\frac{g}{2v_i^2\left(\cos^2\theta_i\right)}\right]x^2 \qquad R = \frac{v_i^2}{g}\sin 2\theta \qquad t = \frac{2v_i \sin\theta}{g}$$

Force and motion:

$$F = ma \qquad W = mg \qquad F_{AB} = -F_{BA} \qquad F_f = \mu F_N$$

Work and Energy:

$$PE = wh = mgh \qquad KE = \tfrac{1}{2}mv^2 \qquad W = Fx\cos\theta \qquad P = \frac{W}{t} = Fv\cos\theta$$

Linear momentum: $p = mv \qquad F\Delta t = \Delta mv = m\left(v_f - v_0\right)$

Circular motion and gravitation:

$$T = \frac{2\pi r}{v} \qquad a_c = \frac{v^2}{r} \qquad F_c = \frac{mv^2}{r} \qquad F_{grav} = G\frac{m_A m_B}{r^2} \qquad 1rev = 360^0 = 2\pi\, rad$$

$$v_T = \frac{(2\pi r)}{T} : \quad \tan\theta = \frac{v^2}{rg} :$$

Rotational motion and angular momentum:

$$\theta = \frac{s}{r} = \left(\frac{\omega_i + \omega_f}{2}\right)t \qquad \omega = \frac{\theta}{t} \qquad \theta = \omega_i t + \tfrac{1}{2}\alpha t^2 \qquad \omega_f = \omega_i + \alpha t \qquad v = \omega r$$

$$I = mk^2 \qquad \omega_f^2 = \omega_i^2 + 2\alpha\theta \qquad \alpha = \frac{\Delta\omega}{\Delta t} = \frac{a_T}{r} \qquad I = \sum mr^2 \qquad KE_{rot} = \tfrac{1}{2}I\omega^2$$

$$\tau = FL = I\alpha \qquad W = \tau\theta \qquad P = \tau\omega \qquad L = I\omega \qquad KE_{total} = \tfrac{1}{2}mv^2 + \tfrac{1}{2}I\omega^2$$

Properties of matter:

$\rho = \frac{m}{V}$ $F = -kx$ $\frac{\Delta L}{L_i} = \frac{1}{Y}\frac{F}{A}$ $\phi = \frac{s}{d} = \frac{1}{s}\frac{F}{A}$ $B = -\frac{\Delta P}{\Delta V / V_0}$

$W_{app} = W\left(1 - \frac{\rho_{fluid}}{\rho}\right)$ $F_B = \rho V g$, (submerged object) $F_B = Mg$ (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:

$PV = nRT$ $n = \frac{m}{M}$ $\Delta Q = \Delta U + \Delta W$: $W = p.\Delta V$ $P_1V_1^{\gamma} = P_2V_2^{\gamma}$ $T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$

$COP_{ref} = \frac{Q_C}{W}$ $COP_{heat\ pump} = \frac{Q_H}{W}$ $W_{isothermal} = nRT \ln\frac{V_2}{V_1}$

$W_{adiabatic} = \frac{1}{\gamma - 1}(P_1V_1 - P_2V_2)$: $COP_{\max - refr} = \frac{T_C}{W}$ $COP_{\max - heat\ pump} = \frac{T_H}{W}$

$e = 1 - \frac{T_c}{T_h} = \frac{work\ done}{input\ heat\ at\ high\ temp}$

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 + 0.61*t* (°C)

$\tau = \frac{2\pi x_0}{v_0} = 2\pi\left(\frac{x_0}{v_0}\right) = \frac{2\pi}{\omega}$ $f = \frac{1}{2L}\sqrt{\frac{T}{m}}$ $x = x_0\cos(\omega t)$ $I_0 = 10^{-12}\ W/m^2$

Wherever necessary use:

g = 9.8 m/s^2 : ρ_{water} = 1000 kg/m^3 : 1 hp = 746 watts : 1 metric ton = 1000 kg

$P_{atm} = 1.013 \times 10^5$ pascals : $1 litre = 1 \times 10^{-3}\, m^3$: $1 cal = 4.184 J$: $R = 8.314 J / mol.K$:

$M = 4$ for helium ; Volume of a sphere $= (4/3)\pi r^3$; Surface area of a sphere = $4\pi r^2$,

Surface area of a cylinder = $2\pi rL$; $G = 6.67 \times 10^{-11} N.m^2 / kg^2$: 1 pascal =1 N/m^2 :

specific heat of H_2O = 4184 J/kg.^{0}C : s.t.p. = 0^{0}C and 1 atmospheric pressure

c_{ice} = 0.5 cal/g.^{0}C, c_{steam} = 0.46 cal/g.^{0}C = 1920 J/kg.^{0}C (at 100^{0}C, constant volume) ,

H_f = 80 cal/g, H_v = 539 cal/g. 1 litre = 1 x 10^{-3} m^3 : $\cos(90 - \alpha_0) = \cos(\alpha_0 - 90) = \sin\alpha_0$

$\sin(90 - \alpha_0) = -\sin(\alpha_0 - 90) = -(-\cos\alpha_0) = +\cos\alpha_0$

The University of Zambia

Department of Physics

PHY 2112: Atomic Physics, Magnetism in Matter

Final Examination, November 27, 2017/18 Academic year

Instructions: Answer any **five (5)** questions only. They are all of equal marks. The marks are shown in brackets. All working must be shown.

Time duration: Three (3) hours.

Some formulas you may find useful:

$h = 6.625 \times 10^{-34}$ J.s

1u = 931.494 MeV/c^2

$m_o c^2 = 510$ keV

$m_p = 1.00814$u

$m_n = 1.008665$u

$e = 1.6 \times 10^{-19}$ C

$N_A = 6.02 \times 10^{23}$/mole

$\sigma = 5.67 \times 10^{-8}\text{Wm}^{-2}\text{K}^{-4}$

$m_e = 9.11 \times 10^{-31}$

$E = \frac{hc}{\lambda} = h\nu$

$\lambda = \frac{h}{p}$

$I_o = I_o e^{-\mu x}$

$E = e\sigma A T^4$

$E = mc^2$

$KE_{max} = h\nu + \varphi$

$\lambda_f - \lambda_i = \frac{h}{m_o c}(1 - \cos\theta)$

$N = N_o e^{-\lambda t}$

$\lambda_{max} T = 2.90 \times 10^{-3}$m

Q1 (a) In order that an object be visible to the naked eye, the intensity of light entering the eye from the object must be at least 1.5×10^{-11} $Jm^{-2}s^{-1}$. What is the minimum rate at which photons must enter the eye so that an object is visible, given that the diameter of the pupil is 0.7cm? Assume wavelength of the light involved is 5600×10^{-10} m. [8]

(b) Show that the Planck radiation formula,

$$I(\nu) = \frac{8\pi h\nu^3}{c^3} \frac{1}{e^{\left(\frac{h\nu}{kT}\right)} - 1}$$

reduces to the Rayleigh-Jeans law, i.e.

$$I(\nu)d\nu = \frac{8\pi\nu^2}{c^3} kTd\nu.$$

at low frequencies or long or long wave-lengths. [4]

(c) (i) At what wavelength does the maximum intensity of the radiation from a black-body occur at a temperature of 300 K? [2]

(ii) Suppose the temperature T of a black-body is increased by 10%. Show that the percent change in the total energy radiated per unit time by the body is 46.4%. [6]

Q2 (a) (i) State the de Broglie hypothesis [2]

(ii) Derive an expression for the de Broglie wavelength associated with an electron which has been accelerated through a potential difference V.

[7]

(b) Suppose that X rays of energy 100 keV undergo Compton scattering on a target.

(i) Calculate the energy of the X rays scattered at an angle of 60° to the direction of the incident photons. [7]

(ii) Calculate the kinetic energy of the recoiling electron. [2]

(c) Briefly, discuss the mechanism by which *bremsstrahlung* radiation is produced in the target of the X ray tube. [2]

Q3 (a) To produce X rays of minimum wavelength $\lambda_{min} = 1.377 \times 10^{-10}$ m from a copper target in an X ray tube, one must operate the tube at a voltage of 9000 V. Use this information to show that Planck's constant is approximately 6.616×10^{-34}J.s. [6]

(b) A beam of light of wavelength $5550\dot{A}$ strikes a metal surface for which the threshold is 7320 $\dot{A}$. Calculate

(i) the maximum velocity of the emitted electrons; and

(ii) the stopping potential, V_s for these electrons.

[14]

Q4 (a) Differentiate between chemical and nuclear reactions taking into account the following aspects of the same: [6]

(i) Impact on atomic number and mass number of the reactants and products involved

(ii) Magnitudes of energies involved.

(iii) Particles involved.

(b) Define *binding energy* as understood in nuclear physics. Hence compute the binding energy of lithium ($^{7}_{3}Li$). [5]

Data: Mass of $^{7}_{3}Li$ = 7.01822u

(c) A radioactive sample contains 3.50μg of pure $^{11}_{6}C$ whose half-life is 20.4 min.

(i) How many moles of the element are present initially?

(ii) What is the activity of the sample initially?

(iii) What is the activity of the sample after 8.00 hours? [8]

(d) A $^{10}_{5}B$ is struck by an α particle releasing a proton and a product nucleus in the process. Write down the equation of this reaction and identify the product nucleus. [2]

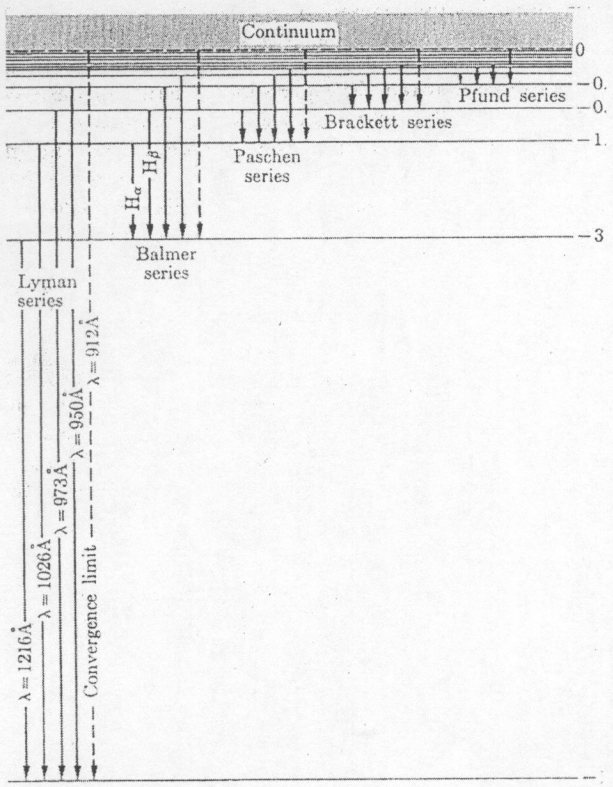
Q5 (a) Discuss the arrangement of negative and positive charges inside the atom according to the plum pudding model. [2]

(b) Discuss the results of the Rutherford α scattering experiment that prompted him to make the following conclusions: [6]

(i) The atom was mostly empty space
(ii) The atomic nucleus was very tiny, positive and massive

(c) (i) State Niels Bohr's three basic postulates [6]

(ii) Calculate the ionization energy of the hydrogen atom from the following data: The wavelength of the Balmer series limit is $3645\dot{A}$ and the wavelength of the first line in the Lyman series is $1215.7\dot{A}$. [6]



Q6 (a) The average energy released in the fission process is 200 MeV per fission. If a reactor is working at an electrical power level of 6 MW and is 60% efficient, calculate the number of fissions required per second in order to produce this power. [5]

(b) (i) A neutron causes a ${}^{235}_{92}U$ nucleus to fission producing ${}^{97}_{40}Zr$ and ${}^{134}_{Z}Te$ and some neutrons. Determine the atomic number of Te and the number of neutrons released. [2]

(ii) A particle is constrained to move in a circular orbit under a centripetal force given by the equation

$$F = kr$$

where r is the distance between the particle and the center of the circle. Assuming that Bohr's postulates apply to this system, show that the radii of the circle are quantized and given by the equation

$$r_n^2 = \frac{n\hbar}{\sqrt{mk}}$$ [6]

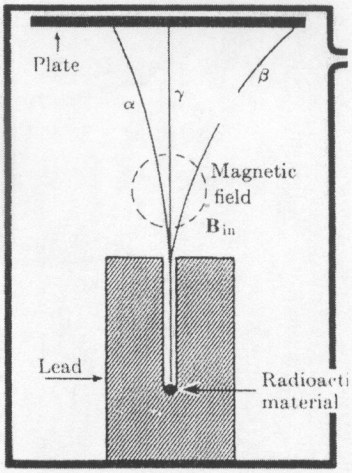
(c) A star is determined to have a temperature of 3000K and radiates 400 times as much energy per unit time as the Sun. Show that the radius of this star in terms of the Sun's radius is $80R_{sun}$. Sun's surface temperature = 6000K.

[7]

Q7 (a) Distinguish between "hard" and "soft" X-rays taking into account the following: [3]

(i) Penetrating power in matter
(ii) Wavelength.

(b) The following diagram shows the paths of radiations coming out from a radioactive source. Study it carefully and then answer the questions that follow.



(i) If the α, β and γ rays are deflected as shown, what is the direction of the magnetic field? [2]

(ii) The same deflections can be achieved using the electric field. Sketch a similar diagram and illustrate how this can be done. [4]

(iii) State the reason (or reasons) why the whole set-up is in a vacuum and why the radioactive material is in a lead housing. [3]

(c) For certain K_α X rays, the linear absorption coefficient of copper is 13.9 cm^{-1}

(i) Show that the tenth-value layer of this absorber is 0.166 cm [4]

(ii) What thickness of copper is required to ensure that $\frac{10}{16}$ of the intensity of these X-rays are absorbed? [4]

END OF PHY 2112 EXAMINATION

The University of Zambia

Department of Physics

Deferred Examinations 2017/2018

Thermodynamics and Properties of Matter - PHY 2231

Duration: Three Hours **Marks: 100**

Instructions

- This paper contains seven questions. All questions carry equal marks.
- Attempt any five questions.
- Show all your working clearly. Omission of essential work will result in loss of marks.
- Marks allocated for each question are indicated in brackets [ ].
- Unless otherwise stated, take:
  1. the acceleration due to gravity to be $g = 9.8$ m.s^{-2}
  2. the universal gas constant as $R = 8.314$ J.mol^{-1}.K^{-1}

FORMULAE THAT MAY BE USEFUL

$Y = \frac{\sigma}{\epsilon}$	$\Delta L = \alpha L_o \Delta T$	$\tau = Y I_g \frac{d^2y}{dx^2}$	$PV = nRT$	$C_v = \left(\frac{\partial U}{\partial T}\right)_V$
$C_P = \left(\frac{\partial Q}{\partial T}\right)_P$	$\Delta Q = mc\Delta T$	$\frac{dQ}{dt} = -k(T - T_0)$	$dS = \frac{dQ}{T}$	$A_1 v_1 = A_2 v_2$

1 (a) State the difference between elastic deformation and plastic deformation. [3]

(b) A vertical steel rod 3 m long has a radius of 1.2 cm. A mass of 95 kg is hang at its lower end. Determine:

(i) the tensile stress; [3]

(ii) the tensile strain; [3]

(iii) the elongation of the rod. [3]

Young's modulus for steel is $2 \times 10^{11} \mathrm{N/m^2}$.

(c) Show that when a deforming force F causes an extension x in an elastic rod which has stiffness k, the work done is given by

$$W = \frac{1}{2}kx^2.$$

[8]

(2) (a) A block of mass $m = 0.5$ kg is attached to a horizontal spring with spring constant $k = 50$ N/m. At $t = 0.1$ s, the displacement $x = -0.2$ m and the velocity $v = +0.5$ m/s. Assume $x(t) = A\sin(\omega t + \phi)$.

(i) Find ω, A and ϕ. [3+3+3]

(ii) Write the expression for $x(t)$. [2]

(b) A table has three legs that are 1.0 m in length and a fourth leg that is longer by $d = 0.5$ mm. A steel cylinder of mass $M = 300$ kg is placed on the table (which has mass $m << M$) so that all the four legs are compressed and the table is now level and not wobbly anymore. The legs are cylindrical with cross-sectional area $A = 1.0\ \mathrm{cm^2}$ and Young's modulus $Y = 1.3 \times 10^{10}\ \mathrm{Nm^2}$.

What are the magnitudes of the forces on the legs from the floor? [9]

3 (a) List the basic assumptions that are made in the theory of bending of beams. [5]

(b)(i) With regard to moments of inertia of an object about an axis of rotation, what do you understand by the term "radius of gyration"? [2]

(ii) The geometric moment of inertia of a rectangular beam with breadth b and thickness d is given by

$$I_g = \frac{bd^3}{12}.$$

Use the definition of the radius of gyration k to show that for this beam

$$k = \frac{d}{\sqrt{12}}.$$

[3]

(c) A cantilever of length l and negligible mass is loaded with a weight W at the free end. Show that the maximum depression of the cantilever is

$$y_{max} = \frac{W}{3YI_g} l^3$$

[10]

where Y is the Young's modulus of the cantilever and I_g is its geometric moment of inertia.

(4) (a) State the zeroth law of thermodynamics. [2]

(b) A 300-g steel ball at 250 °C is placed in a 100-g aluminium calorimeter that contains 400 g of a liquid at 20 °C.

If the final temperature is 32 °C, what is the specific heat capacity of the liquid. [8]

(c)(i) State Carnot's theorem. [2]

(ii) Show that the efficiency ϵ of a heat engine operating in a Carnot cycle between a hot reservoir at temperature T_H and a cold reservoir at temperature T_C, and which uses an ideal gas as a working substance is given by

$$\epsilon = 1 - \frac{T_C}{T_H}.$$

[8]

(5)(a) A car tyre with an internal volume of 0.015 m^3 is filled to an absolute pressure of 300 kPa at 15 °C. After a long run, the pressure rises to 330 kPa.

(i) What is the temperature of the air in the tyre, assuming that the volume remains constant? [3]

(ii) What mass of air must be removed for the pressure to return to 300 kPa? [3]

Take the effective molecular mass of molecules of air to be 29 g/mol.

(b) For a quasistatic, adiabatic process show that

(i) $PV^{\gamma} = \text{constant}$ [8]

where $\gamma = C_p/C_v$. C_p and C_v are the molar specific heats at constant pressure and constant volume respectively.

Hence show that:

(ii) $TV^{\gamma-1} = \text{constant}$; [3]

(iii) $T^{\gamma}P^{1-\gamma} = \text{constant}$. [3]

(6)(a) State the second law of thermodynamics in terms of:

(i) the Clausius statement; [2]

(ii) entropy. [2]

(b) When the temperature of the surroundings is 20 °C, a particular liquid takes 5 minutes to cool from 80 °C to 50 °C. Show that it would take this liquid 10 minutes to cool from 60 °C to 30 °C. [8]

(c) At low temperatures, the molar specific heat of solids is given by Debye's law

$$C = \frac{kT^3}{T_D^3}$$

where $k = 1945$ J/mol.K and T_D is the Debye temperature characteristic of the solid.

Calculate the heat input required to raise the temperature of 2.4 moles of aluminium ($T_D = 400$ K) from 10 K to 20 K. [8]

(7) (a) Determine the amount of energy required to break a drop of mercury of radius 10^{-3} m into one million droplets of equal size. N/m. [6]

The surface tension of mercury is 550×10^{-3}

(b)(i) In the kinetic theory of gases, what assumptions are made about the molecules in a gas? [3]

(ii) Use the kinetic theory of gases and the ideal gas law to show that

$$\nu_{\text{rms}} = \sqrt{\frac{3RT}{M}}$$

where ν_{rms} is the root mean square speed of the molecules, T is the temperature, R is the gas constant and M is the molecular mass of the gas. [7]

(c) Show that at 30 $^{\circ}$C and 2 atm, the number density of molecules of an ideal gas is 4.83×10^{19} molecules/cm^3. [4]

End of Examination

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
DEPARTMENT OF PHYSICS
2017/18 END YEAR EXAMINATION

PHY-2522: ANALYTICAL MECHANICS AND SPECIAL THEORY OF RELATIVITY

Time allowed: **3 Hours**

Instructions

- **This examination paper contains 7 questions. 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 each answer sheet.**

Where necessary, you may use the following:

In plane polar coordinates

$$x = r\cos\theta, \qquad y = r\sin\theta$$

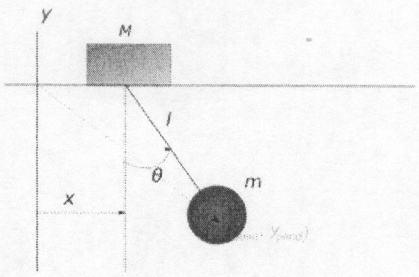
$$\vec{v} = \dot{r}\hat{\vec{r}} + r\dot{\theta}\hat{\vec{\theta}} \qquad \vec{a} = \left(\ddot{r} - r\dot{\theta}^2\right)\hat{\vec{r}} + \left(r\ddot{\theta} + 2\dot{r}\dot{\theta}\right)\hat{\vec{\theta}}$$

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{q}_k}\right) - \frac{\partial L}{\partial q_k} = Q_k, \qquad p_k = \frac{\partial L}{\partial \dot{q}_k}, \quad \dot{q}_k = \frac{\partial H}{\partial p_k}, \quad \frac{\partial H}{\partial t} = -\frac{\partial L}{\partial t}, \quad -\dot{p}_k = \frac{\partial H}{\partial q_k},$$

$$x' = \gamma(x - vt), \quad t' = \gamma\left(t - \frac{Vx}{c^2}\right), \quad y' = y, \quad z' = z, \quad \gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}, \text{ speed of light } c = 3\times10^8 \text{ m/s}$$

$$\frac{\partial^2 u(x,t)}{\partial t^2} = \frac{T}{\mu}\frac{\partial^2 u(x,t)}{\partial x^2}, \qquad \gamma L = L_0, \quad I_{sphere} = \frac{2}{5}Ma^2, \qquad I_{disk} = \frac{1}{2}Ma^2$$

Q1 Consider a pendulum of mass m and length ℓ, which is attached to a support of mass M, which can move along a line in the x-direction as shown in the figure below. Let x be the coordinate along the line of the support, and let the position of the pendulum be denoted by the angle θ from the vertical.



(a) Determine the potential and kinetic energy of the system. **[4 marks]**

(b) Show that the Lagrangian function of the system is

$$L = \frac{1}{2}(M+m)\dot{x}^2 + m\dot{x}l\dot{\theta}\cos\theta + \frac{1}{2}ml^2\dot{\theta}^2 + mgl\cos\theta \qquad \textbf{[5 marks]}$$

(c) Confirm that the equations of motion arising from the Lagrangian formalism are:

$$ml^2\ddot{\theta} + ml(\ddot{x}\cos\theta + g\sin\theta) = 0 \text{ and} \qquad \textbf{[6marks]}$$

$$(M+m)\ddot{x} + ml\ddot{\theta}\cos\theta - ml\dot{\theta}^2\sin\theta = 0 \qquad \textbf{[5 marks]}$$

Q2 A disturbance at a certain point resulted in the following two waves

$$y_1 = 4\cos(5x - 20t)$$

and

$$y_2 = 4\cos(5x + 20t)$$

(a) Calculate the distance between the disturbances carried by the two waves after 4 s. **[4 marks]**

(b) A certain harmonic wave varies as a function of position and time according to the equation

$$y = 10\cos(10x - 20t)$$

(i) Calculate the distance between two consecutive peaks of the wave. **[2 marks]**

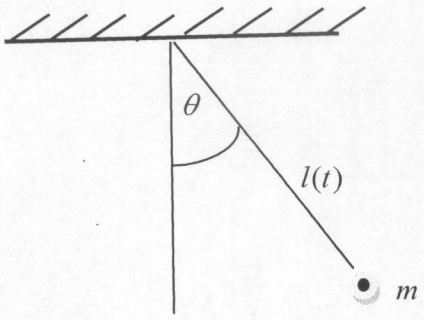
(ii) Calculate the time taken for one complete oscillation of a particle in the wave. **[2 marks]**

(c) A wave of frequency 500 Hz has a phase velocity of 360 m/s.

(i) How far apart are two points 60^0 out of phase? **[8 marks]**

(ii) What is the phase difference between two displacements at a certain point at time 10^{-3} s apart? **[4 marks]**

Q3 A point mass m acted on by gravity as shown in the figure below is suspended from a ceiling by a thin and massless wire whose length is a function of time $l(t)$.



(a) Calculate the kinetic energy of the system. **[5 marks]**

(b) What is the potential energy of the system? **[2 marks]**

(c) Find the Hamiltonian of the system. **[5 marks]**

(d) Eliminate p_θ and show that the equation of motion for θ is

$$\ddot{\theta} + 2\frac{\dot{l}}{l(t)}\dot{\theta} + \frac{g}{l(t)}\sin\theta = 0$$ **[6 marks]**

(e) Explain the difference between this equation and that of a normal simple pendulum where the length of the rod is inextensible. **[2 marks]**

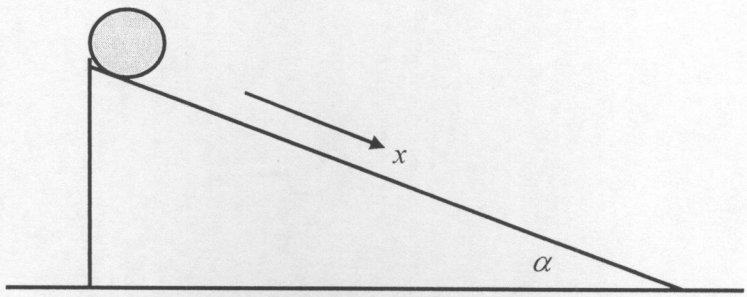
Q4(a) A solid sphere of mass m kg and radius a is rolling without slipping down an incline as shown in the figure below.

(i) Find the expression for the conjugate momentum for the x-coordinate. **[8 marks]**

(ii) Using the Hamiltonian method, show that the acceleration of the sphere down the plane is given by

$$\ddot{x} = \frac{5}{7}g\sin\alpha$$ **[6 marks]**

where g is the acceleration due to gravity.



(b) Explain how your result above would change if the sphere was not rolling. **[4 marks]**

(c) State one major difference between the Lagrangian formalism and the Hamiltonian formalism with reference to the generalized coordinates. **[2 marks]**

Q5(a) State the two main postulates of the special theory of relativity. **[3+1 marks]**

(b) If $\alpha^2 + \beta^2 = \frac{1}{v^2}$, show that the differentiable function $f(t + \alpha x + \beta y)$ where α and β are constants is a solution to the 2-D wave equation (α and β are constants).

$$\frac{\partial^2 u}{\partial t^2} = v^2\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2}\right)$$ **[8 marks]**

(c) Show that the equation of a spherical electromagnetic wave propagating with constant speed c is not invariant under the Galilean transformations. **[8 marks]**

Q6 Frame S' has a speed $v = 0.6c$ relative to frame S. Clocks are adjusted so that $t = t' = 0$ at $x = x' = 0$. Two events occur along the x-axis with the first event occurring at $x_1 = 10\,\text{m}$, $t_1 = 3\times10^{-7}\,\text{s}$. The second event occurs at $x_2 = 50\,\text{m}$, $t_2 = 4\times10^{-7}\,\text{s}$.

(a) What is the distance between the two events as measured in the S' frame? **[8 marks]**

(b) What is the time difference as measured in S' between the two events? **[8 marks]**

(c) A particle is moving with a speed of $0.5c$. Calculate the ratio of the rest mass to the mass while in motion. **[4 marks]**

Q7(a) Consider a metre stick moving parallel to its length at velocity close to the velocity of light. What is the length of the metre stick when its mass is 3/2 of its rest mass? **[10 marks]**

(b) Assume that the equation of motion of a mass m attached to a spring of spring constant k on a flat horizontal frictionless surface is given by

$$-k(x_2 - x_1) = m\frac{d^2 x_2}{dt^2}$$

where x_1 is the equilibrium position of the mass and x_2 is its displacement at any time t. Show from the classical transformation laws that the equation of motion given above is invariant and has the same form with respect to an observer at rest with the surface and by a second observer moving with a constant velocity v along the direction of the spring. **[10 marks]**

**********END OF PHY 2522 EXAMINATION**********

The University of Zambia

Department of Physics

PHY 2611 Deferred Examination: Electricity and Magnetism.

Wednesday, 26th December, 2018.

Instructions: Answer five(5) questions only. All are of equal marks.

Time duration: Three(**3**) hours only. All working must be shown

Some formulars and expressions you may find useful.

$$\int x dx = \frac{x^2}{2} + C \qquad \varepsilon = -N\frac{d\varphi}{dt}$$

$$E = \frac{1}{4\pi\varepsilon_o}\frac{q}{r^2} \qquad i = qf$$

$$R = \rho\frac{L}{A} \qquad I_{rms}^2 = \frac{1}{T}\int_0^T i^2 dt$$

$$\int B.dl = \mu_o \int j.dA \qquad V = EL$$

$$X_L = \omega L \qquad i = \frac{dq}{dt}$$

$$X_C = \frac{1}{j\omega L}$$

$$E = \frac{Q}{4\pi\varepsilon_o}\frac{1}{r^2}$$

$$\int E.dS = \frac{\int dq}{\varepsilon_o}$$

$$C = \frac{\varepsilon_o A}{d}$$

Q1 (a) The linear charge density λ on a certain non-conducting rod is given by the expression $\lambda = 5 + kx^2$ where k is a constant. Given that the rod is of length $L = 10$ cm, find the total charge Q on the rod, figure 1 [6]

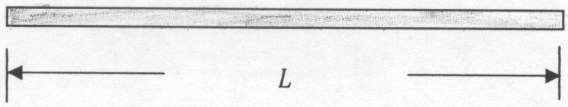


Figure 1

(b) Figure 2 shows equal positive charges, $+q = 20\mu$C located at the corners of an equilateral triangle of side $a = 20$ cm.

(i) Show that the **electric field** at the center of the triangle is zero [7]

(ii) What are the magnitude and direction of the **force** on the charge at P due to the two charges at the base? [7]

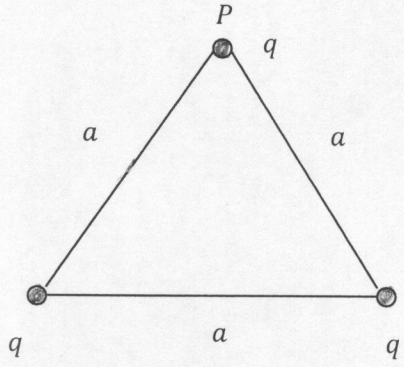


Figure 2

Q2 (a) A non-conducting sphere, figure 3 has a charge Q **uniformly** distributed in its volume of radius R. Show that the electric field function $E(r)$ for points inside the sphere is given by $E(r) = \frac{Qr}{4\pi\varepsilon_o R^3}$ [6]

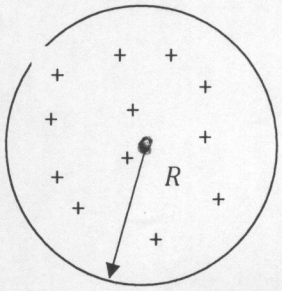


Figure 3

(b) A non-conducting sphere has a charge distributed in its volume of radius R with a charge density, ρ given by

$$\rho = \rho_o r^2$$

Derive and **plot** the function for the variation of the electric field at all points inside and outside the sphere. [8]

(c) A parallel plate capacitor is filled with two dielectrics as shown in figure 3.2. Show that the capacitance, C is given by

$$C = \frac{2\varepsilon_o A}{d}\left(\frac{k_1 k_2}{k_1 + k_2}\right)$$ [6]

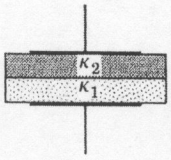


Figure 4

Q3 (a) (i) State Kirchhoff's laws for circuit analysis. [3]

(ii) Find the currents I_1, I_2 and I_3 in the network of figure 5 [9]

All resistances are in ohms.

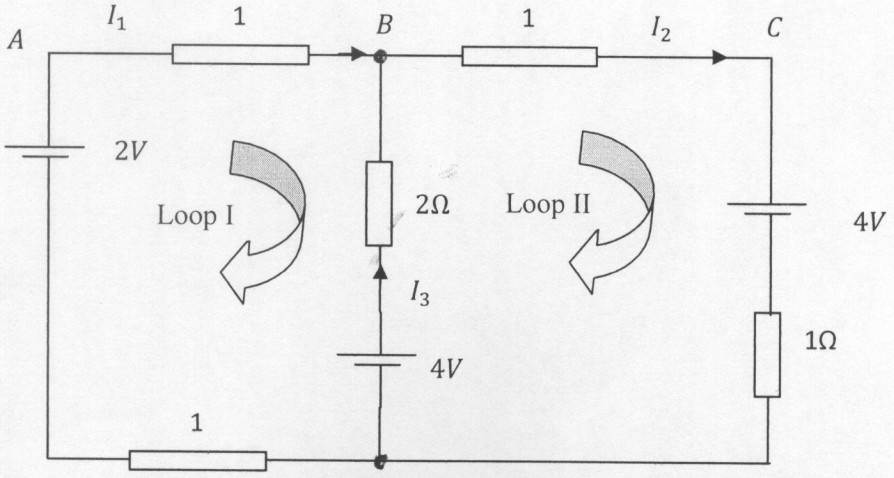


Figure 5

(b) A copper wire and an iron wire of equal length $l = 200$ cm and diameter $d = 1$mm are joined in series and a potential difference $V = 10$ volts is applied between the ends of the composite wire. Calculate [8]

(i) the potential difference across each wire

(ii) the current density j in each wire

(iii) the electric field in each wire

Data: resistivity of copper, $\rho_{cu} = 1.68 \times 10^{-8}\Omega$.m

resistivity of iron, $\rho_{Fe} = 9.71 \times 10^{-8}\Omega$.m

Q4 (a) A metal rod of length L moves with a velocity v in a direction perpendicular to its axis and to a constant magnetic field of induction B as shown in figure 6

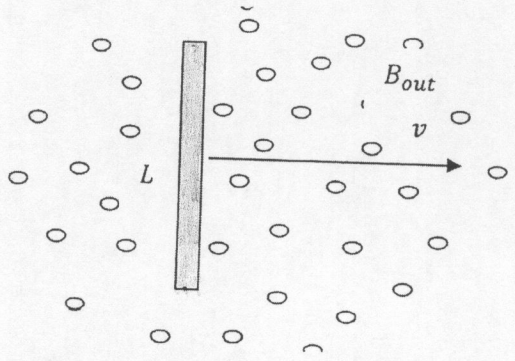


Figure 6

(i) Write down the expression for the force on the charge carriers within the rod by virtue of the motion of the rod. [2]

(ii) What will be the magnitude and direction of the electric field set up by the charge separation in the rod due to this motion? [3]

(iii) Write down the magnitude and state the polarity of the potential difference that will develop between the ends of the rod. [3]

(iv) Suppose the rod moves (slides) on a stationary conducting loop as in figure 7, what current will flow in the loop if the resistance of the loop and rod is R? [2]

(v) Calculate the emf induced by the motion of the rod by means of Faraday's law and compare the result with that you obtained in (iii) [3]

(vi) Write down the expression for the power generated in the loop [2]

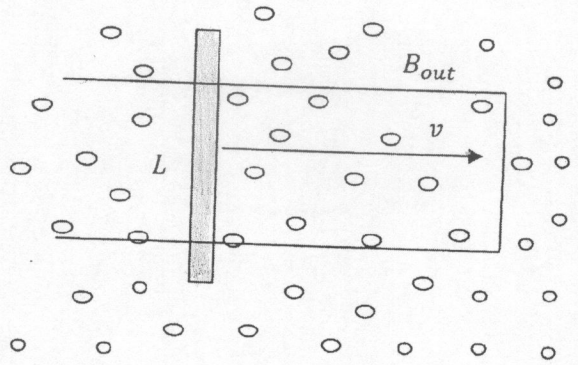


Figure 7

(b) In figure 8 the magnetic flux through the loop perpendicular to the plane of the coil and directed into paper is varying according to the relation

$$\varphi_B = 6t^2 + 7t + 1$$

Where φ_B is in milliwebers (1 milliweber = 10^{-3}weber) and t is in seconds

(i) what is the magnitude of the emf induced in the loop when 2.0 sec? [2]

(ii) what is the direction of the current through R? Explain how you arrive at the answer. [3]

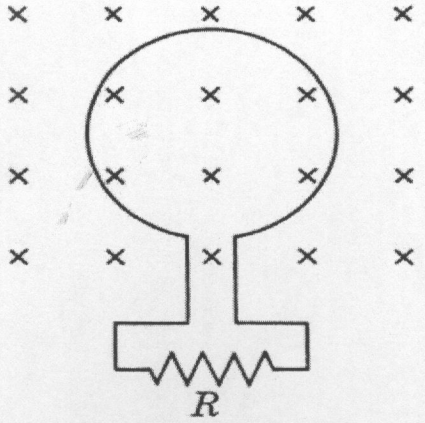


Figure 8

Q5 (a) (i) State what is meant by the rms of a physical quantity such as current. A mathematical statement would be acceptable as long as you define the symbols used

[2]

(ii) Derive the expression for the rms value for the following, figure 9

[8]

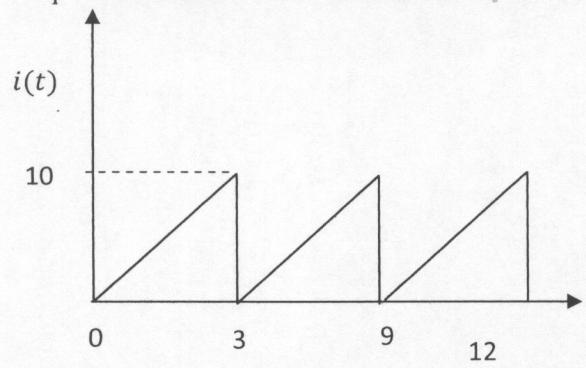


Figure 9

(b) A series RLC ac circuit has $R = 425\Omega$, $L = 1.25\text{H}$, $C = 3.50\mu\text{F}$ with $\omega = 377\text{s}^{-1}$. Take $\Delta V_{max} = 150\text{V}$. Determine

(i) Determine the **inductive** and **capacitive** reactances for the circuit [3]

(ii) the impedance of the circuit [3]

(iii) the maximum current in the circuit [2]

(iv) The phase angle between the current and the voltage [2]

Q6 (a) State Lenz's law [2]

(b) The motion of the bar in the following figure generates an emf in the loop.

State the **direction (clockwise or anticlockwise)** and **magnitude** of the generated current and then show that this is consistent with Lenzi's law, figure10. Hint: Take Lenz's law as just another form of law of energy conservation. [10]

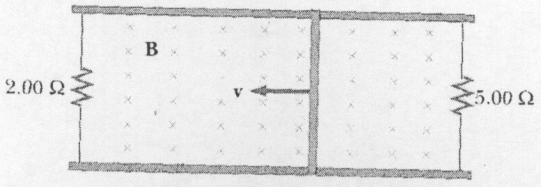


Figure 10

(c) (i) State Ampere's law [2]

(ii) A flat coil is wound so that it contains a very large number of turns per unit distance along its radius, figure 11. If this number is Z, show that the magnitude of the magnetic field at the center of such a coil of inner radius a and outer radius b, carrying a current i is given by [6]

$$B = \frac{\mu_o}{2} iZln\left(\frac{a}{b}\right) \text{ Tesla}$$

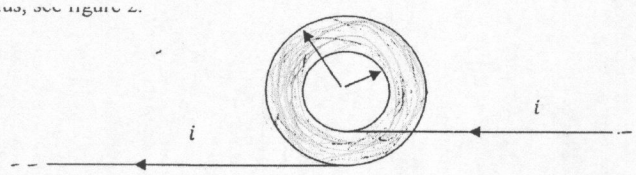


Figure 11

Q7 (a) A long cylindrical conductor of radius R carries a current as shown in figure 12. However, the current density j is not uniform over the cross-sectional area of the conductor but is a function of the radius according to the relation

$$j = br$$

where b is a constant. Determine the expression for the magnetic field B at distances

(i) $r_1 < R$ [5]

(ii) $r_2 > R$ [5]

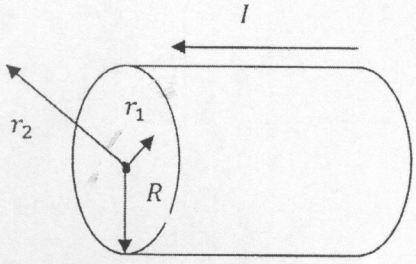


Figure 12

Note: All distances are measured from the center of the cylinder.

(b) A charged particle (charge magnitude $q = 20\mu C$) is whirled in a horizontal circle at 3000 revolutions per minute, figure 13. Determine

(i) the magnitude of the circulating current [3]

(ii) the magnitude of the magnetic field created at the center of the circle by the circulating charged particle [5]



Figure 13

(c) Magnetic field lines do not intersect. What fundamental problem would arise if they intersected at a point? [2]

END OF PHY 2611 DEFERRED EXAMINATION

The University of Zambia

School of Natural Sciences

Department of Physics

Deferred 2017/2018 Academic Year Examinations

PHY 2712 – Optics

Duration: 3 hours **Maximum Marks: 100**

Instructions

- This examination paper contains 7 questions. Attempt any 5 questions.
- Each question carries 20 marks. Marks allocated for each question are indicated in brackets [ ].
- Show all your working clearly. Omission of essential work will result in loss of marks.
- Write your computer number clearly on the answer booklets.

CONSTANTS THAT MAY BE USEFUL

$e = 1.602 \times 10^{-19}$ C

$m_e = 1.6 \times 10^{-27}$ kg

$m_p = 9.11 \times 10^{-31}$ kg

$\varepsilon_0 = 8.85 \times 10^{-12}$ $C^2 N^{-1} m^{-2}$

$h = 6.63 \times 10^{-34}$ J s

$\mu_0 = 4\pi \times 10^{-7}$ N s^2 C^{-2}

$c \cong 3.0 \times 10^8$ m/s

1 Å = 0.1 nm

$n_{water} = 1.33$

$n_{glass} = 1.5$

$n_{air} = 1$

FORMULAE THAT MAY BE USEFUL

$n_1 \sin\theta_1 = n_2 \sin\theta_2$	$\frac{1}{f} = \frac{1}{s_o} + \frac{1}{s_i}$	$\frac{n_1}{s_o} + \frac{n_2}{s_i} = \frac{n_2 - n_1}{R}$
$\frac{1}{f} = \left(\frac{n_2}{n_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$	$M_T = \frac{y_i}{y_o}$	$D = P = \frac{1}{f}$
$u_E = \frac{1}{2}\varepsilon_o E^2$	$u_B = \frac{1}{2\mu_o} B^2$	$u_{total} = \varepsilon_o E^2 = c\varepsilon_o EB$
$\upsilon = \frac{1}{V} = \frac{n_D - 1}{n_F - n_C}$	$v = \frac{1}{\sqrt{\mu_o \varepsilon_o}}$	$M_T = \frac{-s_i}{s_o}$
$M_T = \frac{-x_i}{f} = -\frac{f}{x_o}$	$n = \frac{\sin\theta_i}{\sin\theta_r}$	$M_T = \frac{f_1 s_i}{d(s_o - f_1) - s_o f_1}$
$f_o = \frac{n_1}{n_2 - n_1} R$	$M_T = M_{T1} M_{T2}$	$s_i = \frac{f_2 d - [f_1 f_2 s_o / (s_o - f_1)]}{d - f_2 - [f_1 s_o / (s_o - f_1)]}$
$x_i x_o = f^2$	$k = \frac{2\pi}{\lambda}$	$n \equiv \frac{c}{v} = \sqrt{\frac{\varepsilon\mu}{\varepsilon_0 \mu_0}}$
$v = \nu\lambda$	$\omega = kv = ck = 2\pi\nu$	$\frac{1}{v^2}\frac{\partial^2 \psi(x,t)}{\partial t^2} = \frac{\partial^2 \psi(x,t)}{\partial t^2}$
$\psi(x,t) = A\sin(kx - \omega t + \xi)$	$V = \frac{n_F - n_C}{n_D - 1}$	$E_o = \frac{1}{\sqrt{\mu_o \varepsilon_o}} B_o$
$\frac{\partial E_z}{\partial y} = -\frac{\partial B_x}{\partial t}$	$\frac{\partial B_x}{\partial y} = -\mu_o \varepsilon_o \frac{\partial E_z}{\partial t}$	$\mu_o \varepsilon_o \frac{\partial^2 E_z}{\partial t^2} = \frac{\partial^2 E_z}{\partial y^2}$
$\mu_o \varepsilon_o \frac{\partial^2 B_x}{\partial t^2} = \frac{\partial^2 B_x}{\partial y^2}$	$E_z(y,t) = E_o \sin(ky \pm \omega t)$	$B_x(y,t) = B_o \sin(ky \pm \omega t)$
$-\frac{2}{R} = \frac{1}{s_o} + \frac{1}{s_i}$	$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$	$b.f.l. = \frac{f_2(d - f_1)}{[d - (f_1 + f_2)]}$
O.P.L. $= \int_S^P n(s)ds$	$\psi_2(r + \delta, t) = A\cos(kr - \omega t + k\delta)$	$f.f.l. = \frac{f_1(d - f_2)}{[d - (f_1 + f_2)]}$

$f_i = \frac{n_2}{n_2 - n_1} R$	$h_1 = -\frac{f(n_l - 1)d}{R_2 n_l}$	$b.f.l. = f + h_2$
$f.f.l. = f + h_1$	$h_2 = -\frac{f(n_l - 1)d}{R_1 n_l}$	$\frac{1}{f} = (n-1)\left[\frac{1}{R_1} - \frac{1}{R_2} + \frac{(n_l - 1)d}{n_l R_1 R_2}\right]$

Question 1

(a) Define the following terms

i. Dispersion of white light [1]

ii. Polarization of light [1]

(b) Considering a gypsy's crystal ball as a thick lens, its focal length in terms of the radius R and refractive index n can be determined by rewriting lens formula as

$$\frac{1}{f} = (n-1)\left[\frac{1}{R} + \frac{1}{R} + \frac{(n-1)2R}{-nR^2}\right]$$

i. Show that the ball's focal length is

$$f = \frac{nR}{2(n-1)}$$

[5]

ii. Determine the location of its principal points. [2]

iii. Where will sunlight be focused from the vertex, by a 4-inch diameter ball of index 1.5? [3]

(c) Use Fermat's principle (calculus version) to arrive at the law of reflection. Show an associated diagram representing the derivation. [9]

Question 2

(a) Explain why white light entering a glass prism at incident angle to the normal on one interface with air leaves the other interface in a spectrum of seven component colours but the same light entering a glass rectangular block on one side leaves the other side as white light. [4]

(b) A spherical mirror is to be designed so that it forms an erect half-sized image of an object if that object is 100 cm from the vertex. For such a design

i. Where will the image be located? [4]

ii. What type of image will be formed? [1]

iii. Find the radius of curvature of the mirror. [2]

iv. What kind of mirror will be used? [1]

(c) A positive meniscus convexo-concave thin lens (n = 1.5) whose radii of curvature are 5 cm and 10 cm is positioned in contact with a plano-concave thin lens (n = 1.6) of radius 6 cm.

i. What is the effective focal length of the lens system? [6]

ii. Compute the lens system's power. [2]

Question 3

(a) What is a lens? [1]

(b) Imagine an electromagnetic plane wave in vacuum whose **E**-field (in SI units) is given by

$$E_x = 10^3 \sin[\pi(4 \times 10^6 z - 12 \times 10^{14} t)],\ E_y = 0,\ E_z = 0.$$

Determine the

(i) speed, [2]

(ii) wavelength, [3]

(iii) period, [1]

(iv) initial phase, [1]

(v) and **E**-field strength. [1]

(c) (i) If a convex lens having a refractive index of 1.5 has a focal length of 20 cm in air, what will be the focal length when it is immersed in water? [4]

(ii) A thin bi-convex glass (n_g = 1.5) lens has radii of curvature of 30 cm and 60 cm. If it is to form a half-sized image of a ceiling electric bulb on a paper screen, what must be the lens-to-bulb and lens-to-screen distances? [7]

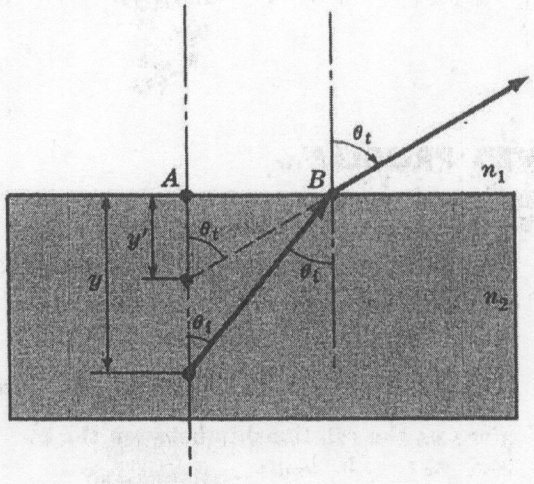
Question 4

(a) Imagine that we have two media (of indices n_1 and n_2) separated by a planar interface. An object in the more dense medium (n_2) is a distance y below the interface. An observer above the boundary will see the object as if it were a distance y' below it.

(i) Using Snell's law and the diagram below, prove that y' is given by

$$y' = y\frac{n_1}{n_2}$$

in terms of y and the refractive indices, assuming the line of sight to be nearly normal to the interface. [6]

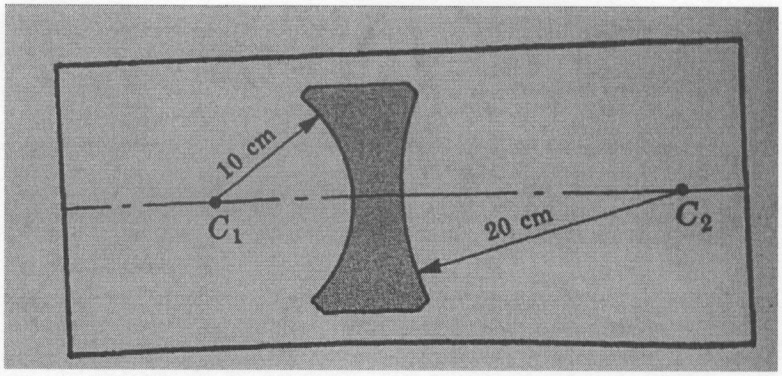


(ii) A fish appears to be 2 m below the surface of a pond when viewed from almost directly above by an angler. Considering the expression in part (i) above, what is the actual depth of the fish? [3]

(b) Draw two diagrams showing the front focal length (f.f.l.) and also the back focal length (b.f.l.) situations for a point source (S) on the axis of a thick lens so that the emerging rays are parallel and for an incident parallel bundle of rays converging to a point, respectively. Show clearly that if the incoming and outgoing rays are extended each will intersect on a surface such that in the paraxial approximation these surfaces reduce to the planes known as the first and second principal points, respectively. Indicate the associated principal points on the sketches. [8]

(c) (i) Compute the focal length of the bi-concave thin lens depicted in the figure below, assuming that it is made of flint glass (n_l = 1.66) and is immersed in carbon disulphide (n_m = 1.63). [2]

(ii) Is the resultant lens' effect diverging or converging the rays impinging on it from its left side? [1]

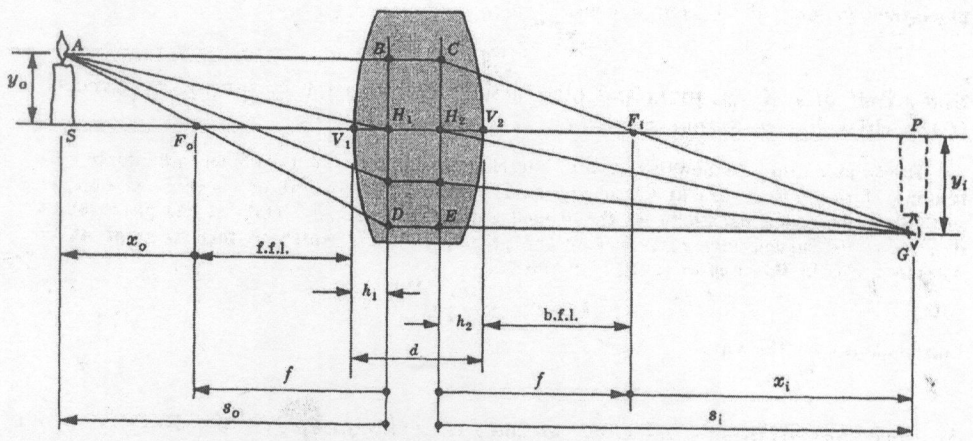


Question 5

(a) Explain how a Cartesian ovoid forms when a light wave is propagating from a less to a higher refractive index medium. Draw an accompanying diagram of the interface showing spherical waves from a source (S) to a point P where they converge. [6]

(b) A bi-concave lens of focal length -60 mm is mounted in a cardboard cylinder 120 mm in front of a plano-convex lens of radius 60 mm and index 1.5. Find the effective focal length of the system. [4]

(c) A double convex lens has radii of 5 cm and 20 cm, a thickness of 2 cm and an index of refraction of 3/2. The following figure may be used as an aid for computing values of various parameters.



i. Determine the focal length referenced from each of the principal planes, [2]

ii. Evaluate both principal points, h_1 and h_2, distances from each respective vertex, [4]

iii. Compute the image distance for an object, e.g., a candle, at 16.5 cm in front of V_1, [2]

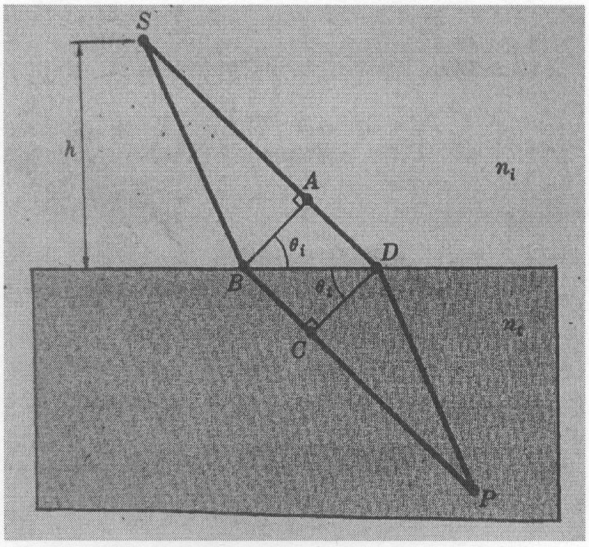
iv. Calculate the values of the front focal length, and also [1]

v. the back focal length. [1]

Question 6

(a) Write an expression for a linearly polarized wave of angular frequency ω propagating in the positive z-direction with its plane of vibration at 30 degrees to the zx-plane. Include a sketch of the wave propagating in three-dimensional space. [6]

(b) Use the alternative statement of Fermat's principle to arrive at Snell's law of refraction without calculus. Consider the following diagram for your derivation.



[9]

(c) A piece of dense flint glass is made into a prism. The refractive indices for red, yellow and blue light are specified as $n_C = 1.64357$, $n_D = 1.64900$ and $n_F = 1.66270$, respectively, by the glass manufacturer. Find this glass'

i. dispersive power, and [3]

ii. dispersive constant. [2]

Question 7

(a) State Fermat's principle of least time. [1]

(b) The *Gregorian reflecting telescope* is a centered system consisting of a large parabolic primary mirror which collects incident light, bringing it to bear on a small concave ellipsoidal secondary mirror. The rays reflect off the secondary and converge back through a hole in the primary. Draw a ray diagram and discuss the locations of the various foci. [6]

(c) A negative meniscus thin lens of radii 60 cm and 30 cm and having an index of refraction 1.55 is held horizontally with its concave side facing upwards. The concavity is then filled with a transparent oil of index 1.65.

(i) Determine the dioptric power of the compound thin lens assuming it to be immersed in air. [8]

(ii) Describe the image of the object 100 cm in front of the lens. [5]

End of PHY 2712 Examination

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The University of Zambia

School of Natural Sciences
Department of Physics
2017/18 Academic Year
End of Year University Examinations
PHY3032: Computational Physics 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.**
- **All relevant algorithms have been provided.**
- **Include comments to describe operations of different sections of your codes.**
- **Omission of essential work may lead to loss of marks.**

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Physical Constants

Standard atmosphere, 1 atm = 101325 Pa	Density of water at 20°C, $\rho_{water} = 1000$ kg/m^3
Specific heat capacity of oil is 1450J/kg.K	Elementary charge $q = 1.602176462\times10^{-19}$ C
Density of mercury at 20°C, $\rho_{mercury} = 13600$ kg/m^3	Universal gas constant $R = 8.314472$ J mol^{-1} K^{-1}
Planck constant $h = 6.62606876\times10^{-34}$ J.s	Boltzmann's constant $k = 1.3806503\times10^{-23}$ J K^{-1}
Reduced Planck constant $\hbar = h/2\pi = 1.054571800\times10^{-34}$ J.s/rad	Acceleration due to gravity $g = 9.80665$ m.s^{-2}
Stefan-Boltzmann constant $\sigma = 5.6704\times10^{-8}$ Wm^{-2}K^{-4}	Specific heat capacity of water $c_w = 4184$ J/kg.K
Speed of light in vacuum $c = 2.99792\times10^{8}$m/s	Proton mass, $m_p = 1.67262158\times10^{-27}$ kg
Gravitation constant $G = 6.67384\times10^{-11}$ Nm^{2}kg^{-2}	Electron mass, $m_e = 9.1093888$ kg
Avogadro constant $N_A = 6.02214199\times10^{23}$ mol^{-1}	Magnetic constant $\mu_o = 4\pi\times10^{-7}$ NA^{-2}

FORMULAE AND ALGORITHMS THAT MAY BE USEFUL

1. **TAYLOR SERIES EXPANSION**

The Taylor series expansion of any continuous and differentiable function $y = f(x)$ around a point $x = x_0$ is given by

$$f(x) = \sum_{n=0}^{\infty} \frac{f^n(x_0)}{n!}[x - x_0]^n,$$

where $f^n(x_0)$ denotes the nth derivative of $f(x)$.

2. **LAGRANGE INTERPOLATION**

Consider a set of $n+1$ data points $(x_0, y_0), (x_1, y_1), (x_2, y_2), ..., (x_n, y_n)$. the Lagrange Interpolating Polynomial of degree n is generally given by

$$p_n(x) = \sum_{k=0}^{n} L_k(x) y_k,$$

where $L_k(x) = \prod_{\substack{i=0 \\ i \neq k}}^{n} \frac{x - x_i}{x_k - x_i}$ for $k = 0, 1, 2, ..., n$,

or $$L_k(x) = \frac{[x - x_0][x - x_1][x - x_2]...[x - x_{k-1}][x - x_{k+1}]...[x - x_n]}{[x_k - x_0][x_k - x_1][x_k - x_2]...[x_k - x_{k-1}][x_k - x_{k+1}]...[x_k - x_n]}.$$

3. NEWTON RAPHSON ALGORITHM

$$x_{i+1} = x_i - \frac{f(x_i)}{f'(x_i)};\ f'(x_i)$$

4. COMPOSITE TRAPEZOIDAL ALGORITHM

$$\int_{x_{\min}}^{x_{\max}} f(x)dx \approx \frac{h}{2}[V + 2W],$$

Such that $h = \frac{x_{\max} - x_{\min}}{n}$ where $n =$ number of subintervals and

$V = f(x_{\min}) + f(x_{\max})$ while $W = \sum_{i=1}^{n-1} f(x_i)$.

Q1. (a) Distinguish between for following computer terminologies:

(i) Storage and Memory **[4]**

(ii) Data and Information **[4]**

(iii) Gigabyte [GB] and Gibibyte [GiB] **[4]**

(iv) Pseudocode and a Flow Chart **[4]**

(v) A tested algorithm and a verified algorithm, **[4]**

(b) Show that an unformatted computer storage device with a rating of 1Terabyte has 976562500 kibibytes. **[5]**

Q2. (a) Consider a set of N -data points $[x_i, y_i]$; for $i = 1, 2, 3....N$. Assuming a straight line model of the form

$$y = a_0 + a_1 x,$$

is fitted to the data, use the Chi-square merit function

$$\chi^2 = \frac{1}{N}\sum_{i=1}^{N}[y_i - y]^2$$

to show that

$$a_0 = \frac{S_{xx}S_y - S_x S_{xy}}{NS_{xx} - S_x^2},$$

$$a_1 = \frac{NS_{xy} - S_x S_y}{NS_{xx} - S_x^2},$$

where $S_x = \sum_{i=1}^{N} x$, $S_y = \sum_{i=1}^{N} y_i$, $S_{xx} = \sum_{i=1}^{N} x_i^2$, $S_{xy} = \sum_{i=1}^{N} x_i y_i$ and $S_{yy} = \sum_{i=1}^{N} y_i^2$. **[16]**

(b) The factorial of any positive integer n is given by

$$n! = n[n-1][n-2][n-3]....\times 4\times 3\times 2\times 1$$

such that $0! = 1$. Write a Fortran 90 code that can evaluate $n!$ for $n \leq 20$ supplied via a computer keyboard. **[9]**

Q3. (a) Gamma ray spectroscopy can be done using a Sodium Iodide detector with a multichannel analyser. In one experiment, data in table 2 was collected.

Table 1: **Data of Channel Number and corresponding Counts per Channel for ^{137}Cs.**

Channel Number	Counts per channel
64	80
65	120
66	170
67	225
68	270
69	290
74	130
75	70
79	10

Given that the data in table 2 is saved in an input file called *spectroscopy.txt*, write a Fortran 90 code that can use the *iostat* Fortran 90 intrinsic function to automatically count and read the total number of data sets, N_{max}, in *spectroscopy.txt* with capabilities of error detection in the data. **[10]**

(b) The normal distribution function $F(x)$ is defined as

$$F(x)=\frac{1}{\sqrt{2\pi}}\exp\left(-\frac{x^2}{2}\right).$$

Write a Fortran 90 code that has a driver program which

(i) supplies a value of x to a user defined function $F(x)$, **[6]**

(ii) uses the DO WHILE statement to evaluate values of $F(x)$ for $-5\le x\le 5$ in steps of 0.001, **[4]**

(iii) stores values of x and corresponding values of $F(x)$ in a file called "output.txt" correct to 4 decimal places, **[5]**

Q4. (a) The van der Waals equation of state can be expressed as

$$f(P,v,T,a,b)=0,$$

where

$$f(P,v,T,a,b)=\left[P+\frac{a}{v^2}\right]\left[v-b\right]-RT,$$

such that P is the gas pressure, $v=V/n$ is its volume V per unit mole n, T is absolute temperature of a gas, $R=0.0820578$ litre-atm/mol.K is the universal gas constant while a and b are constants that are characteristic of individual gasses.

If P,T,n,a and b are known, then

$$f(v)=0,$$

and the equation reduces to

$$f(v)=\left[P+\frac{a}{v^2}\right]\left[v-b\right]-RT.$$

Consider a sample of Oxygen gas at 5.0 atm pressure and temperature of $27^{\circ}\mathrm{C}$. In the case of oxygen, $a=1.36$ litres^2-atm/mol^2 and $b=0.003183$ litres/mol. Starting with initial guess 6.0 litres/mol use the Newton-Raphson algorithm to estimate v correct to 5 decimal places. **[13]**

(b) Hence, or otherwise, write a code using Fortran 90 that implements that Newton-Raphson algorithm using double precision variable declaration to estimate the value of estimate v correct to 14 decimal places. **[12]**

Q5. (a) A cylindrical tank 2.0 meters high stands on its circular base of diameter 1.00m and is initially filled with water. At the bottom of the tank there is a hole of diameter 1.00cm, which is opened at some instant, so that the water starts draining under the influence of gravity. The rate at which the water level h in the tank decreases can be modelled by the initial value problem

$$\frac{dh}{dt} = -0.002656\sqrt{h} \quad ; \qquad h(t_0) = 2.0000 .$$

Apply the Euler – Cauchy algorithm to the above initial value problem, choosing a step size of $\Delta t = 1.0$s seconds, and show that the water levels in the tank after 7.0s is $h_7 \approx 1.9703$m.

Note: $t = t_0 + n\Delta t$ for $n = 0,1,2,3,4,5,...$ while $t_0 = 0$. **[13]**

(b) Hence, or otherwise, write a Fortran 90 code that implements the Euler – Cauchy algorithm to estimate the height h of the water level every millisecond. The code should display a "tank empty" message when $h = 0$. **[12]**

Q6. The Fresnel sine integral, used in optics, is given by

$$S(u) = \int_0^u \sin\left(\frac{\pi}{2}x^2\right)dx$$

(i) Use the composite Trapezoidal rule with 10 subintervals to show, correct to 6 decimal places, that

$$S(1) = 0.438263 .$$ **[12]**

(ii) Hence, or otherwise, write a Fortran 90 code (using quad precision computations) that implements the composite Trapezoidal rule with 100000 subintervals to evaluate $S(u)$, and display the result on a screen correct to 8 decimal places. The values of the upper limit should vary in the range $0 \le u \le 8.5$ in steps of 0.1. **[13]**

– END OF PHY3032 EXAMINATION –

UNIVERSITY OF ZAMBIA

DEPARTMENT OF PHYSICS

SCHOOL OF NATURAL SCIENCES

Deferred 2017/18 Academic Year Examinations

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.

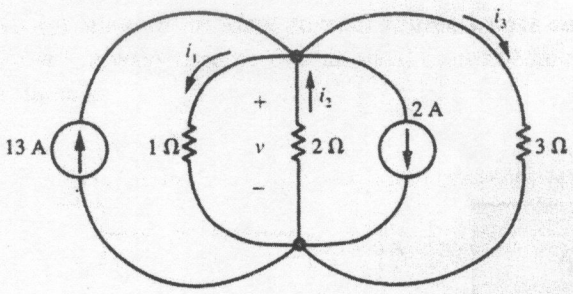
Time duration: three hours.

Some formulae that you might find useful:

$np = n_i^2$	$v = \eta V_T \ln\left(\frac{i}{I_s} + 1\right)$	$i = I_s\left(e^{v/\eta V_T} - 1\right)$	$r = \eta \frac{V_T}{I_Q}$
$V_{eff} = V_{rms} = \sqrt{\frac{1}{T}\int_0^T v(t)^2\, dt}$	$V_{av} = \frac{1}{T}\int_0^T v(t) dt$	$T = \frac{1}{\sqrt{1 + \left(\frac{1}{\omega RC}\right)^2}}$	$T = \frac{1}{\sqrt{1 + (\omega RC)^2}}$
$I_E = I_C + I_B$	$I_C = \beta I_B$	$R = \rho \frac{L}{A}$	$f(E_C) = \frac{1}{1 + e^{E_g/2K_BT}}$
$\frac{n}{N} = e^{-E_g/k_BT}$	$\sigma \approx n\mu_n q$	$\sigma \approx p\mu_p q$	$n \approx \frac{n_i^2}{N_A}$
$V_T = \frac{T}{11586}$	$\rho = \frac{1}{\sigma}$	$W = \frac{1}{2} LI^2$	$X_C = \frac{1}{\omega C}$
$f(E_C) = \frac{1}{1 + e^{E_g/2K_BT}}$	$p \approx \frac{n_i^2}{N_D}$	$r = \eta \frac{V_T}{I_Q}$	$\sigma = (n\mu_e + p\mu_h)q$

1. a) Define a dependent current or voltage source. [1]

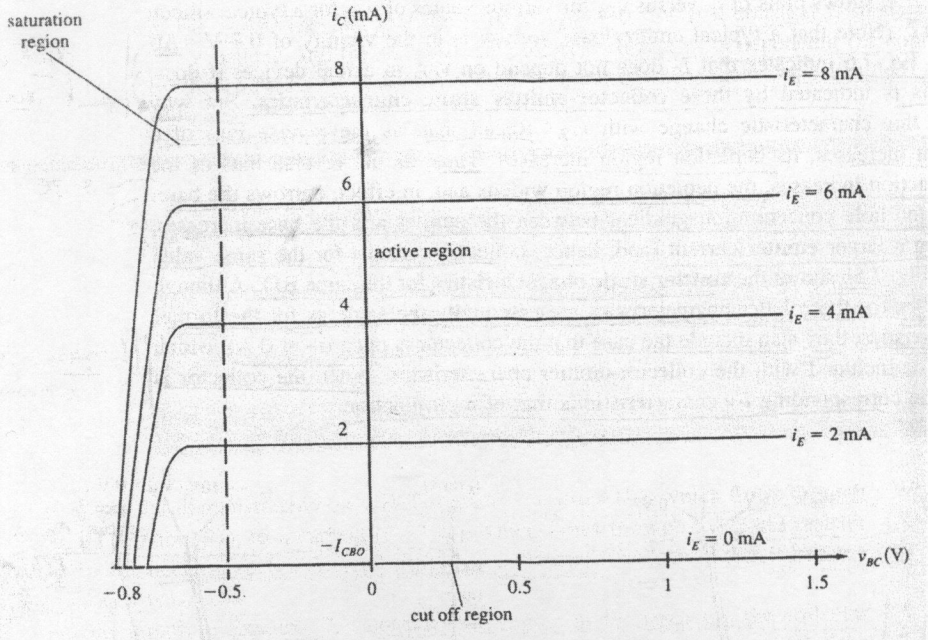
b) For the given circuit below,



(i) Find the voltage v in the two-node circuit. [3]

(ii) Find the values of currents i_1, i_2 and i_3. [3]

c) For the given common-base configuration collector static characteristics of a typical *pnp* BJT in the figure below, discuss the operation of the transistor in **active region**, **saturation region** and **cut-off region** modes in terms of voltage ranges, current ranges, forward bias and/or reverse bias that apply for each of the three cases. [9]



d)(i) A bar of silicon with intrinsic electron density 1.4 x 10^{16} electrons/m^3 is doped with impurity atoms until the hole density is 8.5 x 10^{21} holes/m^3. The mobilities of the electrons and holes are $\mu_n = 0.14$ m^2/V-s and $\mu_p = 0.05$ m^2/V-s. Find the electron density of the extrinsic material and determine whether the extrinsic material is *p*-type or *n*-type. [4]

(ii) At 300 K, the intrinsic concentration of Si is 1.5 x 10^{16} m^{-3}, the free-electron mobility is 0.13 m^2/V-s and the mobility of holes is 0.05 m^2/V-s. Find the conductivity and resistivity of this semiconductor. [5]

2. a) Why is a semiconductor referred to as bipolar while a metal is known to be unipolar? [2]

b) Using the following circuit figure,

(i) show that the instantaneous power absorbed by the load is given by [2]

$$p = \frac{R_L v_{oc}^2}{(R_o + R_L)^2},$$

(ii) prove that the maximum power is transferred to the load when

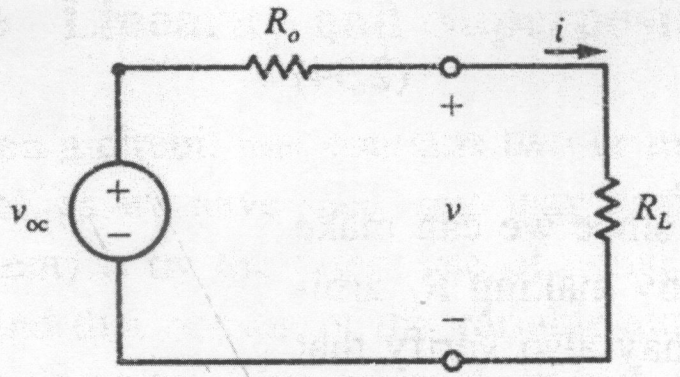
$$R_o = R_L,$$

considering the $\frac{dP}{dR_L} = 0$ condition. [6]

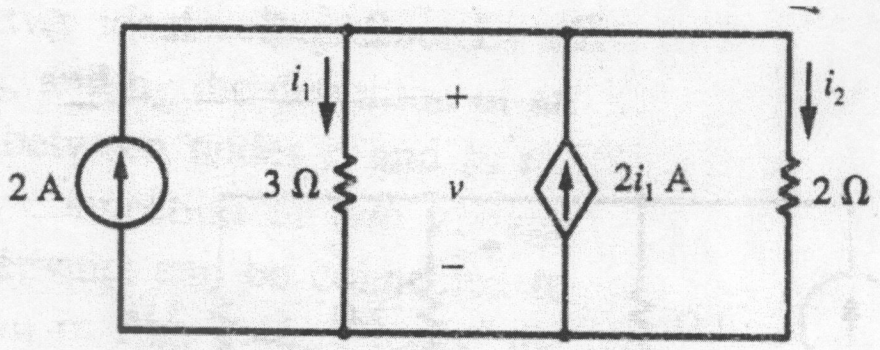
(iii) Hence, write an expression for the maximum power absorbed. [2]

(iv) Justify the fact that the expression obtained in part (iii) is actually representing the maximum power absorbed by the load, by providing a convincing argument or proof.

[1]

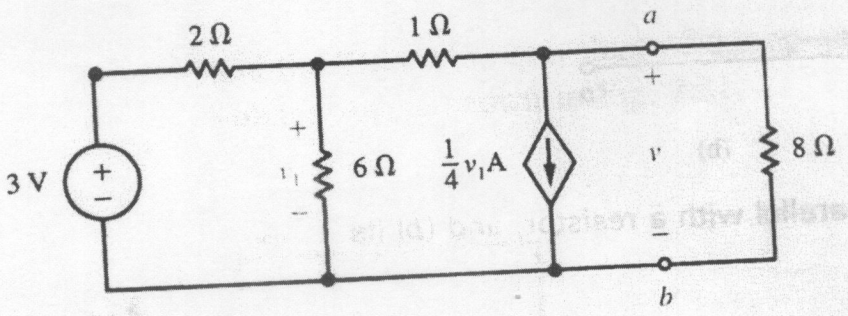


c) In the following circuit, the value of the dependent current source depends on the current i_1 through the 3-ohm resistor, the value of the dependent source is $2i_1$ with units of amperes. Find the currents i_1 and i_2, and also the value of the dependent current source. [8]



d) Draw the transistor symbols of the *npn* BJT and *pnp* BJT clearly showing the direction of the conventional current flows. [4]

3. a) For the circuit below, use Norton's Theorem to calculate the short-circuit current (i_{sc}) and the output resistance (R_o) as follows:



(i) redraw the given circuit replacing the 8-ohm 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]

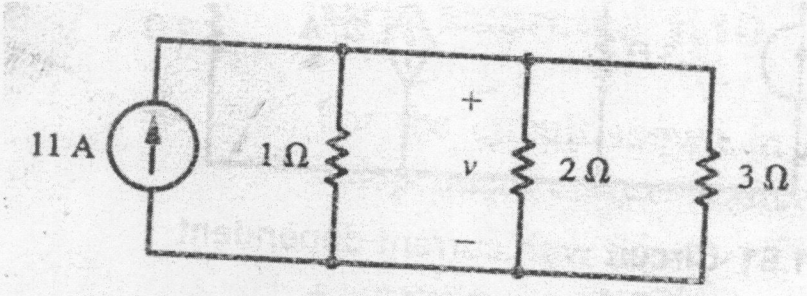
(v) apply KCL at this new node to illustrate that this $v_1 = 0.6\ v_o$. [4]

(vi) prove that the output current $(i_o) = 0.55v_o$ and then find R_o. [5]

(vii) calculate v_{oc} by effecting Thevenin's Theorem from the appropriate results above. [1]

(viii) draw both the Norton equivalent circuit and the Thevenin's equivalent circuit showing the values of each circuit element with the load resistor (R_L). [1]

d) For the circuit shown below,



(i) Determine the resistance loading the current source. [3]

(ii) What is the voltage across the 1-ohm resistor? [2]

4. a) For an intrinsic semiconductor, the position of the Fermi level on an energy-band diagram can be determined by equating n to p as follows:

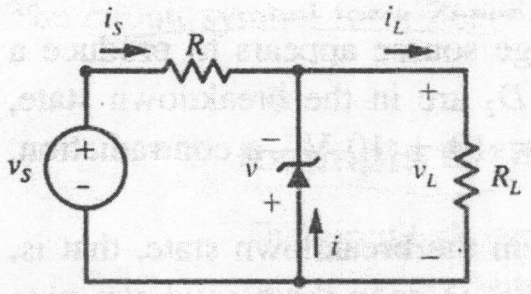
$$2\left(\frac{2\pi m_e^* k_B T}{h^2}\right)^{3/2} e^{[(E_F - E_C)/k_B T]} = 2\left(\frac{2\pi m_h^* k_B T}{h^2}\right)^{3/2} e^{[(E_V - E_F)/k_B T]}.$$

Show that

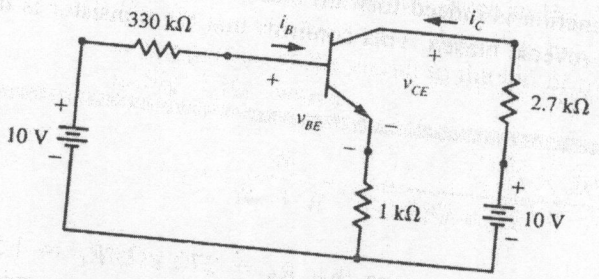
$$E_F = \frac{E_C + E_V}{2} + \frac{3}{4} ln\left(\frac{m_h^*}{m_e^*}\right)$$

[5]

b) For the voltage-regulator circuit given below, suppose that the Zener diode has a breakdown voltage of 6 V and maximum current rating of 50 mA. The supply voltage is 24 V and the series resistance is 300 Ω. Determine the range of values for R_L for which the diode will operate in the breakdown state, i.e., v = -6 V (or v_L = 6 V) and $-50 \le i \le -5$ mA. [10]



c) For the circuit shown below, assume that the *npn* BJT operates in the active region. The BJT has β = 100.



(i) What configuration is the *npn* BJT connected? [1]

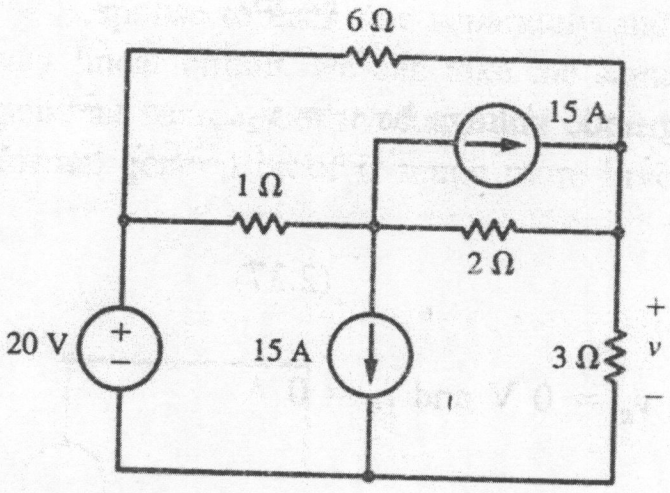
(ii) Given that v_{BE} = 0.7 V and $i_C = 100i_B$, draw the resulting model circuit by modifying the given circuit using equivalent circuit elements, showing the necessary current directions clearly. [1]

(iii) Find i_B, i_C and V_{CE}. [3 + 1 + 4]

5. a) State Thevenin's Theorem. [1]

b) State Kirchhoff's voltage law. [1]

c) (i) Find the voltage v indicated in the following circuit by employing the principle of superposition. [9]



(ii) Explain how you would treat dependent sources in each case when determining the responses due to either current sources or voltage sources of a given circuit as you apply the principle of superposition in comparison to treatment of independent sources (only) in part (i) above. [3]

d) Find the voltage v_0 for the circuit shown below where the silicon diode has a saturation current of 10 nA at 300 K as follows:

(i) Draw the *dc* equivalent circuit of the given figure. [1]

(ii) Using the graphical method or numerical method $i_{dc} = I_Q$ = 7.96 mA and $v_{dc} = V_Q$ = 0.704 V by assuming that v = 0.700 V. Sketch the graphical analysis of the diode operation showing the *i-v* characteristic curve, load line, V_γ, and the quiescent point.

By KVL, 1.5 = v_{dc} + 100i_{dc} and also $i_{dc} = I_s\left(e^{v_{dc}/\eta V_T} - 1\right)$ are the two useful equations.

[2 + 2]

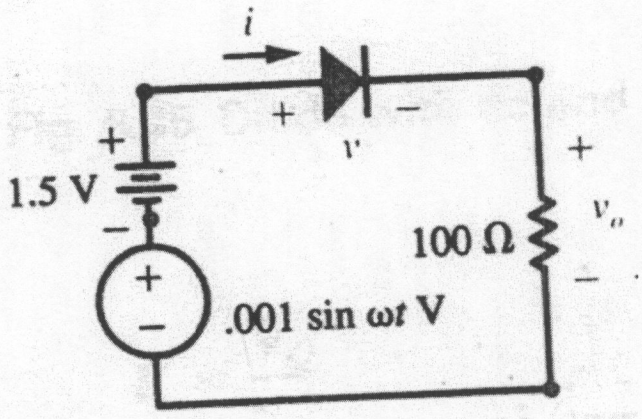
(iii) Show that, or Use the voltage divider formula to find, $v_{o(dc)} = 0.796$ V. [2]

(iv) Draw the *ac* equivalent circuit for the given figure. [1]

(v) Find r, the dynamic or *ac* resistance. [1]

(vi) Find $v_{o(ac)}$. [1]

(v) Write the expression for v_o. [1]



6. a) What are the other two configurations in which a transistor may be connected in a circuit besides that common-collector configuration? [2]

b) To compare the sine-wave current with a direct current, the joule heat produced in a resistor is considered. Given that *ac* current and *ac* voltage are

$$i = I_p \sin(wt) \text{ and}$$

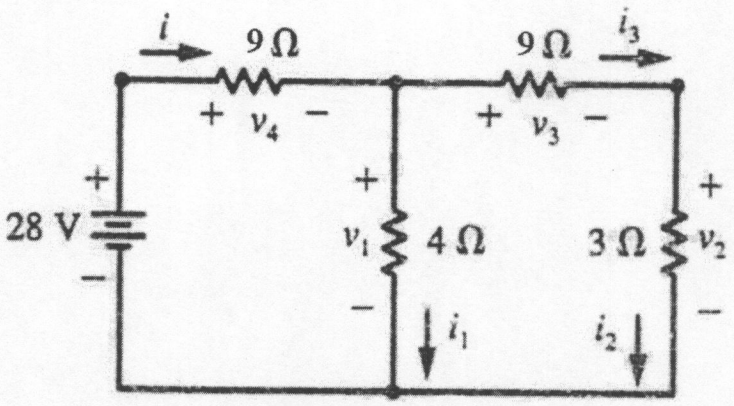
$$v = V_p \sin(wt + \phi)$$

where I_p and V_p are the maximum or peak amplitude values, and ϕ is the phase difference, the average power calculated by averaging the IR losses over a complete cycle is

$$P_{av} = \frac{I_p^2 R}{2}.$$

Find an expression for the effective value, or *rms* value, of an alternating current by comparing the average power above with the joule heating in a resistor given by *dc* $I^2 R$. [4]

c) For the circuit shown below,



(i) apply Kirchhoff's current law, Ohm's law, Kirchhoff's voltage law at respective circuit points to write necessary expression of the labelled current and voltages to show that $v_2 = 1.75$ V, [10]

(ii) use the voltage-divider formula to find v_1. [5]

(ii) calculate i_1, and [1]

(ii) apply the current-divider formula to find i. [3]

END

THE UNIVERSITY OF ZAMBIA

DEPARTMENT OF PHYSICS

SCHOOL OF NATURAL SCIENCE

2018 Mid-Year University Examinations

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:

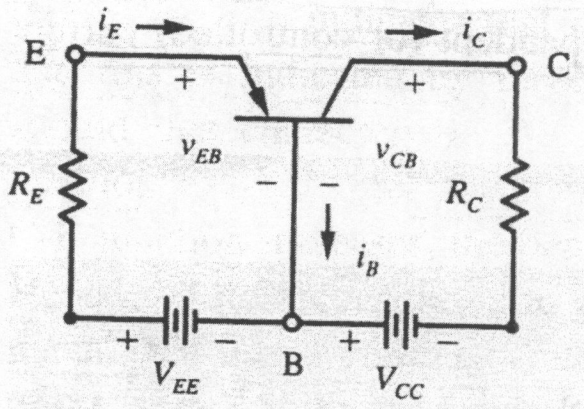
$np = n_i^2$	$v = \eta V_T \ln\left(\frac{i}{I_s} + 1\right)$	$i = I_s\left(e^{v/\eta V_T} - 1\right)$	$r = \eta \frac{V_T}{I_Q}$
$V_{eff} = V_{rms} = \sqrt{\frac{1}{T}\int_0^T v(t)^2\, dt}$	$V_{av} = \frac{1}{T}\int_0^T v(t) dt$	$T = \frac{1}{\sqrt{1 + \left(\frac{1}{\omega RC}\right)^2}}$	$T = \frac{1}{\sqrt{1 + (\omega RC)^2}}$
$I_E = I_C + I_B$	$I_C = \beta I_B$	$R = \rho \frac{L}{A}$	$f(E_C) = \frac{1}{1 + e^{E_g/2K_BT}}$
$\frac{n}{N} = e^{-E_g/k_BT}$	$\sigma \approx n\mu_n q$	$\sigma \approx p\mu_p q$	$n \approx \frac{n_i^2}{N_A}$
$V_T = \frac{T}{11586}$	$\rho = \frac{1}{\sigma}$	$W = \frac{1}{2} LI^2$	$X_C = \frac{1}{\omega C}$
$f(E_C) = \frac{1}{1 + e^{E_g/2K_BT}}$	$p \approx \frac{n_i^2}{N_D}$	$r = \eta \frac{V_T}{I_Q}$	$\sigma = (n\mu_e + p\mu_h)$

1. a) State Kirchhoff's current law. [1]

b) The circuit shown below has a silicon *pnp* bipolar junction transistor (BJT). Given that $R_E = 500\ \Omega$, $R_C = 1.2\ \text{k}\Omega$, $V_{EE} = 3$ V and $V_{CC} = 6$ V, analyse this circuit to confirm that the BJT is biased (i.e., operating) in the active region. The two approximations for the mode operation are $v_{EB} = 0.7$ V (i.e., the E-B junction is forward biased) while

$$i_C = \alpha i_E$$

where $\alpha \sim 1$ (i.e., the C-B junction is reverse biased).



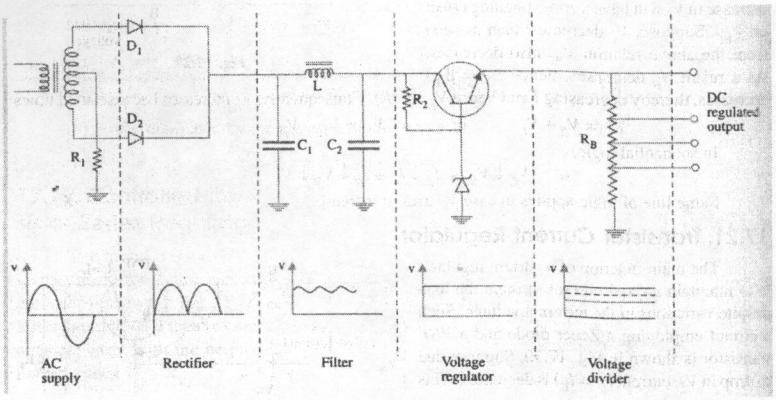
(i) Apply Kirchhoff's voltage law (KVL) around the loop on the left to show that $i_E = 4.6$ mA. [3]

(ii) Apply KVL around the loop on the right to find v_{CB}. [4]

(iii) Assuming that the cut-in voltage for typical silicon is $V\gamma = 0.5$ V, use the results in parts (i) and (ii) above to explain that they confirm this BJT as operating in active region. [2]

(iv) Draw the model circuit of the given circuit that shows the behavior of the BJT. [3]

c) The figure below shows a design of a complete power supply circuit.



(i) What is the type of rectifier in this circuit? [1]

(ii) Name the filter shown and also explain what each electric element (i.e., C_1, L and C_2) does to the rectified signal. [1 + 5]

(iii) Draw a typical *i-v* characteristic curve for a Zener diode and then discuss how it is used for voltage regulation in the given power supply circuit. [5]

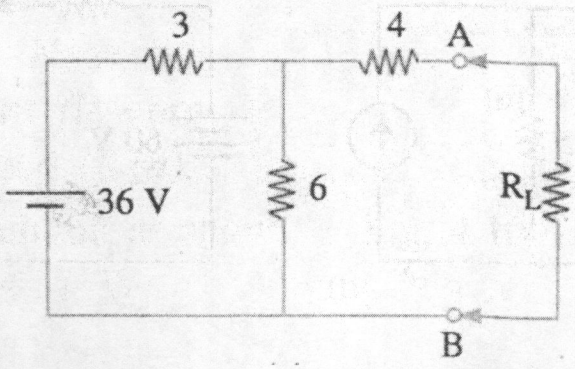
2. a) What are the other two configurations in which a transistor may be connected in a circuit besides that common-collector configuration? [2]

b) For the circuit given below,

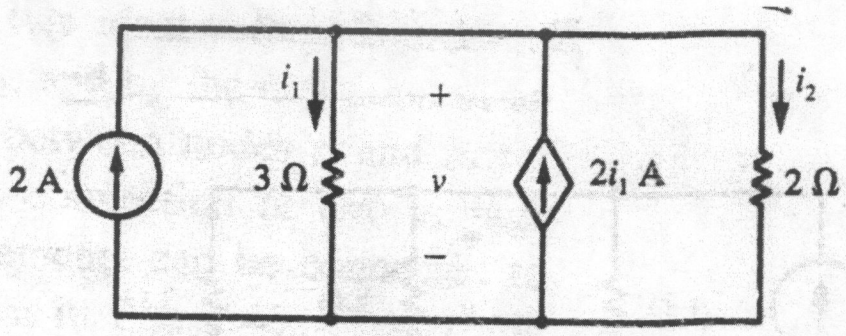
(i) draw a circuit that would enable you to perform the maximum power transfer theorem calculations, [1]

(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) evaluate the value of this maximum power transferred to the load resistance. [6]



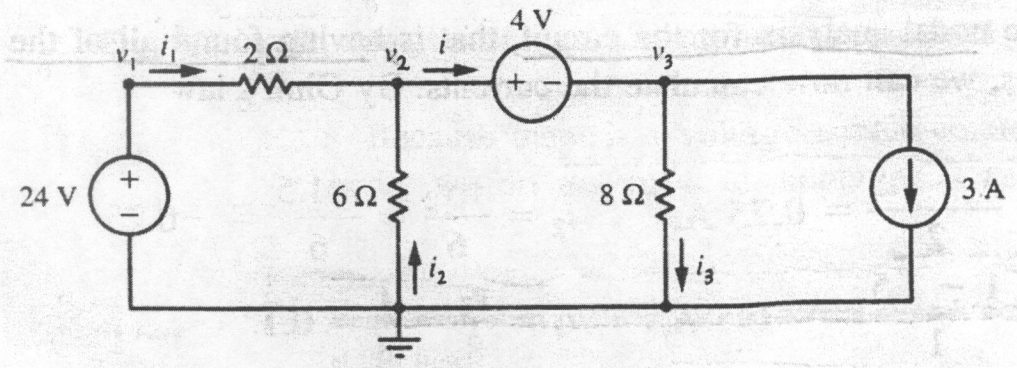
c) In the following circuit, the value of the dependent current source depends on the current i_1 through the 3-Ω resistor, the value of the dependent source is $2i_1$ with units of amperes. Find the currents i_1 and i_2, and also the value of the dependent current source. [8]



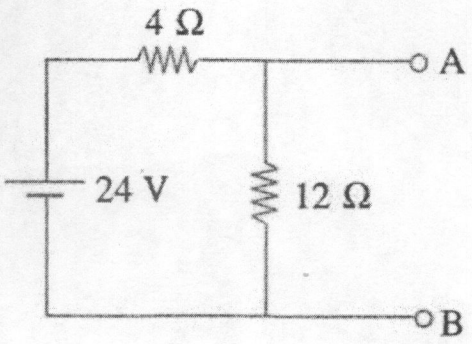
d) Draw the transistor symbols of the *npn* BJT and *pnp* BJT clearly showing the direction of the conventional current flows. [4]

3. a) State Norton's Theorem. [1]

b) For the circuit shown below, the 4 V source is connected between two nonreference nodes. Find the node voltages and the labelled currents. [19]



c) For the circuit shown below,



Determine

(i) the current I_N, and also [2]

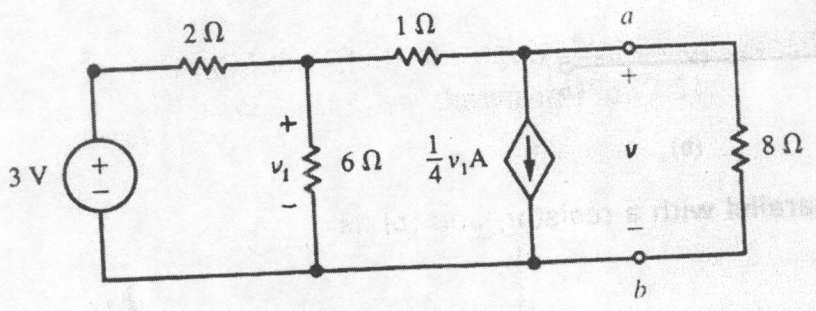
(ii) the resistance R_N [3]

using the Norton theorem.

4. a) State Kirchhoff's voltage law. [1]

b) At 300 K, the intrinsic concentration of silicon is 1.5×10^{16} m^{-3}, the free-electron mobility is 0.13 m^2/V-s and the mobility of holes is 0.05 m^2/V-s. Find the conductivity and resistivity of this semiconductor. [4]

c) For the circuit below, use Norton's Theorem to calculate the short-circuit current (i_{sc}) and the output resistance (R_o) as follows:



(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]

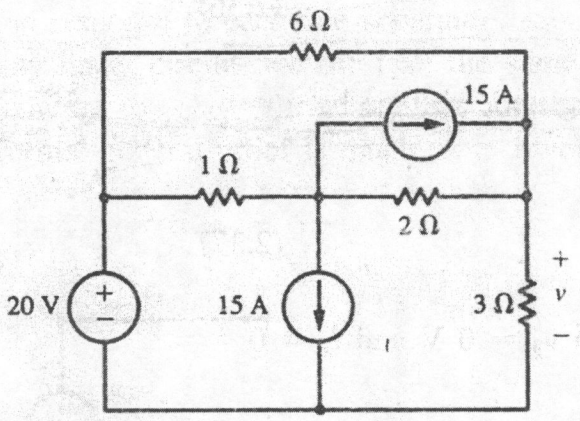
(vi) prove that the output current $(i_o) = 0.55v_o$ and then find R_o. [5]

(vii) calculate v_{oc} by effecting Thevenin's Theorem from the appropriate results above. [1]

(viii) draw both the Norton equivalent circuit and the Thevenin's equivalent circuit showing the values of each circuit element with the load resistor (R_L). [1]

5. a) State Thevenin's Theorem. [1]

b) Use the principle of superposition to analyse the following circuit.



(i) Compute the value of response to the top or upper independent current source of 15 A, labeling it v_{t15A}. [9]

(ii) Given that the response to the 20 V independent voltage source is $v_{20V} = 12$ V and of the bottom 15 A current source is $i_{b15A} = -6$ V, show that the total response voltage across the 3Ω resistor is $v = 18$ V by the effecting the superposition principle. [2]

(iii) Compare how you would treat both dependent sources and independent sources when determining the response due to either an independent current or voltage source of a given circuit as you apply the principle of superposition. [2]

c) Find the voltage v_0 for the circuit shown below where the germanium diode has a saturation current of 10 nA at 300 K as follows:

(i) Draw the *dc* equivalent circuit of the given figure.

(ii) Using the graphical method or numerical method $i_{dc} = I_Q = 7.96$ mA and $v_{dc} = V_Q = 0.704$ V by assuming that $v = 0.700$ V. Sketch the graphical analysis of the diode operation showing the *i-v* characteristic curve, load line, V_γ, and the quiescent point. By KVL, $1.5 = v_{dc} + 100 i_{dc}$ and also $i_{dc} = I_s\left(e^{v_{dc}/\eta V_T} - 1\right)$ are the two useful equations.

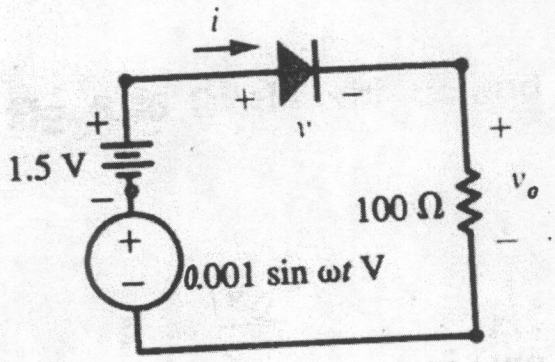
(iii) Show that, or Use the voltage divider formula to find, $v_{o(dc)} = 0.796$ V.

(iv) Draw the *ac* equivalent circuit for the given figure.

(v) Find r, the dynamic or *ac* resistance.

(vi) Find $v_{o(ac)}$.

(v) Write the expression for v_o. [11]



6. a) Why is a semiconductor referred to as bipolar while a metal is known to be unipolar? [2]

b) To compare the sine-wave current with a direct current, the joule heat produced in a resistor is considered. Given that *ac* current and voltage are

$$i = I_p \sin(wt) \text{ and}$$

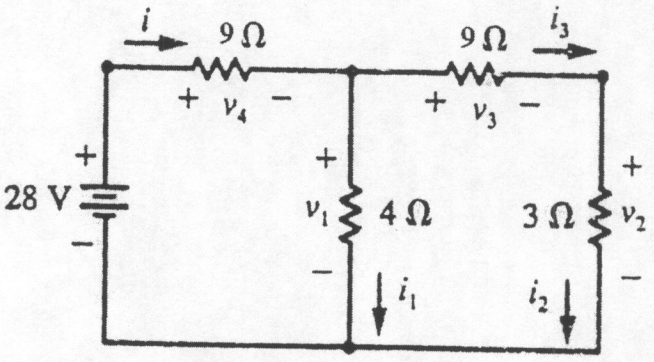
$$v = V_p \sin(wt + \phi)$$

where I_p and V_p are the maximum or peak amplitude values, and ϕ is the phase difference, the average power calculated by averaging the IR losses over a complete cycle is

$$P_{av} = \frac{I_p^2 R}{2}.$$

Find the expression for the effective value, or *rms* value, of an alternating current by comparing the average power above with the joule heating in a resistor by *dc* I^2R. [4]

c) For the circuit shown below,



(i) apply Kirchhoff's current law, Ohm's law, Kirchhoff's voltage law at respective circuit points to write necessary expression of the labelled current and voltages to show that $v_2 = 1.75$ V, [10]

(ii) use the voltage-divider formula to find v_1. [3]

(iii) calculate i_1, and [3]

(iv) apply the current-divider formula to find i. [3]

END

UNIVERSITY OF ZAMBIA
DEPARTMENT OF PHYSICS
UNIVERSITY EXAMINATIONS
2017/18

PHY3531: INTRODUCTION TO QUANTUM MECHANICS

TIME: THREE HOURS
ANSWER: ANY FOUR QUESTIONS
ALL QUESTIONS CARRY EQUAL MARKS
TOTAL MARKS: 100

Useful information

$$j = \frac{\hbar}{2mi}(\Psi^* \frac{d}{dx}\Psi - \Psi \frac{d}{dx}\Psi^*), \quad \int_{-\infty}^{\infty} e^{-x^2} dx = \sqrt{\pi}$$

$$[AB, C] = A[B, C] + [A, C]B$$

$$[A, BC] = B[A, C] + [A, B]C$$

$[L_i, L_j] = i\hbar L_k$ with i, j and k taken in cyclical order

$$\int \psi^* A\phi dV = \int (A\psi)^* \phi dV$$

$$dV = \sin\theta d\theta d\phi$$

1. (**a**) (**i**) Interpret the wave function $\Psi(\mathbf{r}, t)$ and give the mathematical property of the wave function which follows from this interpretation.[3marks]

(**b**) Explain why the following functions are not acceptable wave functions:

(**i**) $\Psi(x,t) = A\sqrt{\sin x}e^{-i\omega t}$ [2 marks]

[2 marks]

(**ii**) $\Psi(x,t) = A\cot x e^{-i\omega t}$ [2 marks]

(**iii**) $\Psi(x,t) = Ae^{x^2}e^{-i\omega t}$ [2 marks]

(**c**) Prove that if the potential energy acting on a particle is independent of time, the time-dependent Schroedinger equation

$$-\frac{\hbar^2}{2m}\nabla^2\Psi(\mathbf{r},t) + V(\mathbf{r})\Psi(\mathbf{r},t) = i\hbar\frac{\partial}{\partial t}\Psi(\mathbf{r},t)$$

separates into two equations. [7 marks]

(**ii**) Show that in such a case the wave function has the form

$$\Psi(\mathbf{r},t) = \psi(\mathbf{r})e^{-i\omega t}$$

[[3 marks]

(**iii**) Show that for such a potential, the probability density is time-independent. [2 mark]

2. (**a**) A particle with energy E is trapped in a cube of dimension L so that the potential has the form

$$V(x,y) = \begin{cases} \infty & \text{for } x < 0 \text{ and } y < 0 \\ 0, & \text{for } 0 \le x \le L \text{ and } 0 \le y \le L \\ \infty & \text{for } x > L \text{ and } y > L \end{cases}$$

(**i**) Sketch the potential in both the x and y directions. [2 marks]

(**ii**) Explain why the Hamiltonian of the particle inside the box is

$$H = -\frac{\hbar^2}{2m}\frac{\partial^2}{\partial x^2} - \frac{\hbar^2}{2m}\frac{\partial^2}{\partial y^2}$$

. [2 marks]

(**iii**) Show that the normalised eigenfunctions of the particle are given by

$$\psi_{n_x n_y}(x,y) = \frac{2}{L}\sin\frac{n_x\pi x}{L}\sin\frac{n_y\pi y}{L} \quad \text{where } n_x, n_y = 1, 2, 3, ...$$

and that the energy eigenvalues are

$$E_{n_x n_y} = \frac{\pi^2 \hbar^2}{2mL^2} \left(n_x^2 + n_y^2\right)$$

[17 marks]

(**iv**) Explain why the eigenfunctions are sometimes degenerate and determine the degree of degeneracy of the first excited state. [2marks]

(**v**) Write down the degenerate eigenfunctions for the first excited state. [2marks]

3. (**a**) (**i**) Prove that the operator

$$H = -\frac{\hbar^2}{2m} \frac{d^2}{dx^2}$$

is linear and Hermitian. Assume that the functions on which it acts vanish at $\pm\infty$. [6 marks]

(**ii**) Show that the expectation value of a dynamical variable represented by a Hermitian operator is real and hence explain why such operators are important in quantum mechanics [4 marks]

(**iii**) Prove that if two operators commute, they have simultaneous eigenfunctions. [4marks]

(**b**) (**i**) Prove that the eigenfunctions of a Hermitian operator corresponding to different eigenvalues are orthogonal if the spectrum is nondegenerate. [4 marks]

(**ii**) Write down the eigenvalues of

$$Y_{00}(\theta, \phi) = \frac{1}{\sqrt{4\pi}}$$

and

$$Y_{2,-2}(\theta, \phi) = \sqrt{\frac{15}{16\pi}} \sin^2 \theta e^{-2i\phi}$$

remembering that the functions are eigenfunctions of L^2 and L_z [2 marks

(**iii**) Prove that the eigenfunctions are orthogonal. [5 marks]

4. The ladder operators for the one-dimensional harmonic oscillator are

$$a_+ = \frac{\widehat{p}_x}{(2m\hbar\omega)^{1/2}} + i\left(\frac{m\omega}{2\hbar}\right)^{1/2}\widehat{x}$$

and

$$a_- = \frac{\widehat{p}_x}{(2m\hbar\omega)^{1/2}} - i\left(\frac{m\omega}{2\hbar}\right)^{1/2}\widehat{x}$$

and they obey the commutation relation $[a_-, a_+] = 1$. In terms of these operators, the Hamiltonian is

$$H = \frac{\hbar\omega}{2}\left(a_+a_- + a_-a_+\right)$$

(**i**) Show that the Hamiltonian can also be written as

$$H = \hbar\omega\left(a_+a_- + \frac{1}{2}\right)$$

and

$$H = \hbar\omega\left(a_-a_+ - \frac{1}{2}\right)$$

. [4 marks]

(**ii**) Show that the commutators of the ladder operators with the Hamiltonian are

$$[H, a_+] = \hbar\omega a_+$$

and

$$[H, a_-] = -\hbar\omega a_-$$

. [4 marks]

(**iii**) Hence show that a_+ converts an eigenfunction of the harmonic oscillator into the one for the next higher energy and a_- converts it into the one for the next lower energy. [4 marks]

(**iv**) Explain why there is a ground-state eigenfunction and why it satisfies the differential equation

$$\frac{1}{\sqrt{2}}\left(-\frac{i\hbar}{(m\hbar\omega)^{1/2}}\frac{d}{dx} - i\left(\frac{m\omega}{\hbar}\right)^{1/2}x\right)\psi_0 = 0$$

. [4 marks]

(**v**) Show that the function $\psi_0 = A\exp\left(-m\omega x^2/2\hbar\right)$ satisfies this equation [4 marks]

(vi) Given that the ground-state eigenfunction for the harmonic oscillator has the form

$$\psi_1 = A_0 \exp\left(-m\omega x^2/2\hbar\right)$$

where A_0 is a constant, obtain the unnormalised the first-excited state eigenfunction. [3marks]

(viii) Write down the Hermite polynomials $H_n(\xi)$ corresponding to $n = 0$ and $n = 1$. [2 marks]

5.(a) A particle of mass m incident from the left encounters a potential of the form

$$\begin{aligned} V(x) &= 0, \quad x \leq 0 \quad \text{(Region I)} \\ &= V_1, \; 0 \leq x \leq a \quad \text{(Region II)} \\ &= V_2, \quad x \geq a \quad \text{(Region III)} \end{aligned}$$

The energy of the particle is such that $E > V_2$ while $V_2 > V_1$.

(i) Sketch the potential. [2 marks]

(ii) Show that in the three regions the eigenfunction takes the following forms:

$$\psi_I(x) = Ae^{ikx} + Be^{-ikx}, \quad k = \sqrt{\frac{2mE}{\hbar^2}} \quad \text{(Region I)}$$

$$\psi_{II}(x) = Ce^{iqx} + De^{-iqx}, \quad q = \sqrt{\frac{2m\left(E - V_1\right)}{\hbar^2}} \quad \text{(Region II)}$$

$$\psi_{III}(x) = Fe^{i\lambda x}, \quad \lambda = \sqrt{\frac{2m\left(E - V_2\right)}{\hbar^2}} \quad \text{(Region III)}$$

[10 marks]

(iii) Interpret each of the terms in the expressions above. [3 marks]

(iv) Show that the reflection and transmission coefficients R and T are given by

$$R = \left|\frac{B}{A}\right|^2 \quad \text{and} \quad T = \frac{\lambda}{k}\left|\frac{F}{A}\right|^2$$

[4 marks]

(v) Justify and write down the equations that would be used to determine B and F in terms of A. Do not attempt to solve for B and F. [6 marks]

(vi) Explain how the behaviour of the particles differs from that in the classical case. [2 marks]

6. (**a**) (**i**) Show that the Cartesian components of the angular momentum operator $\mathbf{L} = -i\hbar\mathbf{r} \times \nabla$ are

$$L_x = -i\hbar\left(y\frac{\partial}{\partial z} - z\frac{\partial}{\partial y}\right), \quad L_y = -i\hbar\left(z\frac{\partial}{\partial x} - x\frac{\partial}{\partial z}\right), \quad L_z = -i\hbar\left(x\frac{\partial}{\partial y} - y\frac{\partial}{\partial x}\right)$$

[4 marks]

(**ii**) Given that $L^2 = L_x^2 + L_y^2 + L_z^2$ and that the commutation relations for the components of $\mathbf{L}$ are

$$[L_i, L_j] = i\hbar L_k, \qquad (i, j, k) \text{ in cyclical order,}$$

show that $[L^2, L_z] = 0$. [4 marks]

(**iii**) Explain the importance of the result in (**ii**). [2 marks]

(**b**) The operators for the components of the angular momentum $\mathbf{L}$ in spherical polar coordinates are

$$L_x = i\hbar\left(\sin\varphi\frac{\partial}{\partial\theta} + \cot\theta\cos\varphi\frac{\partial}{\partial\phi}\right),$$

$$L_y = i\hbar\left(-\cos\varphi\frac{\partial}{\partial\theta} + \cot\theta\sin\varphi\frac{\partial}{\partial\phi}\right)$$

and

$$L_z = -i\hbar\frac{\partial}{\partial\phi}$$

(**i**) Show that the ladder operators $L_\pm = L_x \pm iL_y$ are given by

$$L_+ = \hbar e^{+i\phi}\left(\frac{\partial}{\partial\theta} + i\cot\theta\frac{\partial}{\partial\phi}\right)$$

$$L_- = \hbar e^{-i\phi}\left(-\frac{\partial}{\partial\theta} + i\cot\theta\frac{\partial}{\partial\phi}\right)$$

[6 marks]

(**ii**) Given that

$$Y_{10}(\theta, \phi) = A_0\cos\theta$$

show that the unnormalised forms of $Y_{11}(\theta, \phi)$ and $Y_{1-1}(\theta, \phi$ are

$$Y_{1,-1}(\theta, \phi) = A_{-1}\sin\theta e^{-i\phi}$$

and

$$Y_{11}(\theta, \phi) = A_{11} \sin\theta e^{i\phi}$$

[6 marks]

(iii) Show that the three functions $Y_{10}(\theta, \phi)$ and $Y_{1\pm1}(\theta, \phi)$ are eigenfunctions of L_z with respective eigenvalues 0, $\pm\hbar$. [3 marks]

END OF EXAMINATION

UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
DEPARTMENT OF PHYSICS
MID-YEAR EXAMINATION
2017/2018 ACADEMIC YEAR

PHY4021
MATHEMATICAL METHODS FOR PHYSICS

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:	Saturday, 7th July 2018.

Formulae that may be needed:

1.
$$u_x = v_y, \quad u_y = -v_x, \quad u_r = \frac{v_\theta}{r}, \quad v_r = -\frac{u_\theta}{r}$$

2.
$$\frac{1}{1-q} = \sum_{m=0}^{\infty} q^m = 1 + q + q^2 + \ldots, \quad |q| < 1$$

3. Integration by use of the path:
$$\int_C f(z)\, dz = \int_a^b f[z(t)]\dot{z}(t)\, dt.$$

4. Cauchy's integral formula:
$$\oint_C \frac{f(z)}{z - z_0}\, dz = 2\pi i f(z_0).$$

5.
$$f^{(n)}(z_0) = \frac{n!}{2\pi i} \oint_C \frac{f(z)}{(z - z_0)^{n+1}}\, dz, \qquad (n = 1, 2, \ldots)$$

6.
$$\sum_{m=0}^{\infty} q^m = 1 + q + q^2 + \ldots = \frac{1}{1-q}, \quad |q| < 1$$

7.

$$\left|\frac{z_{n+1}}{z_n}\right| \leq q < 1, \quad \text{for } n \text{ greater than some } N$$

8.

$$\lim_{n\to\infty}\left|\frac{z_{n+1}}{z_n}\right| = L.$$

9.

$$\sqrt[n]{|z_n|} \leq q < 1, \quad \text{for } n \text{ greater than some } N$$

10.

$$\lim_{n\to\infty}\sqrt[n]{|z_n|} = L$$

11.

$$\begin{aligned} R &= \frac{1}{L^*}, \quad L^* = \lim_{n\to\infty}\left|\frac{a_{n+1}}{a_n}\right| \\ R &= \frac{1}{\tilde{L}}, \quad \tilde{L} = \lim_{n\to\infty}\sqrt[n]{|a_n|} \\ R &= \frac{1}{\tilde{l}}, \quad \tilde{l} = \text{largest limit of } \lim_{n\to\infty}\sqrt[n]{|a_n|} \end{aligned}$$

12.

$$e^z = \sum_{n=0}^{\infty}\frac{z^n}{n!} = 1 + z + \frac{z^2}{2!} + \ldots.$$

13.

$$\begin{aligned} \cos z &= \sum_{n=0}^{\infty}(-1)^n\frac{z^{2n}}{(2n)!} = 1 - \frac{z^2}{2!} + \frac{z^4}{4!} - + \ldots \\ \sin z &= \sum_{n=0}^{\infty}(-1)^n\frac{z^{2n+1}}{(2n+1)!} = z - \frac{z^3}{3!} + \frac{z^5}{5!} - + \ldots \end{aligned}$$

14.

$$\begin{aligned} \cosh z &= \sum_{n=0}^{\infty}\frac{z^{2n}}{(2n)!} = 1 + \frac{z^2}{2!} + \frac{z^4}{4!} + \ldots \\ \sinh z &= \sum_{n=0}^{\infty}\frac{z^{2n+1}}{(2n+1)!} = \frac{z}{1!} + \frac{z^3}{3!} + \frac{z^5}{5!} + \ldots \end{aligned}$$

15.

$$f(z) = \sum_{n=0}^{\infty}a_n(z-z_0)^n + \sum_{n=1}^{\infty}\frac{b_n}{(z-z_0)^n}$$

16.

$$(\cosh z)' = \sinh z, \quad (\sinh z)' = \cosh z$$

17.

$$\cosh iz = \cos z, \quad \sinh iz = i\sin z, \quad \cos iz = \cosh z, \quad \sin iz = i\sinh z$$

18.

$$\operatorname*{Res}_{z=z_0} f(z) = \lim_{z\to z_0}(z-z_0)f(z)$$

19.

$$\operatorname*{Res}_{z=z_0}\frac{p(z)}{q(z)} = \frac{p(z_0)}{q'(z_0)}$$

20.

$$\operatorname*{Res}_{z=z_0} f(z) = \frac{1}{(m-1)!} \lim_{z \to z_0} \left\{ \frac{d^{m-1}}{dz^{m-1}} [(z-z_0)^m f(z)] \right\}$$

21.

$$\oint_C f(z)\, dz = 2\pi i \sum_{j=1}^{k} \operatorname*{Res}_{z=z_j} f(z)$$

22. Integrals of rational trigonometric functions of $\sin\theta$ and $\cos\theta$ (integration taken counterclockwise)

$$\int_C f(z)\, \frac{dz}{iz} = 2\pi i \sum_{j=1}^{k} \operatorname*{Res}_{z=z_j} \left[\frac{f(z)}{iz} \right]_{z=z_0}, \qquad C: \ |z| = 1$$

where $f(z)$ is obtained from $f(\cos\theta, \sin\theta)$ by the substitutions

$$\cos\theta = \frac{1}{2}\left(z + \frac{1}{z}\right), \qquad \sin\theta = \frac{1}{2i}\left(z - \frac{1}{z}\right)$$

23. Improper integrals of rational functions:

$$\int_{-\infty}^{\infty} f(x)\, dx = 2\pi i \sum \operatorname{Res} f(z)$$

24.

$$e^z = \sum_{n=0}^{\infty} \frac{z^n}{n!}, \qquad \cos z = \sum_{n=0}^{\infty} (-1)^n \frac{z^{2n}}{(2n)!}, \qquad \sin z = \sum_{n=0}^{\infty} (-1)^n \frac{z^{2n+1}}{(2n+1)!}$$

25. The roots of the quadratic equation

$$ax^2 + bx + c = 0$$

are given by

$$\frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

26.

$$y(x) = \sum_{n=0}^{\infty} a_n x^n$$

27.

$$A^{-1} = \frac{1}{\det A} \begin{bmatrix} a_{22} & -a_{12} \\ -a_{21} & a_{11} \end{bmatrix}$$

28.

$$\int_a^b u \frac{dv}{dx}\, dx = [uv]_a^b - \int_a^b \frac{du}{dx} v\, dx$$

29. Euler-Lagrange equation for $F(y, \dot{y}, x)$

$$\frac{\partial F}{\partial y} - \frac{d}{dx}\left(\frac{\partial F}{\partial \dot{y}}\right) = 0$$

QUESTION 1

(a) Define the following terms: An open set, a connected set, and a domain. Give two examples of a set which is not connected. (7 marks)

(b) Give the condition for a complex function to have a limit at a point z, i.e., define the limit of a complex function. Include a diagram. (4 marks)

(c) Give the definition of the derivative of a complex function. (3 marks)

(d) Using the definition of differentiation of a complex function, determine whether or not the function $f(z) = \overline{z} + 2z^2 + 3z$ is differentiable. (11 marks)

QUESTION 2

(a) Use the ratio test to determine whether or not the series below converges, then check your answer with the root test. Try the 'limit' form of the tests first. If these fail then try the more general form of the tests. If a particular test fails, state so clearly.

$$\sum_{n=1}^{\infty} \frac{(2i)^n n!}{n^n}.$$

(6 marks)

(b) Find the center and radius of convergence of the power series

$$\sum_{n=0}^{\infty} \frac{3n+4}{2^n}(z-2-i)^n.$$

Use any two of the three formulae to find R. At least one of the methods used must not fail.

(10 marks)

(c) Find the radius of convergence of the series

$$\sum_{n=0}^{\infty} \frac{1}{(1-i)^n}(z-i)^n,$$

and of its derived series by some test, thereby verifying that they are equal. Give the centers of the two series. (9 marks)

QUESTION 3

(a) Explain when a Laurent series is to be used instead of a power series and give the form of the region in which it applies. Define the term *residue*.

(5 marks)

(b) Evaluate the residues at the singular points that lie inside the circle $|z| = 1.5$ of the following function

$$f(z) = \frac{z - \frac{1}{4}}{z^2 + 3z + 2}.$$

(12 marks)

(c) Evaluate the following integral by the residue method

$$\oint_C \frac{\cosh z}{z^2 - 3iz}\, dz,$$

where C is the unit circle counter clockwise. (8 marks)

QUESTION 4

(a) Use Gauss elimination to solve

$$\begin{aligned} w + x + y &= 3 \\ -3w - 17x + y + 2z &= 1 \\ 4w - 17x + 8y - 5z &= 1 \\ -5x - 2y + z &= 1 \end{aligned}$$

(11 marks)

(b) Find the eigenvalues and eigenfunctions of the matrix

$$A = \begin{bmatrix} 8 & -4 \\ 2 & 2 \end{bmatrix}.$$

(14 marks)

QUESTION 5

(a) Solve the differential equation

$$(x+1)y' - (2x+3)y = 0$$

by the power series method. (18 marks)

(b) Prove that your series solution of part (a) can be written in the form

$$y = a_0(x+1)e^{2x}.$$

(7 marks)

QUESTION 6

(a) Beginning with the functional

$$I = \int_a^b F[y(x), \dot{y}(x), x]\, dx,$$

derive the Euler-Lagrange equation. (20 marks)

(b) Determine the Euler-Lagrange equation when F does not depend on y, i.e., when $F = F[\dot{y}(x), x]$. (5 marks)

END

The University of Zambia

School of Natural Sciences
Department of Physics
2017/18 Academic Year
Mid-Year University Examinations
PHY4031: Computational Physics II

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.

Wherever necessary, include appropriate comment when writing programs.

SOME USEFUL PHYSICAL CONSTANTS

Acceleration due to gravity, $g = 9.81\ \text{ms}^{-2}$	Universal gas constant, $R = 8.314\ \text{Jmol}^{-1}\text{K}^{-1}$
Density of mercury, $\rho_{\text{mercury}} = 13600\ \text{kg/m}^3$	Density of water, $\rho_{\text{water}} = 1000\ \text{kg/m}^3$
Newton's Gravitation Constant, $G = 6.674\times10^{-11}\ \text{m}^3\text{kg}^{-1}\text{s}^{-2}$	Stefan Boltzmann constant, $\sigma = 5.672\times10^{-8}\ \text{Wm}^{-2}\text{K}^{-4}$
Planck's constant $h = 6.6261\times10^{-34}\ \text{J.s}$	Boltzmann's constant $k = 1.38066\times10^{-23}\ \text{J/K}$
Speed of light in vacuum $c = 2.9979\times10^{8}\ \text{m/s}$	Specific heat capacity of water at 20°C is $c_w = 4184\ \text{Jkg}^{-1}\text{K}^{-1}$

Q1. **(a)** Gamma ray spectroscopy can be done using a Sodium Iodide detector with a multichannel analyser. In one experiment, data in table 2 was collected.

Table 1: **Data of Channel Number and corresponding Counts per Channel for** ^{137}Cs.

Channel Number	Counts per channel
64	80
65	120
66	170
67	225
68	270
69	290
70	300
71	290
72	220
74	130
75	70
79	10

Given that the data in table 2 is saved in an input file called *spectroscopy.txt*, write a Fortran 90 code that can use the *iostat* Fortran 90 intrinsic function to automatically count and read the total number of data sets, $N_{\max}$, in *spectroscopy.txt* with capabilities of error detection in the data. **[10]**

(b) Consider a continuous time dependent signal given by

$$g(t) = 5 + 3\cos(4\pi t).$$

Sampling the signal at a frequency of 4Hz, from $t = 0$ to $t = 3/4$ s, find the 4-point Discrete Fourier Transform [DFT] of $g(t)$. **[15]**

Q2. **(a)** Consider the integral

$$\frac{1}{\sqrt{2}}\int_0^1 e^{-x^2}\,dx.$$

Use the Simpson's rule, with 10 subintervals to show that numerical value of the integral is approximately 0.829412. 0.528084 **[15]**

(b) The following Fortran 90 code was written by a student with a view to evaluating the integral

$$\int_1^2 e^{-x^2}\,dx,$$

using the Composite Trapezoidal rule with 1000 subintervals.

```
      IMPLICIT NONE
            INTEGER :: i, n, k
      DOUBLE PRECISION :: x, dx, V, W, G, a = 1.0d0, b
      n=1000; i=1, k=n-1 , dx=(b-a)/dble(n); V=F(a);
      DO WHILE(i <= k)
      x=a+dble(i)*dx ; W=W+F(x)
      Write(*,1000) i, F(x), W
      ENDDO
2000  FORMAT(a10,2x,f10.6)
                  G=(dx/2.0d0)*(V+(2.0d0*W))
      WRITE(*,2000) 'Approximate Integral =',G
      END PROGRAM
            DOUBLE PRECISION FUNCTION F
            DOUBLE PRECISION :: x
                  F(x)=exp(-x^2)
                  Return
            END FUNCTION F
```

However, this code has ten errors. Identify the errors, and write the correct Fortran 90 code, including comments to describe sections of the code. **[10]**

Q3. **(a)** Table 1 shows magnitudes of the Heliospheric Magnetic Field[HMF] data observed by the ACE spacecraft. The HMF is measured in nano Tesla [nT] while time is expressed in decimal years.

Table 2: Time series of HMF as observed by the ACE Satellite

Time t [Years]	HMF [nT]
1997.62	5.9961
1998.63	6.9480
2000.08	7.1632

Use the Quadratic Lagrange Interpolation to show that the value of HMF, correct to 4 decimal places, when $t = 1998.81$ years is 7.0485 nT. **[7]**

(b) Consider two matrices

$$\mathbf{A} = \begin{bmatrix} 11 & 2 \\ 3 & 4 \end{bmatrix} \text{ and } \mathbf{X} = \begin{bmatrix} 15 \\ 6 \end{bmatrix}.$$

If the matrix elements for $\mathbf{A}$ and $\mathbf{X}$ are saved in a file called "*matrixA.txt*" and "*vectorX.txt*", respectively, write a ,Fortran 90, code that can

(i) compute the product $\mathbf{Y} = \mathbf{AX}$, **[3]**

(ii) compute the transpose matrix $\mathbf{A}^T$, **[2]**

(iii) print the output to a computer screen. **[1]**

(c) Consider the function $y = 2e^{-nx}$, where n is an integer. Write a code, in Fortran 90, which can compute values of this function for $-1 \le x \le 1$ in steps of 0.1 for each integer value of n from $n = 1, 2, 3, ..., 100$. Save each set of values in 50 different files with the same name but different serial numbers. **[12]**

Q4. A satellite placed at the L1 Lagrange point will orbit the Earth in perfect synchrony with the Moon, always staying between the two. The distance of the center of the Earth to the L1 Lagrange point satisfies the transcendental equation

$$f(x)=\frac{a_1}{x^2}-\frac{a_2}{[1-x]^2}-a_3x=0;\quad x\neq 1.$$

Here $a_1=\dfrac{GM}{R^2}\approx 269.827\times10^{-5}$, $a_2=\dfrac{Gm}{R^2}\approx 331.886\times10^{-7}$ and $a_3=\omega^2R\approx 272.395\times10^{-5}$ such that $M=5.974\times10^{24}$ kg and $m=7.348\times10^{22}$ kg are the Earth and Moon masses, respectively, $R=3.844\times10^{8}$ m the distance between the centers of the Earth and Moon, $\omega=2.662\times10^{-6}$ s^{-1} is the angular velocity of the Moon and the satellite, G is the Newton's law of gravitational constant while $x=r/R$ and $0<x<1$.

(a) Show that

(i) $$f'(x)=-\frac{2a_1}{x^3}-\frac{2a_2}{[1-x]^3}-a_3;\quad x\neq 1,$$ **[3]**

(ii) $$\frac{f(x)}{f'(x)}=\frac{0.0000331886[1-x]^{-2}+0.00272395x-0.00269827x^{-2}}{0.00539653x^{-3}+0.0000663771[1-x]^{-3}+0.00272395}.$$ **[3]**

(b) By implementing the Newton-Raphson algorithm, and starting with initial guess of 0.5, show that the value of

(i) x at the L1 point, correct to 6 decimal places, is 0.848192, **[17]**

(ii) r at the L1 point is 3.26045×10^{6} m. **[2]**

The University of Zambia
School of Natural Sciences
Department of Physics
2017/18 Academic Year
Mid-Year University Examinations
PHY4121: Nuclear Experimental Techniques

Attempt <u>any four</u> questions. All questions carry equal marks. The marks are shown in brackets.

Time: Three 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.

==========

Wherever necessary use:

g =	9.8 m/s^2
charge of an electron =	1.6×10^{-19}C
1 barn =	10^{-24} cm^2
mass of an electron =	9.1×10^{-31} kg
1 eV =	1.6×10^{-19}J
1 a.m.u. =	931.5 MeV $= 1.66 \times 10^{-27}$ kg
$N_{Av.}$ =	6.02×10^{23} per mole
1 curie =	3.7×10^{10} disintegrations/s
Planck's constant h =	6.63×10^{-34} J.s

Some equations you may find useful:

$$h\upsilon' = \frac{h\upsilon}{1+\frac{h\upsilon}{m_0 c^2}(1-\cos\theta)} \qquad \Omega = \frac{\pi a^2}{d^2} \qquad N = N_0 e^{-\Sigma_t x} \qquad m = \frac{n}{1+n\tau} \qquad \mu_a = \mu / N = \frac{\mu A}{\rho N_A}$$

$$n - m = n m \tau \qquad \mu_m = \frac{\mu}{\rho} = \frac{\sigma N}{\rho} = \frac{N_A \sigma}{atomic\ mass} \qquad E_r = \frac{V_0}{r \ln(b/a)} \qquad N = \frac{\dot{m}}{M} N_{Avo}$$

Q1 (a) A radioactive atom (decay constant λ_1) decays to a radioactive daughter atom with a decay constant λ_2. Initially there are N_1^0 nuclei of the parent element and no daughter nuclei.

[12]

Show that the number of daughter nuclei N_2 at time $t > 0$ is

$$N_2 = N_1^0 \frac{\lambda_1}{\lambda_2 - \lambda_1}\left(e^{-\lambda_1 t} - e^{-\lambda_2 t}\right).$$

Draw on the same graph the curves showing the decay of A and the growth and decay of B.

(b) Hence show by calculation or otherwise, that if N_o is the initial parent atoms present, the time at which the number of daughter radioactive atoms is maximum is t_{max} where

$$t_{\max} = \frac{\ln(\lambda_2 / \lambda_1)}{(\lambda_2 - \lambda_1)},$$

given λ_1 = decay constant of the parent nuclide, and λ_2 = decay constant of the daughter nuclide.

[8]

(c) ${}^{7}_{4}Be$ undergoes electron capture and decays to ${}^{7}_{3}Li$. Investigate if it can decay by the competitive decay mode of β^+ emission. Take the masses ${}^{7}_{4}Be = 7.016929\,\text{amu}$, ${}^{7}_{3}Li = 7.016004\,\text{amu}$. $m_0c^2 = 0.511\,MeV$ [5]

Q 2 (a) How long should one irradiate an ^{115}In foil (100 mm^2 area, 1 mm thick) in a thermal neutron flux of 10^{14} neutrons per m^2 per sec to obtain 1 m.Ci (3.7 x 10^7 Bq.) of activity? [8]

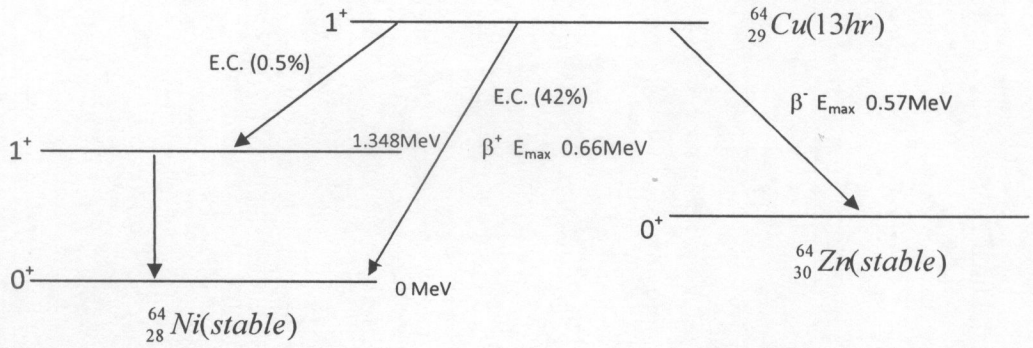
[Given, σ = 194 b. ρ = 7.3 x10^3 kg.m^{-3}. T = 54 min., N_A = 6.023 x 10^{23} per mole].

$$A_\infty = \frac{\sigma m N_A \phi}{A}$$

(b) For the decay scheme given,

(i) Explain the meaning of the symbols and describe fully the particle and photon emissions that occur. [8]

(ii) Sketch (not to scale) separately the form of the electron and photon energy spectra. [4]



(c) Mention two types of neutron sources and briefly describe how neutrons are produced in each case. [5]

Q 3(a) The density of iron is about 8×10^3 kg/m^3. The neutron capture cross section of iron is about 2.5b.

What fraction of an incident beam of neutrons is absorbed by a sheet of iron 1cm thick?

Calculate also the mean free path of neutrons in iron. [7]

(b) A block of *aluminium* 2cm thick is used in an experiment to measure the total neutron cross section with a well-collimated neutron beam. If the neutron detector registers 1000 counts/second with the cylinder removed from the neutron beam, and 100 counts with the cylinder inserted in the beam, calculate the total cross section of a*luminium* for these neutrons. Density of aluminium is 2.7 g/cm^3 and the mass of a mole of aluminium is 27 grams. [12]

(c) A *non-paralysable* counter with negligible background gives exactly 12,000 counts in an 1 second period when a standard source is in place. An identical source is placed beside the first, and the counter now records 23,000 counts in 1 second. What is the counter dead-time?

[6]

Q4 (a) Write short notes on *full-energy peak efficiency*, *relative efficiency*, and *intrinsic efficiency* of a radiation detector. [9]

(b) Total absorption coefficient for 5 MeV photons in lead in about 0.04 cm^2/g.

(i) If the density of lead is taken as 11.3 g/cm^2, what is the *half-value thickness* of lead for these gamma rays? [3]

(ii) What thickness of lead would be required to reduce the intensity of such photons to 0.06 of the initial value? [4]

(c) Draw a block diagram of the basic components of a scintillation spectrometer. Explain briefly the function of each component. [9]

Q 5(a) State the three major differences in the properties of organic and inorganic scintillation materials. [6]

Explain the function of the "activator" in a *NaI(Tl)* scintillator. [4]

(b) Calculate the pulse amplitude from the anode of a *PM* tube used with a *NaI(Tl)* scintillator under the following conditions:

A 1 MeV electron loses all its energy in the scintillators. The absolute scintillation efficiency of *NaI(Tl)* is 13%, and 4 eV of energy is required to produce each photon.

Efficiency of light collection to the photocathode is 50%, average quantum efficiency of the photocathode is 20%; 80% of the photo-electrons are collected at the first dynode.

Assume that the *PM* tube has 10 stages with a multiplication factor $\delta = 2.5$ per stage. The anode load resistance is 100 kΩ, and the anode capacitance is 100 pF. [12]

(c) Explain the following statement: In a windowless proportional counter, the output pulse height from an alpha particle source will increase with increasing alpha energy, whereas for beta particles the opposite is usually true. [3]

Q6 (a) Illustrate the differences between various types of gas counters operated in the pulse mode by plotting the amplitude of the observed pulse *versus* the applied voltage to the detector for events depositing two different amounts of energy within the gas. Explain in short the salient features of the figure. [12]

(b) A portion of a pulse height spectrum taken with a Multi-Channel Analyzer using a High Purity Germanium detector is given below:

Channel	Counts	Channel	counts	Channel	counts
27	162	34	511	41	430
28	199	35	506	42	418
29	251	36	550	43	366
30	301	37	599	44	329
31	347	38	590	45	295
32	432	39	510	46	232
33	434	40	491	47	159

(i) Plot the data and find the number of counts under the peak by direct summation assuming that the data consists of a constant background *plus* a Gaussian-shaped peak.

(ii) Estimate the constant background level.

(iii)If the energy calibration is 0.1513 keV/channel, what is the energy of the peak and its *FWHM* in keV? [13]

[Write your computer number on the graph paper and attach it firmly with the answer book]

==End of PHY4121 Final Examination==

The University of Zambia
School of Natural Sciences
Department of Physics
University Examinations 2018
PHY4132: Theoretical Nuclear Physics

Attempt <u>any four</u> questions. All questions carry equal marks. The marks are shown in brackets. Clearly indicate on the answer script cover page which questions you have attempted.

Time: Three hours. **Maximum marks = 100.**

Write your computer number clearly on the answer book.

Wherever necessary use:

ε_0 = 8.85 × 10^{-12} C^2/N.m^2	$m_{hydrogen\ atom}$ = 1.007825 a.m.u.
$m_{neutron}$ = 1.008665 a.m.u. = 939.551 MeV	m_{alpha} = 4.002603 a.m.u.
1 a.m.u. = 931.5 MeV = 1.6604 × 10^{-27} kg	m_p = 1.67 × 10^{-27} kg = 938.28 MeV
c = 3 × 10^8 m/s	m_e = 9.11 × 10^{-31} kg = 0.511 MeV
h = 6.63 × 10^{-34} J-s	e = 1.6 × 10^{-19} C
$\hbar$ = 6.58 × 10^{-22} MeV-s = 1.05 × 10^{-34} J-s	1eV = 1.6 × 10^{-19} J
1 fermi = 10^{-15} m	1 barn = 10^{-28} m^2
Avogadro's constant = 6 x 10^{23} per mole	Velocity of light = 3 x 10^8 m.sec^{-1}.
$\left(e^2/4\pi\varepsilon_0\right)$ = 1.44 MeV-fermi	$m=\left(m_0c^2/c^2\right)\equiv\left(MeV/c^2\right)$
$\tan\left(A+B\right)=\dfrac{\tan A+\tan B}{1-\tan A\tan B}$	$e^2/\hbar c=(1/137)$ $\hbar c$ = 197.33 MeV-fermi

$(1s_{1/2})^2,(1p_{3/2})^4,(1p_{1/2})^2,(1d_{5/2})^6,(2s_{1/2})^2,(1d_{3/2})^4,(1f_{7/2})^8,(2p_{3/2})^4,(1f_{5/2})^6,(2p_{1/2})^2,(1g_{9/2})^{10}$,[50]

$E=\dfrac{\hbar^2}{2\Im}\left[J(J+1)-BJ^2(J+1)^2\right]$. $\Delta E_C=\dfrac{3}{5}\dfrac{e^2}{R}\left[Z^2-(Z+1)^2\right]$ $Z_0=\dfrac{\beta}{2\gamma}$

Q1. (a) Define nuclear radius. Define *skin thickness.* Where do you expect skin thickness to be comparable to the nuclear radius? [9]

A form of charge distribution in the nucleus which is widely used is given by

$$\rho(r) = \frac{\rho_1}{1 + \exp[\frac{r - R_e}{Z_1}]}$$

where R_e and Z_1 are adjustable parameters.

(i) Explain how R_e can be determined from the knowledge of $\rho(r)$. [3]

(ii) Explain the physical significance of the identity $R = r_0 A^{1/3}$. [3]

(b) State in some detail which physical quantities are subject to conservation laws in nuclear reactions. [10]

Q2. (a) Mention the origin of each term in the following expression for the average binding energy of a nucleus having Z protons, N neutrons and A nucleons:

$$B.E. = a_1 A - a_2 A^{2/3} - a_3 \frac{Z^2}{A^{1/3}} - a_4 \frac{(N-Z)^2}{A} + \delta, \text{ where}$$

$\delta = a_5 A^{-3/4}$ for even-even nuclei,
$= 0$ for odd-even and even-odd nuclei
$= -a_5 A^{-3/4}$ for odd-odd nuclei. [15]

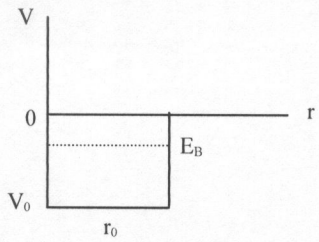
(b) Neglecting the pairing energy correction, use the above formula to obtain the Q-value of the symmetrical fission of a nucleus (A,Z) into two fragments $(\frac{A}{2}, \frac{Z}{2})$ as a function of the mass and atomic numbers. Assume the following values for the various coefficients:

a_1 = 15.5 MeV a_2 = 16.8 MeV a_3 = 0.72 MeV

a_4 = 19 MeV a_5 = 33.5 MeV

What is the condition for positive energy release? [10]

Q 3. A neutron is bound in the lowest possible state *(l = 0)* to a heavy nucleus. The binding energy is E_B = 25 MeV (***E*** = -25 MeV). The potential acting on the neutron is V_0 = 50 MeV; the radius r_0 of the well is not known:



i) solve the radial wave equation for $l = 0$ inside and outside the well, and sketch the wave function u [8]

ii) apply boundary conditions at $r = r_0$ to obtain an equation between the pertinent wave numbers and r_0 [8]

iii) find the numerical values of the wave numbers and solve the equation mentioned under (ii) for r_0. [9]

(For the reduced mass use *m = 1 a.m.u.).*

Q4. (a) How does the inclusion of a strong spin-orbit coupling in the single-particle shell model of the nucleus lead to the splitting of a state of given ***l***? Show that the splitting is proportional to $(2l + 1)$. [12]

(b) The ground state spins and parities of the following nuclei are given in brackets. Compare these values with the predictions of the single-particle shell model of the nucleus.

$$^{11}_{5}B\left(\frac{3^-}{2}\right),\ ^{16}_{7}N\left(2^-\right),\ \text{and}\ ^{25}_{13}Al\left(\frac{5^+}{2}\right).$$ [6]

(c) Explain why the $0^+ \rightarrow 0^+$ gamma decay transition will not allow any *gamma radiation*. Name the most common $0^+ \rightarrow 0^+$ transition. [5+2]

Q5(a). Show that an alpha particle with total energy E_o incident on a potential barrier of energy V ($V > E_o$) and of thickness b has a quantum probability of penetrating it. Sketch the energy diagram showing the incident and transmitted waves of the particle. [7+2]

(b) What do you understand by *allowed* and *forbidden* beta transitions? [2+2]

For the following beta transitions

(i) deduce the degree of *forbiddenness* of the transitions, and

(ii) explain the transitions in terms of the single-particle shell model.

$^{39}_{18}Ar$ to $^{39}_{19}K$ $\qquad$ $^{7}_{3}Be$ to $^{7}_{4}Li$ [2+2]

(c) Consider a bound-state problem of a particle of mass *m* moving in a spherically symmetric potential well of depth $-U_0$ and width *a*:

$U(r) = 0$ if $r > a$ and $= -U_0$ if $r \leq a$.

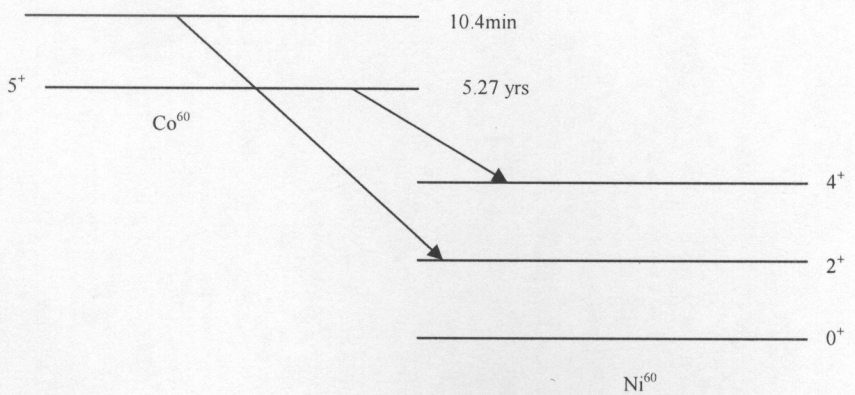
(i) Write down the Schrödinger equation, neglecting the orbital angular momentum (take $l = 0$).

(ii) Making a transformation of the wave function *R(r)* to a new radial wave function *u(r)* by a relation, $R(r) = \frac{u(r)}{r}$, and show that the equation for the function *u(r)* reduces to a simple form $\frac{d^2u}{dr^2} + \frac{2m}{\hbar^2}(E - U_0)u(r) = 0$ [8]

Q6(a). $^{108}_{47}Ag$ has a spin and parity 1^+. It is beta-unstable with a mean life-time of 3.4 minutes. It has an excited state at 109 keV excitation energy, spin and parity 6^+, which is an *isomeric state* with a mean life of 180 years.

Explain how an excited state of a nucleus can be more stable than the ground state. [8]

(b) $^{60}_{28}Ni$ has an excited state that decays to a lower excited state and then to the ground state in two successive electric quadrupole transitions. On the basis of this information, what are the possible spin and parity assignments for these two excited states of the *Ni* nucleus? [8]



(c) What *multipole* types of gamma-ray transitions are likely to be predominant if the J^{π} of the initial and final nuclei are given as below?

(i) $(½)^{+}$ to $(½)^{+}$

(ii) 1^{+} to 0^{+}

(iii) $(3/2)^{+}$ to $(½)^{+}$ [9]

==End of PHY4132 2018 Examination==

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
Department of Physics
2017/2018 ACADEMIC YEAR
Mid Year University Examinations
PHY 4221 - Solid State Physics I

Duration : 3 Hours
Total marks: 100
INSTRUCTIONS
This question paper contains six questions.
Answer any four questions. Each question has 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.

ADITIONAL INFORMATION

Planck's constant $h = 6.62*10^{-34}$ J/s, electron charge $e = 1.602*10^{-19}$ C, electron mass $m_e = 9.11*10^{-31}$ kg, proton mass $m_p = 1.67*10^{-27}$ kg, neutron mass $m_n = 1.67*10^{-27}$ kg, Avogadro's constant $A_v = 6.022*10^{23}$ mol^{-1}, Boltzmann constant $k_B = 1.38*10^{-23}$ JK^{-1}, Permitivity of free space $\epsilon_0 = 8.85*10^{-12}s^2m^{-2}$, permeability of free space $\mu_0 = 4\pi x10^{-7}$, Bohr magneton $\mu B = 9.274x10^{-24}$ Am^2
The first four diffraction peaks correspond to (110), (200), (112), and (220) for bcc; (111), (200), (220), and (311) for fcc; and (110),(220), (311), (400) for diamond structure.

$$\vec{b}_1 = 2\pi\frac{\vec{a}_2 * \vec{a}_3}{\vec{a}_1.\vec{a}_2 * \vec{a}_3}; \vec{b}_2 = 2\pi\frac{\vec{a}_1 * \vec{a}_3}{\vec{a}_1.\vec{a}_2 * \vec{a}_3}; \vec{b}_3 = 2\pi\frac{\vec{a}_1 * \vec{a}_2}{\vec{a}_1.\vec{a}_2 * \vec{a}_3}; < n >= \frac{\sum_s se^{(-s\hbar\omega/k_BT)}}{\sum_s e^{(-s\hbar\omega/k_BT)}};$$

$$\int_0^{+\infty}\frac{x}{e^x-1}dx = 1.51; \int_0^{+\infty}\frac{x^3}{e^x-1}dx = \frac{\pi^4}{15}; \int_{-\infty}^{+\infty}\frac{x^3e^x}{(e^x+1)^2}dx = \frac{\pi^2}{3}$$

Density of states $D(\omega) = \frac{L}{\pi}\frac{dk}{dw}$ in 1 dimension; $D(\omega) = \frac{Vk^2}{2\pi^2}\frac{dk}{dw}$ in 3 dimensions.

QUESTION 1

(a) What is a free electron gas? (1 mark)
(b) The work function of a metal is the minimum energy required to remove an electron from the metal and is typically 4.52 eV. Deduce a value for the penetration length of the electron wave function outside the metal for electrons of the Fermi energy 4.52 eV. (4 marks)
(c) Estimate the Fermi temperatures of
(i) $^{201}_{80}$Hg, mercury, (density = 13700 kgm^{-3}). (3 marks)
(ii) the neutrons in a neutron star (density = 2.5x10^{17} kgm^{-3}). (3 marks)
(d) The atomic radius of potassium is 2.45 Å. Taking the Bravais lattice of potassium to be bcc, calculate its
(i) Fermi energy at 0 K. (3 marks)
(ii) Fermi velocity. (3 marks)
(e) Show that the number of energy states available for the electrons in a cubical box of 0.01 m side lying below an energy of 4 eV is 3.62x10^{24}. (6 marks)
(f) The Fermi energy of copper is 7.04 eV. Show that the fermi energy at 300 K is 7.0399 eV. (2 marks)

QUESTION 2

(a) Sketch three cubic lattice cells and draw the following lattice planes: (001), (201) and (111). (6 marks)
(b) A simple model of a noble gas crystal consists of a fcc lattice with a Lennard-Jones interaction

$$U(r) = -4\epsilon[(\frac{\sigma}{R})^6 - (\frac{\sigma}{R})^{12}]$$

between the nearest neighbors in the lattice only. Here, R is the nearest neighbor distance, and the parameters are ϵ= 0.0121 eV, σ = 4.30 Å for argon.
(i) How many nearest neighbours does each site have on a fcc lattice? (1 mark)
(ii) What is the nearest-neighbour distance in terms of the lattice constant, **a**, of the conventional cubic unit cell of argon? (1 mark)
(iii) Find the total cohesive energy E for a large crystal of N argon atoms (neglecting surface effects) and the lattice constant **a** of the cubic unit cell. Compare with the experimental values **a**≈13.6 Å and E/N≈0.098 eV/atom. (9 marks)
(iv) How is bonding achieved in noble gases? (3 marks)
(c) An atom **A** has an ionisation energy of 3.5 eV and an atom **B** has an

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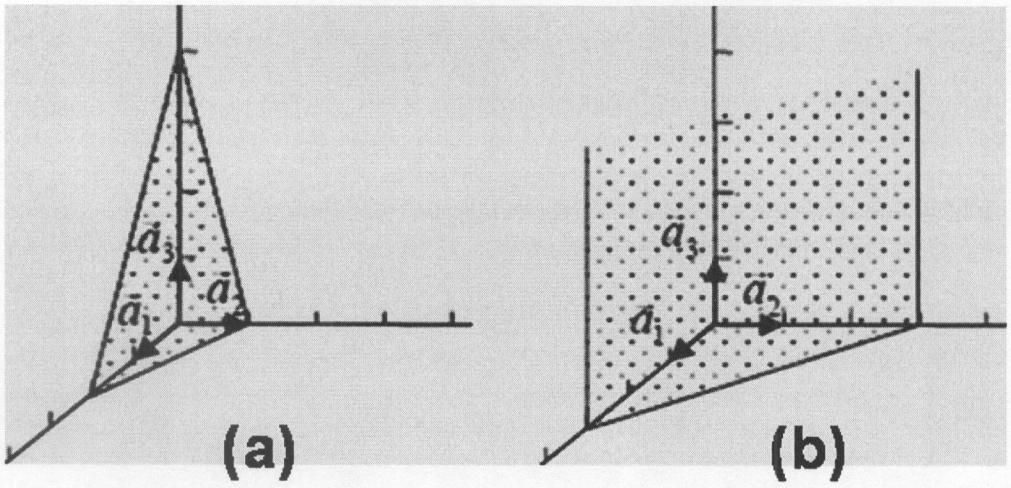
(iv) How is bonding achieved in noble gases? (3 marks)
(c) An atom **A** has an ionisation energy of 3.5 eV and an atom **B** has an electron affinity of 2 eV. What is the energy released or absorbed in placing the two atoms 4.5 Å apart? (5 marks)

QUESTION 3

(a) What is a phonon? Draw its symbol. (2 marks)
(b) (i)With the help of vector diagrams, explain what is meant by normal and Umklapp processes. (4 marks)
(ii) Differentiate between optical and acoustical branches of diatomic linear lattice. Why are these branches so named? (2 marks)
(c) Derive the dispersion relationship for a one dimensional monoatomic lattice,and show that the phase velocity is equal to the group velocity for such a lattice at low frequencies. (7 marks)
(d) Ultraviolet light of wavelength 4500 Å undergoes scattering from a crystal of refractive index 1.72. Calculate the maximum frequency of the phonon generated and the fractional change in the frequency of the incident radiation given that the velocity of sound in the crystal is 12500 m/s (5 marks)
(e) Figure out the miller indices of the following lattice planes. (The arrows are the basic vectors of the lattice.) (4 mark)



QUESTION 4

(a) Prove that the reciprocal lattice vector $\vec{G}= h\vec{b}_1+k\vec{b}_2+l\vec{b}_3$ is perpendicular to the plane hkl, and that the distance between two adjacent parallel planes is $2\pi/|\vec{G}|$. (6 marks)
(b) Show that taking the reciprocal lattice of the reciprocal lattice gives the real space lattice again. Also, prove that $|\vec{a}_1.\vec{a}_2\text{x}\vec{a}_3| = \text{V}$ (volume of a unit cell)

(9 marks)

(c) Find the Miller indices for the planes with each of the following sets of intercepts
(i) $3\vec{a}_1$, $3\vec{a}_2$, $2\vec{a}_3$ (ii) $5\vec{a}_1$, -$6\vec{a}_2$, $\vec{a}_3$ (4 marks)
(d) The primitive translation vectors of a two dimensional lattice are $\vec{a}_1 = 4\hat{i} + 1\hat{j}$, $\vec{a}_2 = 3\hat{j}$ and $\vec{a}_3 = 1\hat{k}$.
Determine its reciprocal lattice vectors ($\vec{b}_1$, $\vec{b}_2$, $\vec{b}_3$). (6 marks)

QUESTION 5

(a) Show that $\mathbf{c/a} = (8/3)^{1/2}$ for hcp close packing of hard spheres. (4 marks)
(b) Powder specimens of three different monoatomic cubic crystals are analyzed with a Debye-Scherrer camera. It is known that one sample is fcc, one is bcc, and one has the diamond structure. The approximate positions of the first four diffraction rings in each case are:

A	B	C
28.8°	42.2°	42.8°
41.05°	49.2°	73.15°
50.8°	72.2°	89°
59.6°	87.25°	115.2°

Identify the crystal structures of A, B and C. (8 marks)
(c) Use the equation $m(dv/dt + v/\tau) = eE$ for the electron drift velocity v to show that the conductivity at frequency ω is

$$\hat{\sigma}(\omega) = \sigma(0)\left(\frac{1 + i\omega\tau}{1 + (\omega\tau)^2}\right)$$

(7 marks)
(d) Show that
(i) $\sigma(0) = \sigma_1(\omega = 0) = \sigma_{dc} = \frac{1}{4\pi}\omega_p^2\tau$ (2 marks)
(ii) $AL\sigma E^2$ (where A is the cross section area, L is the length of a conductor, σ is the conductivity and E is the electric field) is the power loss due to collision of an electron in a conductor. (4 marks)

QUESTION 6

(a) Derive the temperature dependence of the lattice specific heat capacity predicted by Einstein's model, and deduce its variation at low and high temperatures. (10 marks)
(b) The Debye temperature and the Fermi energy for copper are 317 K and 7 eV, respectively, while the number of valence electrons per atom is 1. At what

temperature are the contributions from the lattice and electronic specific heats equal? (5 marks)

(c) (i) Write the expression for the Fermi-Dirac distribution function (1 mark)

Discuss the behaviour of the Fermi-Dirac distribution

(ii) at T→0 K. (1 marks)

(iii) at any temperature for $E = \mu$. (1 marks)

(iv) at high temperatures. (2 marks)

(d) Derive Wiedemann-Franz law for metals at not too low temperatures. (2 marks)

(e) Give any three basic assumptions of the Drude model. (3 marks)

———END OF EXAMINATIONS———



THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
Department of Physics
2017/2018 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.
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Additional information can be found at the end of this question paper.

QUESTION 1

(a) Draw energy bands of a crystal as a function of interatomic spacing. [3]

(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. [3]

(c) Sketch a figure showing a pentavalent impurity atom (P) in a silicon crystal. Also draw an energy level diagram of such a crystal with a pentavalent impurity. [5]

(d) 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 1.65×10^{17} atoms/m^3. [4]

(ii) The sample is then doped with 2×10^{23} phosphorus atoms/m^3. Determine the equilibrium hole concentration, the conductivity and the Fermi level relative to the intrinsic level. [6]

(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. [4]

QUESTION 2

(a) Derive the Clausius-Mossotti relation that expresses the relationship between the dielectric constant and atomic polarizability? [9]

(b) A paramagnetic material has SC structure with a cubic edge of 2.5 Å. If the saturation value of magnetization is 1.8×10^6 A m^{-1}, Calculate the magnetization contributed per atom in Bohr magnetrons. [6]

(c) Using the Kronig-Penney model, show that for $P \ll 1$, the energy of the lowest energy band is

$$E = \frac{\hbar^2 P}{ma^2}.$$

[7]

(d) What is meant by effective mass of an electron? What is its significance? Discuss the conditions when the effective mass of an electron becomes infinity. [3]

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QUESTION 3

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(a) Differentiate between type I and type II superconductors? [2]

(b) How does the energy gap in superconductors differ from the energy gap in insulators? How does the energy gap vary with temperature for superconductors? [4]

(c) The critical fields at 17 K and 20 K of NbGe alloy are 14.14 T and 8.5 T, respectively. Determine the transition temperature and the critical field at 0 K. [10]

(d) 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]

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QUESTION 4

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(a) Distinguish between the characteristic features of paramagnetism and ferromagnetism. Comment on the temperature dependence of susceptibility for these two types of magnetism. [3]

(b) Derieve the Curie law of paramagnetism. [7]

(c) 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]

(d) A ferromagnetic crystal with $J=\frac{5}{2}$ and $g = 2$ has a Curie temperature of 125 K. Calculate the intrinsic flux density near 0 K. Also calculate the ratio of magnetization at 300 K in the presence of an external field of 50 Oe to the spontaneous magnetization at 0 K? [8]

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QUESTION 5

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(a) Briefly define ferroelectricity and piezoelectricity; and state the difference between insulators and dielectrics. [4]

(b) Find the frequency dependence of the electronic polarizability of an electron having the resonance frequency ω_0, treating the system as a simple harmonic oscillator. [7]

(c) The optical index of refraction and the dielectric constant of sodium chloride crystal are 1.53 and 5.9 respectively. Determine the percentage of ionic polarizability. [8]

(d) Estimate the energy gap for Niobium (T_C=9.3 K) at T = 0 and show that the minimum photon wavelength needed to break the Cooper pair is $4.4\text{x}10^{-4}$ m. [6]

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QUESTION 6

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(a) A magnetic material has a magnetization of 2300 A m^{-1} and produces a flux density of 0.00314 Wb m^{-2}. Calculate the magnetizing force and the relative permeability of the material..[5]

(b) Sketch and clearly label the three types of antiferromagnetic ordering. [6]

(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 NbGe at T_c, if T_c = 23 K, γ = 3 x 10^4 ergs/mol.K and $H_c(0)$ = 2000 Gauss.

[9]

(d) The London penetration depth for a superconductor at 3 K and 7.09 K are 39.61 nm and 173 nm respectively. Show that the superconducting temperature of this superconductor is 7.2 K. [5]

.....END OF EXAMINATION.....

ADITIONAL INFORMATION

Planck's constant h = 6.62x10^{-34} J/s, 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, Avogadro's constant A_v = 6.022x10^{23} mol^{-1}, Boltzmann constant k_B = 1.38x10^{-23} JK^{-1}, Permitivity of free space ϵ_0 = 8.85x$10^{-12}s^2m^{-2}$, permeability of free space $\mu_0 = 4\pi$x10^{-7}, Bohr magneton μ_B =9.274x10^{-24} Am^2

$$N_C = 2\left[\frac{2\pi m_n^* k_B T}{h^2}\right]^{\frac{3}{2}}$$

$$N_V = 2\left[\frac{2\pi m_h^* k_B T}{h^2}\right]^{\frac{3}{2}}$$

$$n = (N_C N_V)^2 exp\left(\frac{E_V - E_C}{2k_B T}\right);$$

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

$$y = \left(\frac{g\mu_B JB}{k_B T}\right); B_J(y) \approx \frac{y(J+1)}{3J}$$

$$H_c(T) = H_c(0)\left(1 - \left(\frac{T}{T_c}\right)^2\right)$$

$$\chi = \frac{\mu_0 N \mu_B^2}{3k_B T} g^2 J(J+1)$$

$$L = \sum m_l$$

$$\int_0^{+\infty} \frac{x}{e^x - 1} dx = 1.51; \int_0^{+\infty} \frac{x^3}{e^x - 1} dx = \frac{\pi^4}{15}; \int_{-\infty}^{+\infty} \frac{x^3 e^x}{(e^x + 1)^2} dx = \frac{\pi^2}{3}$$

$$g = 1 + \frac{J(J+1) + S(S+1) - L(L+1)}{2J(J+1)}$$

$$\int_0^{\infty} x^4 e^{-x} dx = 24$$

$$\lambda_k = \frac{\hbar^2 k^2}{2m}$$

$$\alpha = \frac{2mE}{\hbar^2}$$

$$\cos(2\Theta) = \cos^2\Theta - \sin^2\Theta$$

$$\sin(2\Theta) = 2\sin\Theta\cos\Theta$$

$$\tan(2\Theta) = \frac{2\tan\Theta}{1 - \tan^2\Theta}$$

$$\sinh(x) = \frac{e^x - e^{-x}}{2}$$

$$\cosh(x) = \frac{e^x + e^{-x}}{2}$$

$$\tanh(x) = \frac{e^x - e^{-x}}{e^x + e^{-x}}$$

The University of Zambia

Department of Physics

Final Examination PHY 4242, December 2017-8

All questions carry equal marks. The marks are shown in brackets.

Time: 3 hours. **Maximum marks = 100**

Instructions:

Attempt any 4 questions, all fullquestions carry equal marks.

Useful Equations:

$$\mathrm{SI}=\frac{4500}{\left(v/c\right)^2} \quad : \quad \frac{\text{Radiation energy loss}}{\text{Ionisation energy loss}}=\frac{E_k Z}{820} \quad : \quad I=I_o e^{-\mu x} \quad : \quad \mathrm{HVL}=\frac{\ln 2}{\mu}$$

$$\mu_{\mathrm{en}}=\mu\frac{E_a}{h\nu} \quad : \quad \lambda=\frac{1.24}{h\nu} \quad : \quad \Delta\lambda=0.00243(1-\cos\phi) \quad : E_{\max}=h\nu_{\max}=\frac{hc}{\lambda_{\min}}$$

$$\Phi=\frac{N}{A} \quad : \quad \phi=\frac{\Phi}{t}=\frac{N}{A.t} \quad : \quad \Psi=\Phi E=\frac{NE}{A} \quad : \quad I=\psi=\phi E=\frac{NE}{At}$$

$$I=\psi=\sum_{i=1}^{m} f_i\phi E_i \quad : \quad X=\frac{Q}{m}: \quad \frac{\Phi}{X}=\frac{2.11\times10^{14}}{h\nu\left(\mu_{en}\right)_m} \quad : \quad D(\mathrm{Gy})=\frac{E/m}{1\mathrm{J/kg}}$$

$$\mathrm{DE(Sv)}=D(\mathrm{Gy})\times\mathrm{QF} \quad : \quad \mathrm{ED(mSv)}=D(\mathrm{mGy})\times W_R \quad : \quad E=JW$$

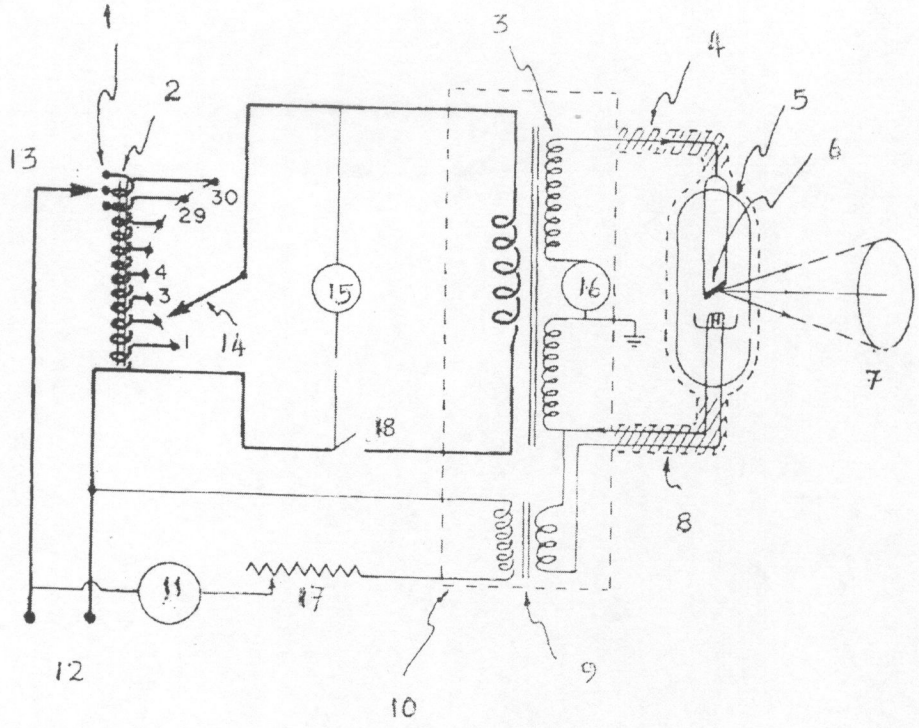
$$\Psi=\frac{JW}{\rho\left(\mu_{en}\right)_m} \quad : \quad \frac{V}{X}=\frac{1.29v}{C+C_e}$$

Constants:

$W=33.85\mathrm{eV}$ **:** Avagadro's number = 6.023 x 10^{23} : 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

1Gy = 1 J/kg : 1 R = 0.869 rad in air : 1C/kg = 33.85 J/kg

Q 1 **a)** Name the numbered components of the schematic diagram of a self-rectified X-ray generator shown below. [18]



b) Explain the reason why rotating anode targets are preferred in X-ray tube designs. [3]

c) What is the purpose of fitting two filaments in two cathode structures [4]

Q 2 **a)** Explain with the aid of a diagram how you would measure the apparent focal spot of an x-ray tube with a pin-hole camera; take into consideration the dimensions of the actual focal spot in the x-ray tube. [10]

b) An apparent focal spot of 2 mm is projected from an x-ray tube. The true focal is 7 mm.

i) What is the target angle for using the line focus principle? [5]

ii) Why is the heel effect greater in an x-ray beam from a target with a small angle? [3]

iii) Explain why x-ray tube target material affects the efficiency of x-ray production [2]

c) A dose of 60 Gy is delivered uniformly to 150 g mass of tissue. How much energy in joules is absorbed by each gram of tissue and by the entire tissue mass? [5]

Q 3 **a)** A chest x-ray uses 10^{15} photons to expose film with an area of 30 cm x 40 cm during an exposure of 0.10 second. Assume all photons have energy of 70 keV. Find:

i) The photon fluence
ii) The photon flux.
iii) The energy fluence, and
iv) The intensity I. [9]

b) A dose of 60 Gy is delivered uniformly to a 150 g mass of soft tissue. How much energy in joules is absorbed by each gram of tissue and by the entire tissue mass? [5]

c) Give a brief explanation of the principles on which the following dosimetry systems are based:

i) Calorimetric;

ii) Fricke; and

iii) Thermoluminescence. [11]

Q 4 **a)** It is desired to reduce a beam of gamma rays to 1/16 of its intensity. The gamma rays have an energy of 1 MeV and lead is to be used as shielding material.

i) How many half value layers are required?
ii) How many centimeters of lead are needed given that $(\mu_{en})_{\text{Pb}} = 0.431\text{cm}^{-1}$.

[8]

b) A thimble chamber with an air-equivalent wall receives an exposure of 0.015 C/kg in one minute. The volume of the chamber is 0.46 cm^3.What is the ionization current from the chamber? [5]

c)) i) What is the purpose of a simulator in treatment planning?

ii) Why are multiple radiation beams often used for radiotherapy?

iii) In radiotherapy, what is a phantom? [6]

d) Perspex is normally used as a nearly tissue equivalent material to make dose measurements and it has a density of 1.19 g/cm^3. The composition of Perspex is given below, calculate the effective atomic number of this material. [6]

Atomic number	Fraction by weight
1	0.080538
6	0.599848
8	0.319614

Q 5 **a)** Draw a well labeled diagram of a free air-ionization chamber and explain its operation. [10]

b) A Condenser ionisation chamber has a sensitivity of 7750 v/C-kg. The volume of the chamber is 0.46 cm^3. The capacitance is six times the capacitance of the charger-reader. What is the capacitance of the chamber? [10]

c) A diagnostic tube has a target which is sloped at 17^0. The electrons are focused along a strip of the anode 2.5 mm wide. How long should this strip be to yield a projected focal spot of 2.5 mm x 2.5 mm. Explain your answer with a diagram? [5]

Q 6 **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) The tenth-value layer is the thickness of slab of matter necessary to attenuate the beam of x or γ rays to one tenth of the intensity with no attenuation present. Assuming good geometry and mono-energetic photons, show that the tenth value layer equals 2.30/μ, where μ is the total linear attenuation coefficient. [5]

c) Attenuation measurements for an x-ray beam from 120 kVp x-ray generator yield the following results:

Added filtration (mmAl)	Percent transimission
1.0	60.2
2.0	41.4
3.0	30.0
4.0	22.4
5.0	16.9

Plot the data on a semi-log graph paper and determine the following:

i) The first HVL.
ii) The second HVL.
iii) The homogeneity coefficient of the X-ray beam.
iv) Explain the term "filtration" in relation to X-ray beams [10]

End of Exam

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

DEPARTMENT OF PHYSICS

2017/18 MID-YEAR UNIVERSITY EXAMINATIONS

PHY 4411 : Analogue Electronics II

Time : Three hours. **Maximum marks = 100.**

Attempt any **FOUR** questions.

All questions carry equal marks.

The marks are shown in brackets.

Q1. (a) Using relevant circuit diagrams, discuss the effect of input bias current on a feedback operational amplifier. [10]

(b) The following specifications apply to a differential amplifier comprised of two operational amplifiers.

$R_2=R_F=2.2\ k\Omega$ $R_3=R_1=1\ k\Omega$ $f_0=5\ Hz$ $A=200\ 000$ $R_i=2\ M\Omega$ $f_0=5\ Hz$

$V_X=700\ mV$ pp and $V_y=500\ mV$ pp sine waves at 500Hz.

The operational amplifier is 741C and it is initially nulled. Calculate [9]

(i) the voltage gain

(ii) the bandwidth

(iii) the input resistance seen by each signal source

(iv) the output voltage of the amplifier

(c) For a non-inverting amplifier, suppose that the circuit is nulled and the voltage across terminals $+V_{CC}$ and $-V_{CC}$ measures 25 V d.c. Because of poor voltage regulation, the voltage across terminals $+V_{CC}$ and $-V_{CC}$ varies with time from 22.5 V to 27.5 V. Determine the change in error voltage caused by the change in d.c. supply and hence determine the output voltage of the amplifier. [6]

The operational amplifier is MC1741 with $R_1=100\ \Omega$, $R_F=4.7\ k\Omega$ and $\frac{\Delta V_{io}}{\Delta V}=\frac{15.85\mu V}{V}$.

Q2. (a) Explain Millers theorem and show how this theorem is useful in deriving the input resistance of a voltage shunt feedback amplifier. [8]

(b) Design a twin-T operational amplifier notch filter with a center notch frequency of 1 kHz. [8]

(c) Design an input voltage compensating network for the μA715 operational amplifier for which the input offset voltage is 5 mV maximum. The operational amplifier uses a ±13 V supply voltage and is to be used as an inverting amplifier. [9]

Q3. (a) The non-compensated operational amplifier MC1539 has a gain of A=120,000 and the following break frequencies.

f_{01} = 5kHz, f_{02} = 320kHz, f_{03} =1MHz and f_{04} = 2MHz

(i) Write the open loop gain equation and phase angle equation as a function of break frequencies. [4]

(ii) Determine the magnitude of the gain and phase shift between the input and output voltages when the frequency of operation is 100 kHz. [5]

(b) (i) Consider the amplifier shown below. If V_{in}=5 V, what is V_{out}? [4]

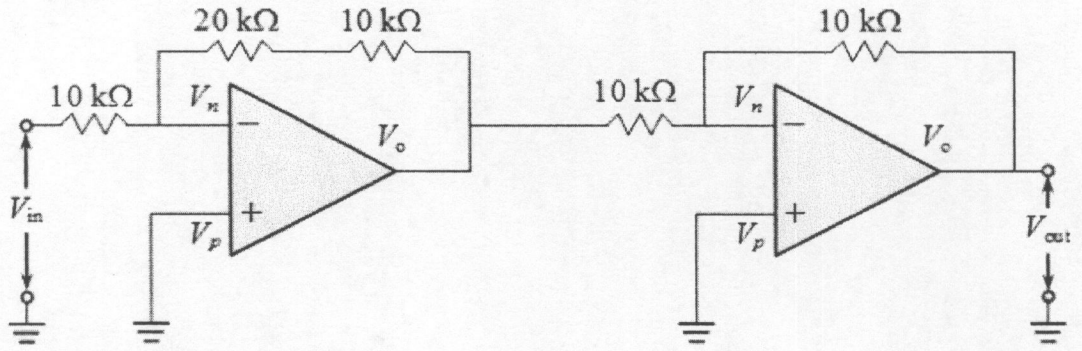


Figure 1

(ii) The following circuit represents an inverting scaling amplifier. Compute the value of R_{oM} and V_O. [6]

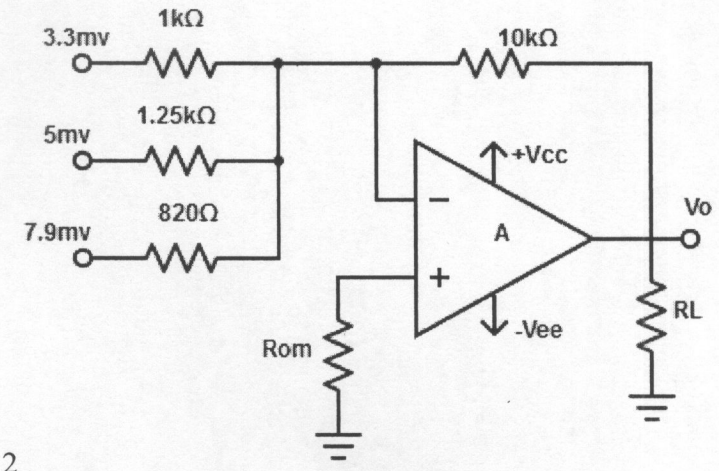


Figure 2

(c) An integrator circuit has R_1 = 100 kΩ and C_F= 4μF. If the input voltage is maintained at 0.5 V then

(i) find the resulting output voltage

(ii) sketch (to scale) the resulting output voltage, and

(iii) calculate the time taken for the output voltage to reach -6 V. [6]

Q4. (a) (i) Design a first order high pass Butterworth filter for a cut off frequency of 2 kHz and pass band gain of 4. [9]

(ii) Using the frequency scaling technique, change the cut off frequency of the above filter to 2.5 kHz. [3]

(b) Derive the equation for the voltage gain of a first order high pass Butterworth filter. [6]

(c) If the cut-off frequency of the filter is 2.5 kHz, find the gain (in dB) of the above filter for the following input signal frequencies. Draw the frequency response curve of the filter. [7]

100Hz, 1000Hz, 2500Hz, 10000Hz.

Q5. (a) (i) With a suitable diagram, explain the Barkhausen criterion for sustained oscillations. [7]

(ii) Draw the circuit diagram of a Wien bridge oscillator and explain the conditions to be satisfied to maintain oscillations. [6]

(b) Figure shows the circuit diagram of an oscillator. Identify the oscillator and determine the operating frequency of oscillation. [4]

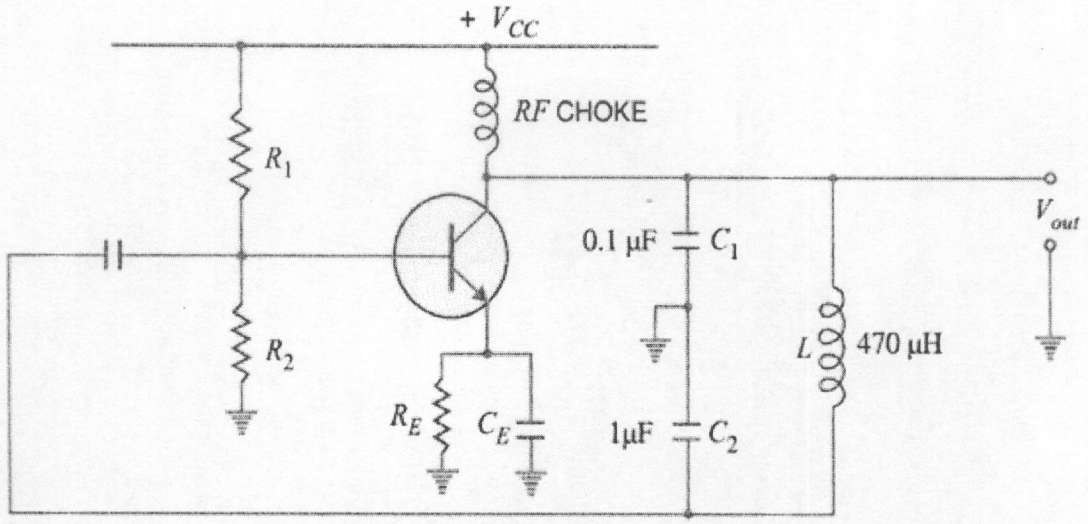


Figure 3

(c) Design a phase shift oscillator to produce a frequency of 800 kHz. [8]

Q6. (a) Derive an equation for the output voltage of the following circuit. [7]

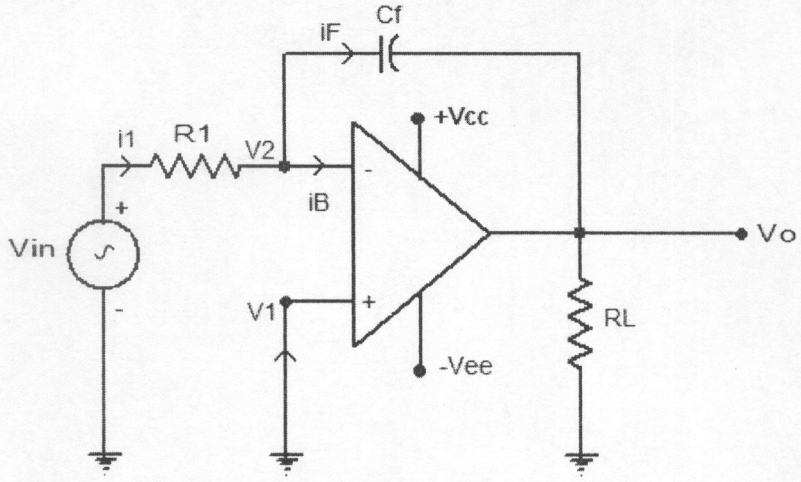


Figure 4

(b) Trace the input and output waveforms for the comparator circuit shown below if V_{in} = 5 V and V_{ref} = 1 V. Briefly explain how it works. [6]

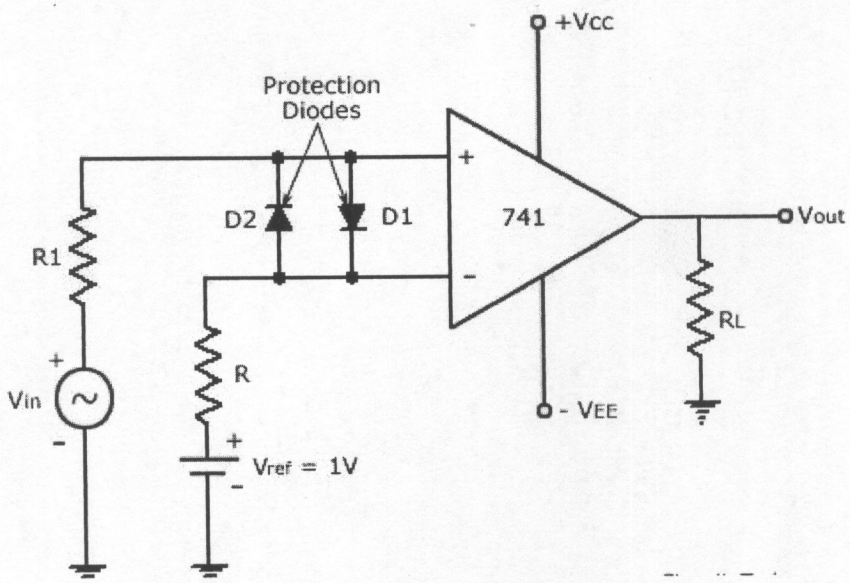


Figure 5

(c) Write short notes on [12]

(i) Transient response

(ii) Thermal current drift

(iii) Inverting zero crossing detector

(iv) Notch filter

END OF PHY 4411 EXAMINATION

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THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
DEPARTMENT OF PHYSICS

2018 ACADEMIC YEAR FINAL EXAMINATION

PHY4422: DIGITAL ELECTRONICS II

TIME: THREE HOURS MAXIMUM MARKS : 100

Attempt ANY FOUR questions
All questions carry equal marks.
The marks are shown in brackets.

8085 / 8080A Instruction summary by Functional Groups

DATA TRANSFER (COPY)

Hex	Mnemonic	Hex	Mnemonic	Hex	Mnemonic	Hex	Mnemonic
40	MOV B,B	58	MOV E,B	70	MOV M,B	1A	LDAX D
41	MOV B,C	59	MOV E,C	71	MOV M,C	2A	LHLD
42	MOV B,D	5A	MOV E,D	72	MOV M,D	3A	LDA
43	MOV B,E	5B	MOV E,E	73	MOV M,E	2	STAX B
44	MOV B,H	5C	MOV E,H	74	MOV M,H	12	STAX D
45	MOV B,L	5D	MOV E,L	75	MOV M,L	22	SHLD
46	MOV B,M	5E	MOV E,M	77	MOV M,A	32	STA
47	MOV B,A	5F	MOV E,A	78	MOV A,B	01	LXI B
48	MOV C,B	60	MOV H,B	79	MOV A,C	11	LXI D
49	MOV C,C	61	MOV H,C	7A	MOV A,D	21	LXI H
4A	MOV C,D	62	MOV H,D	7B	MOV A,E	31	LXI SP
4B	MOV C,E	63	MOV H,E	7C	MOV A,H	F9	SPHL
4C	MOV C,H	64	MOV H,H	7D	MOV A,L	E3	XTHL
4D	MOV C,L	65	MOV H,L	7E	MOV A,M	EB	XCHG
4E	MOV C,M	66	MOV H,M	7F	MOV A,A	D3	OUT
4F	MOV C,A	67	MOV H,A	06	MVI B	DB	IN
50	MOV D,B	68	MOV L,B	0E	MVI C	C5	PUSH B
51	MOV D,C	69	MOV L,C	16	MVI D	D5	PUSH D
52	MOV D,D	6A	MOV L,D	1E	MVI E	E5	PUSH H
53	MOV D,E	6B	MOV L,E	26	MVI H	F5	PUSH PSW
54	MOV D,H	6C	MOV L,H	2E	MVI L	C1	POP B
55	MOV D,L	6D	MOV L,L	36	MVI M	D1	POP D
56	MOV D,M	6E	MOV L,M	3E	MVI A	E1	POP H
57	MOV D,A	6F	MOV L,A	0A	LDAX B	F1	POP PSW

ARITHMETIC

Hex	Mnemonic	Hex	Mnemonic	Hex	Mnemonic	Hex	Mnemonic
80	ADD B	CE	ACI	D6	SUI	23	INX H
81	ADD C	90	SUB B	DE	SBI	33	INX SP
82	ADD D	91	SUB C	09	DAD B	05	DCR B
83	ADD E	92	SUB D	19	DAD D	0D	DCRC
84	ADD H	93	SUB E	29	DAD H	15	DCR D
85	ADD L	94	SUB H	39	DAD SP	1D	DCR E
86	ADD M	95	SUB L	27	DAA	25	DCR H
87	ADD A	96	SUB M	04	INR B	2D	DCR L
88	ADC B	97	SUB A	0C	INR C	35	DCR M
89	ADC C	98	SBB B	14	INR D	3D	DCR A
8A	ADC D	99	SBB C	1C	INR E	0B	DCX B
8B	ADC E	9A	SBB D	24	INR H	1B	DCX D
8C	ADC H	9B	SBB E	2C	INR L	2B	DCX H
8D	ADC L	9C	SBB H	34	INR M	3B	DCX SP
8E	ADC M	9D	SBB L	3C	INR A		
8F	ADC A	9E	SBB M	03	INX B		
C6	ADI	9F	SBB A	13	INX D		

LOGICAL

Hex	Mnemonic	Hex	Mnemonic	Hex	Mnemonic	Hex	Mnemonic
37	STC	A9	XRA C	B3	ORA E	BD	CMP L
A0	ANA B	AA	XRA D	B4	ORA H	BE	CMP M
A1	ANA C	AB	XRA E	B5	ORA L	BF	CMP A
A2	ANA D	AC	XRA H	B6	ORA M	FE	CPI
A3	ANA E	AD	XRA L	B7	ORA A	07	RLC
A4	ANA H	AE	XRA M	F6	ORI	0F	RRC
A5	ANA L	AF	XRA A	B8	CMP B	17	RAL
A6	ANA M	EE	XRI	B9	CMP C	1F	RAR
A7	ANA A	B0	ORA B	BA	CMP D	2F	CMA
E6	ANI	B1	ORA C	BB	CMP E	3F	CMC
A8	XRA B	B2	ORA D	BC	CMP H		

BRANCHING

Hex	Mnemonic	Hex	Mnemonic	Hex	Mnemonic
C3	JMP	D7	RST 2	EC	CPE
C2	JNZ	DF	RST 3	F4	CP
CA	JZ	E7	RST 4	FC	CM
D2	JNC	EF	RST 5	C9	RET
DA	JC	F7	RST 6	C0	RNZ
E2	JPO	FF	RST 7	C8	RZ
EA	JPE	CD	CALL	D0	RNC
F2	JP	C4	CNZ	D8	RC
FA	JM	CC	CZ	E0	RPO
E9	PCHL	D4	CNC	E8	RPE
C7	RST 0	DC	CC	F0	RP
CF	RST 1	E4	CPO	F8	RM

CONTROL

Hex	Mnemonic
00	NOP
76	HLT
F3	DI
FB	EI
20	RIM
30	SIM

Q1. (a) Explain the general purpose registers of 8085 microprocessor. [5]

(b) (i) What is the importance of flag registers in a microprocessor? [2]

(ii) What are the flags available in 8085? Explain the functions of each of them. [10]

(c) Draw the structure of the 4096 bit Read Only Memory (ROM). [8]

Q2. (a) (i) Define the memory map of a computer. Explain the memory map of a (32K×8) memory chip with figure. [13]

(ii) Explain how the memory map can be changed by modifying the hardware of the chip select line. [7]

(b) What do you understand by word length of a computer? Explain with examples. [5]

Q3. (a) Write a program to load the data byte 8EH in register D and F7H in register E. Mask the higher order bits from first data byte (8EH) and lower order bits from second data byte (F7H). Display the results at PORT 00H and PORT 01H. [8]

(b) The memory location 8075H contains 12H and the memory location 8094H contains 22H. Using figures show the contents of various registers upon execution of each instruction for the program shown below. [12]

```
LXI B, 8075H
LXI D, 8094H
LDAX B
MOV L,A
LDAX D
STAX B
MOV A, L
STAX D
HLT
```

(c) Assume the accumulator has 7AH and the carry flag is reset. Write the instruction to rotate the contents of the accumulator left through carry twice. Show the contents of accumulator before and after each instruction. [5]

Q4. (a) Write a program to find square from look up table. The squares of data are stored in certain memory locations in the tabular form. This is called a look up table. [7]

The number 09D is in the memory location 8500H.
The result is to be stored in the memory location 8501H.
The table for square is stored from 8600 to 8609H.
The address of the memory locations is in hexadecimal. The number and squares are to be entered in decimal.

Look-up table

Address (Hex)	Square (Decimal)
8600	00
8601	01
8602	04
8603	09
8604	16
8605	25
8606	36
8607	49
8608	64
8609	81

(b) Write short notes on Cache memory and cache controller. [6]

(c) (i) Design a circuit to read eight ON/OFF switches connected to the input port with address 01H and turn on the devices connected to an output port with address 01H. [6]

The appliances connected are as follows.

Air conditioner-ON	Television-OFF
Microwave oven-OFF	Radio-ON
Light 1- ON	Light 2- ON
Light 3 - OFF	Light 4 -ON

(ii) Write a program to keep the lights 1 and 4 ON continuously without affecting the functions of the other appliances, even if someone turns off the switch. [6]

Q5. (a) Using connection abbreviations, implement the following functions on a Field Programmable Logic Array (FPLA) circuit. [10]

$$X = \overline{(A + \overline{BC} + CD)} + \overline{\overline{BC}}$$

$$Y = \overline{(\overline{A} + \overline{D}).(\overline{B} + \overline{D})}$$

$$Z = \overline{\overline{A}\,\overline{B}}$$

(b) (i) The accumulator contains the data byte DBH and the carry CY=1. Show the contents of accumulator after executing the instruction RAR. [3]

(ii) The accumulator contains the data byte CFH and the memory location 8050H contains the data byte DEH. Show the contents of the accumulator after executing the instruction XRA M. Your answer should include the connections to the respective gates. [6]

(c) Write short notes on minterms and maxterms with example. [6]

Q6. (a) Simplify the following expression using Karnaugh map technique. [6]

$$X = \overline{A\overline{B}.(A+C)} + \overline{A}B.\ \overline{A+\overline{B}+\overline{C}}$$

(b) Simplify the following expressions using Karnaugh map technique. [12]

$$f_1 = \Sigma m\,(1, 3, 6, 7, 8, 10, 12, 14, 15)$$

$$f_2 = \Pi M\,(0,4,9,10,11,14,15)$$

(c) Minimize the following multiple output functions. Show only the shared Karmaugh map and simplify it. [7]

$$f_1 = \Sigma m\,(0, 1, 2, 5, 6, 7) + d(3,4)$$

$$f_2 = \Sigma m\,(2, 4, 5, 6) + d(0,4)$$

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
DEPARTMENT OF PHYSICS
SECOND TERM EXAMINATIONS 2018
PHY4535 QUANTUM MECHANICS II

TIME: THREE HOURS
ANSWER: ANY FOUR QUESTIONS
MAXIMUM MARKS: 100

Useful Information

$$\hbar = 1.054 \times 10^{-34} \text{ Js}, \; e = 1.6 \times 10^{19} \; C$$

$$\begin{vmatrix} H_{11}^{'} - E^{(1)} & H_{12}^{'} & \ldots & H_{1\alpha}^{'} \\ H_{21}^{'} & H_{22}^{'} - E^{(1)} & \ldots & H_{2\alpha}^{'} \\ \ldots & \ldots & \ldots & \ldots \\ H_{\alpha 1}^{'} & H_{\alpha 2}^{'} & \ldots & H_{\alpha\alpha}^{'} - E^{(1)} \end{vmatrix} = 0$$

Eigenfunctions of a particle in an infinite potential well between $x = 0$ and $x = L$:

$$\psi_n(x) = \sqrt{\frac{2}{L}} \sin \frac{n\pi x}{L}, \quad n = 1, 2, 3, ...$$

---

1. (**a**) Show that the expression for the first-order energy correction in nondegenerate time-independent perturbation theory is

$$E_n^{(1)} = \left\langle \psi_n^{(0)} \left| H' \right| \psi_n^{(0)} \right\rangle$$

where H' is the perturbation. [12 marks]

(**b**) A particle moving in a one-dimensional potential well with walls at $x = 0$ and $x = L$ is acted upon by the perturbation $H' = \lambda p_x$. Find the first-order corrections to the energy of the states. [13 marks]

2. A three-dimensional harmonic oscillator has the Hamiltonian

$$H = \frac{p_x^2}{2m} + \frac{1}{2}kx^2 + \frac{p_y^2}{2m} + \frac{1}{2}ky^2 + \frac{p_z^2}{2m} + \frac{1}{2}kz^2$$

(**i**) Assuming only the eigenvalue equation of the linear harmonic oscillator

$$\left(-\frac{\hbar^2}{2m}\frac{d^2}{dx^2} + \frac{1}{2}kx^2 \right) \phi_n(x) = (n + \frac{1}{2})\hbar\omega\phi_n(x)$$

show that the eigenfunctions are given by

$$\Psi_{n_1 n_2 n_3}(x,y) = \phi_{n_1}(x)\phi_{n_2}(y)\phi_{n_3}(z), \quad n_1, n_2, n_3 = 0, 1, 2, 3....$$

[8 marks]

(**ii**) Show that the energy eigenvalues are given by

$$E_{n_1 n_2 n_3} = (n_1 + n_2 + n_3 + \frac{3}{2})\hbar\omega$$

[2 marks]

(**iii**) Explain why the first excited state is three-fold degenerate. [2 marks]

(**iv**) If such an oscillator is in the first excited state and is acted upon by the perturbation $H' = \varepsilon$, where ε is a constant, show that the first-order correction to the energy of the states is

$$E^{(1)} = \varepsilon$$

[11 marks]

(**v**) Explain your result. [2 marks]

3. (**a**) The use of the variational method for estimating ground-state energies and eigenfunctions is based on the result

$$\langle H \rangle \geq E_0$$

where E_0 is the ground-state energy and $\langle H \rangle$ is the expectation value of the Hamiltonian for a selected trial function. Prove this result. [7 marks]

(**b**) A particle of mass m moves in the one-dimensional square-well potential

$$\begin{aligned} V &= 0; \ 0 < x < L \\ V &= \infty; \ x < 0, x > L \end{aligned}$$

(**i**) Consider the variational trial function

$$\phi_\alpha(x) = x^\alpha (1-x)^\alpha$$

Write down an expression for the expectation value $\langle E \rangle_\alpha$ of the energy, Your expression should contain no derivatives. Do not attempt to evaluate the integrals. [6 marks]

(**ii**) The integrals may be evaluated to give

$$\langle E \rangle_\alpha = \frac{\hbar^2}{2mL^2} \frac{2\alpha(4\alpha+1)}{2\alpha - 1}$$

(**iii**) Explain why only positive values of α are acceptable. [2 marks]

(**iv**). Use the variational principle to obtain an estimate of the ground-state energy and compare with the exact value

$$E = \frac{\pi^2\hbar^2}{2mL^2}.$$

[8 marks]

(**v**) Write down an approximation to the probability density of the ground state. [2 marks]

4. (**a**) When the intrinsic spin of the electron is taken into account, but with any interaction between the orbital angular momentum and the spin neglected, the Hamiltonian of the hydrogen atom is

$$H = H_{\text{usual}} + H_{\text{spin}}.$$

where H_{usual} is the regular hydrogen-atom Hamiltonian and H_{spin} is due to the interaction of the spin magnetic moment with applied magnetic field.

(**i**) Explain why spin is described using matrices. [2 marks]

(**ii**) Use separation of variables to show that when the magnetic field is not a function of the coordinates, the solution of the time-independent Schroedinger equation is

$$\Psi_{nlmm_s} = \psi_{nlm}(r,\theta,\phi)\chi_{m_s}$$

where

$$\psi_{nlm}(r,\theta,\phi) = R_{nl}(r)Y_{lm}(\theta,\phi) \text{ corresponding to energy } E_n = -\frac{13.6}{n^2} \text{ eV}$$

is the solution for the hydrogen atom without spin and χ_{m_s} is the solution of the spin eigenvalue equation

$$H_{\text{spin}}\chi_{m_s} = \varepsilon_{\text{spin}}\chi_{m_s}$$

[6 marks]

(**b**) In a uniform magnetic field $\mathbf{B}$ pointing in the z direction, the spin potential energy is

$$H_{\text{spin}} = \frac{\hbar\mu_B B}{2\sqrt{2}} \begin{pmatrix} 0 & 1-i \\ 1+i & 0 \end{pmatrix}$$

where μ_B is the Bohr magneton.

(**i**) Show that the spin eigenvectors are

$$\chi_\pm = \frac{1}{\sqrt{2}} \begin{pmatrix} 1 \\ \pm\frac{\sqrt{2}}{1-i} \end{pmatrix} \text{ with respective eigenvalues } \varepsilon_{\text{spin}\pm} = \pm\frac{\hbar\mu_B B}{2}$$

[10 marks]

(**ii**) Hence write down the total energy of the atom in eV. [2 marks]

(**b**) The energy levels of a hydrogen-like atom of atomic number Z are given by

$$E_n = -\frac{13.6Z^2}{n^2} \text{ eV}$$

Such an atom has $Z = 27$ and is in the state $n = 3$.

(**i**) Give the energy of the atom in this state. [1 marks]

(**ii**) Enumerate and give the total number of all the states corresponding to this value of n, using the actual quantum numbers of the dynamical variables to distinguish among the states. Do not neglect spin. [2 marks]

(**iii**) Calculate the frequency of the photon emitted when the atom decays from this level to the ground state. [2 marks]

5.(**a**) Show that with the aid of the complete set $\{\phi_k\}$the wave-mechanics expectation value

$$\langle A \rangle = \int \psi^* A \psi dV$$

can be transformed into the matrix-mechanics expression

$$\langle A \rangle = [\psi]^\dagger [A] [\psi]$$

making sure to define all the quantities that appear in the new expression. [6 marks]

(**b**) In a certain basis, the Hamiltonian of a 3-dimensional system is

$$[H] = \begin{pmatrix} 0 & -i & 0 \\ i & 0 & 0 \\ 0 & 0 & 2 \end{pmatrix}$$

(**i**) Explain why this Hamiltonian is guaranteed to give real eigenvalues for the energy. [2 marks]

(**ii**) Show that the eigenvalues of the Hamiltonian are $E = -1, 1, 2$ and that the corresponding eigenvectors are

$$[\chi_2] = \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix}, \quad [\chi_{-1}] = \frac{1}{\sqrt{2}} \begin{pmatrix} i \\ 1 \\ 0 \end{pmatrix} \text{ and } [\chi_{+1}] = \frac{1}{\sqrt{2}} \begin{pmatrix} -i \\ 1 \\ 0 \end{pmatrix}$$

[12 marks]

(**iii**) Show that the eigenvectors possess the property

$$\sum_k |\chi_k\rangle \langle\chi_k| = 1$$

and explain the significance of this. [2 marks]

(**iv**) Obtain the expectation value of the operator

$$[H] = \begin{pmatrix} 1 & 1 & 0 \\ 1 & 1 & 0 \\ 0 & 0 & -1 \end{pmatrix}$$

in the state of lowest energy. [3 marks]

6. (**i**) Given that intrinsic spin has quantum number $s = 1/2$, explain why the possible values for the z component of spin are $\pm\hbar/2$. [2 marks]

(**ii**) Assuming that orthonormal eigenfunctions $\chi_\pm$ of S_z and S^2 exist such that

$$S_z\chi_\pm = \pm\frac{\hbar}{2}\chi_\pm \text{ and } S^2\chi_\pm = \frac{3}{4}\hbar^2\chi_\pm$$

show that

$$[S_z] = \begin{pmatrix} \frac{\hbar}{2} & 0 \\ 0 & -\frac{\hbar}{2} \end{pmatrix} \quad \text{and} \quad [S^2] = \frac{3}{4}\hbar^2 \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}$$

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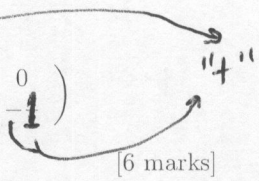

[6 marks]

(**iii**) Show that the normalised eigenvectors of $[S_z]$ are

$$[\chi_+] = \begin{pmatrix} 1 \\ 0 \end{pmatrix} \quad \text{and} \quad [\chi_-] = \begin{pmatrix} 0 \\ 1 \end{pmatrix}$$

. [4 marks]

(**iv**) Show that $[S_z]$ and $[S^2]$ commute and explain what this confirms. [4 marks]

(**v**) Given that the commutators for the spin operators are given by $[[S_i], [S_j]] = i\hbar[S_k]$ (with i, j and k taken in cyclical order) verify this expression for one pair of operators, given that

$$[S_x] = \frac{\hbar}{2}\begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} \quad \text{and} \quad [S_y] = \frac{\hbar}{2}\begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix}$$

. [4 marks]

(**vi**) Show that $[S_x]$ and $[S_y]$ have the same eigenvalues as $[S_z]$ and explain why symmetry considerations guarantee this. [5 marks]

******END OF EXAMINATION*****

THE UNIVERSITY OF ZAMBIA
PHYSICS DEPARTMENT
UNIVERSITY EXAMINATIONS – 2018

PHY4815 - PHYSICS OF RENEWABLE ENERGY RESOURCES

TIME: 3 HOURS MAX MARKS: 100

ATTEMPT ANY **FOUR** (4) QUESTIONS. ALL QUESTIONS CARRY EQUAL MARKS. THE MARKS ARE SHOWN IN BRACKETS.

You may use the following information:

Boltzmann constant $k = 1.38 \times 10^{-23}$ JK^{-1}
Gas constant R = 8314 J/kmol.K
1 electron volt = 1.6×10^{-19} J
Stefan's constant σ = 5.67×10^{-8} W/m^{2}K^4
Sun's radius R_s = 6.96×10^8m
Mean Earth-Sun distance r_0 = 1.496×10^{11}m
Solar constant I_{sc} = 1367 Wm^{-2}
Earth's radius R_e = 6.37×10^6m
Planck's constant h = 6.6×10^{-34}J.s
Speed of light c = 3.0×10^8m.s^{-1}

In the usual notation

$$E_0 = \left(\frac{r_0}{r}\right)^2 = 1 + 0.033 \cos\left(\frac{360\, d_n}{365}\right)$$

$$\delta = 23.45° \sin\left[\frac{360}{365}(d_n + 284)\right]$$

$$\cos\theta_z = \sin\delta \sin\phi + \cos\delta \cos\phi \cos\omega$$

$$\tan\psi = \frac{\cos\delta \sin\omega}{\cos\delta \sin\phi \cos\omega - \sin\delta \cos\phi}$$

$$\cos\psi = \frac{\sin\alpha \ \sin\varphi - \sin\delta}{\cos\alpha \ \cos\varphi}$$

$$\cos\theta = (\sin\varphi \cos\beta - \cos\varphi \sin\beta \cos\gamma) \sin\delta + (\cos\varphi \cos\beta + \sin\varphi \sin\beta \cos\gamma) \cos\delta \cos\omega + \cos\delta \sin\beta \sin\gamma \sin\omega$$

$$\omega = 15^\circ (12 - t); \quad \omega_s = \cos^{-1}(-\tan\phi \tan\delta)$$

Solar time = clock time + $4(L_l - L_s)$ min + EOT

Wien's Law: $\lambda_{max} T = 2898$ μm.K

The emissive power of a black body $B_\lambda(T)$ (in W/m^2 per unit wavelength range) is

$$B_\lambda(T) = \frac{2\pi hc^2}{\lambda^5\left(e^{\frac{hc}{\lambda kT}} - 1\right)}$$

Direct flux on an inclined surface

$$F^{dir} = I_{sc} \cos\theta \exp\left(-\frac{\tau}{\cos\theta_z}\right)$$

The convective heat flux from a plate to a glazing

$$J = h_d(T_2 - T_1)$$

In a single heat exchanger the exit temperature is

$$T_{f,e} = T_B - (T_B - T_{f,i}) \exp\left(-\frac{U_L L}{\dot{m} C_f}\right),$$

and the heat extraction rate is

$$\dot{Q} = \dot{m} C_f (T_B - T_{f,i}) \left[1 - \exp\left(-\frac{U_L L}{\dot{m} C_f}\right)\right].$$

Fresnel's equations

$$r_{\parallel} = \left[\frac{n_r^2 \cos\theta_i - n_i \sqrt{n_r^2 - n_i^2 \sin^2\theta_i}}{n_r^2 \cos\theta_i + n_i \sqrt{n_r^2 - n_i^2 \sin^2\theta_i}}\right]^2$$

$$r_{\perp} = \left[\frac{n_i \cos\theta_i - \sqrt{n_r^2 - n_i^2 \sin^2\theta_i}}{n_i \cos\theta_i + \sqrt{n_r^2 - n_i^2 \sin^2\theta_i}}\right]^2$$

Overall reflectance and transmittance of a single glazing are

$$R = r\left[1 + \frac{\alpha^2(1-r)^2}{1-\alpha^2 r^2}\right]$$

$$T = \frac{\alpha(1-r)^2}{1-\alpha^2 r^2}$$

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

$$\rho = \frac{1}{e(n\mu_n + p\mu_p)}$$

The law of mass action

$$n_i p_i = np$$

The reverse saturation current density is

$$J_0 = DT^3 exp\left(-\frac{\varepsilon_g}{kT}\right)$$

The forward current density is

$$J = J_0\left[\exp\left(\frac{eV}{kT}\right) - 1\right]$$

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

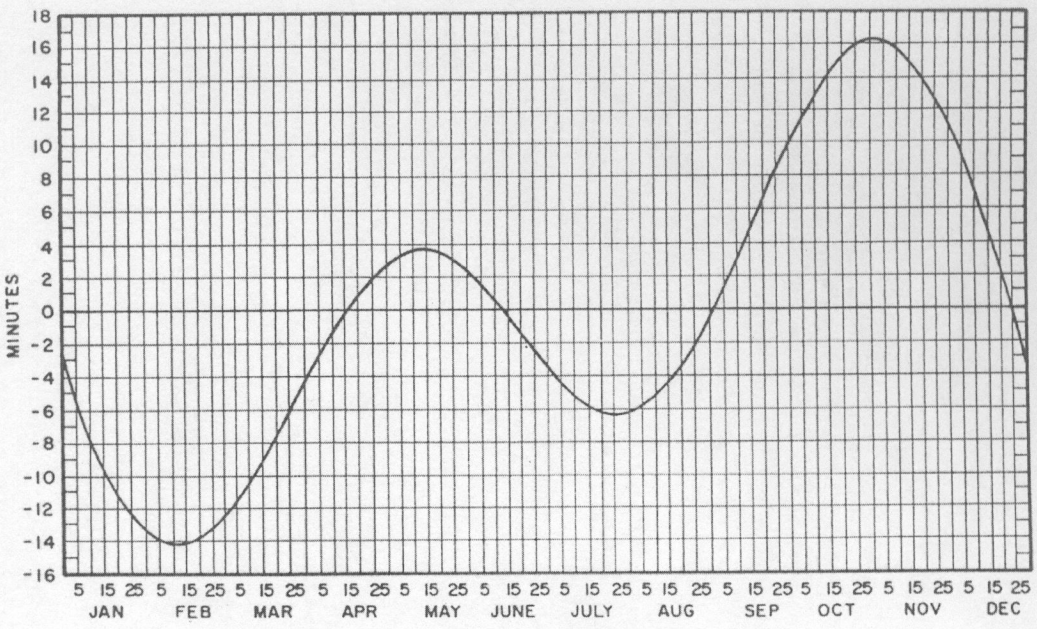

TABLE *The function $f(x)$*

$x(\mu m\text{-}K)$	$f(x)$	$x(\mu m\text{-}K)$	$f(x)$	$x(\mu m\text{-}K)$	$f(x)$
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 horizontal solar panel is situated in Dakar (Senegal). The latitude of Dakar is 14.7°N and the longitude 17.4°W. The standard longitude of Dakar is 15°W. On 31st March at 10.00 hour the optical thickness of the atmosphere is r = 0.2. Find

(i)	declination	[3]
(ii)	solar time	[4]
(iii)	hour angle	[2]
(iv)	sunset hour angle	[3]
(v)	day length	[2]
(vi)	angle of incidence of direct radiation on the panel	[6]
(vii)	direct solar flux incident on the panel	[5]

Q.2

(a) The equation of heat transfer from plate to glazing can be written as

$$J = U_d^{(c)}(T_P - T_g) + U_d^{(r)}(T_P - T_g)$$

and that from glazing to surroundings as

$$J = U_\infty^{(c)}(T_g - T_a) + U_\infty^{(r)}(T_g - T_a)$$

Using the above equations and assuming the heat transfer coefficients to be constant, obtain an expression for the overall heat transfer coefficient of the collector and explain its significance with the help of a network of resistors. [12]

(b) A flat-plate solar heating panel with one glazing has T_p=80°C and T_{sky}=T_a=30°C. The coefficients for heat transfer from the plate to the glazing are $U_{d,}^{(c)}$= 3 W/m^2-°C and $U_{d,}^{(r)}$=5W/m^2-°C. The coefficients for heat transfer from the glazing are $U_\infty^{(c)}$= 9 W/m^2-°C and $U_\infty^{(r)}$= 7 W/m^2-°C.

(i)	Draw the equivalent resistor network to represent the system, clearly showing the values of the heat transfer coefficients on each of the resistors.	[4]
(ii)	Find the overall heat transfer coefficient for the system.	[4]
(iii)	Find the flux loss from the absorber.	[2]
(iv)	Find the temperature of the glazing.	[3]

Q.3 (a)

(i) Clearly explaining the physics involved, obtain the conditions for anti-reflective coating for a given wavelength of light at normal incidence. [8]

(ii) Find the index of refraction of a film that can make glass (n_g = 1.5) non-reflective at normal incidence. What is the minimum thickness of this film that must be deposited in order to make the glass non-reflective at normal incidence for red light with wavelength $\lambda_0 = 0.7\mu m$? [4]

(b)

(i) What is a selective surface? Show qualitatively on an absorption vs wave-length graph a real selective surface and an ideal selective surface. Briefly explain the significance of the cut-off wavelength for a selective surface and how it is chosen. [6]

(ii) Consider a black plate (a =ε =1) suspended in space outside the atmosphere. The plate is facing the Sun and the back is silvered to avoid any radiation losses. Find the plate temperature under steady state. [3]

(iii) If the plate in (ii) above is coated with an ideal selective surface with cut-off wavelength 4μm, find the steady state temperature of the plate. [4]

Q.4

(a) In a single-stage heat exchanges, a pipe carrying water passes through a tank containing fluid at a given constant temperature. Describing the physical processes involved, obtain, in terms of the rate of flow of water, the inlet temperature of water, the length of the tank and the heat transfer coefficient for the pipe, steady state expressions for

(i) the exit temperature of the water, and

(ii) the rate of heat extracted. [10+3]

(b) A single solar heating panel uses water (C_f = 4186 J.kg^{-1}.°C^{-1}) as the transfer fluid. The water is flowing at a rate $\dot{m}$ = 10g.s^{-1}. It enters the panel at 20°C and leaves at 60°C. The fluid is carried to a storage tank by an exterior pipe 20 m long whose overall heat transfer coefficient per unit length is $\overline{U}_L$ = 0.2 W.m^{-1}.°C^{-1}. The ambient temperature is T_a=15°C. Find

(i) the temperature of the water entering the storage tank,

(ii) the percentage of the heat produced by the panel that is lost by the pipe. [9+3]

Q.5 (a) Define optical efficiency, thermal efficiency and overall efficiency of a heating panel. Express the overall efficiency in terms of the optical and thermal efficiency. List few considerations which should be given to construct an efficient solar heating panel? [6]