

# **THE UNIVERSITY OF ZAMBIA**

## **SCHOOL OF NATURAL SCIENCES**

### **2016/2017 END OF YEAR EXAMS**

1. BIO 1412 MOLECULARBIOLOGY GENETICS
2. BIO 2302 BASIC MICROBIOLOGY (theory paper)
3. BIO 2812 DIVERSITY OF ANIMALS (theory paper)
4. BIO 3712 ANIMAL PHYSIOLOGY (theory paper)
5. CHE 1000 INTRODUCTION TOCHEMISTRY
6. CHE 2112 INTRODUCTORY BIOCHEMICAL
7. CHE 2522 FUNCTIONAL GROUP AND ARENE CHEMISTRY
8. CHE 2615 BASIC PHYSICAL CHEMISTRY
9. CHE 3122 ENERGY TRANSDUCTION SYSTEM
10. CHE 3222 INSTRUMENTAL METHODS OF CHEMICAL ANALYSIS
11. CHE 3422 ORGANOMETALLICS AND REACTION MECHANISMS
12. CHE 3522 POLYFUNCTIONAL COMPOUNDS, MOLECULARS REARRANGEMENT  
ANDORGANIC SYSTEM
13. CHE 4222 FOOD, DRUGS, PESTICIDES AND DETERGENTS ANALYSIS
14. CHE 4522 PHYSICAL ORGANIC CHEMISTRY AND NATURAL PRODUCTS CHEMISTRY
15. CSC 2000 COMPUTER PROGRAMMING
16. CSC 2202 OPERATING SYSTEMS
17. CSC 2702 DATABASES AND INFORMATIONS MANAGEMENT SYSTEMS
18. CSC 2912 NUMERICAL ANALYSIS
19. CSC 3120 DIGITAL ELECTRONICS
20. CSC 3402 FUNDAMENTALS OF ARTIFICIAL INTELLIGENCE
21. CSC 3600 SOFTWARE ENGINEERING
22. CSC 3612 IT PROJECT MANAGEMENT
23. CSC 3712 ADVANCED DATABASES
24. CSC 3750 MANAGEMENT INFORMATION SYSTEMS
25. CSC 4035 WEB PROGRAMMING AND TECHNOLOGIES
26. CSC 4130 ADVANCED HARDWARE DESIGN AND IMPLEMENTATION
27. CSC 4630 ADVANCED SOFTWARE ENGINEERING
28. CSC 4631 SOFTWARE TESTING AND MAINTENANCE
29. CSC 4642 SOFTWARE QUALITY ASSURANCE
30. CSC 4722 DISTRIBUTED SYSTEMS
31. CSC 4792 DATA MINING AND DATA WAREHOUSING

32. GES 1310	INTRODUCTION TO GEOGRAPHY
33. GES 2130	THE GEOGRAPHY OF AFRICA WITH SPECIAL REFERENCE TO ZAMBIA
34. GES 2420	RESEARCH AND STATISTICAL METHODS IN GEOGRAPHY
35. GES 3142	ECONOMIC GEOGRAPHY
36. GES 3262	BIOGEOGRAPHY
37. GES 3330	ENVIRONMENT AND DEVELOPMENT
38. GES 3342	ENVIRONMENTAL PLANNING AND MANGEMENT
39. GES 4165	MIGRATION, REFUGEES AND ENVIRONMENT
40. GES 4292	HYDRO-GEOMORPHOLOGY OF DRAINAGE BASINS
41. GES 4372	TOURISM, ENVIRONMENT AND DEVELOPMENT
42. MAT 1100	FOUNDATION MATHEMATICS
43. MAT 1110	FOUNDATION MATHEMATICS AND STATISTICS FOR SOCIAL SCIENCES
44. MAT 2100	ANALYTIC GEOMETRY AND CALCULUS
45. MAT 2110	ENGINEERING MATHEMATICS I
46. MAT 2300	INTRODUCTION TO REAL ANALYSIS
47. MAT 2602	INTRODUCTION TO STATISTICS
48. MAT 3100	ADVANCED CALCULUS
49. MAT 3110	ENGINEERING MATHEMATICS II
50. MAT 3300	REAL ANALYSIS
51. MAT 3902	PROBABILITY THEORY
52. MAT 4212	MODULE AND FIELD THEORY
53. MAT 4300	ELEMENTS OF FUNCTIONAL ANALYSIS
54. MAT 4622	CATEGORICAL DATA ANALYSIS
55. PHY 1010	INTRODUCTORY PHYSICS
56. PHY 2112	ATOMIC AND MODERN PHYSICS
57. PHY 2522	ANALYTICAL MECHANICS AND SPECIAL THEORY OF RELATIVITY
58. PHY 2712	OPTICS
59. PHY 3032	COMPUTATIONAL PHYSICS I
60. PHY 3531	INTRODUCTION TO QUANTUM MECHANICS
61. PHY 4242	FUNDAMENTALS OF MEDICAL PHYSICS
62. PHY 4442	DIGITAL ELECTRONICS II
63. PHY 4545	QUANTUM MECHANICS II
64. PHY 4815	PHYSICS OF RENEWABLE ENERGY RESOURCES

**THE UNIVERSITY OF ZAMBIA  
SCHOOL OF NATURAL SCIENCES**

**2016 FINAL EXAMINATIONS**

**BIO 1412 MOLECULAR BIOLOGY AND GENETICS  
THEORY PAPER**

**TIME: THREE HOURS**

**INSTRUCTIONS:**

1. Use the answer sheet provided to answer the questions
  2. Answer all questions.
  3. Choose the best answer.
  4. Each correct answer carries 4 marks.
  5. Each wrong answer carries (-1) mark.
  6. A blank space carries (-1) mark.
  7. I don't know carries 0 mark.
  8. The table of the genetic code is given on the last page of the examination.
  9. Hand over the question paper and answer sheet at the end of the examination.
  10. You are not allowed to communicate with other candidates during the examination.
  11. Copying and use of electronic devices will lead to disqualification.
  12. Do not turn this page until you are requested to do so.
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1. Which of the following is **true** about RNA synthesis?
  1. RNA synthesis is always in the 5' – 3' direction.
  2. RNA synthesis is always in the 3' – 5' direction.
  3. RNA polymerase needs a primer to initiate transcription.
  4. Uracil is transcribed from thymine.
  5. Incoming ribonucleotides are added to the 2' hydroxyl of the ribose sugar.
  6. I do not know.
  
2. Which of the following best describes the 'cap' modification of eukaryotic mRNA?
  1. A modified guanine nucleotide added to the 3' end of the transcript.
  2. A modified guanine nucleotide added to the 5' end of the transcript.
  3. A modified adenine nucleotide added to the 3' end of the transcript.
  4. A modified adenine nucleotide added to the 5' end of the transcript.
  5. A group of adenine nucleotides added to the 5' end of the transcript.
  6. I do not know.
  
3. Which of the following statements regarding splicing of the eukaryotic primary RNA transcript is correct?
  1. Exons are removed and introns are retained in the mature mRNA transcript.
  2. Introns are removed and exons are retained in the mature tRNA transcript.
  3. Introns are removed and exons are retained in the mature rRNA transcript.
  4. Splicing takes place in the cytoplasm.
  5. Splicing takes place in the nucleus.
  6. I do not know.
  
4. The role of an inducer that regulates a repressible operon is to ...
  1. bind to the promoter region and decrease the affinity of RNA polymerase for the promoter.
  2. bind to the promoter region and block the attachment of RNA polymerase to the promoter.
  3. increase the production of inactive repressor proteins.
  4. bind to the repressor protein and activate it.
  5. bind to the repressor protein and inactivate it.
  6. I do not know.
  
5. Peptidyl transferase is associated with the ...
  1. ribosome.
  2. RNA splicing.
  3. DNA template strand.
  4. nucleus.
  5. DNA replication.
  6. I do not know.
  
6. Which of the following is **not** a characteristic of the genetic code?
  1. The sequence is decoded 5'→3'.
  2. The code is not overlapping.
  3. The code is degenerate.
  4. Each amino acid has only one codon.
  5. The code is universal.
  6. I do not know.



7. Which of the following is **correct** about nonsense codons?
1. Codons that code for multiple amino acids.
  2. Codons that code for no amino acids.
  3. Codons that cause translation to stop.
  4. Both 2 and 3 above are correct.
  5. Codons that are degenerate.
  6. I do not know.
8. Arrange the following events of eukaryotic mRNA synthesis in the correct order:  
A: 3'-polyadenylation; B: termination; C: splicing; D: 5'-capping; E: initiation
1. ECDAB
  2. EABDC
  3. CBEDA
  4. EBDAC
  5. DEBCA.
  6. I do not know
9. The small subunit of ribosome binds to the ...
1. 5'end of mRNA.
  2. 3'end of mRNA.
  3. 5'end of tRNA.
  4. 3'end of tRNA.
  5. 5'end of DNA.
  6. I do not know.
10. Which of the following is related to Mendel's law of segregation?
1. Chromosomes are inherited in discrete units from one generation to the next.
  2. Genes can exist in different forms, known as alleles.
  3. Homologous chromosomes separate during gamete formation.
  4. Genes on different chromosomes are inherited independently.
  5. Genes on same chromosome are inherited independently.
  6. I do not know.
11. Which is the **correct** description of a dominant trait?
1. The most common trait in the population.
  2. The trait that is expressed in a heterozygous organism.
  3. A trait that reappears in the F<sub>2</sub> of a monohybrid cross.
  4. A trait that confers a selective advantage to the organism and thus increases its frequency of reproduction.
  5. A combination of both pure parental traits.
  6. I do not know.
12. A test cross is used to determine ...
1. the genotype of the dominant parent.
  2. the genotype of the recessive parent.
  3. the phenotype of the dominant parent.
  4. the phenotype of the recessive parent.
  5. all of the above.
  6. I do not know.

13. A dihybrid test cross ratio is ...
1. 3:1
  2. 1:2:1
  3. 1:1:1:1
  4. 9:3:3:1
  5. 9:3:4
  6. I do not know.
14. ABO blood types are an example of ...
1. continuous variation.
  2. multiple allelic inheritance.
  3. sex-linked inheritance.
  4. complete dominance.
  5. incomplete dominance.
  6. I do not know.
15. Explain why X and Y chromosomes are a non-homologous pair.
1. They do not share all the genes.
  2. They do not line up with each other during meiosis.
  3. One is autosomal while the other one is a sex chromosome.
  4. They are not the same shape.
  5. 3 and 4 above explain why they are non-homologous.
  6. I do not know.
16. Crossing over is more frequent in ...
1. males than in females.
  2. females than in males.
  3. hybrids than in pure parental lines.
  4. hemizygous than homozygous individuals.
  5. parents than in offspring.
  6. I do not know.
17. Which of the following might you suspect to be the cause of an unexpected F<sub>2</sub> dihybrid phenotypic ratio.?
1. Epistasis
  2. Linkage
  3. Back cross.
  4. Lethal allele
  5. Both 1 and 2
  6. I do not know.
18. Which of the following statements is **not correct**?
1. Chromatin uncoils to form chromosomes.
  2. Chromatin is found within the nucleus.
  3. Chromatin is made up of the DNA double helix and associated proteins.
  4. Chromosomes can be seen just as cell division is about to occur.
  5. Each species generally has a characteristic number of chromosomes.
  6. I do not know.

19. Which of the following stages has a distinct nuclear envelope but indistinct chromatin threads?
1. interphase
  2. Prophase
  3. metaphase
  4. anaphase
  5. telophase
  6. I do not know.
20. Following synapsis during meiosis I, the separation of homologous chromosomes means that ...
1. both chromosomes of each homologous pair reach each haploid daughter cell.
  2. both chromosomes of each homologous pair reach each diploid daughter cell.
  3. one chromosome from each homologous pair reaches each haploid daughter cell.
  4. one chromosome from each homologous pair reaches each diploid daughter cell.
  5. one chromosome from each pair of chromatids reaches each diploid daughter cell.
  6. I do not know.
21. During which phase are sister chromatids lined up at the equator?
1. prophase I
  2. prophase II
  3. telophase I
  4. metaphase II
  5. anaphase II
  6. I do not know.
22. If there are 20 chromatids in a cell, how many centromeres are there?
1. 5
  2. 10
  3. 20
  4. 30
  5. 40
  6. I do not know.
23. Which phase describes centrioles beginning to move apart in animal cells?
1. telophase
  2. anaphase
  3. early metaphase
  4. metaphase
  5. prophase
  6. I do not know.
24. The number of mitotic cell divisions required to produce 256 cells from one cell is ...
1. 8
  2. 128
  3. 50
  4. 64
  5. 16
  6. I do not know.

25. Which of the following help(s) to hold the DNA strands apart while they are being replicated?
1. Primase
  2. Ligase
  3. DNA polymerase
  4. Single-strand binding proteins
  5. Exonucleases
  6. I do not know.
26. A particular triplet of bases in the template strand of DNA is 3' AGT 5'. The corresponding codon for the mRNA transcribed is ....
1. 5' UCA 3'
  2. 3' UGA 5'.
  3. 5' TCA 3'.
  4. 3'ACU 5'.
  5. 3'UCA5'.
  6. I do not know.
27. Which enzyme catalyses the elongation of a new DNA strand in the 5' to 3' direction?
1. Primase
  2. DNA ligase
  3. DNA polymerase III
  4. Topoisomerase
  5. Helicase
  6. I do not know.
28. Choose the correct statement in relation to the experiment by Messelson and Stahl.
1. Sodium chloride is used to separate DNA molecules by capillarity.
  2. Sodium chloride is used to create a density gradient.
  3. The experiment was used to demonstrate the synthesis of the lagging strand.
  4. Results of the experiment proved that DNA is synthesised in the 5' to 3' direction.
  5. DNA molecules are separated by density gradient centrifugation.
  6. I do not know.
29. The Okazaki fragment is synthesised in the...
1. same direction as the growing fork.
  2. opposite direction to the growing fork.
  3. 3' to 5' direction.
  4. 2' to 3' direction.
  5. 3' to 1' direction.
  6. I do not know.
30. The DNA sequence for the start codon is...
1. ATG.
  2. AUG.
  3. TUC
  4. TAC
  5. AAT.
  6. I do not know.

31. Processing of eukaryotic primary mRNA transcript involves the addition of...
1. adenine nucleotides on the 5' end.
  2. a methylated adenine on the 5' end.
  3. many guanine nucleotides on the 3' end.
  4. a methylated guanine on the 5' end.
  5. many uracil nucleotides on the 3' end.
  6. I do not know.
32. During amino acid activation in prokaryotic translation, ...
1. tRNA binds to the 30s ribosomal subunit.
  2. tRNA binds to the 50s ribosomal subunit.
  3. an amino acid binds to its tRNA.
  4. an in-coming amino acid binds to the A-site of the ribosome.
  5. an amino acid reacts with ATP.
  6. I do not know
33. During the initiation of prokaryotic translation, the ...
1. 30s ribosomal subunit binds to tRNA
  2. 30s ribosomal subunit binds to mRNA
  3. 40s ribosomal subunit binds to tRNA
  4. 50s ribosomal subunit binds to mRNA
  5. 60s ribosomal subunit binds to tRNA
  6. I do not know.
34. In the function of the *lac* operon in *E. coli*, the *lac* genes are transcribed only in the absence of glucose because glucose is ...
1. an inducer.
  2. a regulator.
  3. not needed by *E. coli*.
  4. needed in the breakdown of lactose.
  5. preferred energy source.
  6. I do not know.
35. An operon is a/an ...
1. RNA sequence made up of codons that work together.
  2. group of proteins that work together.
  3. group of amino acids that build proteins that work together.
  4. double stranded DNA sequence of nucleotides.
  5. single stranded DNA sequence of related genes.
  6. I do not know.
36. To which structure on the chromosome do spindle fibers attach during cell division?
1. Telomere.
  2. Kinetochore.
  3. Homologous site.
  4. Centromere.
  5. Histone.
  6. I do not know

37. Which of the following contains all the hereditary information?
1. DNA.
  2. messenger RNA.
  3. transfer RNA.
  4. messenger and transfer RNA.
  5. messenger RNA and ribosomal RNA.
  6. I don't know.
38. Explain what happens during the G<sub>1</sub> phase of the cell cycle.
1. Chromosome replication.
  2. DNA replication.
  3. Synthesis of enzymes and other proteins.
  4. Replication of organelles.
  5. 2 and 4 above.
  6. I do not know
39. What event in cell division coincides with breakdown of the nuclear envelope?
1. Formation of a wall plate.
  2. Formation of four haploid chromosomes.
  3. Formation of spindle fibres.
  4. Alignment of chromosomes along the equatorial plate.
  5. Separation of sister chromatids.
  6. I do not know.
40. Describe a tetrad in a dividing cell.
1. A pair of chromatids held together by a centromere.
  2. A set of chromosomes at anaphase of mitosis.
  3. A pair of centrioles in a dividing animal cell.
  4. A pair of homologous chromosomes after chromosome replication.
  5. A pair of cells at the end of mitosis.
  6. I do not know.
41. 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 are produced.
  3. Occurrence of two cell divisions, one after the other.
  4. Process that occurs in somatic cells of an organism.
  5. Occurrence of chromosome recombination.
  6. I do not know.
42. Which of the following processes would contribute to genetic variation within a population?
1. Mitotic prophase
  2. Prophase I.
  3. Mitotic metaphase.
  4. Anaphase I.
  5. Metaphase II.
  6. I do not know.

43. The DNA sequence which is expressed into a specific character is called a/the...
1. phenotype.
  2. protein.
  3. genotype.
  4. histone.
  5. nucleosome.
  6. I do not know.
44. A mother with brown hair and blue eyes and a father with black hair and brown eyes have a son with black hair and blue eyes; the traits of their son are best explained by...
1. gene interaction.
  2. multiple alleles.
  3. co-dominance.
  4. sex linkage.
  5. independent assortment.
  6. I do not know.
45. A student crossed wrinkled-seeded (rr) pea plants with round seeded (RR) pea plants. Only round seeds were produced by the resulting plants in F<sub>1</sub> generation. This illustrates the principle of ...
1. independent assortment.
  2. segregation.
  3. dominance.
  4. gene interaction.
  5. codominance.
  6. I do not know.
46. Given a parental cross of tall plants (TT) with short plants (tt), which of the following is the appropriate test cross?
1. TT x tt
  2. Tt x Tt
  3. TT x TT
  4. Tt x tt
  5. TT x Tt
  6. I do not know.
47. Which of the following principles of heredity was proposed by Gregor Mendel?
1. Incomplete dominance.
  2. Multiple alleles.
  3. Sex linkage.
  4. Independent assortment.
  5. Gene interaction
  6. I do not know.

48. Long hair in rabbits is governed by a dominant allele (L) and short hair by its recessive allele (l). Black hair results from the action of its dominant allele (B) and brown from the recessive allele (b). What is the expected phenotypic ratio from the cross LIBb x LIBb?

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

49. Chi squared test is used ...

1. mainly for data based on continuous traits.
2. to confirm whether results obtained agree or disagree with theoretical results.
3. to test whether the trait under investigation is controlled by DNA or RNA.
4. to confirm whether the experimental material is from the same source.
5. to confirm whether the test material is homozygous or heterozygous.
6. I do not know.

50. Choose the statement which explains why some alleles are always inherited together.

1. Recombination keeps them together.
2. They are linked.
3. They are on different chromosomes.
4. They are unlinked.
5. They assort independently.
6. I do not know.

51. Which type of alleles are responsible for blood group AB?

1. Dominant alleles.
2. Codominant alleles.
3. Recessive alleles.
4. Incomplete dominance alleles.
5. Lethal alleles.
6. I do not know.

52. A man with blood group AB is married to a woman also with blood group AB. What proportion of their children would have blood group A?

1.  $\frac{1}{4}$
2.  $\frac{2}{3}$
3.  $\frac{1}{3}$
4.  $\frac{3}{4}$
5.  $\frac{1}{2}$
6. I do not know.

53. Which one of the following characteristics shows continuous variation?

1. Human skin colour.
2. Human height.
3. Human intelligence.
4. Plant productivity.
5. All of the above.
6. I do not know.



54. Which of the following statements is **false** about continuous characters?
1. They are influenced by both genotype and environment.
  2. They are determined by many genes.
  3. Phenotypic measurements form a range of values.
  4. They are also called quantitative characters.
  5. They are controlled by a single gene.
  6. I do not know.
55. In epistasis ...
1. one gene alters the effect of another.
  2. one gene is controlled by three or more alleles.
  3. one character is controlled by many genes.
  4. two genes are entirely independent of each other.
  5. there is allelic interaction between two different genes.
  6. I do not know.
56. When the cross AaCc (Agouti) x AaCc (Agouti) was executed, the offspring phenotypes comprised the following proportions:
- |        |     |
|--------|-----|
| Agouti | 106 |
| Albino | 50  |
| Black  | 12  |
- These results are caused by ...
1. codominance.
  2. epistasis.
  3. sex-linkage between the two genes.
  4. multiple allelic effect of the genes.
  5. polygenic effect of the genes.
  6. I do not know
57. What is the sex chromosome content of a human sperm?
1. X
  2. Y
  3. XX
  4. XY
  5. Both 1 and 2
  6. I do not know
58. A family has 3 boys and 1 girl. What is the chance that the next child will be a girl?
1. 25%
  2. 33%
  3. 50%
  4. 75%
  5. 100%
  6. I do not know

59. Which of the following is true?
1. The expression of an X-linked recessive trait is in higher frequency in females than in males.
  2. The expression of an X-linked recessive trait is in higher frequency in males than in females.
  3. The frequency of an X-linked gene is equal in males and females
  4. X-linked traits always show epistatic pattern of inheritance
  5. The ABO blood group system is controlled by X-linked genes.
  6. I do not know
60. A high proportion of ... pairs is required at the DNA origin of replication.
1. UA
  2. CC
  3. AA
  4. CG
  5. TA
  6. I do not know.
61. The nucleolus of the nucleus is the site where...
1. mRNA poly A tail is synthesized.
  2. rRNA is synthesized.
  3. tRNA is charged.
  4. mRNA is capped.
  5. mRNA is translated.
  6. I do not know.
62. The end of translation is signalled by a/an ... which binds a protein called the ...
1. anticodon, initiation factor.
  2. start codon, initiation factor.
  3. stop codon, elongation factor.
  4. stop codon, release factor.
  5. stop codon, nonsense codon.
  6. I do not know.
63. The role of messenger RNA is to ...
1. act as a catalyst during protein synthesis.
  2. provide genetic information for protein synthesis.
  3. translate the genetic code into a tRNA molecule.
  4. modify tRNA molecules before protein synthesis.
  5. produce new DNA.
  6. I do not know.
64. In the formation of an initiation complex in bacteria, the first 'charged' tRNA is ...
1. formyl-met-tRNA.
  2. ser-tRNA.
  3. tyr-tRNA.
  4. val-tRNA.
  5. cys-tRNA.
  6. I do not know.

65. The enzyme amino acyl-tRNA synthetase...
1. catalyses modification of primary mRNA.
  2. attaches an amino acid to tRNA.
  3. removes tRNA from its amino acid.
  4. catalyses ribosome translocation during translation.
  5. helps tRNA to synthesise proteins.
  6. I do not know
66. Choose the item which is **not** part of the lac operon DNA.
1. Repressor
  2. Regulator
  3. Operator
  4. Promoter
  5. Structural genes
  6. I do not know
67. Separation of non-sister chromatids takes place during...
1. Telophase.
  2. anaphase I.
  3. metaphase II.
  4. prophase I.
  5. anaphase II.
  6. I do not know.
68. What are the possible genotypes for a person who has blood group A?
1.  $I^A I^B$  and  $I^O I^O$
  2.  $I^A I^O$  and  $I^O I^O$
  3.  $I^A I^A$  and  $I^A I^O$
  4.  $I^B I^O$  and  $I^A I^O$
  5.  $I^A I^A$  and  $I^O I^O$
  6. I do not know
69. Which one of the following is an example of discontinuous variation?
1. Human body weight
  2. Human height
  3. Human intelligence
  4. Colour blindness
  5. All of the above.
  6. I do know.
70. Two tall pea plants are crossed, producing 105 tall plants and 32 short plants. The genotypes of the parent plants are ...
1. Tt and TT.
  2. Tt and Tt.
  3. tt and tt.
  4. TT and TT.
  5. None of the above.
  6. I do not know.

71. Determine the F<sub>2</sub> phenotypic ratio in the cross carried out in **question 70** above.

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

72. The basic structural unit of a chromosome is the ...

1. centromere.
2. telomere.
3. kinetochore.
4. nucleosome.
5. centrosome.
6. I do not know.

73. In rose plants, the trait for red colour in flowers is dominant to that for white colour. Suggest the possible genotype of the rose plant with white flowers.

1. Rr
2. rr
3. RR
4. Rw
5. Wr
6. I do not know

74. During replication of DNA...

1. the leading strand template is read in the 3' to 5' direction.
2. the new leading strand is polymerised in the 3' to 5' direction.
3. the new leading strand is polymerised using Okazaki fragments.
4. RNA polymerase has no role in DNA replication.
5. the enzyme ligase helps to break hydrogen bonds between bases.
6. I do not know.

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

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

76. Which of the following enzymes is used to make covalent bonds between nucleotides of DNA?

1. DNA ligase
2. RNA primase
3. DNA polymerase
4. RNA polymerase
5. Both 1 and 3
6. I do not know.

77. What is the role of topoisomerases in the replication of DNA?
1. They prepare double stranded DNA for continuous replication.
  2. They bind to the origins of the replication site within double stranded DNA.
  3. They unzip the double stranded DNA at the replication fork.
  4. They join the DNA nucleotides together with phosphodiester bonds.
  5. They are single-strand DNA stabilisers.
  6. I do not know.
78. The elongation of a new leading strand during DNA synthesis...
1. progresses away from the replication fork.
  2. occurs in the 3'→5' direction.
  3. produces Okazaki fragments.
  4. depends on the action of DNA polymerase.
  5. does not require a template strand.
  6. I do not know
79. In an operon the promoter site ...
1. codes for the repressor protein.
  2. is where the repressor binds.
  3. is where RNA polymerase binds.
  4. codes for the regulator gene.
  5. is where the operator binds.
  6. I do not know
80. The phenomenon known as the 'wobble hypothesis' refers to the ...
1. movement of a tRNA from the A site to the P site of a ribosome.
  2. ability of tRNA to pair with codons that may not match at the third base.
  3. ability of DNA to make more than one type of RNA.
  4. movement of tRNA from the P site to the A site of a ribosome.
  5. movement of multiple ribosomes along the same mRNA.
  6. I do not know.
81. Chiasmata in cell division lead to ... and ....
1. synapsis; crossing over.
  2. crossing over, separation of chromatids.
  3. crossing over; synapsis.
  4. crossing over; chromosomal recombination.
  5. chromosome replication; synapsis.
  6. I do not know.
82. The Meselson-Stahl experiment to show semi-conservative replication had DNA settled in three layers in centrifuge tubes according to their weight. Which layer had the hybrid DNA?
1. Top layer
  2. Middle layer
  3. Bottom layer
  4. Both 1 and 2 above.
  5. Both 1 and 3 above.
  6. I do not know.

83. In the function of the *lac* operon in *E. coli*, the *lac* genes are transcribed in the presence of lactose because...
1. RNA polymerase binds to the operator.
  2. DNA polymerase binds to the promoter.
  3. the repressor cannot bind to the promoter.
  4. it binds to the repressor.
  5. the presence of glucose does not matter.
  6. I do not know.
84. Which of the following statements is **not correct**?
1. An activated amino acid is one that is bound to its specific enzyme.
  2. An amino acid is bound to the terminal 5' hydroxyl group of a charged tRNA.
  3. The anticodon of tRNA recognises the codon on mRNA during translation.
  4. The start codon in bacteria codes for formyl methionine.
  5. The enzymes peptidyl transferase catalyses peptide bond formation between amino acids.
  6. I do not know.
85. Which of the following is **not true** of a codon?
1. It consists of three nucleotides.
  2. It may code for the same amino acid as another codon.
  3. It never codes for more than one amino acid.
  4. It is located on tRNA.
  5. It is the basic unit of the genetic code.
  6. I do not know.

Use the following information to answer questions 86-88.

A cross between Ss Gg (Straight wing, grey body) and ss gg (curled wing, ebony body) was carried out between two fruit flies (*Drosophila*). Out of 287 progeny, the following results were obtained:

Straight wing, grey body	113
Straight wing ebony body	30
Curled wing, grey body	29
Curled wing, ebony body	115

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

Table 1: Critical chi-squared values

Degrees of Freedom	Probability					
	0.5	0.1	0.05	0.01	0.001	
1	0.5	2.71	3.84	6.64	10.38	
2	1.4	4.60	5.99	9.21	13.82	
3	2.4	6.25	7.82	11.34	16.27	
4	4.4	7.78	9.49	13.28	18.46	

86. Name the type of cross described above.

1. Monohybrid test cross.
2. Monohybrid back cross.
3. Dihybrid test cross.
4. Dihybrid backcross.
5. 3 and 4 above.
6. I do not know.

87. Determine the chi-squared ( $\chi^2$ ) value of the results.

1. 23.72
2. 24.29
3. 25.47
4. 26.07
5. 99.55
6. I do not know

88. The results indicate that ...

1. The hypothesis that the alleles controlling the traits are assorting independently is accepted.
2. The hypothesis that the alleles controlling the traits are assorting independently is rejected.
3. The genes controlling the traits are not linked.
4. The differences between the observed and expected are not significant.
5. The differences between the observed and expected are due to chance.
6. I do not know.

89. The RNA polymerase, a DNA template and a new RNA transcript form ...

1. a transcription complex.
2. a replication complex.
3. a translation complex.
4. complexes 1 and 2 above.
5. complexes 1 and 3 above.
6. I do not know.

90. Identify the protein that is produced by a regulatory gene.

1. Beta galactosidase
2. Inducer
3. Transacetylase
4. Repressor
5. Permease
6. I do not know

91. If Bb is a gene pair of an individual then alleles for this gene pair are ...

1. A and B.
2. a and b.
3. a and A.
4. b and B.
5. Bb and bB.
6. I do not know.

92. Linkage ...
1. prevents homozygous condition.
  2. prevents independent segregation of alleles.
  3. promotes recombination.
  4. prevents the heterozygous condition.
  5. 2 and 3 above.
  6. I do not know.
93. The function of a tRNA is to...
1. provide a site for polypeptide synthesis.
  2. transport its specific amino acid to the ribosome.
  3. help in the assembly of the ribosome.
  4. translate the message on rRNA.
  5. transcribe DNA.
  6. I do not know.
94. In mitosis, chromosome duplication occurs during...
1. interphase.
  2. prophase.
  3. late prophase.
  4. late telophase.
  5. anaphase.
  6. I do not know.
95. A man with blood group AB is married to a woman who is also blood group AB. What percentage of their children will have blood group O?
1. 50%
  2. 67%
  3. 0%
  4. 75%
  5. 25%
  6. I do not know
96. DNA replication starts when ...
1. phosphodiester bonds between adjacent nucleotides break.
  2. The bonds between the nitrogen base and deoxyribose break.
  3. The leading strand produces short segments of DNA.
  4. hydrogen bonds between nucleotides of opposite strands break.
  5. RNA polymerase synthesises short strands of primers.
  6. I do not know.
97. Which one of the following molecules contains introns?
1. Prokaryotic mRNA.
  2. Ribosomal RNA.
  3. Eukaryotic mRNA.
  4. Eukaryotic DNA.
  5. Eukaryotic transfer RNA.
  6. I do not know



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

1. Eukaryotic chromosomes are made up of DNA and proteins.
2. In the chromosomes, the basic proteins are called histones.
3. In the chromosomes, the acidic proteins are called non-histones (phosphates).
4. The basic unit of association between DNA and protein is called a nucleosome.
5. None of the above statements is false.
6. I do not know

99. Describe chromatin.

1. The other name for a chromatid.
2. A repeating unit of a chromosome.
3. An alternative form of a chromatid.
4. A thin thread of nucleic acid plus protein.
5. A sequence of nucleotide bases which code for a complete polypeptide.
6. I do not know.

100. Mitosis is responsible for ...

1. sexual reproduction.
2. growth and tissue repair.
3. gamete formation.
4. chromosomal recombination.
5. chiasma formation.
6. I do not know

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END OF EXAMINATION

**THE UNIVERSITY OF ZAMBIA**  
**SCHOOL OF NATURAL SCIENCES**

2016 ACADEMIC YEAR  
FINAL EXAMINATIONS

BIO 2302: BASIC MICROBIOLOGY  
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. Compare and contrast confluent and diauxic growth in bacteria with named examples.
2. Summarise any four of the following:
  - (a) Biofilm.
  - (b) Endospore.
  - (c) S-layer in bacteria.
  - (d) Halophilic bacteria.
  - (e) Endoflagella.
3. (a) Describe prokaryotic genome.  
(b) Describe mechanisms that cause bacterial variability.
4. Describe the effect of oxygen, temperature and pH on growth of bacteria.

SECTION B

5. Compare and contrast the cultivation of bacteriophages and animal viruses.
6. Summarise any four of the following:
  - (a) Virion particle symmetry.
  - (b) Positive and negative strand RNA viruses.
  - (c) Structure of tobacco mosaic virus (TMV).
  - (d) Retroviruses.
  - (e) Viroid structure and function.
7. (a) Discuss quantification of viruses.  
(b) Describe the characters for the identification of viruses.
8. Compare and contrast life cycles of virulent and temperate bacteriophages.

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END OF EXAMINATION

**THE UNIVERSITY OF ZAMBIA  
SCHOOL OF NATURAL SCIENCES**

2016 ACADEMIC YEAR  
FINAL EXAMINATIONS

BIO 2812: DIVERSITY OF ANIMALS  
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.

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SECTION A: INVERTEBRATES

1. Describe the general body characteristics and life cycle of class Trematoda.
2. Compare and contrast habitat/environmental relationships among classes of phylum Annelida.
3. Outline the major distinguishing characteristics of subphyla Chelicerata, Crustacea, Myriapoda and Hexapoda.
4. Summarise each of the following:
  - (a) Role of protozoans in food chains.
  - (b) Feeding and digestion in phylum Cnidaria.
  - (c) Adaptations and significance of molluscs in freshwater and terrestrial habitats.
  - (d) Tagmatisation in arthropods.

SECTION B: VERTEBRATES

5. Summarise each of the following:
  - (a) Cyclostoma.
  - (b) Tetrapoda.
  - (c) Actinopterygii.
  - (d) Pisces.
  - (e) Perissodactyla.
6. Compare and contrast classes Cyclostoma and Chondrichthyes.
7. Explain how the class Amphibia is a good representative of subphylum Gnathostomata.
8. Summarise the three subclasses of the class Mammalia indicating animals of each subclass.

---

END OF EXAMINATION

**THE UNIVERSITY OF ZAMBIA  
SCHOOL OF NATURAL SCIENCES  
DEPARTMENT OF BIOLOGICAL SCIENCES**

**FINAL EXAMINATIONS  
BIO 3712 - ANIMAL PHYSIOLOGY**

**THEORY PAPER**

**TIME: THREE (3) HOURS**

**INSTRUCTIONS:** BEGIN EACH QUESTION ON A NEW PAGE.  
READ THE INSTRUCTION(S) AT THE BEGINNING OF EACH SECTION

---

**SECTION A. ANSWER ALL QUESTIONS IN THIS SECTION. EACH QUESTION IS WORTH 20 MARKS.**

- Question 1. Write brief notes on the following terms as they are applied in animal physiology; [20]
- (i) Thermal conformers.
  - (ii) Myogenic muscle contraction.
  - (iii) Fertilization
  - (iv) Photoreceptors
  - (v) Nutrients
- Question 2. With regard to animal physiology;
- (i) State three (3) types of muscles and the functions associated with such types of muscles [6]
  - (ii) In the process of urine formation, the nephron performs four (4) key functions. Use a well-labelled diagram to show the locale for the four functions. [10]
  - (iii) Describe two (2) physiological means through which diving animals conserve oxygen. [4]

**SECTION B. ANSWER ANY TWO (2) QUESTIONS IN THIS SECTION**

- Question 3. In animals;
- i List the components of a dive reflex and state the purpose of such a reflex resulting from an initial stimulus. [8]
  - ii Use the heart as a basis to describe the types of circulatory systems found in vertebrate animals? [6]
  - iii Describe three (3) deviations from the normal continuous reproductive patterns. [6]
- Question 4. Briefly,
- (i) Explain how the liver participates in the process of detoxification in the body of animals. [6]
  - (ii) Explain what is involved in a synaptic vesicle release cycle. [6]
  - (iii) Are acclimatization, acclimation and adaptation one and the same thing? Explain your answer. [8]

Question 5.

Use,

- (i) Examples to briefly discuss the types of chemical messengers found in animals. [8]
- (ii) Illustrations to describe the mechanisms involved in hormone action. [8]
- (iii) Brief explanations to show four (4) natural uses of a pheromone in insects. [4]

Question 6.

State,

- (i) The influence of drugs on synaptic transmission and mention a possible mechanism for this action. [6]
- (ii) The main features of a circulatory system. [6]
- (iii) The main adaptations to the respiratory system in animals. [8]

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**END OF EXAMINATION AND BONNE CHANCE**

**THE UNIVERSITY OF ZAMBIA  
SCHOOL OF NATURAL SCIENCES**

**2016/2017 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 and Periodic Table.

**ADDITIONAL INFORMATION TO THE CANDIDATES:**

Useful data is provided on page 8.

## SECTION A

## ANSWER ALL QUESTIONS

### Question A1

A sample of nitrogen gas,  $N_2$ , is collected in a  $100 \text{ cm}^3$  container at a pressure of  $91,726 \text{ Pa}$  and a temperature of  $565^\circ\text{C}$ . How many grams of nitrogen gas are present in this sample?

### Question A2

A balloon is filled with  $35.0 \text{ dm}^3$  of helium in the morning when the temperature is  $20.0^\circ\text{C}$ . By noon the temperature has risen to  $45.0^\circ\text{C}$ . What is the new volume of the balloon?

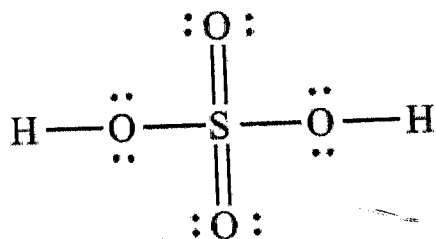
### Question A3

Calculate the energy and the wavelength of light required to excite the hydrogen atom from level  $n = 1$  to level  $n = 2$ .

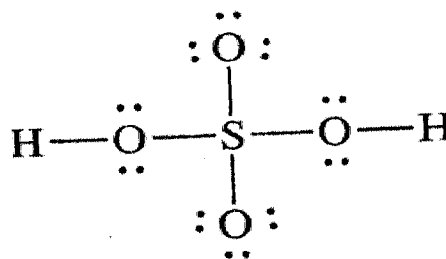
### Question A4

Two structures of sulphuric acid (a) and (b) are shown below. Which structure is the correct one? **Justify** in one line.

(a)



(b)



### Question A5

The rate law for the reaction,  $2\text{Cl}_2\text{O} \rightarrow 2\text{Cl}_2 + \text{O}_2$  at  $200^\circ\text{C}$  is found to be,  $\text{rate} = k[\text{Cl}_2\text{O}]^2$ . Let the initial concentration of  $\text{Cl}_2\text{O}$  to be  $0.10 \text{ M}$ .

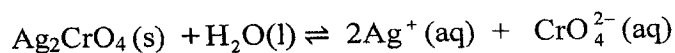
- Calculate the rate of the reaction, if the concentration of  $[\text{Cl}_2\text{O}]$  is reduced to one-third of its original value?
- Determine the concentration of  $[\text{Cl}_2\text{O}]$ , if the rate is doubled.

### Question A6

A first-order reaction has a rate constant,  $k$ , of  $2.00 \times 10^{-3} \text{ s}^{-1}$ . Calculate the time when only 1 percent of reactant remains.

### Question A7

A saturated solution of  $\text{Ag}_2\text{CrO}_4$  has the following equilibrium reaction:



The solubility product of  $\text{Ag}_2\text{CrO}_4$  is  $9.0 \times 10^{-12}$  at  $25^\circ \text{C}$ . Calculate the solubility of  $\text{Ag}_2\text{CrO}_4$  in  $0.0100 \text{ M K}_2\text{CrO}_4$  solution.

### Question A8

$\text{NH}_4\text{Cl}$  is an acidic salt,  $K_b$  of  $\text{NH}_3$  is  $1.8 \times 10^{-5}$ . Calculate the pH of  $0.010 \text{ M NH}_4\text{Cl}$  solution.

### Question A9

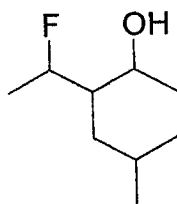
Calculate the freezing point in Kelvin of a solution containing 18 g glucose ( $M_r$  180 g/mol) and 68.4 g of sucrose ( $M_r$  324 g/mol) in 200 g water. The freezing point of pure water is  $0.0^\circ \text{C}$  and  $K_f$  of water is  $1.86 \text{ K/m}$ .

### Question A10

(a) Draw the structure for the following compound:

2-Bromo-8-chloro-4-(1-methylpropyl)nonane

(b) Provide the IUPAC name for the following compound:





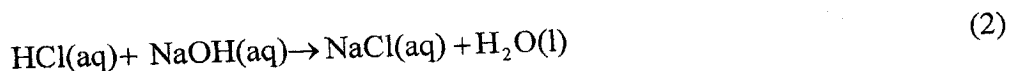
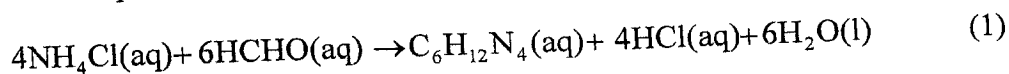
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**SECTION B****ANSWER QUESTION B1 AND ANY THREE QUESTIONS**

---

**Question B1**

In CHE 1000 experiment, the titration using the sequential reaction below was performed.



A 25.00 cm<sup>3</sup> solution containing 0.130 g of general purpose NH<sub>4</sub>Cl was pipetted to the conical flask and 5 cm<sup>3</sup> of formaldehyde, HCHO, was added to it. After reaction (1) was completed, two drops of an indicator were added. The titration required 21.90 cm<sup>3</sup> of 0.100 mol dm<sup>-3</sup> NaOH to reach the endpoint.

- a) Name the indicator used for the titration. [1 Mark]
  - b) Students were advised to rinse the apparatus with appropriate solutions. Name the solutions used for rinsing the burette, the pipette, and the conical flask. [3 marks]
  - c) From the titration reaction (2), determine the moles of HCl in the conical flask. [4 marks]
  - d) (i) Calculate the moles of NH<sub>4</sub>Cl that produced HCl in reaction (1) [3 marks]  
(ii) Determine the mass of NH<sub>4</sub>Cl. [2 marks]
  - e) Calculate percent of NH<sub>4</sub>Cl in the sample of the general purpose reagent used in the titration [2 marks]
- 

**Question B2**

- a) Using the VSEPR model, write the molecular geometry of ozone, O<sub>3</sub>. [2 marks]
  - b) On solving the Schrödinger's wave equation for hydrogen atom, we get a number of wave functions which are characterized by three quantum numbers. **In brief**, state and explain the meaning of these three quantum numbers. [6 marks]
  - c) Use the *spdf* notation (condensed) to write the configurations of Chromium (Cr). [1 mark]
  - d) **Briefly** state and explain the trend in ionization energy and atomic radius across a period and down a group. [6 marks]
-

### Question B3

- a) (i) The normal boiling points of diethyl ether, ethanol and water are given below:

Diethyl ether	34.6 °C
Ethanol	78.3 °C
Water	100.0 °C

Give an explanation based on intermolecular forces for the observed trend in the boiling points of the liquids. [6 marks]

- (ii) An unknown compound exhibits a vapor pressure of 193,800 Pa at 25.5 °C and 329,840 Pa at 48.8 °C. What is  $\Delta_{\text{vap}}H$  of this substance? [3 marks]

- b) The osmotic pressure of a 0.010 mol dm<sup>-3</sup> aqueous solution of CaCl<sub>2</sub> is found to be 68,293 Pa at 25 °C.

- (i) Calculate the van't Hoff factor,  $i$ , for the solution. [3 marks]
- (ii) How would you expect the value of  $i$  to change as the solution becomes more concentrated? Explain. [3 marks]

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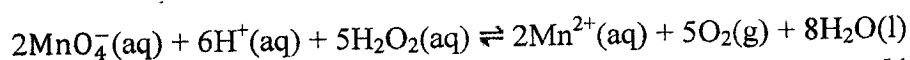
### Question B4

Use the following information to answer questions below.

- |   |  |          |
|---|--|----------|
| 1 | $\text{SO}_4^{2-}(\text{aq}) + \text{H}_2\text{O}(\text{l}) + 2\text{e}^- \rightleftharpoons \text{SO}_3^{2-}(\text{aq}) + 2\text{OH}^-(\text{aq})$          | - 0.93 V |
| 2 | $\text{MnO}_4^-(\text{aq}) + \text{e}^- \rightleftharpoons \text{MnO}_4^{2-}(\text{aq})$   | + 0.56 V |
| 3 | $\text{MnO}_4^{2-}(\text{aq}) + \text{H}_2\text{O}(\text{l}) + 2\text{e}^- \rightleftharpoons \text{MnO}_2(\text{aq}) + 4\text{OH}^-(\text{aq})$             | + 0.59 V |
| 4 | $\text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 8\text{H}^+(\text{aq}) + 5\text{e}^- \rightleftharpoons 2\text{Cr}^{3+}(\text{aq}) + 7\text{H}_2\text{O}(\text{l})$ | + 1.33 V |
| 5 | $2\text{H}^+(\text{aq}) + \text{O}_2(\text{g}) + 2\text{e}^- \rightleftharpoons \text{H}_2\text{O}_2(\text{aq})$   | + 0.68 V |
| 6 | $\text{MnO}_4^-(\text{aq}) + 8\text{H}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{Mn}^{2+}(\text{aq}) + 4\text{H}_2\text{O}(\text{l})$               | + 1.51 V |
| 7 | $\text{H}_2\text{O}_2(\text{aq}) + 2\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons 2\text{H}_2\text{O}(\text{l})$                                    | + 1.77 V |
| 8 | $\text{FeO}_4^{2-}(\text{aq}) + 8\text{H}^+(\text{aq}) + 3\text{e}^- \rightleftharpoons \text{Fe}^{3+}(\text{aq}) + 4\text{H}_2\text{O}(\text{l})$           | + 2.20 V |

- (a) (i) Give the formula of the species which, under standard conditions, is the strongest oxidising agent. [2 marks]

- (ii) Calculate the standard cell potential,  $E^\circ_{\text{cell}}$ , for the following reaction.



[4 marks]

- b) The mass of ethanol in  $5.00 \text{ cm}^3$  of white wine is found by oxidising the ethanol to ethanoic acid using acidified potassium dichromate(VI) solution. The excess acidified potassium dichromate(VI) solution is then determined.

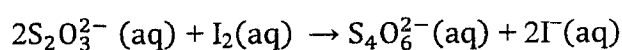
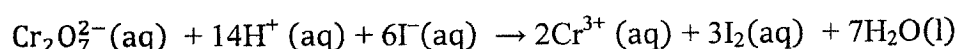
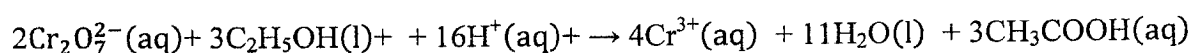
**Step 1**  $5.00 \text{ cm}^3$  of white wine was diluted to  $100.0 \text{ cm}^3$  with distilled water.

**Step 2**  $10.0 \text{ cm}^3$  of acidified potassium dichromate(VI) solution, of concentration  $0.0150 \text{ mol dm}^{-3}$ , was placed in a conical flask with  $1.00 \text{ cm}^3$  of the diluted white wine and left until all the ethanol had been completely oxidised.

**Step 3**  $10 \text{ cm}^3$  (an excess) of potassium iodide solution was added to the flask to react with the remaining potassium dichromate(VI) solution.

**Step 4** The iodine produced was titrated with  $0.0300 \text{ mol dm}^{-3}$  sodium thiosulfate solution.

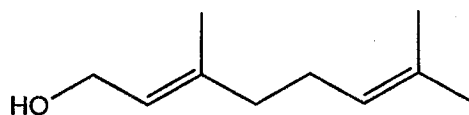
**Step 5** The procedure was repeated twice more. The mean titre of sodium thiosulfate solution was  $9.20 \text{ cm}^3$ . The equations for the reactions taking place are



- (i) Use the equations to determine the mole ratio of  $\text{S}_2\text{O}_3^{2-}$  to  $\text{Cr}_2\text{O}_7^{2-}$  in this series of reactions. [2 marks]
- (ii) Calculate the mass of ethanol in  $5.00 \text{ cm}^3$  of the original white wine. [7 marks]

### Question B5

- a) Geraniol,  $\text{C}_{10}\text{H}_{18}\text{O}$ , a naturally occurring monoterpene, is found in rose, palmarosa and citronella oils. It has rose-like scent and is commonly used in perfumes and food flavours.

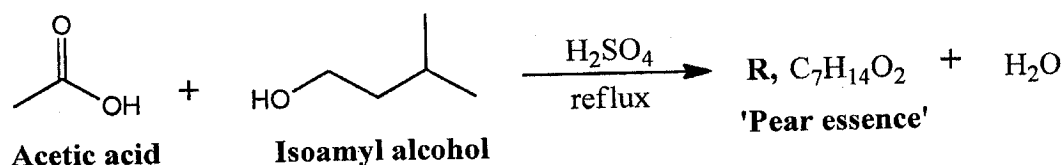


**Geraniol**

- (i) Give the complete IUPAC name for geraniol.

[2 marks]

- (ii) When reacted with excess hydrogen in the presence of palladium (catalyst), geraniol gives a product **P**,  $C_{10}H_{22}O$ . Propose the structure (*bond-line*) for **P** and give balanced chemical equation for the reaction. [3 marks]
- b) Several constitutional (structural) isomers can be written for the molecular formula  $C_4H_8O_2$ .
- (i) Calculate the IHD and state all possible interpretations. [2 marks]
- (ii) One of the isomers, **P**, decolorizes bromine water. Does this isomer have a ring? Give a reason. [2 marks]
- (iii) Give the bond-line formula and IUPAC name for another isomer **Q**, a branched chain molecule,  $pH = 5.2$ . [3 marks]
- (iv) State the isomeric relationship between **P** and **Q**. [1 mark]
- c) The characteristic flavour of the fruit, pear, is ascribed to the molecule **R**,  $C_7H_{14}O_2$  ('pear essence'), which is made by the reaction shown below:



- (i) State the type of reaction, shown above. [1 mark]
- (ii) Suggest the structure (*bond-line*) for **R**. [1 mark]

**END OF EXAM**

## USEFUL DATA

### Physical constants

Avogadro constant, $N_A$	$6.022 \times 10^{23} \text{ mol}^{-1}$
Acceleration due to gravity	$9.8 \text{ m s}^{-2}$
Faraday's constant, $F$	$96485 \text{ C mol}^{-1}$
Mass of electron, $m_e$	$9.11 \times 10^{-31} \text{ kg}$
Planck's constant, $h$	$6.626 \times 10^{-34} \text{ J s}$
Rydberg constant, $R_H$	$1.097 \times 10^7 \text{ m}^{-1}$
Speed of light, $c$	$3.00 \times 10^8 \text{ m s}^{-1}$
Universal gas constant, $R$	$8.3145 \text{ J mol}^{-1} \text{ K}^{-1}$ $0.083145 \text{ L bar mol}^{-1} \text{ K}^{-1}$ $0.08206 \text{ L atm mol}^{-1} \text{ K}^{-1}$ $62.364 \text{ L torr mol}^{-1} \text{ K}^{-1}$ $62.364 \text{ L mmHg mol}^{-1} \text{ K}^{-1}$

### Pressure conversions

$$1 \text{ atm} = 1.01325 \times 10^5 \text{ Pa} = 1.01325 \times 10^5 \text{ N m}^{-2} = 760 \text{ torr} = 760 \text{ mmHg} = 1.01325 \text{ bar}$$

$$\begin{aligned} 1 \text{ bar} &= 1.00000 \times 10^5 \text{ Pa} \\ &= 1.00000 \times 10^5 \text{ N m}^{-2} \end{aligned}$$

### Other conversion factors

$$\begin{aligned} V &= \text{J C}^{-1} \quad 1 \text{ eV} = 1.602 \times 10^{-19} \text{ J} \\ 1 \text{ J} &= 1 \text{ kg m}^2 \text{ s}^{-2} \end{aligned}$$

# 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																
3 Li 6.94 Lithium	4 Be 9.01 Beryllium																
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 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 Lanthanum	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 209 Polonium	85 At 209 Astatine	86 Rn 222 Radon
87 Fr (223.02) Francium	88 Ra 226.03 Radium	89-103 Actinium	104 Rf 261.11 Rutherfordium	105 Db 262.11 Dubnium	106 Sg 266 Seaborgium	107 Bh 264 Bohrium	108 Hs 277 Hassium	109 Mt 266 Meitnerium	110 Ds 271 Darmstadtium	111 Rg 272 Roentgenium	112 Cn 277 Copernicium	113 Nh 288 Nihonium	114 Fl 289 Flerovium	115 Lv 293 Livermorium	116 Lv 293 Livermorium	117 Ts 294 Tennessine	118 Og 294 Oganesson

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

2016 ACADEMIC YEAR 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 FIVE (5) printed pages

### Question 1

- a) **State** the Henderson Hasselbalch equation using acetate as an example. (5marks)
- b) ATP hydrolysis proceeds according to the following equation (at pH8.0)



A 1 mM solution of ATP was hydrolysed enzymatically in a 0.1 M Tris buffer (pH 8.0). (Hint: ATP is introducing  $\text{H}^+$  ions)

- i) **Calculate** the new pH at the end of the reaction. (5marks)
- What** would have been the final pH if
- ii) a 0.01 M Tris buffer (pH 8.0) was used? and also (5marks)
- iii) if no buffer was used? Tris  $\text{pK}_a = 8.1$  (5marks)

### Question 2

- a) List five main functions of proteins? (5marks)
- b) Calculate the length of a polypeptide chain containing 105 amino acid residue If:
- i) It exist entirely in alpha helical form. (2marks)
- ii) The backbone are fully extended and linear (3marks)
- c) Explain the term "**structure underlies function**" giving an appropriate example. (5 marks)
- d) Consider the following peptide gly-ser-arg-phe-pro-leu-arg-met-his. Calculate the net charge of this peptide at pH= 3. (5 marks)

Amino acid	Gly	Ser	Arg	Phe	Pro	Leu	Met	His
$\text{pK}_{a\text{carboxyl}}$	2.35	2.19	1.82	2.20	1.95	2.33	2.13	1.80
$\text{pK}_{a\text{amino}}$	9.78	9.21	8.99	9.31	10.64	9.74	9.28	9.33
$\text{pK}_{a\text{side}}$			12.48					6.04



### Question 3

Understanding Nucleic acid chemistry is essential among other things to understand normal functioning of living organisms, pathogenesis of diseases such as cancer and Human Immune deficiency viral disease (HIV).

- a) Name two nucleoside that are found in human cells. (2 marks)
- b) A sample of double stranded DNA was found to contain adenylate as 23 % of nucleotide residues. Calculate the percentage (%) of GC of this DNA? (3 marks)
- c) Give the common name and IUPAC name of a nucleoside analogue that you know that is used as antiretroviral drug (2 marks)
- d) Explain the mechanism of action of the drug you mentioned in (a) (Hint: Use Chemical structures to show the mechanism). (5 marks)
- e) What is a phospholipid? (2 marks)
- f) Draw the structure of adenosine triphosphate and explain why this molecule is a high energy compound. (6 marks)

### Question 4

- a) Draw the Fischer and Haworth projections of D-sorbitol (5marks).
- b) List five uses of glucuronic acid? (5marks)
- c) Copy and complete the table below

Reagent	Sugar specific to the reagent	Color change by the specific reagent
Barfoed		
Molisch		
Benedict's		
Seliwanoff		
Iodine		

(5marks)

- d) Mannitol and dulcitol are alcohol sugars. Mannitol may be used a drug and dulcitol may cause a pathological condition. List two medical uses of mannitol. (5marks)

### Question 5

- a) Explain the following terms and expressions as they are used in enzyme chemistry: **(3 marks)**
- i) coenzyme group
  - ii) steady-state kinetics
  - iii) induced fit
- b) Using a sketch of graph, show what most likely happens to the rate of reaction of a human enzyme when the temperature is increased gradually from 15°C to 90 °C? Briefly explain your answer. **(6 marks)**
- c) The following data were obtained in a study of an enzyme that is known to follow Michaelis-Menten kinetics.

[S] [ $\mu$ M]	V0 [ $\mu$ mol/min]
0.8	217
2	325
4	433
6	438
1000	647

- d) WITHOUT plotting any graph or linear regression, calculate the  $K_m$  for this enzyme. Show your reasoning (steps) clearly. **(6 marks)**
- e) What is the ratio of (S) to  $K_m$  when velocity (v) is 90 % of  $V_{max}$ ? **(5 marks)**

### Question 6

a) Define the following terms:

(3 marks)

- i) Epimer.
- ii) Mutarotation
- iii) Mutation

b) The reverse transcriptase enzyme was found to be a mutant type. One of the Mutations that may have occurred in his mutant is K181C.

i) What is the meaning of K181C?

(3 marks)

ii) In terms of the nature of amino acids what has occurred with this mutation

(3 marks)

iii) Explain the basis of chromatography as a separation technique

(3 marks)

iv) Ninhydrin is one of the reagent used in chromatography for visualization of amino acids during the separation of amino acid mixture. Write chemical reaction of Ninhydrin reagent with  $\alpha$  amino acid (HINT: Use only chemical structures) and use this to explain why Ninhydrin is used as such.

(8 marks)

**END OF EXAMINATIONS**

**THE UNIVERSITY OF ZAMBIA  
SCHOOL OF NATURAL SCIENCES**

**2016 ACADEMIC YEAR  
FINAL EXAMINATIONS**

**CHE 2522: FUNCTIONAL GROUP AND ARENE CHEMISTRY**

**TIME ALLOWED: THREE (3) HOURS**

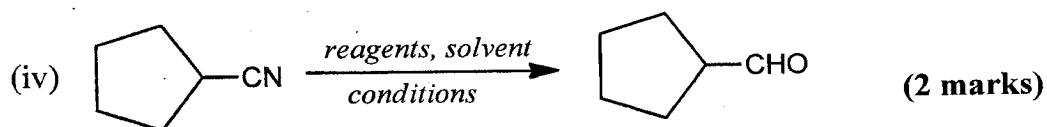
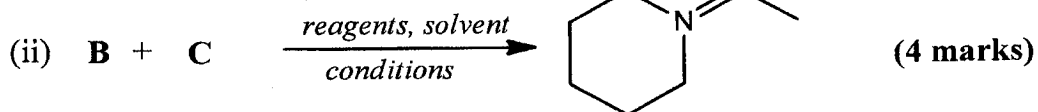
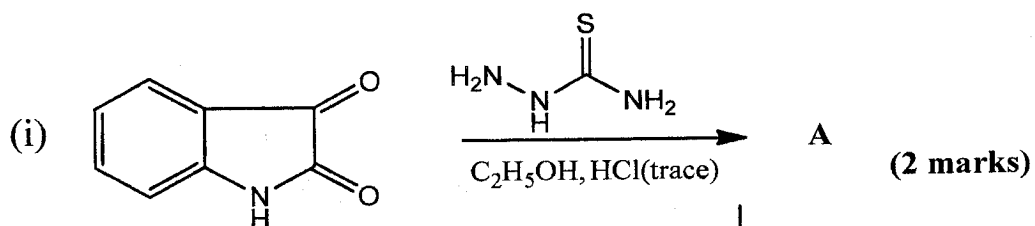
**INSTRUCTIONS:**

1. This paper contains two sections, **section A** and **section B**, and has 7 printed pages. Ensure you have all printed pages.
2. Section A has three (3) questions. Answer only two questions from section A.
3. Section B has three (3) questions. Answer only two questions from section B.
4. All questions carry equal marks (25).
5. Answer section A questions in the main answer booklet.
6. Answer section B questions in separate supplementary answer booklets.
7. **Do not answer questions from section A and section B in the same answer booklet.**
8. Indicate section A/ section B on your answer booklets clearly.
9. Write your TG number (example: TG 9) on the cover page of each answer booklet.
10. Tie all answer booklets together and submit.

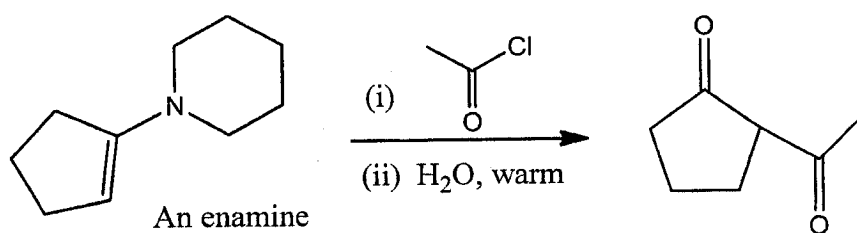
## SECTION A: ANSWER ANY TWO (2) QUESTIONS

### QUESTION A-1

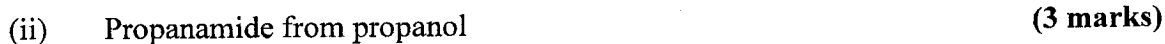
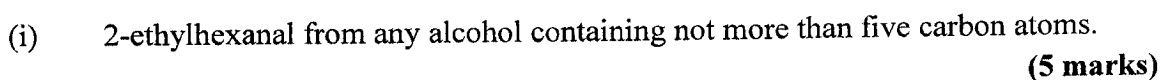
- (a) Provide the missing starting materials/products/ reagents/conditions for the following reactions. **(10 marks)**



- (b) Provide plausible mechanisms for the following transformation. **(7 marks)**

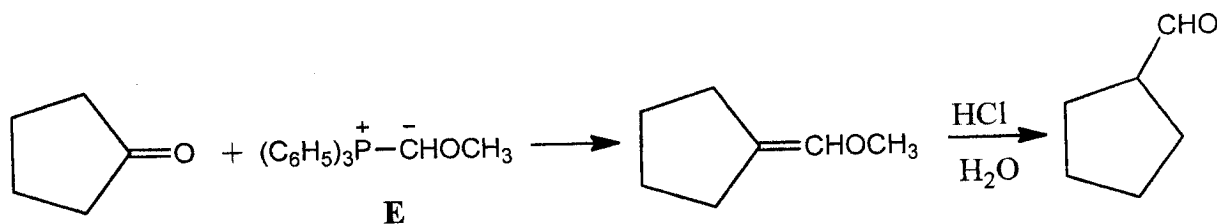


- (c) Suggest a synthesis of the following compounds from indicated starting materials. Show all steps clearly, including the intermediates for each step. Do not write mechanisms.

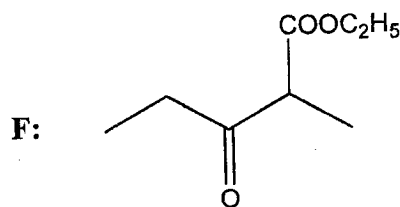


## QUESTION A-2

(a) A general procedure for the synthesis of aldehydes from ketones is shown below:

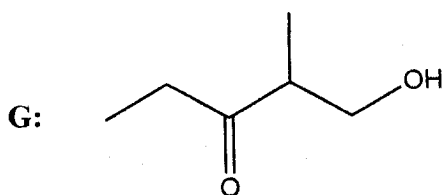


- (i) Give mechanisms of both reactions in the above procedure. (7 marks)
  - (ii) How would you prepare the phosphorane **E** from ethene. Assume that all other reagents are available. (4 marks)
- (b) Upon refluxing with potassium ethoxide in ethanol followed by acidification of the reaction mixture with dilute hydrochloric acid, ethyl propanoate gives a compound **F** in good yield.



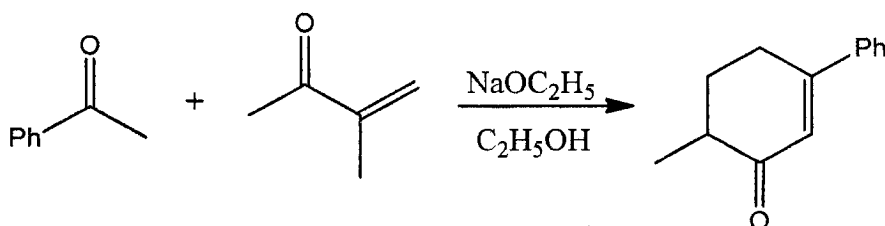
Propose a mechanistic explanation to account for the product **F**, showing resonance stabilisation of the intermediate reactive species. (8 marks)

- (c) How would you make compound **G** from compound **F** shown in QA-2(b) above? (6 marks)



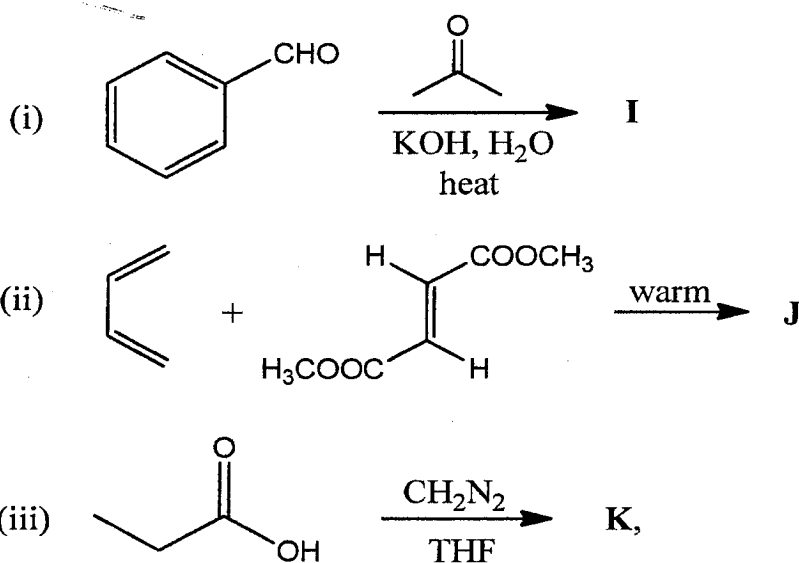
### QUESTION A-3

- (a) Upon heating with 25% aqueous sodium hydroxide solution, phenylglyoxal ( $\text{C}_6\text{H}_5\text{COCHO}$ ) gives a racemic mixture of sodium mandalate ( $\text{C}_6\text{H}_5\text{CHOHCOONa}$ ). Propose plausible mechanism for this reaction. **(5 marks)**
- (b) A general procedure, called Robinson Annulation, for synthesis of 2-cyclohexenones important intermediates in organic synthesis, from acyclic starting materials is shown below:



The Robinson annulation involves two sequential processes - Michael addition to give an adduct, which then undergoes intramolecular aldol condensation to give 2-cyclohexenones. Using this information, write the mechanism of the reaction shown above. **(11 marks)**

- (c) Propose synthesis of pentanoic acid from butanoic acid. Show all steps clearly, including the intermediates. **Do not** write reaction mechanisms. **(5 marks)**
- (d) Identify the major organic product(s) of ANY TWO of the following reactions. Show stereochemical structure, where pertinent. Do not write mechanisms. **(4 marks)**



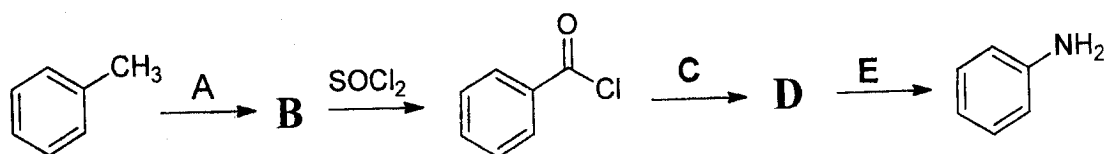
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SECTION B: ANSWER ANY TWO (2) QUESTIONS

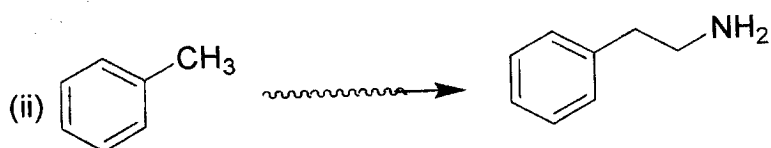
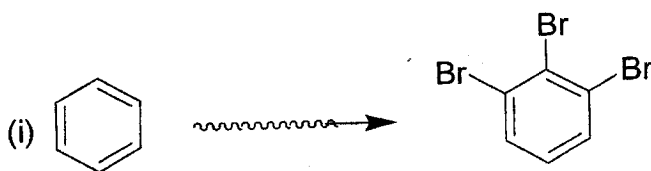
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QUESTION B-1

- (a) The reaction sequence below shows how a methyl group on a benzene ring can be replaced by an amino group.



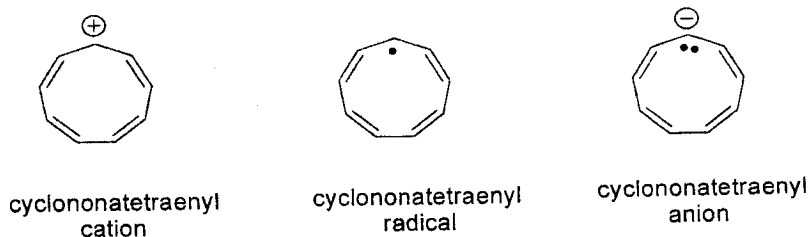
- (i) Supply the missing reagents and intermediates.
- (ii) Provide a mechanism for the conversion of intermediate **D** to the target molecule.
- (b) You are given separate unlabelled samples of a 1°, 2°, and 3°, amine. Clearly stating any visible changes that might take place, describe a chemical test of how you would identify the three compounds. Give any chemical reaction involved.
- (c) Using a different method for each part, but taking care in each case to select a *good* method, show how each of the following transformations might be accomplished. Full marks will not be awarded for lengthy indirect routes when more direct methods are available.



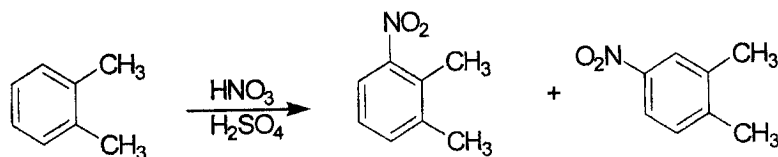


## QUESTION B-2

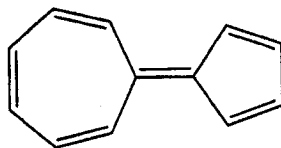
- (a) Use the **Frost circle method** to show the pattern of molecular orbitals in 1,3,5,7-cyclononatetraenyl and use it to label its cation, radical, and anion as aromatic, anti-aromatic, or not aromatic.



- (b) Before spectroscopy was invented, *Korner's absolute method* was used to determine whether a disubstituted benzene derivative was the *ortho*, *meta*, or *para* isomer. *Korner's method* involves adding a third group (often a nitro group) and determining how many isomers are formed. For example, when *o*-xylene is nitrated, two isomers are formed.



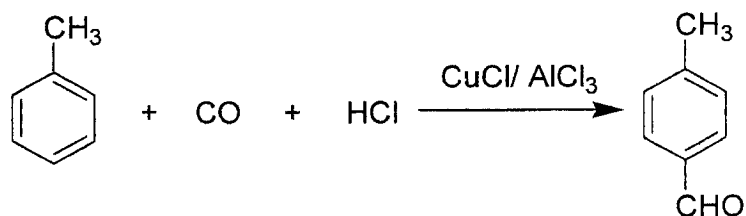
- (i) How many isomers are formed by nitration of *m*-xylene?
  - (ii) How many isomers are formed by nitration of *p*-xylene?
  - (iii) A turn-of-the-century chemist isolated an aromatic compound of molecular formula  $C_6H_4Br_2$ . He carefully nitrated this compound and purified three isomers of formula  $C_6H_3Br_2NO_2$ . Propose structures for the original compound and three nitrated derivatives.
- (c) The following hydrocarbon has an unusually large dipole moment. Explain how a large dipole moment might arise.



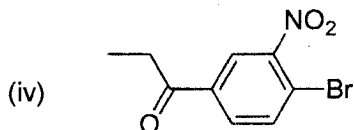
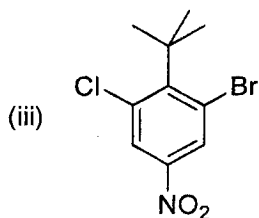
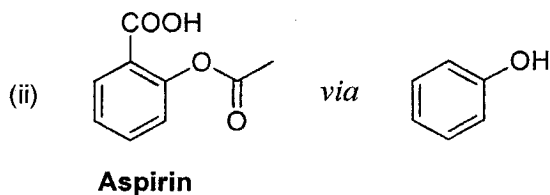
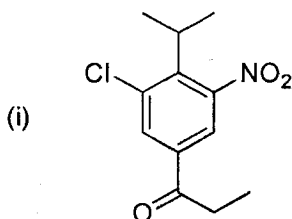
- (d) Acetanilide is less reactive than aniline toward electrophilic substitution. Explain.

### QUESTION B-3

- (a) (i) In the *Gatterman-Koch reaction*, a formyl group (-CHO) is introduced directly onto a benzene ring. For example, reaction of toluene with CO and HCl in the presence of mixed CuCl/AlCl<sub>3</sub> gives *p*-methylbenzaldehyde. Propose a mechanism.



- (ii) Draw resonance structures for the intermediates from reaction of an electrophile at the *ortho*, *meta*, and *para* positions of nitrobenzene. Which intermediates are most stable?
- (b) Starting with benzene and using any other reagents of your choice, design a synthesis for each of the following compounds. Full marks will not be awarded for lengthy indirect routes when more direct methods are available.



**END OF EXAMINATION**

**UNIVERSITY OF ZAMBIA**  
**SCHOOL OF NATURAL SCIENCES**  
**FINAL EXAMINATIONS 2016/2017 ACADEMIC YEAR, SEPTEMBER 2017**  
**C2615: BASIC PHYSICAL CHEMISTRY**

**Duration: Three (3) Hour**

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**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:**

$$R = 8.314 \text{ J mol}^{-1} \text{ K}^{-1} = 0.08206 \text{ L atm mol}^{-1} \text{ K}^{-1}$$

Molar volume of gas at STP =  $22.4 \text{ dm}^3 \text{ mol}^{-1}$ , STP = 273 K and 1 atm, 1 cal = 4.18 J

$$1 \text{ atm} = 1.01325 \times 10^5 \text{ Pa} = 1.01325 \times 10^5 \text{ Nm}^{-2}$$

---

**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)  $200 \text{ cm}^3$  of oxygen is collected over water at  $25^\circ\text{C}$  and 1 atm. If the oxygen obtained is dried at constant temperature of  $25^\circ\text{C}$  and 1 atm, what volume will it occupy?
- (iii) What volume will be occupied by the water removed from the oxygen if maintained at  $25^\circ\text{C}$  and 1 bar? (The equilibrium vapour pressure of water at  $25^\circ\text{C}$  is 0.04 bar)
- (b) Suppose 0.167 g of ethanol,  $\text{C}_2\text{H}_5\text{OH}$ , was injected into  $100 \text{ cm}^3$  a gas syringe. The syringe placed in a boiling water bath for several minutes. The atmospheric pressure was 0.99 bar and the temperature of the bath was  $100^\circ\text{C}$ .
- (i) What volume of ethanol would have been produced under these conditions?
- (ii) Make comment on the suitability of the syringe used.

### Question 2

- (a) Define the term *internal energy* as used to describe chemical systems.
- (b) Calculate the change in internal energy for the reaction given below using the data provided at 25 °C.



Substance	NaCl (s)	H <sub>2</sub> SO <sub>4</sub> (l)	HCl(g)	Na <sub>2</sub> SO <sub>4</sub> (s)
$\Delta H^\circ$ (kJ mol <sup>-1</sup> )	- 410	- 810	- 92	-1383

- (c) Explain how water freezing at -10 °C can be thermodynamically spontaneous, even though entropy decreases.
- (d) Determine the amount of heat required to convert 10 g of ice at 0 °C to vapour at 100 °C. For water  $\Delta_{\text{fus}} H = 334 \text{ J g}^{-1}$ ,  $\Delta_{\text{vap}} H = 2,257 \text{ J g}^{-1}$  and  $C_p = 4.18 \text{ J g}^{-1} \text{ }^\circ\text{C}^{-1}$ .

### Question 3

- (a) A CHE2615 student studying kinetics of a reaction  $\text{A} + \text{B} \rightarrow \text{C}$  collected following data:

$$[\text{B}] = 10.00 \text{ mol dm}^{-3}$$

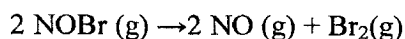
Time	[A] mol dm <sup>-3</sup>
0	0.1000
10	0.0900
20	0.0800
30	0.0700
40	0.0600
50	0.0500

Then she repeats the experiment with  $[\text{B}] = 5.0 \text{ mol dm}^{-3}$

Time	[A] mol dm <sup>-3</sup>
0	0.1000
10	0.0975
20	0.0950
30	0.0925
40	0.0900
50	0.0875

- (i) Plot concentration time graph for the results with  $[B] = 5.0 \text{ mol dm}^{-3}$ .
- (ii) What is the order of reaction with respect to A.
- (iii) What is the concentration of B at 50 minutes in each experiment?
- (iv) What is the pseudo rate constant ( $k$ ) when  $[B] = 5.00 \text{ mol dm}^{-3}$ . Calculate the pseudo rate constant when  $[B]$  is  $10 \text{ mol dm}^{-3}$ .
- (v) Calculate the order with respect to B.
- (vi) Write the rate law with the value of rate constant with its unit.

(b) The reaction



is a second order with respect to NOBr. If  $[\text{NOBr}]_0 = 7.5 \times 10^{-3} \text{ M}$ .

- (i) How much NOBr will be left after a reaction time of 10 minutes?
- (ii) Determine the half-life of this reaction.
- (iii) Complete the sketch given for the reaction with a rate constant,  $k, = 0.810 \text{ M}^{-1} \text{ s}^{-1}$  at  $10^\circ \text{C}$

Rate

$[\text{A}]^2$

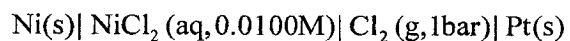
#### Question 4

A saturated solution of silver chloride AgCl has a specific conductance of  $2.28 \times 10^{-4} \Omega^{-1} \text{ m}^{-1}$  at  $25^\circ \text{C}$ . The specific conductance of the water used to make up this solution is  $0.116 \times 10^{-4} \Omega^{-1} \text{ m}^{-1}$ . The limiting molar ionic conductance of the two ions are  $\Lambda_{\text{Ag}^+}^\circ = 0.00619$  and  $\Lambda_{\text{Cl}^-}^\circ = 0.00763 \Omega^{-1} \text{ m}^2 \text{ mol}^{-1}$ .

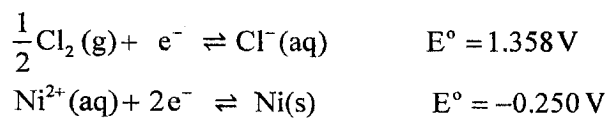
- (a)
  - (i) Calculate molar solubility,  $s$ , of AgCl in  $\text{mol L}^{-1}$
  - (ii) Determine the  $K_{\text{sp}}$  of AgCl.
- (b) From the following data calculate the molar conductance at infinite dilution of  $\text{NH}_4 \text{OH}$ .  
Molar conductance at infinite dilution of  $\text{Ba(OH)}_2$ ,  $\text{BaCl}_2$ , and  $\text{NH}_4 \text{Cl}$  are  $0.05254$ ,  $0.02799$ , and  $0.014985 \Omega^{-1} \text{ m}^2 \text{ mol}^{-1}$  respectively. Hint : balance the ions and simplify.
- (c) A  $0.00100 \text{ M}$  acetic acid has a resistance of  $21605 \Omega$  when measured in a conductance cell of cell constant  $105.0 \text{ m}^{-1}$ . The molar conductance at infinite dilution of acetic acid is  $0.03905 \Omega^{-1} \text{ m}^2 \text{ mol}^{-1}$ .
  - (i) Calculate the specific conductance of the electrolyte.
  - (ii) Determine the degree of dissociation of acetic acid.

### Question 5

Consider a cell



The reduction potentials of the cell at 25 °C are given below.



- (a) Using an appropriate ionic strength of the electrolyte, calculate the mean activity coefficient of  $\text{NiCl}_2$ , using the Debye- Hückel limiting law.
- b) Write the cell reaction.

**END OF EXAMINATION**

THE UNIVERSITY OF ZAMBIA  
SCHOOL OF NATURAL SCIENCES

2016 ACADEMIC YEAR

FINAL EXAMINATIONS

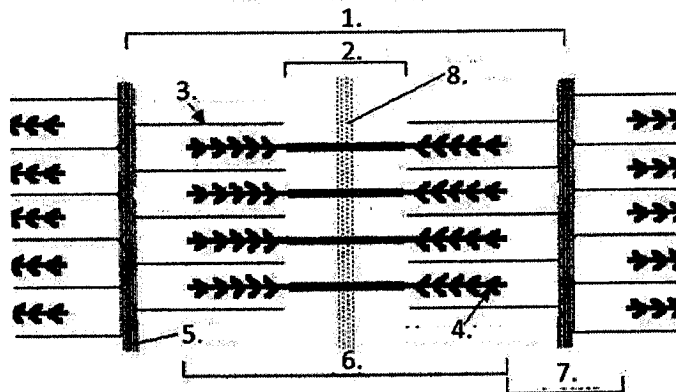
CHE 3122: ENERGY TRANSDUCTION SYSTEMS

INSTRUCTIONS TO CANDIDATES:

1. Time: **three (3) hours**
  2. All questions carry **equal** marks (20 marks each)
  3. Answer **any** Five (5) questions
  4. Write your computer number on **all** answer booklets
  5. This examination consists of **six (6)** questions and **four (4)** printed pages
-

## Question 1

- a) **Name** the three different kinds of muscles and explain how each one of them is controlled. [6 marks]
- b) **Explain** in detail the role of calcium ions in muscle contraction. [6 marks]
- c) Look at the diagram below and then **give** the names of the numbered components in a table form: [8 marks]



Skeletal muscle system

## Question 2

**Describe** the flow of electrons from the photosystem II to the Photosystem I starting with the absorption of light by light harvesting complex of photosystem II [20 marks]



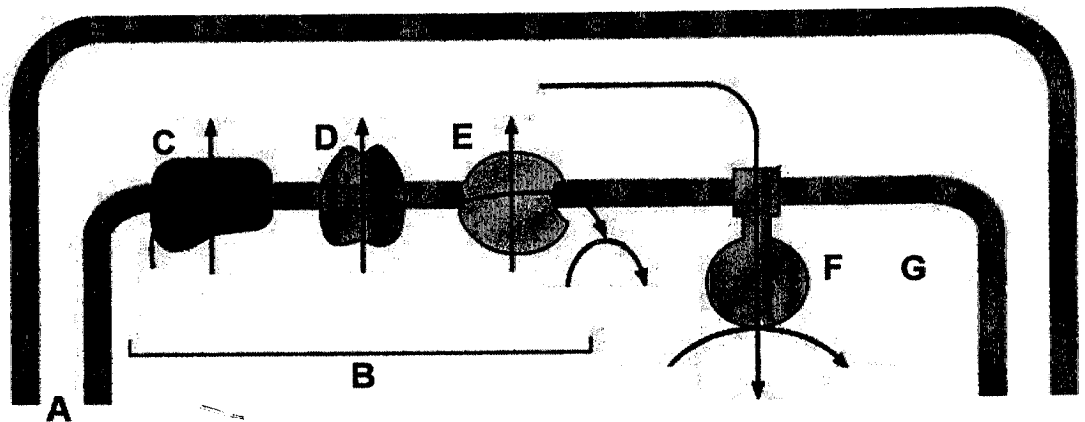
### Question 3

Photosynthesis occurs in two phases light and dark phase. These phases are associated with the photosystem I and II, electron acceptors, electron carriers, pigments among other things.

- i) **What** is photosynthesis? [2 marks]
- ii) **Define** (a) photosynthetic pigment (b) Accessory pigments [2 marks]
- iii) **Give** the chemical structure of one of the accessory pigments the you know [4 marks]
- iv) **Briefly** describe the structure of the chloroplast [12 marks]

### Question 4

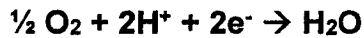
- a) **Copy** and fill in details of the diagram below. [15 marks]



- b) For each of the following, **state** the part of the electron transport chain inhibited.
- i) Rotenone
  - ii) Azide
  - iii) Oligomycin
  - iv) DCCD
  - v) Cyanide
- [5 marks]

### Question 5

a) Consider the following:



$$E^\circ = +0.815 \text{ V}$$



$$E^\circ = -0.315 \text{ V}$$

- i) **Write** the overall balanced spontaneous reaction observed [ 4 marks]
- ii) **Calculate** the energy released for the reaction in part (i) [6 marks]
- b) The permeability constants for a human neuron at rest, are  $pK=1.33 \times 10^{-5}$ ,  $pCl=1.99 \times 10^{-6}$  and  $pNa=1.92 \times 10^{-8}$  respectively. If the following data was collected in a patch clamp experiment, **calculate** the membrane potential of the neuron. [10 marks]

Ion	Concentration in cytoplasm (mM)	Concentration in Extracellular Fluid (mM)	Equilibrium potential (mV)
Na <sup>+</sup>	15	150	+60
K <sup>+</sup>	150	5	-90
Cl <sup>-</sup>	7	110	-70

### Question 6

- a) **Give** a stoichiometric composition of the ATPsynthase protein complex. [4 marks]
- b) For the following, state whether the statement is **True or False**: [ 4 marks]
- i) The ATPase belongs to ABC type of transporters
  - ii) DNP enhances ATP formation in the electron transport chain
  - iii) FMN carries one electron at a time in the electron transport chain
  - iv) GLUT 3 transporter is ubiquitously expressed in all tissues
- c) **Explain** with the help of a neat diagram, the mechanism of the Na<sup>+</sup>/K<sup>+</sup> ATPase pump. [10 marks]
- d) **How** many ATP molecules will be synthesized if only 7 protons are translocated from the intermembrane space? [ 2 marks]

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**End of Examination**

Faraday's const.

96,485 C mol<sup>-1</sup>

THE UNIVERSITY OF ZAMBIA  
SCHOOL OF NATURAL SCIENCES

2016/2017 ACADEMIC YEAR FINAL EXAMINATIONS

CHE3222 INSTRUMENTAL METHODS OF CHEMICAL ANALYSIS

TIME: THREE HOURS

INSTRUCTIONS

1. There are **five** questions in this examination paper.
  2. Answer any **four** questions.
  3. Answer questions **1** and **2** in a separate answer booklet and the remaining questions in another booklet.
  4. Questions carry equal marks.
- 

**Question 1**

- (a) Band broadening in chromatographic based analyses can lead to inaccurate qualitative and quantitative analysis. The van Deemter equation is an equation that includes the main factors contributing to column band broadening.
  - (i) Write the Van Deemter equation and state what each constant represent
  - (ii) Mention the four factors that lead to band broadening.
- (b) A chromatographic analysis for the chlorinated pesticide Dieldrin gives a peak with a retention time of 8.68 min and a baseline width of 0.29 min.
  - (i) How many theoretical plates are involved in this separation?
  - (ii) Given that the column used in this analysis is 2.0 meters long, what is the height of a theoretical plate?
- (c) State the main components of the High Performance Liquid Chromatography and the use of each of the stated main component.
- (d) **Briefly**, give **four** reasons why Solid Phase Extraction (SPE) is a better method for sample preparation in comparison to liquid-liquid extraction.

### Question 2

- (a) Gas-chromatograph (GC) is an important technique widely applied in analytical chemistry. Name the main components of the GC machine and their use.
- (b) The guard column is one important component used in HPLC. **Briefly** state three reasons why the use of the guard column is important in a HPLC machine.
- (c) One important step in the Solid Phase Extraction protocol is conditioning of the column. **In brief**, state the reason for conditioning of the column.
- (d) In a chromatographic analysis of lemon oil, a peak for limonene has a retention time of 8.36 min with a baseline width of 0.96 min.  $\gamma$ -Terpinene elutes at 9.54 min, with a baseline width of 0.64 min. What is the resolution between the two peaks?

### Question 3

- (a) Describe three mechanisms responsible for the transport of dissolved species to and from an electrode surface.
- (b) Ion selective electrode and reference electrode pair was placed in exactly 100ml of the sample; a reading of 21.6mV was obtained. After the addition of exactly 10ml of a standard solution with a concentration of 100 $\mu$ g/ml, the electrode pair reading gave a reading of 43.7mV. The response slope of the indicator electrode was previously determined to be 57.8mV. What is the sample concentration?
- (c) An unknown amount of  $\text{Co}^{2+}$  ions in a sample produces a faradaic current of 12.3 $\mu$ A on a normal pulse voltammogram. After 0.100ml of  $1.0 \times 10^{-3}\text{M}$   $\text{Co}^{2+}$  is added to the original volume of 5.00ml, the new current is 28.2 $\mu$ A. Calculate the original amount of cobalt in the sample.
- (d) What are liquid-junction potentials and how do they arise? How can they be eliminated or minimized?

### Question 4

- (a) Describe the differences in theory of operation and equipment needed for potentiometric and voltammetric measurements. List any guiding theoretical expressions that relate activity or concentration of an analyte to a measured electrochemical signal.
- (b) Explain the difference between an indicator electrode and a reference electrode. Name two indicator electrodes and two reference electrodes.

- (c) In coulometric titration of  $\text{Fe}^{2+}$  with  $\text{Ce}^{4+}$  which were generated at the cathode the resistance was  $R = 150 \, \Omega$ , potential was 0.705 V and the end point was reached after 352 seconds. Calculate the amount of iron in microgrammes ( $\mu\text{g}$ ).  
[Atomic mass Fe = 55.85;  $Q = 96487$  coulombs/mol]
- (d) Calculate (i) the standard state potential (ii) the equilibrium constant and (iii) the potential when  $[\text{Ag}^+] = 0.020\text{M}$  and  $[\text{Cd}^{2+}] = 0.050\text{M}$ , for the following reaction taking place at  $25^\circ\text{C}$ .
- $$\text{Cd(s)} + 2\text{Ag}^+(\text{aq}) \rightleftharpoons \text{Cd}^{2+}(\text{aq}) + 2\text{Ag(s)}$$
- $E^\circ_{\text{Ag}^+/\text{Ag}} = 0.7996\text{V}$  and  $E^\circ_{\text{Cd}^{2+}/\text{Cd}} = -0.4030\text{V}$

### Question 5

- (a) Describe three mechanisms responsible for the transport of dissolved species to and from an electrode surface.
- (b) The determination of riboflavin in vitamin formulations can be carried out polarographically because it is more easily reduced than other vitamin B factors. A 250.1mg vitamin tablet is dissolved to form a 100.00ml solution. A 10.0ml aliquot of this solution was added to a 0.10M phosphate supporting electrolyte at pH 7.2 and diluted to 50ml. the diffusion limited current was  $0.28 \, \mu\text{A}$ . A 50.0ml standard 4.10ppm riboflavin solution in the same electrolyte gave diffusion limited current of  $0.45 \, \mu\text{A}$ . Calculate the riboflavin concentration in the diet supplement.
- (c) Anodic Stripping Voltammetry (ASV) has the best detection limits of any voltammetric methods available today. Briefly outline the steps involved in an ASV analysis and indicate why it has detection limits superior to the other electrochemical methods we covered.
- (d) Ions that react with  $\text{Ag}^+$  can be determined electrogravimetrically by deposition on a silver anode:
- $$\text{Ag(s)} + \text{X}^- \longrightarrow \text{AgX(s)} + \text{e}^-$$
- (i) What will be the final mass of a silver anode used to electrolyze 75.00ml of 0.02380M KSCN if the initial mass of the anode is 12.4638g?
- (ii) At what anode potential versus SCE cathode will 0.10M  $\text{Br}^-$  be deposited as  $\text{AgBr(s)}$ ?

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END OF EXAMINATION

**UNIVERSITY OF ZAMBIA**  
**SCHOOL OF NATURAL SCIENCES**  
**CHEMISTRY DEPARTMENT**

**2016 Academic Year Deferred Final Examination**

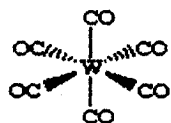
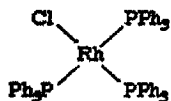
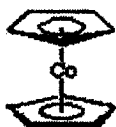
**CHE 3422 – Organometallics & Reaction Mechanisms**

**Answer any FOUR questions**  
**All questions carry equal marks**  
**Duration: 3 HOURS**

**07/09/17**

**Question 1**

(a) State electron count in each of the following organometallic complexes via anionic and neutral methods:



(b) Draw possible structures for the following complexes

(i)  $\text{Mn}_2(\text{CO})_{10}$

(ii)  $\text{Co}_2(\text{CO})_8$

## Question 2

- (a) In which of the following complexes is orbital contribution to the magnetic moment quenched? Justify your answer. (i)  $(\eta^5-Cp)_3Tb(NCMe)$   
(ii)  $[Yb(OH)_6]^{3-}$
- (b) The values for formation constants for each step in the formation of  $[Ni(en)_3]^{2+}$  are  $\log K_1 = 7.52$ ,  $\log K_2 = 6.28$  and  $\log K_3 = 4.26$  at  $30^\circ C$  in  $1.0M$   $KCl$ .
- (i) What is  $\log \beta_3$  for the overall formation of  $[Ni(en)_3]^{2+}$ ?
- (ii) Why do values of  $K$  decrease with  $K_1 > K_2 > K_3$ ? (10marks)
- (c) Explain how nuclei are held together.

## Question 3

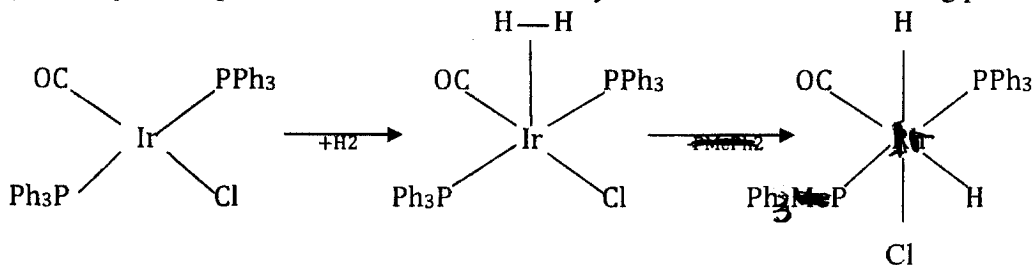
- (a) (a) Predict the products of the following and justify your answers:
- (i)  $\beta$  decay by  $C-14$ .
- (ii)  $\alpha$  decay by  $N-7$
- (b) How many alpha particles are emitted in the radioactive decay series starting with  $^{235}_{92}U$  and ending with  $^{207}_{82}Pb$ ?
- (c) How many beta particles are emitted?
- (d) Can you tell how many gamma particles are emitted?(yes/no, give reasons)

## Question 4

- (a) Give approximate range of CO stretching frequency in neutral complexes in  $cm^{-1}$  for the following types of CO bonding:

- (i) Free CO
- (ii) Terminal M-CO
- (iii)  $M \begin{array}{l} \diagup \\ \diagdown \end{array} C=O$
- (iv)  $M \begin{array}{l} \diagup \\ \diagdown \\ \diagup \\ \diagdown \end{array} C=O$

- (b) Identify and explain the reaction mechanism by which this reaction is taking place?



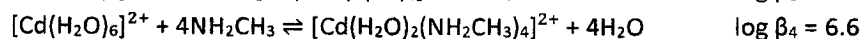
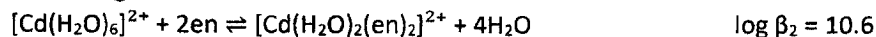
(c) Organometallic complexes undergo several reactions including migration and insertion among others.

(I) What is migration? Give an example?

(II) What is insertion? Give an example?

### Question 5

(a) Account for the difference in cumulative or overall stability constants for the following reactions:



(b) (i) Differentiate between the usefulness of cis Platin and trans Platin.

(ii) Magnetic moments for the following ISOELECTRONIC species of lanthanides and actinides are lower for actinides. Why? Neptunium(VI) & Cerium(III) and Neptunium(V) & Praseodymium(III).

(iii) Confirm that the term symbols for both  $\text{La}^{3+}$  and  $\text{Lu}^{3+}$  is  $^1\text{S}_0$

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END OF EXAM



**THE UNIVERSITY OF ZAMBIA  
SCHOOL OF NATURAL SCIENCES**

**2016 ACADEMIC YEAR  
FINAL EXAMINATIONS**

**CHE 3522  
POLYFUNCTIONAL COMPOUNDS, MOLECULAR REARRANGEMENTS  
AND ORGANIC SYNTHESIS**

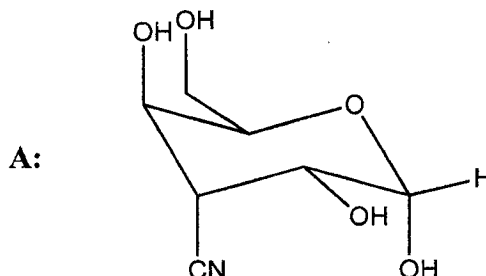
**TIME ALLOWED: THREE (3) HOURS**

**INSTRUCTIONS:**

1. This paper contains five questions and has 5 printed pages. Ensure you have all 5 printed pages.
2. Answer any four (4) questions.
3. Each question carries 25 marks.
4. Please present your answers in a neat and logical manner.

## QUESTION ONE

- (a) Suggest an efficient synthesis of the sugar derivative **A**, shown below, from D-galactose. Show all steps, including the intermediates, clearly. Please do not write reaction mechanisms. (10 marks)

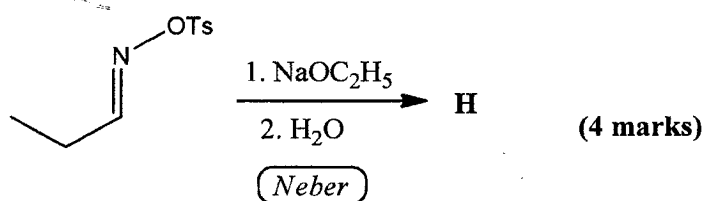


- (b) Ruff degradation of a D-aldopentose, **B**, gives a D-aldotetrose **C**. Upon reduction with sodium borohydride, **B** gives an optically inactive alditol, while **C** gives an optically active alditol. When **B** is used as starting material for Kiliani-Fischer synthesis, two diastereomeric aldohexoses **D** and **E** are produced. Upon sodium borohydride reduction, **D** gives an alditol **F**, while **E** gives an alditol **G**. The  $^{13}\text{C}$  NMR spectrum of **F** shows two signals and that of **G** shows six signals.

(i) Propose structures for **B-G**. (6 marks)

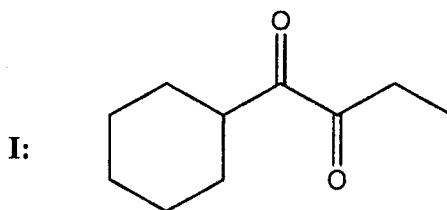
(ii) Show the reactions involved in the formation of **C** and **D** from **A**. (5 marks)

- (c) Identify the product for the following reaction (molecular rearrangement is involved).

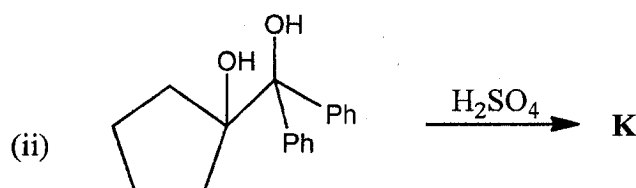
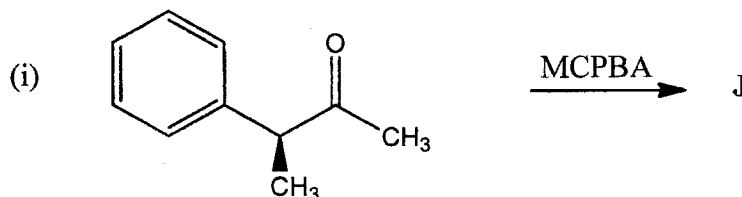


## QUESTION TWO

- (a) Briefly explain what is meant by the term “Umpolung” in organic synthesis. Devise a synthesis of the compound **I**, shown below, using dithiane chemistry. (8 marks)



- (b) Propose the plausible mechanisms and give the structure of the expected major product, including pertinent stereochemistry, where relevant, of the following reactions. Show all steps clearly. [*Note*: molecular rearrangement is involved in each case]. (14 marks)



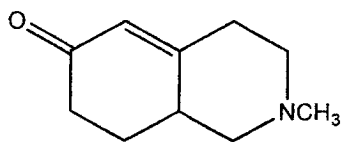
- (c) Give the structure of the ketohexose that gives the same osazone as D-mannose and the reagents needed for osazone formation. (3 marks)

### QUESTION THREE

- (a) Show how glucose and fructose can be distinguished by periodic acid oxidation. Briefly explain. (6 marks)
- (b) (i) Formation of peptide bond is usually accomplished by treating a mixture of N- and C- protected amino acids with DCC. On this basis, propose a synthesis of the peptide ala-gly. (9 marks)
- (ii) Give mechanism of the peptide bond formation step in your, using RCOOH to represent the N-protected amino acid and R<sup>1</sup>NH<sub>2</sub> to represent the C-protected amino acid. (5 marks)
- (c) Give the acetoacetic ester synthesis of 4-oxopentanoic acid. Show all steps clearly, including the intermediates. (5 marks)

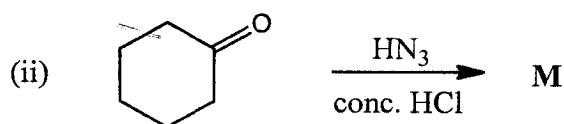
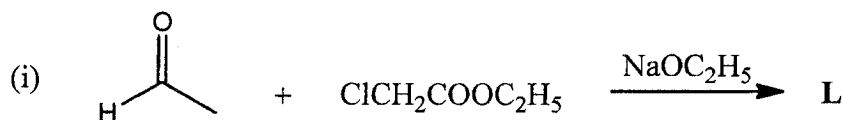
## QUESTION FOUR

- (a) Using the disconnection approach, suggest an efficient synthesis of compound **R**, the odor principle of most citrus fruits, from readily available non-heterocyclic starting materials-exception: assume that only pyrrolidine and pyridine are available. Show all steps of your proposed synthesis, including the intermediates, clearly. **(10 marks)**



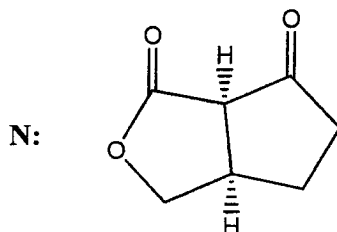
- (b) The rare amino acid L-dopa (3, 4-dihydroxyphenylalanine) is a useful drug for treatment of Parkinson's disease.
- (i) Show all steps, including the intermediates in the Strecker synthesis of L-dopa from catechol (1, 2-dihydroxybenzene). **(6 marks)**
- (ii) Give mechanism for the Strecker reaction step in the synthesis. **(5 marks)**

- (c) Predict the products of the following reactions: **(4 marks)**

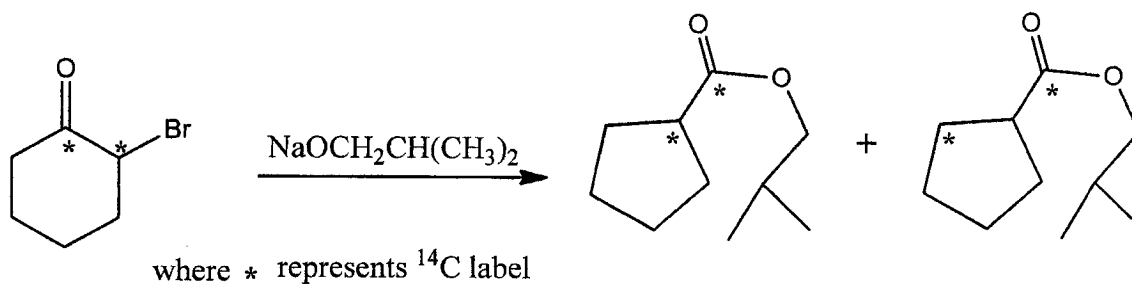


## QUESTION FIVE

- (a) Applying the disconnection approach, propose a synthesis for the molecule **N**, shown below, from readily available starting materials. Show the retrosynthetic analysis, and each step of the proposed synthesis, including the intermediates, clearly. Please do not write reaction mechanisms. **(12 marks)**



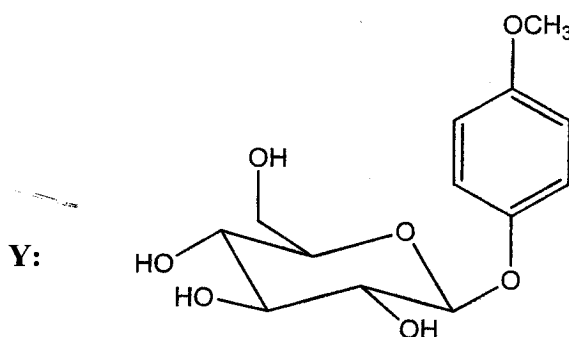
- (b) Upon treatment with  $\text{NaOCH}_2\text{CH}(\text{CH}_3)_2$ , the doubly  $^{14}\text{C}$  labelled 2-bromocyclohexanone gives ester with one  $^{14}\text{C}$  label remaining on the carbonyl carbon and the other  $^{14}\text{C}$  label is split equally as shown below.



Provide a mechanistic explanation to explain this result.

(7 marks)

- (c) Give the Koenigs-Knorr synthesis for the compound **Y**. Show all steps, including the intermediates clearly. Assume that the sugar and the aglycon are available. (6 marks)



**END OF EXAMINATION  
GOOD LUCK!**

THE UNIVERSITY OF ZAMBIA  
SCHOOL OF NATURAL SCIENCES

2016/2017 ACADEMIC YEAR FINAL EXAMINATIONS

CHE4222 FOOD, DRUGS, PESTICIDES AND DETERGENT ANALYSIS

TIME: **THREE HOURS**

**INSTRUCTIONS**

- 1 There are **five** questions in this examination paper.
  - 2 Answer any **four** questions.
  - 3 Questions carry equal marks
  - 4 Show your reasoning and/or calculations clearly.
- 

**Question 1**

- (a) Briefly describe the Gas Chromatograph analysis of drugs. Include all the necessary steps.
- (b) Briefly define the meaning of presumptive test. Name three presumptive tests that are carried out on drugs and name the presumptive test used for analysis of cannabis sativa.
- (c) Briefly explain how a microcrystalline test is carried. What is the main application of this test?
- (d) Classification of pesticides can be in terms of their chemical structures. There are generally four classes of pesticides based on their structures. Name the four classes of pesticides and give an example of a pesticide that can be categorized under each of the four classes.

**Question 2**

- (a) When sampling water for pesticide analysis, one should consider the possible presence of anaerobic conditions in the lower layers and algal growth in the surface layers leads might influence stability of pesticides. Hence data on basic physicochemical parameters should be available. Mention the at least **five** of these key parameters to be recorded when carrying out water sampling.
- (b) Give a **brief description** of the steps that are involved in SPE.

- (c) During GC analysis of drugs, a derivitization step is usually essential. Give three reasons why this step is necessary.
- (d) Sample storage is a critical step in analysis of pesticides to prevent their degradation.
  - (i) How could one prevent photo-degradation and biodegradation of dissolved pesticides?
  - (ii) Why is it necessary to maintain the pH of the sample solution prior to analysis?
  - (iii) Why is it a must not to store pesticides samples in plastic containers?

### Question 3

- (a) You are brought a 'top secret' new product that needs to be analyzed for fat. The person bringing you the sample indicates that since it is 'top secret' he cannot tell you anything about the product. You inform him that you cannot analyze the sample until you know something about it. Explain why this is the case. Additionally, what questions would you ask the person about the product that would enable you to analyze the sample for fat?
- (b) (i) What is peroxide value?
- (ii) A 5.00g sample of food grade oil was reacted with excess KI to determine peroxide value. The free iodine was titrated with a standardized solution of 0.10N  $\text{Na}_2\text{S}_2\text{O}_3$ . The amount of titrant required was 0.60ml blank corrected. Calculate the peroxide value of the oil.
- (c) Describe acid value and iodine value. Unlabeled product smells like butter. How would you confirm whether it is butter or margarine and what compound(s) may give such odour?
- (d) Describe how you would obtain oil from sunflower seeds and how would you determine two important quality factors of this oil.

### Question 4

- (a) The amount of ascorbic acid,  $\text{C}_6\text{H}_8\text{O}_6$ , in orange juice was determined by oxidizing the ascorbic acid to dehydroascorbic acid,  $\text{C}_6\text{H}_6\text{O}_6$ , with a known excess of  $\text{I}_3^-$ , and back titrating the excess  $\text{I}_3^-$  with  $\text{Na}_2\text{S}_2\text{O}_3$ . A 5.00ml sample of filtered orange juice was treated with 50.00ml of excess 0.0102M  $\text{I}_3^-$ . After the oxidation was complete, 13.82ml of 0.07203M  $\text{Na}_2\text{S}_2\text{O}_3$  was needed to reach the starch indicator end point. Report the concentration of ascorbic acid in milligrammes per 100ml.

- (b) A 20ml sample of juice requires 25ml of 0.1N NaOH titrant. What would be the percent acid if the juice is:
- (i) Apple juice
  - (ii) Orange juice
  - (iii) Grape juice?
- (c) Describe the procedure you would use to determine whether pasteurization or sterilization of your milk has been enough.
- (d) Explain the difference between acid value and hydroxyl value in an organic sample.

#### Question 5

- (a) A 5.00g sample of oil was saponified with excess KOH. The unreacted KOH was then titrated with 0.500N HCl (standardized). The difference between the blank and the sample was 25.8ml of titrant. Calculate the saponification value.
- (b) How would you differentiate soap from a non soap detergent and how would you test for detergency, foaming power and total fatty matter of these products?
- (c)
- (i) Distinguish between Reichert value and Polenske value.
  - (ii) How would you recommend determining the end point in the titration of tomato juice to determine the titratable acid? Why?
- (d)
- (i) Distinguish the following: beers, wines, champagnes and spirits.
  - (ii) Explain how you would determine the alcohol strength in the above products.

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END OF EXAMINATION



THE UNIVERSITY OF ZAMBIA  
SCHOOL OF NATURAL SCIENCES  
DEPARTMENT OF CHEMISTRY

**2016/2017 ACADEMIC YEAR**

**CHE4422 – Metal Chemistry and their Application to Organometallics and Catalysis**

**Time Allowed:**                      **Three (3) Hours only**

- 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.

### Question One

Answer **any five (5)** of the following part:

- (a) State the main components of cobalamine.
- (b) TEL is more harmful than inorganic lead. Explain why?
- (c) Show mechanism with which Arsenic poisoning can be removed by BAL.
- (d) Name **four** transition metals and **two** non-transition metals that play important roles in biological process.
- (e) Discuss the application of zeolites in shape selectivity catalysis.
- (f) Hemoglobin and myoglobin differ significantly in their mode of binding with di-oxygen molecule.

### Question Two

- (a) Discuss the *isolobal concept* as enunciated by the 1981 Chemistry Nobel Laureate **Ronald Hoffmann**.
- (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:

$\text{CH}_3$ ,  $\text{CH}_2$ ,  $\text{CH}$ ,  $\text{CH}_3^-$ ,  $\text{CH}_2^-$ ,  $\text{CH}^-$ ,  $\text{CH}_3^+$ ,  $\text{CH}_2^+$ , and  $\text{CH}^+$ .

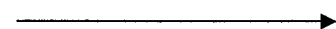
- (c) Isolobal analogies find tremendous utility in suggesting new compounds. Formation of metal-metal bonds differ from others in the use of *d* orbitals on both atoms, in addition to the usual *s*- and *p*- bonds.

For the species,  $[\text{Re}_2\text{Cl}_8]^{2-}$ ,

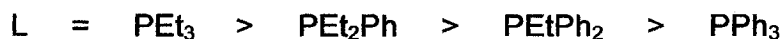
- (i) State the bond order
- (ii) Show the bonding Interactions between metal *d orbitals*, and hence
- (iii) Show the relative energies of orbitals formed from *d*-orbital interactions

### Question Three

- (a) Why are heat and/or light often necessary for catalytic behaviour of transition metal complexes?  
What types of substances are most likely to poison transition metal complexes, and why?
- (b) Explain the variation in the following rates of the oxidative-addition reaction between MeI and  $\text{IrX(CO)L}_2$  as X and L are changed:

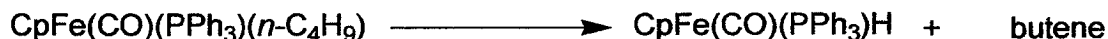


Rate decreases



- (c) Explain the terms  $\alpha$ - and  $\beta$ -hydrogen transfers. Give an example in each case.

The butene product from the reaction:



consists of 1-butene as well as *cis*- and *trans*-2-butene. Keeping in mind the reversibility of the  $\beta$ -hydrogen elimination, write a mechanism to account for this.

- (d) Explain how the facts that  $(\eta^6\text{-C}_6\text{H}_5\text{CO}_2\text{H})\text{Cr(CO)}_3$  is a stronger acid than benzoic acid and that  $(\eta^6\text{-C}_6\text{H}_5\text{NH}_2)\text{Cr(CO)}_3$  is weaker base than aniline show that the  $\text{Cr(CO)}_3$  group withdraws electrons from the aromatic rings.

### Question Four

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 Five

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.

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**END OF CHE4422 EXAMINATION for 2016/2017 ACADEMIC YEAR**

# PERIODIC TABLE OF THE ELEMENTS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
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Atomic number	<b>X</b>	Atomic mass
Name of the element X		

Atomic number <b>X</b> Atomic mass Name of the element X											
1 H 1.01	2 He 4.00										
3 Li 6.94	4 Be 9.01										
5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18						
11 Na 23.00	12 Mg 24.31	13 Al 26.98	14 Si 28.09	15 P 30.99	16 S 32.07	17 Cl 35.45	18 Ar 39.95				
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.88	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc 97.91	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41
87 Fr (223.02)	88 Ra 226.03	89-103	104 Uq 261.11	105 Uup 262.11	106 Uuh 263.12	107 Uus 262.12	108 Uuo 265.00	109 Uue 265			

Hydrogen	Helium										
1 H 1.01	2 He 4.00										
3 Li 6.94	4 Be 9.01										
5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18						
11 Na 23.00	12 Mg 24.31	13 Al 26.98	14 Si 28.09	15 P 30.99	16 S 32.07	17 Cl 35.45	18 Ar 39.95				
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.88	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc 97.91	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41
87 Fr (223.02)	88 Ra 226.03	89-103	104 Uq 261.11	105 Uup 262.11	106 Uuh 263.12	107 Uus 262.12	108 Uuo 265.00	109 Uue 265			

**THE UNIVERSITY OF ZAMBIA**  
**SCHOOL OF NATURAL SCIENCES**

**2016 ACADEMIC YEAR**  
**FINAL EXAMINATIONS**

**CHE 4522**  
**PHYSICAL ORGANIC CHEMISTRY AND NATURAL PRODUCTS**  
**CHEMISTRY**

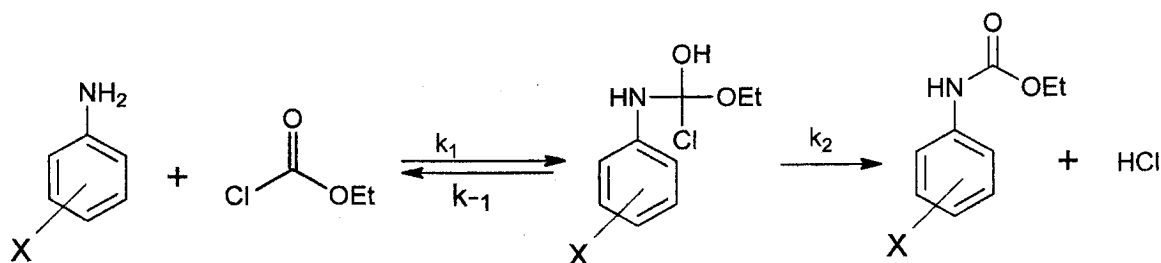
**TIME ALLOWED: THREE (3) HOURS**

**INSTRUCTIONS:**

- 1. This paper contains five questions and has 6 printed pages. Ensure you have all printed pages.**
- 2. Answer any FOUR (4) questions.**
- 3. Each question carries 30 marks.**

## QUESTION ONE

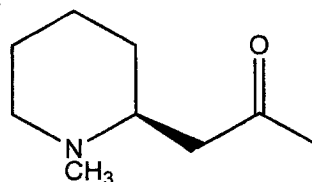
- (a) The Hammett plot of  $\log k$  versus  $\sigma^-$  (values given in the attached table) for the reaction shown below gave a  $\rho^-$  value of -5.56 when substituent X is *p*-OCH<sub>3</sub>, *p*-CH<sub>3</sub>, *m*-CH<sub>3</sub> and H, and  $\rho^-$  value of -1.57 when the substituent X is *p*-Br, *m*-Cl, *m*-NO<sub>2</sub>, and *p*-COOEt.



Provide a detailed mechanistic explanation to account for the difference in the observed values of  $\rho^-$ . (10 marks)

- (b) Isotopic labeling experiments have shown that the anthelmintic pomegranate alkaloid pseudopellitierene is derived from the amino acid, lysine,  $\text{H}_2\text{N}(\text{CH}_2)_4\text{CH}(\text{NH}_2)\text{COOH}$ , and acetyl coenzyme A and the molecule shown below is the key intermediate.

Intermediate:



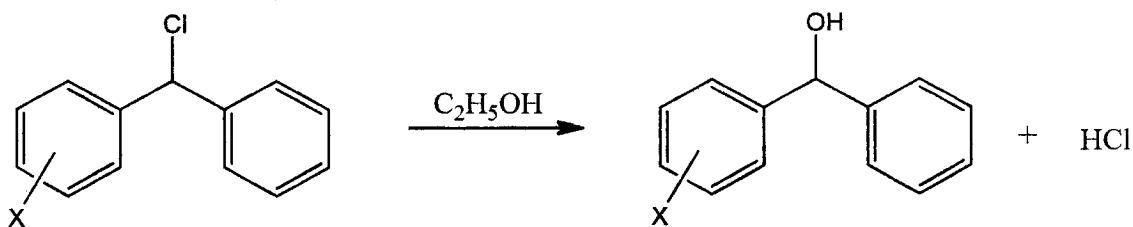
On this basis, provide the plausible biosynthetic pathway for the key intermediate, shown above. (12 marks)

- (c) Periodic acid oxidation of a glucose derivative, X, required 4 molar equivalents of periodic acid and gave 3 moles of formic acid, 1 mole of formaldehyde and 1 mole of OHC-COOH. What is the structure of X? (3 marks)

## QUESTION TWO

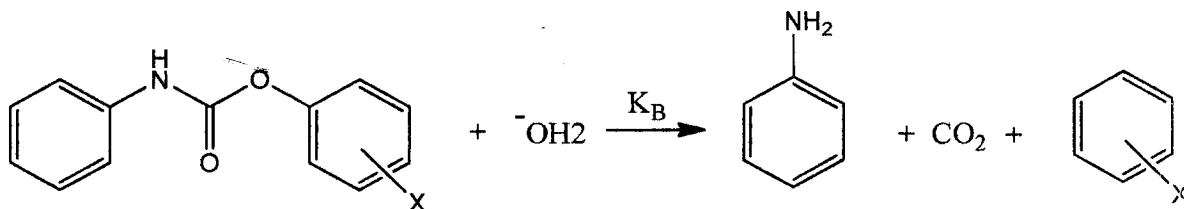
- (a) Briefly explain what is meant by the term primary kinetic isotope effect and draw a fully labeled energy profile diagram for the primary kinetic isotopic effect. Indicate (6 marks)

- (b) The solvolysis of substituted diphenylcarbinyl chlorides was studied in ethanol at 25 °C. A plot of  $\log k$  versus  $\sigma^+$  showed a linear correlation with a slope of -5.1.



Explain the data and suggest a plausible mechanism that is consistent with this observation. (8 marks)

- (c) The base enhanced hydrolysis of phenyl N-phenyl carbamates occurs by the elimination of  $\text{PhO}^-$  group as the rate determining step. Using the  $K_B$  values for other carbamates in the table below, estimate the second order rate constant,  $K_B$ , for 3,4,5-trichlorophenyl N-phenyl carbamate at 25 °C. (11 marks)



X	$K_B$	X	$K_B$
p-CH <sub>3</sub>	$3.0 \times 10^1$	m-Cl	$1.8 \times 10^3$
p-OCH <sub>3</sub>	$2.5 \times 10^1$	m-NO <sub>2</sub>	$1.3 \times 10^4$
p-Cl	$4.2 \times 10^2$	p-NO <sub>2</sub>	$2.7 \times 10^5$

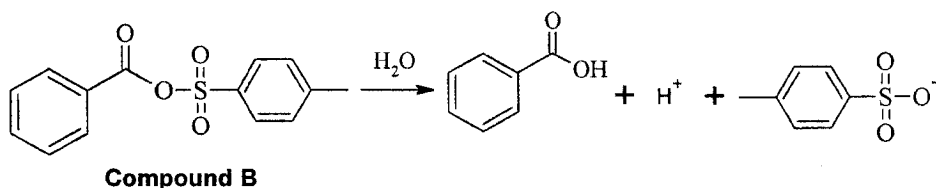
- (i) Write the Swain-Scott equation and provide the meaning of each term.

(2 marks)



(ii) The following reaction proceeds by the  $S_N2$  mechanism with a rate constant,

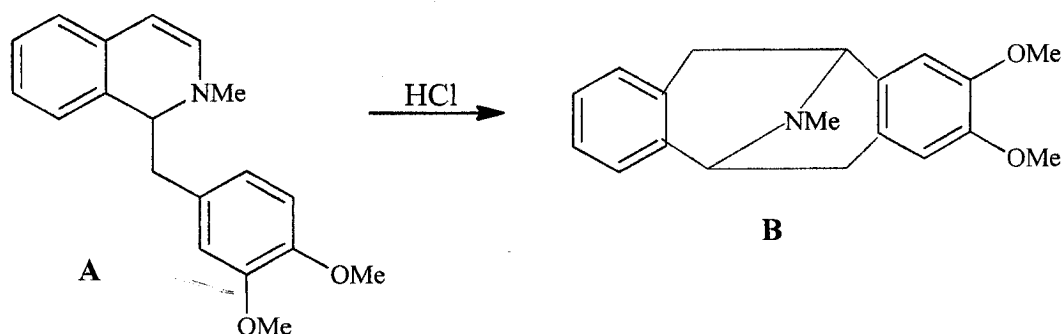
$$k = 0.12 \text{ M}^{-1}\text{s}^{-1}.$$



If the  $\text{H}_2\text{O}$  were replaced with  $\text{N}_3^-$  as a nucleophile, at what rate would you expect the reaction to proceed? The substrate constant for compound **B** is 0.66 and the nucleophilic constant for the  $\text{N}_3^-$  anion is 4.0. (5 marks)

### QUESTION THREE

- (a) Treatment of alkaloid **A** with dilute hydrochloric acid unexpectedly gave the product **B**. Propose a mechanistic explanation to account for this observation. (7 marks)



(b) Experiment data on the disaccharide **C**,  $\text{C}_{12}\text{H}_{22}\text{O}_{11}$ , found in yeast, fungi, algae and

- (i) The disaccharide **C** gives positive Tollens test, undergoes mutarotation and forms a phenylosazone.
- (ii) Bromine water oxidation of **C** gives a compound **D**, which upon acidic hydrolysis gives D-galactose and D-gluconic acid.
- (iii) Exhaustive methylation of **C** followed by acidic hydrolysis of the methylated product yields two molar equivalents of 2,3,4,6-tetra-O-methyl-D-galactose and 2,3,4-tri-O-methyl-D-glucose.

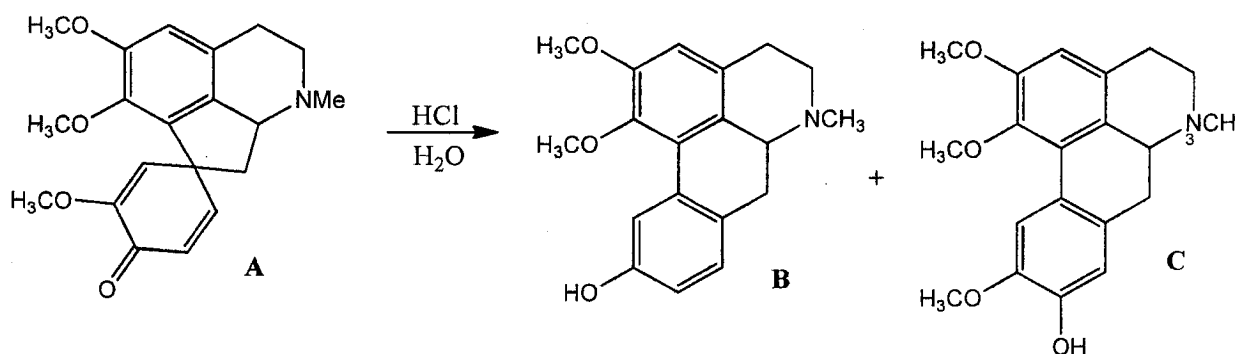
Interpret the data and deduce the structure of **C**.

(11 marks)

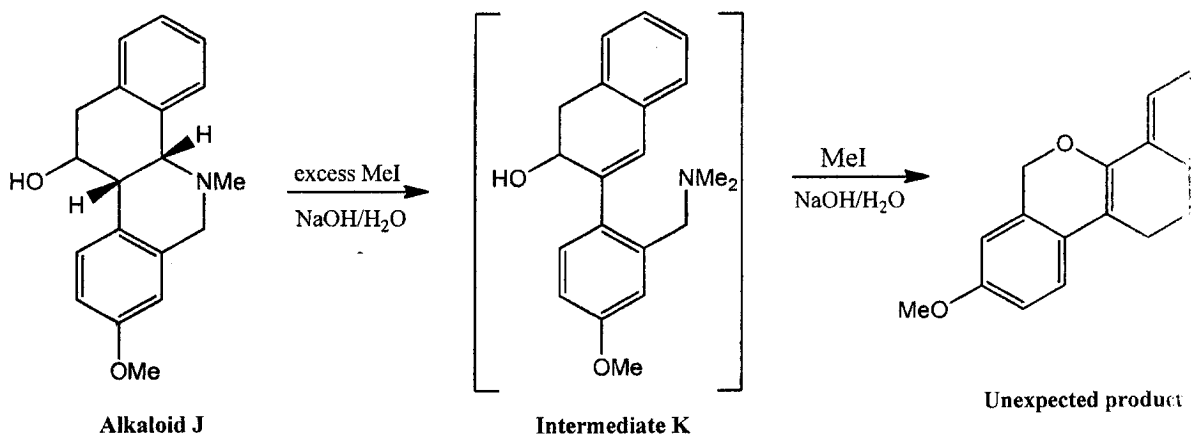
- (c) Name two qualitative tests for the detection of alkaloids and give a general procedure for isolation of alkaloids from plant tissues. (7 marks)

#### QUESTION FOUR

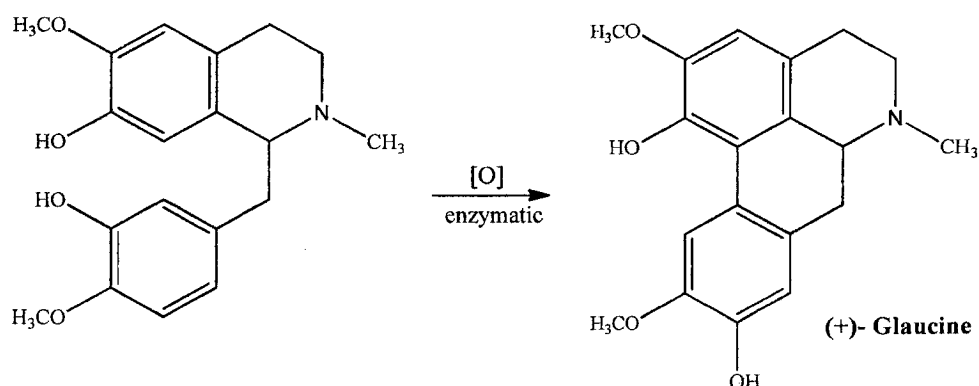
- (a) Upon treatment with hydrochloric acid in methanol, the alkaloid A gave a mixture of two aporphine alkaloids, B and C. Provide a plausible mechanism for this transformation. (6 marks)



- (b) Attempted Hofmann degradation of the alkaloid J with excess methyl iodide and aqueous sodium hydroxide unexpectedly gave a compound L in good yield. The spectroscopic evidence indicates that reaction proceeds via the intermediate K. On this basis, suggest a plausible mechanistic explanation to account for formation of unexpected product L from J. (8 marks)

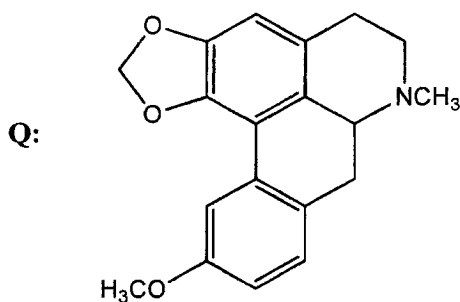


(c) The last step in the biosynthesis of the aporphine alkaloid, (+)-glaucine is shown below. Tracer studies indicate that oxidative phenol coupling is involved. On this basis, provide a mechanistic explanation for this step.



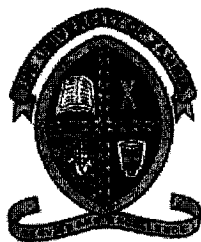
## QUESTION FIVE

- (a) Using the disconnection approach, devise a synthesis for the alkaloid Q shown below. Show all steps clearly. (18 marks)



- (b) Alginic acid from sea weed is used as thickening agent in ice cream and other foods. Acidic hydrolysis of alginic acid gives D-mannuronic acid. Reaction of alginic acid with excess methyl iodide followed by acidic hydrolysis gives 2,3-di-O-methyl D-mannuronic acid. The glycosidic linkages in alginic acid are thought to be beta. Suggest the most likely structure for alginic acid. (7 marks)

**END OF EXAMINATION**



# **THE UNIVERSITY OF ZAMBIA**

School of Natural Sciences

Department of Computer Science

## **FINAL EXAMINATION**

**CSC 2000**

**Computer Programming**

Date: 1<sup>st</sup> September 2017  
Time: 09:00hrs – 12:00hrs  
Duration: 3 Hours  
Venue: AP1

### **Instructions**

1. There are **two (2) sections** in this exam paper.
2. *Answer all the questions in **Section A** and choose any three (3) questions from **Section B***

## **SECTION A. Short answers (40 marks)**

You are required to answer all questions in this section. Each question carries [4 marks]

1. What is polymorphism? How is polymorphism and dynamic binding implemented in java?
2. Explain the four types of access/visibility modifiers used in java.
3. What is inheritance and how is it achieved in java programming?
4. What is the difference between method overriding and method overloading?
5. What is an abstract class?
6. What is the difference between a local variable, an instance variable and a class variable?
7. What are the three steps for creating an Object for a class?
8. What is the difference between Swing and AWT components?
9. Which method must be implemented by all threads?
10. How do you write an infinite loop using the “while” statement, “for” statement?

11/11/16

## SECTION B (60 marks)

Answer any three (3) of the five (5) questions. Each question carries **20 marks**

1.

a) Consider the following code snippet.

```
if (aNumber >= 0)
    if (aNumber == 0)
        System.out.println("first string");
    else System.out.println("second string");
    System.out.println("third string");
```

- i. What output do you think the code will produce if "aNumber" is 3? **[2 marks]**
- ii. Write a test program containing the previous code snippet; make "aNumber" 3. What is the output of the program? Explain why the output is what it is i.e what is the control flow for the code snippet? **[4 marks]**
- iii. Using only braces, spaces and line breaks, reformat the code snippet to make the control flow easier to understand. **[3 marks]**

b) Consider the following class:

```
public class IdentifyMyParts {
    public static int x = 7;
    public int y = 3;
}
```

- iv. What are the class variables? **[1 mark]**
- v. What are the instance variables? **[1 mark]**

- c) What is the output from the following code:[2 marks]

```
IdentifyMyParts a = new IdentifyMyParts();
IdentifyMyParts b = new IdentifyMyParts();
a.y = 5;
b.y = 6;
a.x = 1;
b.x = 2;
System.out.println("a.y = " + a.y);
System.out.println("b.y = " + b.y);
System.out.println("a.x = " + a.x);
System.out.println("b.x = " + b.x);
System.out.println("IdentifyMyParts.x = " +
IdentifyMyParts.x);
```

*y=3  
x=7*

- d) What's wrong with the following program? Write a corrected version of the program.

[3 marks]

```
public class SomethingIsWrong {
    public static void main(String[] args) {
        Rectangle myRect;
        myRect.width = 40;
        myRect.height = 50;
        System.out.println("myRect's area is " +
myRect.area());
    }
}
```

- e) The following code creates one array and one string object. How many references to those objects exist after the code executes? Is either object eligible for garbage collection? How does a program destroy an object that it creates? [4 marks]

*int width = 40;  
int height = 50;  
public SomethingIsWrong (int w, int h) {  
 width = w;  
 height = h;  
 3 myRect  
 int area = w \* h;  
}*

```

...
String[] students = new String[10];
String studentName = "Peter Parker";
students[0] = studentName;
studentName = null;
...

```

Q16 2015

2. Write a class to represent a Lecturer at the University of Zambia.

- a) Each lecturer has a first name, last name, age and man number which is an integer e.g. 009945. **[8 marks]**
- b) All lecturers have the same pay day e.g. 6 which indicates which day of the month they get paid and in this case meaning the 6th day of each month. **[2 marks]**.
- c) Your class should have three constructors: one default constructor, one constructor that initializes the man number and another that initializes the firstname, lastname and man number. **[6 marks]**.
- d) Furthermore, your class should have a printLecturer method that prints out details of the Lecturer when invoked e.g. if you have a lecturer called Pumpkin Zulu who is a female aged 20 and man number 009945 and payday 5, your method should print her details as: "Firstname: Pumpkin; Lastname: Zulu; Age: 20; ~~Man Number~~; Man number: 009945; Payday: 5" excluding the quotes. **[4 marks]**.

3. /

- a) What is wrong with the following interface? Fix the code. **[4 marks]**

```

public interface SomethingIsWrong {
    void aMethod(int aValue){
        System.out.println("Hi Mom");
    }
}

```



- b) Is the following interface valid? [2 marks]

```
public interface Marker {  
  
}
```

- c) Suppose you have written a time server that periodically notifies its clients of the current date and time. Write an interface the server could use to enforce a particular protocol on its clients for setting date, setting time, setting date and time and also accessing the local date and time. [6 marks]
- d) Write a class that implements the interface in 3.c. [8 marks]

4.

- a) What is a thread? [2 marks]
- b) Illustrate and explain the states of a java thread. [4 marks]
- c) What is a java socket? [2 marks]
- d) Write two classes, one for a client and the other for a server. The server should be threaded so as so accommodate multiple client connections. The communication between the client and server should be a simple echo protocol. [12 marks]

5.

- a) What is JDBC? [2 marks]
- b) Explain basic steps in writing a Java program using JDBC. [6 marks]
- c) Explain the four main types of JDBC Drivers. [4 marks]
- d) What are the two different types of statements in JDBC? Give a performance analysis of the two. [4 marks]
- e) A JDBC connection is made using the following method:

```
getConnection(String url, String userName, String  
password);
```

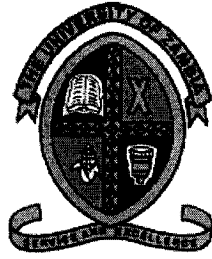
The method establishes a connection to specified database url. It takes following three string types of arguments:

*url*: Database url where stored or created your database,

*userName*: User name of your DB,

*password*: Password of DB.

Write a code block to make a connection and create statement. [4 marks]



**THE UNIVERSITY OF ZAMBIA**  
**School of Natural Sciences**  
Department of Computer Science

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**OPERATING SYSTEMS**  
**CSC2202**

**FINAL EXAMINATION**

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Date: Thursday, 7<sup>th</sup> September, 2017  
Venue: P206  
Time: 09 – 12hrs  
Duration: 3hrs

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**Instructions**

1. This exam has two sections A and B.
2. Answer **ALL** the questions from **Section A**.
3. Answer any **three (3)** questions from **Section B**.
4. **Total number of questions answered should be 5.**
5. Write your answers on a separate answer sheet.

## SECTION A (Answer all questions)

### QUESTION 1 (20 marks)

- A. [2 marks] What other hardware mechanism can be used on a uniprocessor to achieve mutual exclusion?
- B. [3 marks] What are the three main purposes of an operating system?
- C. [2 marks] List two reasons why an operating system designer might choose not to have user threads map 1:1 with kernel threads.
- D. [3 marks] For each of the following traps, indicate whether the trap is synchronous or asynchronous with respect to a user-level program.
  - i. System call
  - ii. Exception
  - iii. Interrupt
- E. [2 marks] Why might it be advantageous to keep a process running on the same processor on which it last ran (this is called processor affinity)?
- F. [4 marks] Imagine that you've been asked to build an operating system for a simple embedded processor. The processor has no virtual memory and no memory translation unit. What functionality must you build into your process loader if you wish to have multiple programs resident in memory?
- G. [4 marks] In a system with virtual memory, how can you share memory between two processes?

### QUESTION 2 (20 marks)

For each synchronization problem described below, select the best synchronization primitives to solve the problem. You may use each primitive as many times as you need to. Briefly, explain why you chose the primitive you did. Select the synchronization primitive from the following list:

1. Counting semaphore
2. Binary semaphore
3. Lock (w/out a CV)
4. Lock and condition variable

- A. **[4 marks]** A common problem in soccer collisions between players jumping for headers (this often leads to concussions). They've decided that clever CSC2202 students could easily solve this problem with a synchronization primitive that would arbitrate which player got to jump up for the header (such primitives would have to be very high performance). Which primitive would you suggest?
- B. **[4 marks]** Mrs Kumar was making pancakes for hungry teenagers. The pancakes come out in batches of three. She'd like a synchronization primitive that would allocate pancakes to teenagers without fighting. (There is no need to worry about leftovers between batches all pancakes are consumed pretty much instantly.) Suggestions?
- C. **[4 marks]** You are competing in a new Olympic event called a distributed relay. One team member has to run one lap at the UNZA track. The next team member must run a lap at the CBU track. The third team member runs a lap at Mulungushi track and the last team member runs a lap at the UNILUS track. Each runner must not start until the previous runner has completed his/her lap. Naturally, the traditional passing of the baton or slapping of the hands won't work, so they've turned to you, to provide the proper synchronization. What mechanism do you use?
- D. **[4 marks]** Competition for parking in UNZA carpark has become brutal due to the massive quantities of potholes accumulating on our streets. The traditional use of spacesavers (things like cones or lawn chairs that mark a spot as being "owned" because someone invested the physical labor in shoveling it out) has become too contentious and the UNZA Department of Engineering is looking for a better solution. They've decided to have security hand out parking tokens and any car without a visible token will be towed to the far reaches of the universe. Each security has a token checkin point and cars must drive to the checkin point to obtain a token for a specific spot and return a token when they leave a spot (cars that do not return tokens within seven minutes of leaving a spot are subject to enormous fines). They would like the checkin points to operate as efficiently as possible, allocating and deallocating spots in parallel as much as possible. What synchronization primitive(s) should they use?
- E. **[4 marks]** It is well known that graduate students (as well as many others) are motivated by free food. After the first couple of years (once classes are complete), a graduate student's day consists mostly of doing research and periodically checking email to

determine if anyone has announced any free food lately. Unfortunately, the better research is going, the less likely students are to check email, and by the time they get to the location of the free food, it's often gone. (While they could configure their mail to alert them every time a new message comes in, most messages do not concern free food, so this would be quite distracting.) There must be a better way can you propose use of a synchronization primitive that would let them receive/see messages only when they concerned free food?

## SECTION B (Choose any three)

### QUESTION 3 (20 marks)

- A. [5 marks] Consider a machine with a physical memory of 8 GB, a page size of 8 KB, and a page table entry size of 4 bytes. How many levels of page tables would be required to map a 46-bit virtual address space if every page table fits into a single page? Be explicit in your explanation.
- B. [4 marks] List the fields of a Page Table Entry (PTE) in your scheme.
- C. [3 marks] Without a cache or TLB, how many memory operations are required to read or write a single 32-bit word?
- D. [6 marks] Briefly describe two approaches to avoiding deadlock.
- E. [2 marks] List two events that may take a process to a ready state.

32 bit

### QUESTION 4 (20 marks)

- A. [6 marks] How much physical memory is needed for a process with three pages of virtual memory (for example, one code, one data, and one stack page)?
- B. Think of the various deadlock detection and prevention algorithms we've discussed in this course, and consider the following snapshot of a system with five processes (P1, P2, P3, P4, P5) and four resources (R1, R2, R3, R4). There are no current outstanding queued unsatisfied requests.

Currently Available Resources

R1	R2	R3	R4
2	1	2	0

3 pages

1 page

3 pages

PG No R  
PT Le R  
PT Address  
P T Volume

1 page

1 page

210  
10

Process	Current Allocation				Max Need				Still Needs			
	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4
P1	0	0	1	2	0	0	3	2	0	0	2	0
P2	2	0	0	0	2	7	5	0	0	7	5	0
P3	0	0	3	4	6	6	5	6	6	6	2	2
P4	2	3	5	4	4	3	5	6	2	0	0	2
P5	0	3	3	2	0	6	5	2	0	3	2	0

1. [5 marks] Is this system currently deadlocked, or can any process become deadlocked? Why or why not? If not deadlocked, give an execution order.

2. [3 marks] If a request from a process P1 arrives for (0, 4, 2, 0), can the request be immediately granted? Why or why not? If yes, show an execution order.

3. [3 marks] If a request from a process P2 arrives for (0, 1, 2, 0), can the request be immediately granted? Why or why not? If yes, show an execution order.

Q3  
Q2  
Q1

$R_1 = 2$   
 $R_2 = 1$   
 $R_3 = 2$   
 $R_4 = 0$

C. [3 marks] Explain why mobile operating systems such as iOS and Android do not support swapping?

### QUESTION 5 (20 marks)

A. For each of the following pairs of terms, identify the context(s) in which they occur. Then define each term and clarify the key difference(s) between the two terms.

1. "host OS" and "guest OS" [3 marks]
2. "page" and "frame" [3 marks]
3. "reference bit" and "dirty bit" [3 marks]
4. "file" and "directory" [3 marks]
5. "disk partition" and "file system volume" [3 marks]

- B. **[5 marks]** When multiple processes need to cooperate, there is a choice between shared memory and inter-process communication (IPC). Compare and contrast these two techniques. Make sure to clarify the role of the operating system in each.

## QUESTION 6

- A. **[4 marks]** What is a process? What is a thread? How are they similar/different?
- B. **[6 marks]** There are many system processes active on any Linux system. These are typically created at system startup, and operate in the background as daemon processes. Give three examples of system (daemon) processes in a Linux system, and briefly state their role in the operation of the system.
- C. **[4 marks]** One of the design decisions in OS memory management is the choice between swapping and paging. Define each of these terms, and clarify their respective roles in OS memory management.
- D. **[6 marks]** Below are three different techniques for organizing the data blocks for each file in a file system. Briefly describe each approach, identifying the strengths and weaknesses of each.
1. Contiguous allocation
  2. Linked allocation
  3. Indexed allocation.

*memory paging*

## QUESTION 7

- A. **[6 marks]** The readers and writers problem can be formulated in several ways with regard to which category of processes can be started when. Carefully describe **three** different variations of the problem, each one favoring (or not favoring) some category of processes. For each variation, specify what happens when a reader or a writer becomes ready to access the database, and what happens when a process is finished.
- B. **[4 marks]** Two computer science students, Keziah and Haward, are having a discussion about inodes. Keziah maintains that memories have gotten so large and so cheap that when



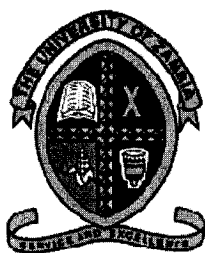
a file is opened, it is simpler and faster just to fetch a new copy of the i-node into the inode table, rather than search the entire table to see if it is already there. Howard disagrees. Who is right and why?

- C. **[5 marks]** A typical printed page of text contains 50 lines of 80 characters each. Imagine that a certain printer can print 6 pages per minute and that the time to write a character to the printer's output register is so short it can be ignored. Does it make sense to run this printer using interrupt-driven I/O if each character printed requires an interrupt that takes 50  $\mu$  sec all-in to service?
- D. **[2 marks]** In which of the four I/O software layers is each of the following done.
- Computing the track, sector, and head for a disk read.
  - Writing commands to the device registers.
  - Checking to see if the user is permitted to use the device.
  - Converting binary integers to ASCII for printing.
- E. **[3 marks]** RAID level 3 is able to correct single-bit errors using only one parity drive. What is the point of RAID level 2? After all, it also can only correct one error and takes more drives to do so.

***END OF EXAM***

***Omnium Optimi!!!***





**THE UNIVERSITY OF ZAMBIA**  
**School of Natural Sciences**  
Department of Computer Science

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**FINAL EXAMINATION**

**DATABASES AND INFORMATIONS  
MANAGEMENT SYSTEMS  
CSC 2702**

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Date: 12<sup>th</sup> SEPTEMBER 2017  
Time: 14:00hrs – 17:00hrs  
Duration: 3 Hours  
Venue: P206

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**Instructions**

1. Answer *all* the questions in Section A.
2. Choose *any THREE (3)* questions in Section B.

## SECTION A

Answer ALL Questions in this section. Both questions carry an equal weight of **20 Marks**.

### Question 1 [20 Marks]

- i. Define the following terms briefly in not more than 3 lines: [ **5 Marks** ]
  - a. *Database*
  - b. *Database program*
  - c. *Database System*
  - d. *Record*
  - e. *Attribute*
- ii. What is a DBMS, and what are its functions? (list at least 3 functions) [ **5 Marks** ]
- iii. Describe the main components you are likely to find in a DBMS environment?  
[ **5 Marks** ]
- iv. Give at least 5 reasons why the file based system approach is desirable over the database approach. [ **5 Marks** ]

### Question 2 [20 Marks]

- i. Explain what it means to say a database displays both *entity integrity* and *referential integrity*? [ **4 Marks** ]
- ii. Define the following terms in relation to the database: [ **4 Marks** ]
  - a. Intentions
  - b. Extension
- iii. Draw a well labelled diagram of the ANSI-SPARC DBMS architecture and describe the different aspect of it. [ **6 Marks** ]
- iv. What are the three components that describe a data model? [ **3 Marks** ]
- v. State three categories in which you can classify data models? [ **3 Marks** ]

## SECTION B

There are FOUR questions in this section. All questions carry an equal weight of **20 Marks**.

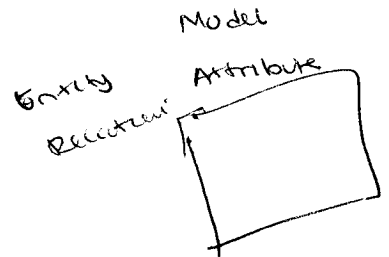
Choose only **three (3)** question!

### Question 1

- i. In relation to Relational Database Model, list at least five (5) attributes that differentiate relations from tables. **[5 Marks]**
- ii. Suppose you wanted to apply for a Job in a database computing environment, what are the five (5) different roles you may likely find? **[5 Marks]**
- iii. What do you mean when you say “cardinality of the relation” and “degree of the relation” when you are talking about relational databases? **[4 Marks]**
- iv. What two conditions must be met before an entity can be classified as a weak entity? Give an example of a weak **[2 Marks]**
- v. Discuss the difference between a composite key and a composite attribute. How would each be indicated in an Entity Relationship Diagram? **[4 Marks]**

### Question 2

- i. Define the following terms: **[5 Marks]**
  - a. *Composite key*
  - b. *Super key*
  - c. *Candidate key*
  - d. *Foreign key*
  - e. *Primary key*
- ii. Briefly describe the four (4) integrity constraints that are associated with relational database model? **[4 Marks]**
- iii. What is the difference between a “view” and “base relation”? **[2 Marks]**
- iv. Give at least 3 reasons why the file based system approach is undesirable over manual filing system? **[3 Marks]**
- v. What three data anomalies are likely to be the result of data redundancy? **[6 Marks]**



### Question 3

- i. What is a partial dependency? With what normal form is it associated? **[4 Marks]**
- ii. Explain the difference between “Functional Dependency” and “Transitive Dependency”. **[4 Marks]**
- iii. What two conditions must be met before an entity can be classified as a weak entity? Give an example of a weak **[4 Marks]**
- iv. Discuss the difference between a composite key and a composite attribute. How would each be indicated in an Entity Relationship Diagram? **[4 Marks]**
- v. Briefly, but precisely, explain the difference between single-valued attributes and simple attributes. Give an example of each. **[4 Marks]**

### Question 4

- i. In database development process, what does the term “fact-finding” mean? **[2 Marks]**
- ii. State when “fact-finding” in Q3 (i) is particularly important during database development life cycle? **[2 Marks]**
- iii. Explain why “fact-finding” is crucial to the database development process? Especially to phase you have stated in Q3 (ii). **[4 Marks]**
- iv. State and briefly explain the five (5) most used fact-finding techniques you may adopt for your database design. **[10 Marks]**
- v. Why is a table whose primary key consists of a single attribute automatically in 2NF when it is in 1NF? **[2 Marks]**

End of Exam!!

Best wishes to you!



# **THE UNIVERSITY OF ZAMBIA**

## **School of Natural Sciences**

Department of Computer Science

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### **FINAL EXAMINATION**

### **CSC 2912**

### **NUMERICAL ANALYSIS**

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Date: 28<sup>TH</sup> AUGUST 2017  
Time: 14:00 – 17:00 hrs  
Duration: 3 Hours  
Venue: NSLT

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### **Instructions**

- The question paper has TWO SECTIONS (A and B).
  - Section A is COMPULSORY.
  - Section B comprises FOUR (4) questions. Answer any THREE (3).
  - Clearly number your answers.
  - Use the marks as a guide to the detail required in your answers while keeping your answers concise and relevant
-

**SECTION A: Answer ALL questions in this section. [40 Marks]**

1.
  - a. Define the following
    - i. Continuity of a function  $f$  at a point  $x_0$  [5 marks]
    - ii. Differentiability of a function  $f$  at a point  $x_0$  [5 Marks]
  - b. Show that if a function is differentiable at a point  $x_0$  then it is also continuous at  $x_0$  [10 Marks]
2.
  - a. State, without proof, the following theorems
    - i. Rolle's theorem [5 Marks]
    - ii. Intermediate value theorem [5 Marks]
  - b. Show that if a function  $f$  is continuous in  $[a, b]$  and that  $f'(x) \neq 0$  for all  $x$  in  $[a, b]$ , then  $f$  can have at most one root in  $[a, b]$  [10 Marks]

**SECTION B: Answer Three (3) of the Four (4) questions. Each question carries 20 marks.**

1.
  - a. Find the third Taylor polynomial for the function  $f(x) = e^{x-1}$  about  $x_0 = 1$ . [10 Marks]
  - b. Use the polynomial above to approximate  $\sqrt{e}$  [5 Marks]
  - c. Use the approximation in b) above to estimate the value of  $e$ . [5 Marks]
2.
  - a. Estimate the interval in which the solution to the following equation could possibly be found.
 
$$x^2 = 2$$
 [4 Marks]
  - b. How many iterations are required to approximate the solution to the equation above to  $10^{-3}$ , accuracy, for the interval above using
    - i. Bisection method. [8 Marks]
    - ii. Fixed point iteration with  $g(x) = 1 + \frac{1}{x+1}$  [8 Marks]
3.
  - a. Derive the three-point formulae for numerical differentiation. [12 Marks]
  - b. Given the following points in the table
 

$x$	0	1	2
$f(x)$	1.00000	0.50000	0.33333

Approximate

    - i.  $f'(1)$  [4 Marks]
    - ii.  $f''(1)$  [4 Marks]



4. /

- a. Derive the Trapezoidal rule for numerical integrals  
 b. Use the composite Simpson's rule, using  $n = 2$ , to estimate

[10 Marks]

[8 Marks]

$$\int_0^2 2^x dx$$

- c. What is the relative error of this approximation?

[2 Marks]

\*\*\*\*\*END OF EXAMINATION\*\*\*\*\*

$$\frac{h}{2} [f(x_0) + f(x_2)]$$

0    0.5    1.0    1.5    2.0

$$h = x_1 - x_0 = x_2 - x_1$$

$$x_2 - x_1 = h$$

$$\int_0^2 2^x dx$$

$$x_1 - x_0 = h$$

$$x_1 - x_0 = 0.5$$

$$2$$

$$n = 2$$

$n = 2$

$n = 4$

0 - 0.5

0.5 - 1.0

1.5 - 2.0

1.5 - 2

$\int_0^2 2^x dx$

0, 1.5, 2

0, 0.5, 1.5, 2

0

**The University of Zambia Examination 2017**  
**School of Natural Science**  
**Digital Electronics CS3120**

**Time: 3 Hours**

**Instructions: Answer any 4 questions**

**All questions carry 25 marks**

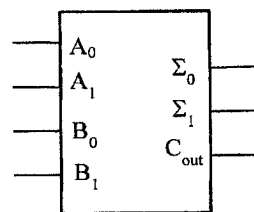
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[14][11]

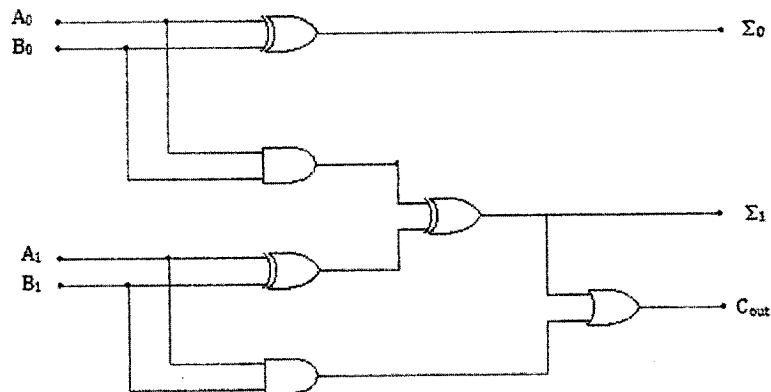
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- ```

graph LR
    A --> NOT1[NOT]
    NOT1 --> OR1[OR]
    B --> OR1
    B --> AND1[AND]
    C --> NOT2[NOT]
    NOT2 --> AND1
    AND1 --> AND2[AND]
    OR1 --> AND2
    D --> OR2[OR]
    AND1 --> OR2
    OR2 --> AND3[AND]
    AND2 --> AND3
    AND3 --> Y
  
```

**[7][7][6][4]**



$$\begin{array}{r} A_1 \quad A_0 \\ B_1 \quad B_0 \\ \hline C_{out} \quad \Sigma_1 \quad \Sigma_0 \end{array}$$



- | $B_1$ | $B_0$ | $A_1$ | $A_0$ | $C_{out}$ | $\Sigma_1$ | $\Sigma_2$ |
|-------|-------|-------|-------|-----------|------------|------------|
| 0     | 0     | 0     | 0     |           |            |            |
| 0     | 0     | 0     | 1     |           |            |            |

c) Create a **k-map** from the **Truth Table** for  $\Sigma_0$  and  $C_{out}$  outputs.

d) From the k-map for the  $C_{out}$  create a Boolean expression in the form of sum of product.  
Draw the circuit.

**Q3.** Why is two's complement representation widely used in computers as opposed to other formats such as pure binary? [10][9][6]

a) Perform the following arithmetic operation in 8 bit 2's complement. Convert the answer back to decimal.

$$-33_{10} + 85_{10} = ?$$

b) Implement a half adder circuit using only NAND gates.

c) Draw a four bit full adder using four full adders.

**Q4.** What is the difference between a multiplexer and a demultiplexer? How are they used in microcontrollers? [4][7][7][7]

a) Write a short description of how a multiplexer functions. Include the **Truth Table**. (3 bit)

b) Draw an active low 2 bit multiplexer.

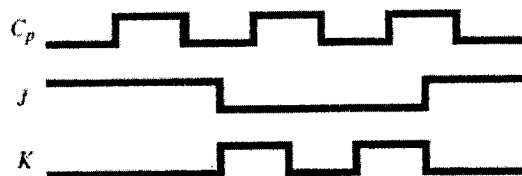
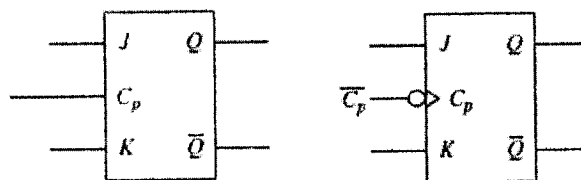
c) Draw an active low 2 bit demultiplexer

**Q5.** What is the advantage of using an edge triggered J-K flip-flop to that of a master slave J – K flip-flop? [4][7][7][7]

a) Draw a 3 bit parallel in serial out shift register using a negative edge triggered J-K flip flops.

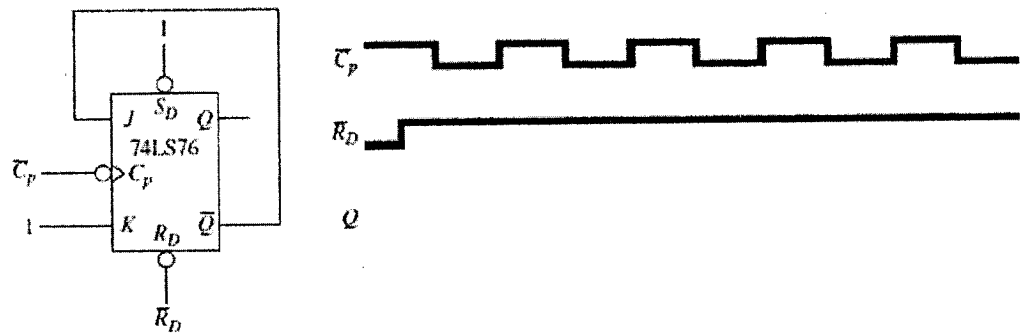
b) Draw the output waveform given that the parallel input is 101.

c) Sketch the output waveforms for the two types of J-K flops given below.

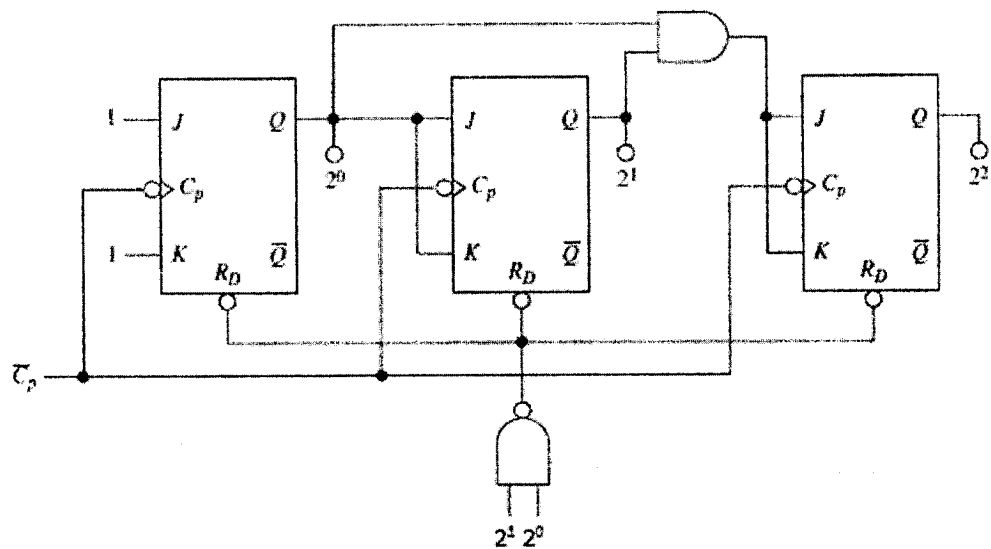


**[5][10][10]**

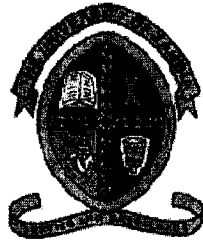
a) Sketch the Q output waveform given the inputs shown.



b) What type of counter is shown in the figure below? Sketch the waveform at  $C_p$ ,  $2^0$ ,  $2^1$  and  $2^2$  for 10 clock pulses for the 3-bit synchronous counter shown below.



**END OF EXAMINATION**



# **THE UNIVERSITY OF ZAMBIA**

## **School of Natural Sciences**

Department of Computer Science

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### **FINAL EXAMINATION**

#### **CSC 3402**

#### **FUNDAMENTALS OF ARTIFICIAL**

#### **INTELLIGENCE**

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Date: 4<sup>TH</sup> SEPTEMBER 2017  
Time: 09:00 – 12:00 HOURS  
Duration: 3 Hours  
Venue: GLT

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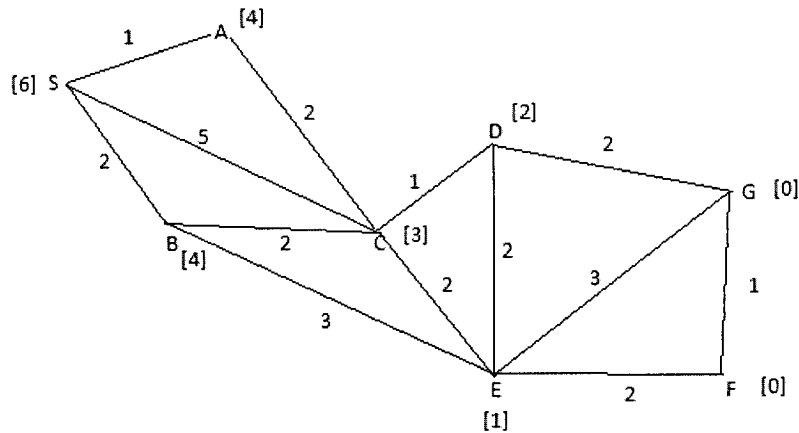
### **Instructions**

- The question paper has TWO SECTIONS (A and B).
  - Section A is COMPULSORY.
  - Section B comprises FOUR (4) questions. Answer any THREE (3).
  - Clearly number your answers.
  - Use the marks as a guide to the detail required in your answers while keeping your answers concise and relevant
-

## SECTION A: Compulsory question [40 Marks]

1.

- a. Consider the graph below, representing a navigation map for a city, in which the numbers on the edges represent the cost and the numbers besides each node represent the heuristic value. You are currently in S and need to be in either G or F.



- i. Is the heuristic admissible? Explain. [5 Marks]
- ii. Is the Heuristic optimistic? Explain. [5 Marks]

- b. For each of the search algorithms listed below and the graph in a) above: [30 Marks]

- Draw the search tree. [5 Marks]
- list the order in which the nodes are traversed. [2 Marks]
- Suggest the goal returned. [1 Mark]
- The path to the goal. [1 Mark]
- Cost to the goal. [1 Mark]

- i. Greedy Best-first search
- ii. Uniform Cost
- iii. A\*

## SECTION B: Answer Three (3) of the Four (4) questions. Each question has 20 Marks.

1.

- a. Describe what a rational agent is. [4 Marks]
- b. For each of the agents below, describe its PEAS environment. (Performance measure, environment type, actuators and sensors). For environment type look at such characteristics as being fully observable, deterministic, discrete etc.
  - i. Football playing agent [8 Marks]
  - ii. Automated cab driver [8 Marks]

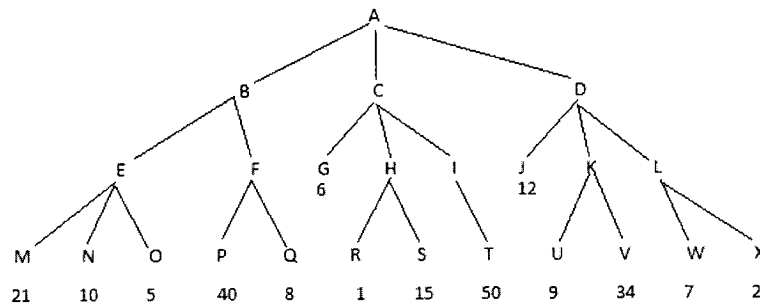
2.

- a. In formulating a problem for search, four components need to be defined. Explain what each of these components are. [8 Marks]

- b. Give a brief description of the difference between a local search algorithm and a normal search like breadth first search. [6 Marks]
- c. Briefly explain the operations of a hill-climbing search. [6 Marks]

3.

- a. MINIMAX algorithm is used in games for a play to choose the next best move by building a search tree. In order to reduce the search space, alpha-beta pruning is employed in this exercise. Briefly explain how alpha-beta operates. [4 Marks]
- b. Consider the game tree below.

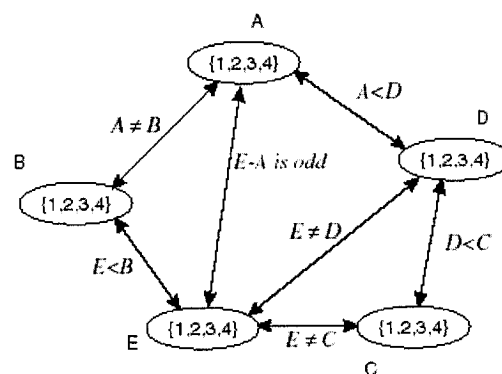


Show how alpha-beta pruning determines the next move by A if A is

- i. Maximiser. [8 Marks]
- ii. Minimiser. [8 Marks]

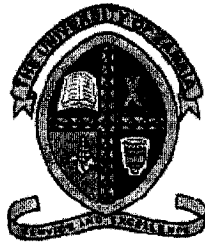
4.

- a. Give three real life problems that can be formulated as CSPs. [6 Marks]
- b. Consider the following constraint graph. Show with clear explanations, the order in which the values are assigned to the values. Tie-breakers include, smaller number better and the lower alphabetically ordered letter is desirable. [Hint: Start by figuring out the initial domains for each variable using arc-consistency and defined constraints then use the heuristics for assigning values]. [14 Marks]



\*\*\*\*\*END OF EXAMINATION\*\*\*\*\*





**THE UNIVERSITY OF ZAMBIA**  
**School of Natural Sciences**  
Department of Computer Science

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**FINAL EXAMINATION**

**CSC 3600**  
**SOFTWARE ENGINEERING**

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Date: 14<sup>TH</sup> SEPTEMBER 2017  
Time: 09:00hrs – 12:00hrs  
Duration: 3 Hours  
Venue: P206

---

**Instructions**

1. Answer all the questions in *Section A* and choose any *three (3)* questions from *Section B*

## **SECTION A**

### **ANSWER ALL QUESTIONS IN THIS SECTION**

#### **QUESTION ONE**

Give five (5) reasons why eliciting requirements is difficult? **[5 MARKS]**

#### **QUESTION TWO**

List three (3) requirements validation techniques? **[3 MARKS]**

#### **QUESTION THREE**

List 4 questions that should be asked when deciding whether to adopt an agile method of software development. **[4 MARKS]**

#### **QUESTION FOUR**

List the three (3) generic process models that are used in software engineering? **[3 MARKS]**

#### **QUESTION FIVE**

What are the three benefits of incremental development, compared to the waterfall model? **[3 MARKS]**

#### **QUESTION SIX**

What is the distinction between computer science and software engineering? **[2 MARKS]**

#### **QUESTION SEVEN**

List five (5) different types of software application. **[5 MARKS]**

#### **QUESTION EIGHT**

When describing a system, explain why you may have to design the system architecture before the requirements specification is complete. **[2 MARKS]**

### **QUESTION NINE**

A small Zambian company has developed a specialized product that it configures specially for each customer. New customers usually have specific requirements to be incorporated into their system, and they pay for these to be developed. The company has an opportunity to bid for a new contract, which would more than double its customer base. The new customer also wishes to have some involvement in the configuration of the system. Explain why, in these circumstances, it might be a good idea for the company owning the software to make it open source. **[8 MARKS]**

### **QUESTION TEN**

Apart from the challenges of heterogeneity, business and social change and trust and security, identify other problems and challenges that software engineering is likely to face in the 21st century (hint: think about the environment). **[5 MARKS]**

**Total marks: 40**

## **SECTION B**

### **ANSWER ANY THREE QUESTIONS IN THIS SECTION**

**EACH QUESTION CARRIES 20 MARKS**

#### **QUESTION ONE**

- a) Explain how the principles underlying agile methods lead to the accelerated development and deployment of software. **[8 MARKS]**
- b) Discover ambiguities or omissions in the following statement of requirements for part of a ticket-issuing system:

An automated ticket-issuing system sells rail tickets. Users select their destination and input a credit card and a personal identification number. The rail ticket is issued and their credit card account charged. When the user presses the start button, a menu display of potential destinations is activated, along with a message to the user to select a destination. Once a destination has been selected, users are requested to input their credit card. Its validity is checked and the user is then requested to input a personal identifier. When the credit transaction has been validated, the ticket is issued. **[4 MARKS]**

- c) Using your knowledge of how an ATM is used, develop a set of use cases that could serve as a basis for understanding the requirements for an ATM system. **[8 MARKS]**

#### **QUESTION TWO**

- a) Develop a sequence diagram showing the interactions involved when a student registers for a course in a university. Courses may have limited enrolment, so the registration process must include checks that places are available. Assume that the student accesses an electronic course catalog to find out about available courses. **[5 MARKS]**
- b) When describing a system, explain why you may have to design the system architecture before the requirements specification is complete. **[3 MARKS]**
- c) A small Zambian company XYZ has developed a specialized product that it configures specially for each customer. New customers usually have specific requirements to be incorporated into their system, and they pay for these to be developed. The company has an opportunity to bid for a new contract, which would more than double its customer base. The new customer also wishes to have some involvement in the configuration of the system. Explain why, in these

circumstances, it might be a good idea for the company owning the software to make it open source. **[8 MARKS]**

- d) What UML diagram types may be used to represent the essential features of a system? **[4 MARKS]**

### QUESTION THREE

- a) What are functional and non-functional requirements? Give two examples of each. **[4 MARKS]**
- b) A new software system is to be developed for engine management in a vehicle. You are the lead software engineer at Toyota Zambia. Choose an appropriate software development lifecycle and suitable modelling notations for the design. Give reasons for your choices. **[3 MARKS]**
- c) Extreme programming expresses user requirements as stories, with each story written on a card. Discuss the advantages and disadvantages of this approach to requirements description. **[6 MARKS]**
- d) How might you use a model of a system that already exists? Explain why it is not always necessary for such a system model to be complete and correct. Would the same be true if you were developing a model of a new system? **[3 MARKS]**
- e) Suggest why it is important to make a distinction between developing the user requirements and developing system requirements in the requirements engineering process. **[4 MARKS]**

### QUESTION FOUR

- a) What is the distinction between validation and verification? **[2 MARKS]**
- b) What is an equivalence partition? Give an example. **[2 MARKS]**
- c) What perspectives may be used for system modelling? **[4 MARKS]**
- d) What is described in a context model? **[4 MARKS]**
- e) What is illustrated in a UML sequence diagram? **[3 MARKS]**
- f) What is the distinction between the terms 'shall' and 'should' in a user requirements document, which is written in natural language? **[2 MARKS]**
- g) What are the principal stages of the requirements engineering process? **[3 MARKS]**

**END OF PAPER**



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**School of Natural Sciences**  
Department of Computer Science

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**IT PROJECT MANAGEMENT**  
**CSC 3612**

**2016-2017 FINAL EXAM**

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Date: 5<sup>TH</sup> September 2017  
Venue: P206  
Time: 14:00hrs – 17:00hrs  
Duration: 3 Hours

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**Instructions**

1. *This examination has two sections*
2. *Answer all questions in Section A. Each question carries 20 marks*
3. *Answer any three questions in Section B. Each question carries 20 marks*

## **Section A**

**Answer all the questions. Each question carries 20 Marks**

### **Question 1 [20 marks]**

1. Explain the tools and techniques used in any five (5) knowledge areas of Project management? [10]
2. List and describe any five (5) important characteristics of organizational culture? [5]
3. Describe about the predictive lifecycle models? [5]

### **Question 2 [20 marks]**

1. Explain the four frames of the organizations? [4]
2. How you will map the nine knowledge area and project management process groups?[10]
3. Describe the scrum activities by process groups?[6]

## **Section B**

**Answer any three questions. Each question carries 20 Marks**

### **Question 3 [20 marks]**

1. Perform a financial analysis for a Project. Assume that the projected costs and benefits for this project are spread over four years as follows: Estimated costs are \$200,000 in Year 1 and \$30,000 each year in Years 2, 3, and 4. Estimated benefits are \$0 in Year 1 and \$100,000 each year in Years 2, 3, and 4. Use a 9 percent discount rate, and round the discount factors to two decimal places. Calculate the NPV, ROI, and year in which payback occurs? [6]
2. Explain the common elements of a project management plan? [8]
3. Explain in detail about the integrated change control? [6]

#### Question 4 [20 marks]

1. Create a WBS for developing an app that you will create and sell online within three months?[5]
2. Give some suggestions for reducing incomplete and changing requirements? [5]
3. What are the different approaches to creating a WBS? [5]
4. What are the best practices for avoiding scope problems? [5]

#### Question 5 [20 marks]

1. What are the processes involved in the project time management? [6]
2. Explain the different types of task dependency? [4]
3. Explain about the critical path analysis and critical chain scheduling? [10]

#### Question 6 [20 marks]

1. What is cost estimating? What are the different types of cost estimates? Explain the basic tools and techniques used for cost estimates? Give some reasons of problems faced in cost estimates [10]

2. Given the following information for a one-year project, answer the following questions.

Planned Value (PV) = \$35,000

Earned Value (EV) = \$30,000

Actual Cost (AC) = \$40,000

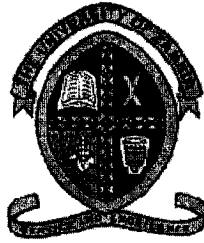
Budget at completion (BAC) = \$150,000

- i. What is the cost variance, schedule variance, cost performance index (CPI), and schedule performance index (SPI) for the project? [4]
- ii. How is the project doing? Is it ahead of schedule or behind of schedule? Is it under budget or over budget? [2]
- iii. Use the CPI to calculate the estimate at completion (EAC) for this project, Is the project performing better or worse than planned?[2]
- iv. Use the SPI to estimate how long it will take to finish this project? [2]



**Question 7 [20 marks]**

1. Explain any five (5) basic tools of quality that help in performing quality control? [10]
2. Describe how you will perform the quality assurance? [5]
3. What is six sigma? How six sigma quality control is unique? [5]



**THE UNIVERSITY OF ZAMBIA**  
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Department of Computer Science

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**FINAL EXAMINATION**

**ADVANCED DATABASES**  
**CSC 3712**

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Date: 8<sup>th</sup> SEPTEMBER, 2017  
Time: 14:00hrs – 17:00hrs  
Duration: 3 Hours  
Venue: P206

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**Instructions**

1. Answer *all* the questions in Section A.
2. Choose *any THREE (3)* questions in Section B.

## SECTION A

Answer all questions in this section. Both questions carry an equal weight of 20 Marks.

### Question 1.

- i. During the process of normalization, what is referred to as partial dependency? [2 Marks]
- ii. What three data anomalies are likely to be the result of data redundancy? How can such anomalies be eliminated? [6 Marks]
- iii. Why is a table whose primary key consists of a single attribute automatically in 2NF when it is in 1NF? [2 Marks]
- iv. How would you describe a condition in which one attribute is dependent on another attribute, when neither attribute is part of the primary key? [4 Marks]
- v. Suppose that someone tells you that an attribute that is part of a composite primary key is also a candidate key. How would you respond to that statement? [6 Marks]

### Question 2.

- i. In your own terms, define what an information system is? [2 Marks]
- ii. Explain the purpose of information system. [4 Marks]
- iii. How do systems analysis and systems development fit into a discussion about information systems? [4 Marks]
- iv. Briefly describe the different phases of the Database Development Life Cycle. [8 Marks]
- v. What is the difference between a *request* and a *transaction*? [2 Marks]

## SECTION B

Choose ONLY three questions from this section. Each question has a total of 20 Marks.

### Question 1.

- i. Explain the difference between a distributed databases and distributed processing. **[4 Marks]**
- ii. Describe a fully distributed database management system? **[2 Marks]**
- iii. What are the components of a DDBMS? **[4 Marks]**
- iv. Briefly describe the transparency features of a DDBMS. **[4 Marks]**
- v. Explain the different types of distribution transparency. **[6 Marks]**

### Question 2.

- i. Discuss the distinction between centralized and decentralized conceptual database design. **[4 Marks]**
- ii. Distinguish between top-down and bottom-up approaches in database design. **[4 Marks]**
- iii. In database designing, what are commonly referred to as business rules? **[2 Marks]**
- iv. Explain why business rules are important to you as a database designer? **[4 Marks]**
- v. What factors are important in a DBMS software selection? **[6 Marks]**

### Question 3.

- i. Describe the three levels of backup that may be used in database recovery management? **[6 Marks]**
- ii. The DBMS does not guarantee that the semantic meaning of the transaction truly represents the real-world event. What are the possible consequences of that limitation? Give an example. **[2 Marks]**
- iii. List and discuss the four transaction properties. **[8 Marks]**
- iv. What is a transaction log, and what is its function? **[2 Marks]**
- v. What is a scheduler, what does it do, and why is its activity important to concurrency control? **[2 Marks]**

Question 4.

- i. In transaction and concurrency control, what is termed as a lock, and how, in general, does it work? **[4 Marks]**
- ii. What is concurrency control, and what is its objective? **[4 Marks]**
- iii. Explain what an exclusive lock is, and under what circumstances is it granted? **[2 Marks]**
- iv. What is a deadlock, and how can it be avoided? Discuss several strategies for dealing with deadlocks. **[6 Marks]**
- v. What are the three types of database critical events that can trigger the database recovery process? Give some examples for each one. **[4 Marks]**

---- End of Exam ----



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**MANAGEMENT INFORMATION SYSTEMS**  
**CSC 3750**

**2016-2017 FINAL EXAM**

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Date: 1<sup>st</sup> September 2017  
Venue: P207  
Time: 09:00hrs – 12:00hrs  
Duration: 3 Hours

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**Instructions**

1. *This examination has two sections*
2. *Answer all questions in Section A. Each question carries 20 marks*
3. *Answer any three questions in Section B. Each question carries 20 marks*

## **Section A**

**Answer all the questions. Each question carries 20 Marks**

### **Question 1 [20 marks]**

1. Explain briefly any three (3) strategic business objectives of information systems? [6]
2. You work for an auto manufacturer and distributor. How could you use information systems to achieve greater customer intimacy? [2]
3. List and describe the organizational, management, and technology dimensions of information systems? [3]
4. Compare the roles played by programmers, systems analysts, information systems managers, the chief information officer (CIO)? [4]
5. Give some reasons why businesses promote collaboration and teamwork? [5]

### **Question 2 [20 marks]**

1. You are advising the owner of Smalltown Computer, a new, local computer repair store that also builds custom computers to order. What competitive strategies could Smalltown Computer exert? [5]
2. Identify and describe the features of organizations that help explain differences in organizations' use of information systems?[5]
3. Identify and describe six ethical principles? [6]
4. List and describe the principal causes of system quality problems? [4]

## **Section – B**

**Answer any three questions. Each question carries 20 marks**

### **Question 3 [20 marks]**

1. Explain how businesses can benefit from virtualization, green computing, and multicore processors?[6]
2. Describe the evolving mobile platform and quantum computing? [4]

3. Define big data and describe the technologies for managing and analyzing it? [6]
4. Explain why data quality audits and data cleansing are essential? [4]

**Question 4 [20 marks]**

1. List and describe alternative ways of locating information on the Web? [6]
2. How are RFID systems used in inventory control and supply chain management? [4]
3. Define computer crime. Provide two examples of crime in which computers are targets and two examples in which computers are used as instruments of crime? [5]
4. Describe the roles of firewalls, intrusion detection systems and antivirus software in promoting security? [5]

**Question 5 [20 marks]**

1. You have been hired by Croydon Visiting Nurse Services, whose business processes are all manual, paper-based processes. How might a CRM system benefit them? [4]
2. Define and compare supply chain planning systems and supply chain execution systems? [4]
3. Describe the unique features of e-commerce? [6]
4. Name and describe the principal e-commerce business models? [6]

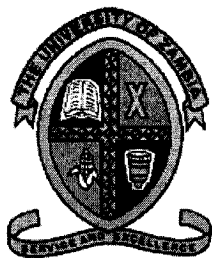
**Question 6 [20 marks]**

1. Define and describe the various types of enterprise-wide knowledge management systems and explain how they provide value for businesses? [6]
2. Describe the role of the following in facilitating knowledge management: portals, wikis, social bookmarking, and learning management systems? [4]
3. Distinguish between an unstructured, semistructured, and structured decision? [3]
4. Describe how MIS, DSS, or ESS provides decision support for each of these groups? [7]



**Question 7 [20 marks]**

1. Define business process management and describe the steps required to carry it out? [6]
2. Explain why the testing stage of systems development is so important. Name and describe the three stages of testing for an information system?[4]
3. Identify and describe the strategies for controlling project risk? [5]
4. Name and describe the groups responsible for the management of information systems projects? [5]



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**WEB PROGRAMMING AND TECHNOLOGIES**  
**CSC4035**

**FINAL EXAMINATION**

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Date: Friday, 1<sup>st</sup> September, 2017  
Venue: P207  
Time: 09 – 12hrs  
Duration: 3hrs

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**Instructions**

1. This exam has two sections A and B.
2. Answer **ALL** the questions from **Section A**.
3. Answer any **three (3)** questions from **Section B**.
4. **Total number of questions answered should be 5.**
5. Write your answers on a separate answer sheet.

## SECTION A [40 marks] – Answer all Questions

1. **[4 marks]** David has an application that needs to receive data from the server. In his research, he finds two options to implement this; JSON and XML. He comes to you for advice on which to pick. Which would you recommend and why?
2. **[16 marks]** MEAN is a free and open-source JavaScript software stack for building dynamic web sites and web applications. The MEAN stack is MongoDB, Express.js, AngularJS (or Angular), and Node.js. Write detailed notes on the following
  - a. MongoDB
  - b. Express.js
  - c. Angular JS
  - d. Node.js
3. **[2 marks]** How many alert dialogs will the following Javascript generate, and what will be displayed in each of them?

```
var x = "10";  
function f(){  
    var x = "4";  
    alert(this.x);  
    function g(){alert(x);}  
    g();  
}  
f();
```

4. **[2 marks]** The following web page is loaded into a web server:

```
<html>  
  <head><title>JavaScript question</title></head>  
  <body>  
    <script type="text/javascript">  
      book = new Array(1,2,3,4,5,6,7,8);  
      document.write(book[1]); book[10]=10;  
      document.write(book[10]);  
    </script>  
  </body>
```

</html>

Once the above web page is loaded what will be the outcome?

5. **[6 marks]** Describe the situations of using External Style Sheets, Embedded (Internal) Style Sheets and Inline Styles. Use both CSS and HTML code to explain how to use each type of the styles.
6. **[8 marks]** Identify and describe four properties that are used in the CSS box model (feel free to draw a figure if you want).
7. **[2 marks]** Explain the differences between POST and GET when sending HTML form data

## SECTION B – Choose any three (3) questions

### QUESTION 1

- A. [2 marks] Below you will see some snippets of HTML from a Web page. Fill in the body of the Javascript function *changeColor* so that the color of the text changes in response to the selection made in the menu

```
<style type="text/css">
  .a {color:red;}
  .b {color:green;}
  .c {color:blue;}
</style>
...
<div id="colorText">Select below to change the color of this text</div>
  <select onchange="changeColor(this.value)">
    <option value="a">Red</option>
    <option value="b">Green</option>
    <option value="c">Blue</option>
  </select>
  <script type="text/javascript">
    //
      function changeColor(value) {
      }
    //]]&gt;
  &lt;/script&gt;</pre></div><div data-bbox="87 590 840 709" data-label="List-Group"><p>B. [4 marks] Explain how client-side form validation is different from server-side form validation. What benefits does each bring?</p><p>C. [4 marks] List two problems of using HTML as a design language. What's the general solution? How does the solution solve the two problems you listed?</p><p>D. [4 marks] Determine the output of the code below. Explain your answer.</p></div><div data-bbox="147 725 789 921" data-label="Text"><pre>var myObject = {
  egg: "plant",
  func: function() {
    var self = this;
    console.log("outer func: this.egg = " + this.egg);
    console.log("outer func: self.egg = " + self.egg);
    (function() {
      console.log("inner func: this.egg = " + this.egg);
      console.log("inner func: self.egg = " + self.egg);
    })();
  }
};
myObject.func();</pre></div><div data-bbox="441 934 534 952" data-label="Page-Footer"><p>Page 4 of 8</p></div>
```

- E. **[6 marks]** Write a simple function (less than 80 characters) that returns a boolean indicating whether or not a string is a palindrome (A palindrome is word, phrase, or sequence that reads the same backward as forward, e.g., *madam* or *nurses run*)

## QUESTION TWO

- A. **[10 marks]** Consider the following HTML file:

```
<!DOCTYPE html>
<html>
  <head>
    <title> Test Page </title>
  </head>
  <body>
    <header ><h1> This is a test page </h1></header>
    <nav id="menu">
      <ul>
        <li><a href ="home.php">Home </a/> </li>
        <li><a href ="login.php">Login </a> </li>
        <li><a href ="register.php">Register </a/> </li>
      </ul>
    </nav>
    <section id="main">
      <article>
        <p>This is a line </p> This is another line with a
        <a href="link.html">link </a> </article>
      <article>
        <p> This is a line.</p>
        <p> This is another line.</p>
      </article>
    </section>
  </body>
</html>
```

Write the CSS rules needed to:

- (1) Change the width of the menu to 400px.
- (2) Make all links in the menu bold
- (3) Change the color of the link in the first article to green
- (4) Turn the list into an inline element
- (5) Delete the Home line of the list

- B. **[2 marks]** What is a RESTful Web Service?

C. **[2 marks]** How would you empty the array below?

```
Var emptyArray = ['this', 'array', 'is', 'full'];
```

D. **[6 marks]** Write an `isPrime()` function that returns `true` if a number is prime and `false` otherwise.

### QUESTION THREE

A. **[10 marks]** Write a JavaScript function that calculates the number of days left till the Christmas Date

B. **[4 marks]** Determine the output of the code below. Explain your answer.

```
var lorem = { ipsum : 1};  
var output = (function(){  
    delete lorem.ipsum;  
    return lorem.ipsum;  
})();  
  
console.log(output);
```

C. **[6 marks]** Discuss eight (8) principles of user interface design clearly stating the problem addressed by each

### QUESTION FOUR

A. **[4 marks]** Determine the output of the code below. Explain your answer.

```
console.log(0.1 + 0.2);  
console.log(0.4 + 0.1 == 0.5);
```

B. **[10 marks]** Convert the data in the table on the next page (Table 1) to an XML document. Choose how you want to represent the data in XML

C. **[4 marks]** Write detailed notes on Document Object Model (DOM)

D. **[2 marks]** Compare XML and HTML

Table 1 - For Q4B

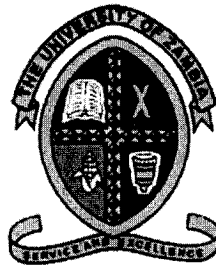
Country	Capital	Population	Area (km <sup>2</sup> )
Denmark	Copenhagen	5 602 628	43 561
Finland	Helsinki	5 426 674	338 534
Iceland	Reykjavik	321 857	103 440
Norway	Oslo	5 051 275	323 787
Sweden	Stockholm	9 555 893	447 420

#### QUESTION FIVE

- A. **[4 marks]** Write a JavaScript program to compute the sum of three elements of a given array of integers of length 3.
- B. **[6 marks]** Write short notes on MVC
- C. **[4 marks]** Give an example of a framework for Mobile Hybrid apps. Compare this with traditional mobile development tools.
- D. **[2 marks]** Write short notes on DNS
- E. **[4 marks]** Write a JavaScript function that reverses a number. e.g. 123 becomes 321

*Omnium Optimi!!!*





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Department of Computer Science

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**FINAL EXAMINATION**

**CSC 4130: ADVANCED HARDWARE  
DESIGN AND IMPLEMENTATION**

Date: Thursday, 31<sup>st</sup> August 2017  
Time: 14:00hrs – 17:00hrs  
Duration: 3 Hours  
Venue: P 206

**Instructions**

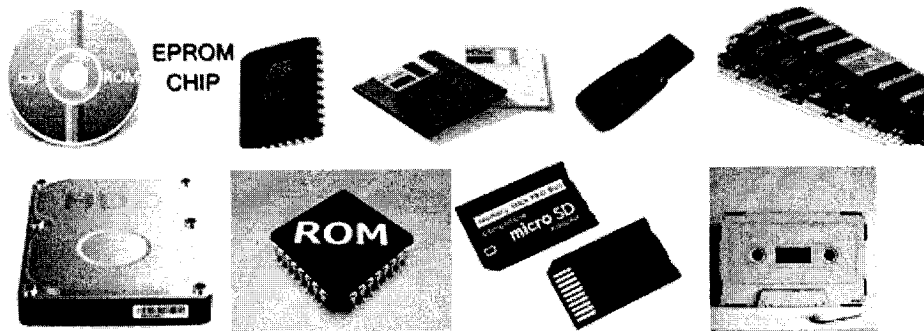
1. There are **six (6)** questions and **two (2)** sections in this paper.
2. Each question carries **20 marks**,
3. You are required to answer a total of Five (5) Questions
  - a. Answer **all** the questions in **Section A**
  - b. Choose **any two (2)** questions from **Section B**

# **SECTION A**

**This section has Three Questions. Answer all the questions**

## **Question I**

- a) Von Neumann architecture has four functional units namely Memory, Input/Output, Arithmetic/Logic unit and Control unit.
- Draw a well labeled diagram of the Von Neumann architecture [2 Marks]
  - Briefly discuss each of the following none Von Neumann architectures [4 Marks]
    - SIMD architecture
    - MIMD architecture
- b) Machine language is a set of instructions executed directly by a computer's central processing unit (CPU). Each instruction performs a very specific task, such as LOAD, JUMP, or an ALU operation on a unit of data in a CPU register or memory.  
**Write the machine code** for the Intel 8085 microprocessor used to add two numbers 2H and 4H [4 Marks]
- c) Computer memory can be defined as any physical device capable of storing information temporarily or permanently as shown in the figures below. Sequential circuits all depend upon the presence of memory. The diagram below shows different kinds of memory.

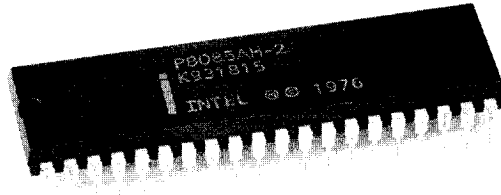


Define the following in relation to computer memory [2 Marks]

- Bit
  - Word
- d) Draw a well labelled diagram showing the memory unit of the following [ 8 Marks]
- DRAM
  - SRAM

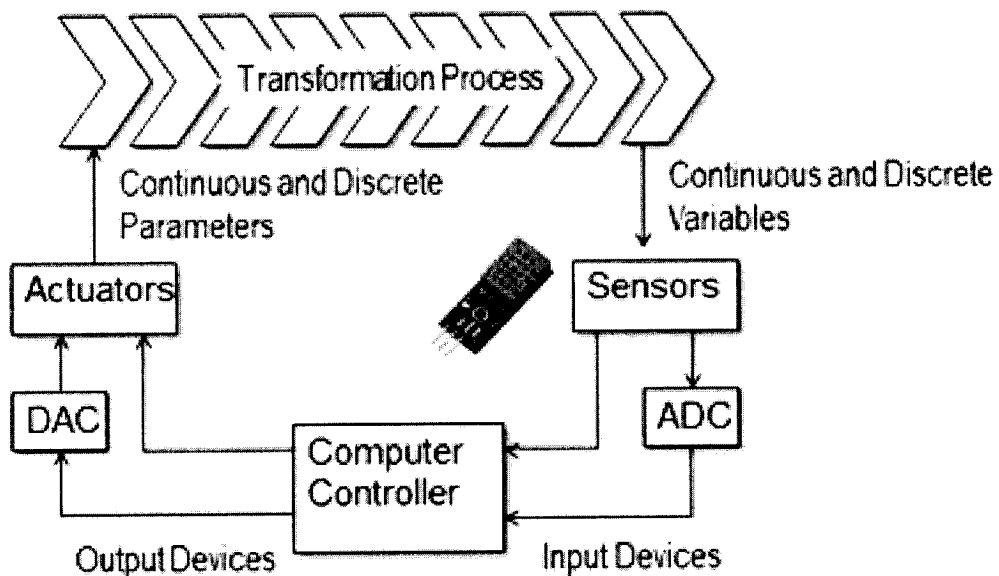
## Question II

- a) The diagram below shows the intel 8085 Microprocessor chipset. This question is based on programming of the intel 8085 Microprocessor based on the **GNUSim8085 Simulator**.



Write an assembly program for the intel 8085 that; [10 Marks]

- i. Adds two numbers (11010011 and 10001010)
  - ii. Subtracts two numbers (10001010 from 11010011)
- b) The diagram below shows the basic principles used by sensors to collect and process information [7 Marks].
- i. Discuss the principle behind sensing technologies
  - ii. Discuss each of the following sensor technologies
    - (1) Proximity
    - (2) Gyroscope
    - (3) Tilt/Acceleration



- c) An actuator is usually activated by a low-level command signal; hence an amplifier may be required to provide sufficient power to drive the actuator. **Name and discuss** the three main categories of the actuators [3 Marks]

## Question III

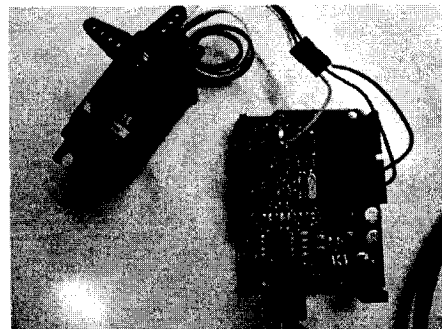
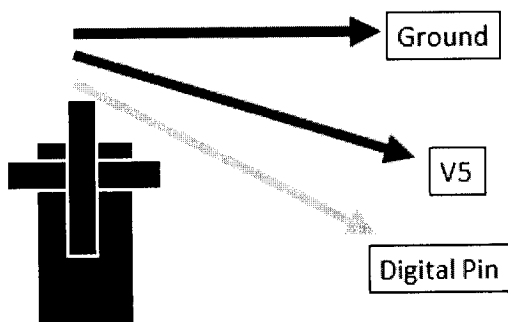
- a) In order to multiply two 8 bit numbers using the Intel 8085 microprocessors, one can use the following algorithm.

**ALGORITHM:**

- 1) Start the program by loading HL register pair with address of memory location
- 2) Move the data to a register (B register)
- 3) Get the second data and load into Accumulator  
Add the two register contents
- 4) Check for carry.  
Increment the value of carry.
- 5) Check whether repeated addition is over and store the value of product and carry in memory location.
- 6) Terminate the program.

Write the assembly language program for 8085 to multiply two 8 bit numbers based on the algorithm above [5 Marks]

- b) A servo motor is a motor that pulses at a certain rate moving its gear at a certain angle. It has three connections: the black is ground, the red is connected to 5V, and the white (yellow wire) is set to the digital pin.



Using PIN 13 as the digital PIN, write the full well commented code for the **Arduino Standard Servo Rotation to Exact Angel** [5 Marks].

- c) An instruction is a binary pattern designed inside a microprocessor to perform a specific function. The entire group of instructions, called the instruction set, determines what functions the microprocessor can perform. The intel 8085 Instruction set can be classified into the following five functional categories:
- i. data transfer (copy) operations,
  - ii. arithmetic operations,
  - iii. logical operations,
  - iv. branching operations, and
  - v. machine-control operations

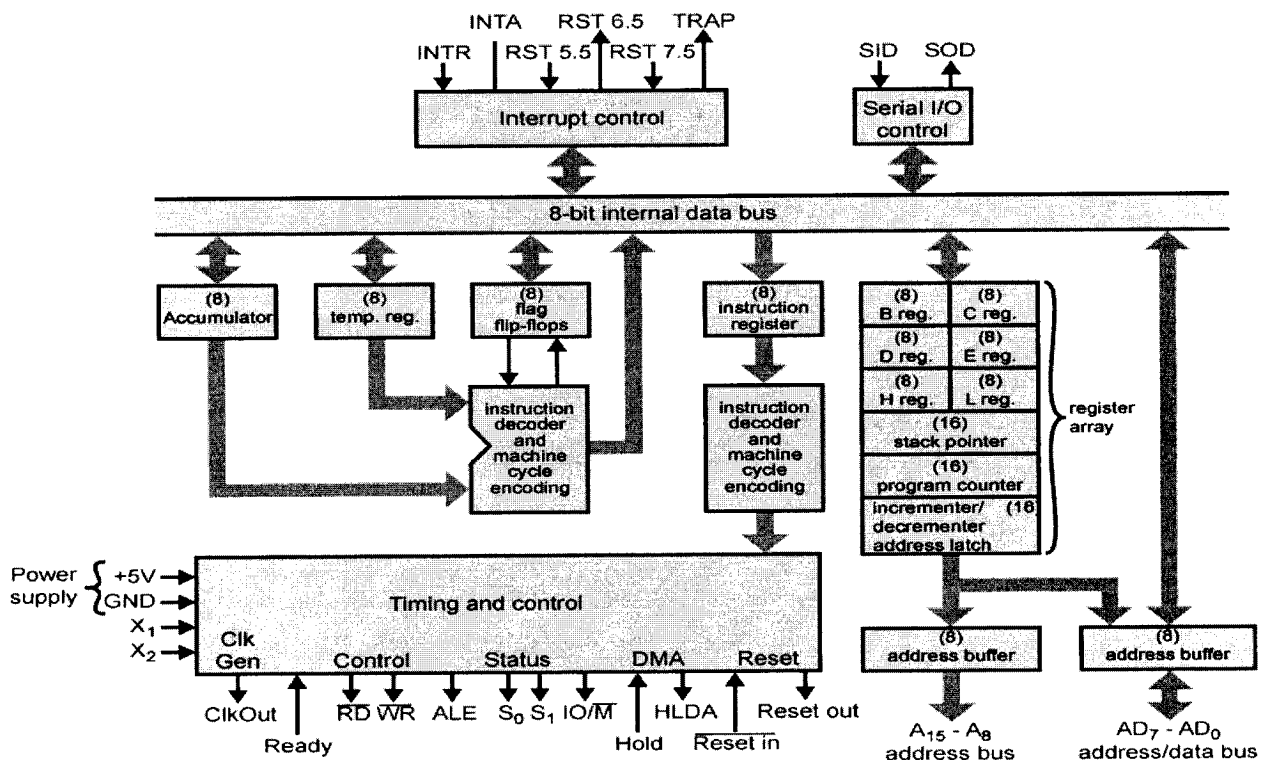
Discuss each of the instruction set with at least one example of the actual instruction performed by the intel 8085 microprocessor [10 Marks].

## SECTION B

This section has **THREE** Questions. Choose any two questions

### Question I

- a) The figure below shows the Intel 8085 CPU Block Diagram. With reference to the diagram below, give the function of each of the following [20 Marks];
- Interrupt Control
  - Serial I/O Control
  - Registers (A, B, D, E, H, L, Acc. Temp, etc)
  - Timing and Control
  - Power Supply
  - Addressing ( $A_x$  and  $AD_x$ )
  - Internal Bus



## **Question II**

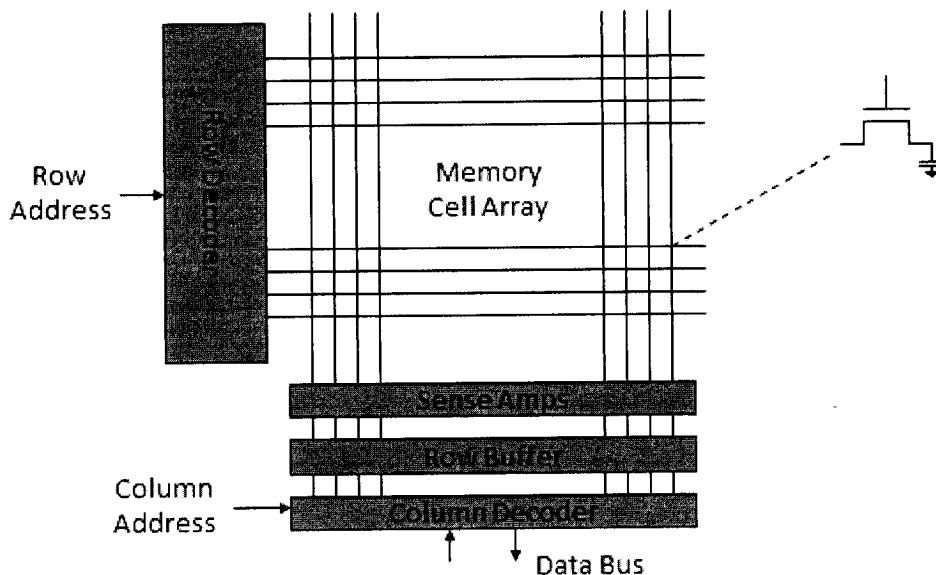
a) Sequential circuits all depend upon the presence of memory. A flip-flop can store one bit of information while a register can store a single word typically 32 or 64 bits. Memory signals fall into three categories namely

- i. Address bus
- ii. Data bus
- iii. Control signals

Discuss each of the categories above [3 Marks]

b) The diagram below shows the basic DRAM Chip Organization. Explain with reference to the diagram below how a computer stores and read data from memory using DRAM as examples. In your discussion make reference to [8 Marks]

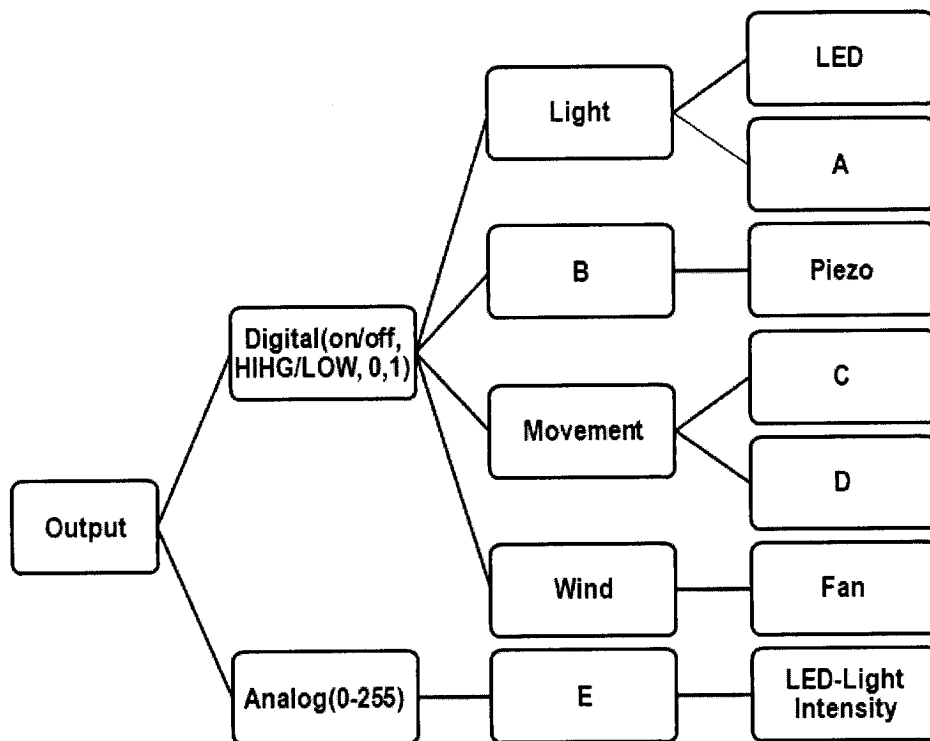
- i. Row Decoder
- ii. Sensing Amps
- iii. Row Buffer
- iv. Column Decoder



c) To implement process control, the computer must collect data from and transmit signals to the production process. Give a brief description for each of the following in relation to computer process interfaces [4 Marks]

- i. Sensors
- ii. Actuators

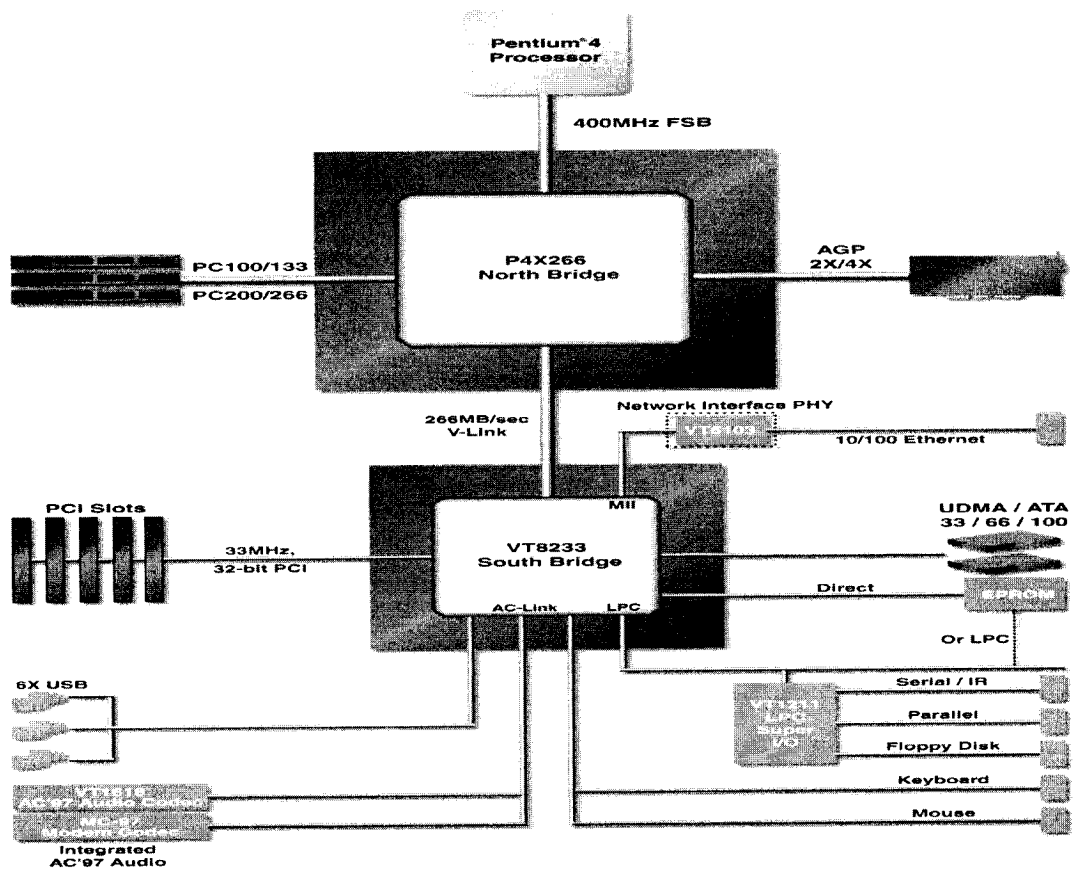
d) Complete the diagram by inserting the missing information labeled A to E [5 Marks]





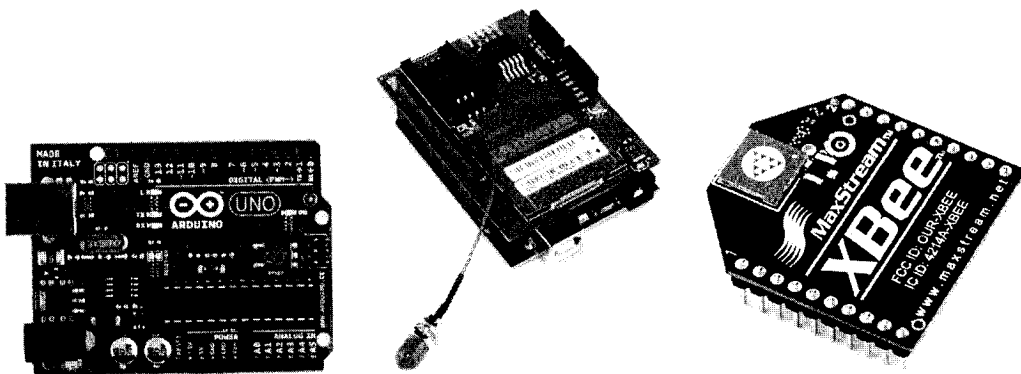
## Question III

- a) A chipset is a group of integrated circuits, sold as one unit, designed to perform one or more related functions. In this course, we focused on chipsets that provide functionality for the CPU. The diagram below shows the Apollo Chipset designed for the Pentium 4 processor.

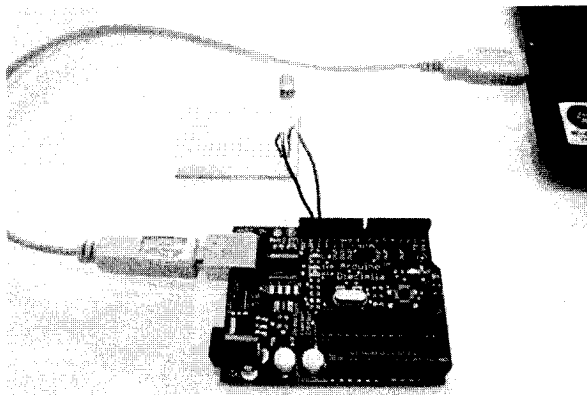
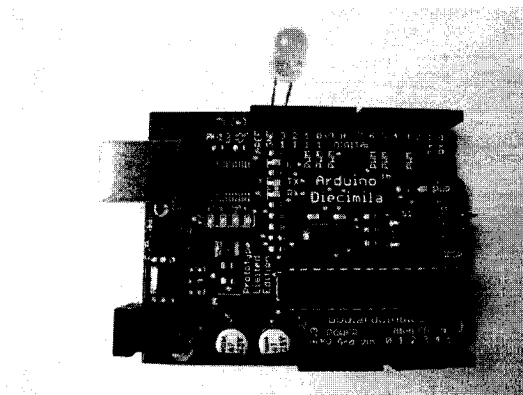


With reference to the diagram above, discuss in detail the functions and roles of the chipsets (North Bridge and South Bridge) in relation to the Pentium 4 processor to manage the operation of the computer [9 Marks]

- b) Identify, name and give the function of each of the following below [6 Marks];



- c) The diagram below shows the setup of the **Arduino Digital Output-LED**. This can either be connected direct on the board or one can use the solderless breadboard. Give the full well commented code that can be used to programme this setup using PIN 13 on the Arduino board [5 Marks]



**End of the Examination**

**THE UNIVERSITY OF ZAMBIA**  
**School of Natural Sciences**  
Department of Computer Science

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**FINAL EXAMINATION**

**CSC 4630**  
**ADVANCED SOFTWARE ENGINEERING**

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Date: 19<sup>th</sup> SEPTEMBER 2017  
Time: 09:00hrs – 12:00hrs  
Duration: 3 Hours  
Venue: P206

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**Instructions**

1. Answer *all* the questions in Section A and choose any *three (3)* questions from Section B

**SECTION A**  
**ANSWER ALL QUESTIONS IN THIS SECTION**

**QUESTION 1 [20 marks]**

- i. What is the difference between a scenario and a use case? When do you use each construct? **[4 Marks]**
  
- ii. Draw a use case diagram for a ticket distributor for a train system. The system includes two actors: a traveler, who purchases different types of tickets, and a central computer system, which maintains a reference database for the tariff. Use cases should include: BuyOneWayTicket, BuyWeeklyCard, BuyMonthlyCard, UpdateTariff. Also include the following exceptional cases: Time-Out (i.e., traveler took too long to insert the right amount), TransactionAborted (i.e., traveler selected the cancel button without completing the transaction), DistributorOutOfChange, and DistributorOutOfPaper. **[6 Marks]**
  
- iii. Draw a class diagram representing a book defined by the following statement: "A book is composed of a number of parts, which in turn are composed of a number of chapters. Chapters are composed of sections." Focus only on classes and relationships. **[4 Marks]**
  
- iv. Extend the class diagram of previous (question iii) to include the following attributes: **[4 Marks]**
  - A book includes a publisher, publication date, and an ISBN
  - A part includes a title and a number
  - A chapter includes a title, a number, and an abstract
  - A section includes a title and a number
  
- v. What is the purpose of modeling? **[2 Marks]**

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**CSC 4630: Advanced Software Engineering – Exam Questions**

**QUESTION 2 [20 marks]**

- i. Consider a workflow system supporting software developers. The system enables managers to model the process the developers should follow in terms of processes and work products. The manager can assign specific processes to each developer and set deadlines for the delivery of each work product. The system supports several types of work products, including formatted text, picture, and URLs. The manager, while editing the workflow, can dynamically set the type of each work product at run time. Assuming one of your design goals is to design the system so that more work product types can be added in the future, which design pattern would you use to represent work products? **[4 Marks]**
  
- ii. Consider a system that includes a database client and two redundant database servers. Both database servers are identical: the first acts as a main server, the second acts as a hot back-up in case the main server fails. The database client accesses the servers through a single component called a “gateway,” hence hiding from the client which server is currently being used. A separate policy object called a “watchdog” monitors the requests and responses of the main server and, depending on the responses, tells the gateway whether to switch over to the back-up server. What do you call this design pattern? Draw a UML class diagram to justify your choice. **[6 Marks]**
  
- iii. List the main symbols found on class diagrams **[2 Marks]**
  
- iv. Imagine you are planning to develop an air-traffic control system. What different kinds of users should you anticipate? **[4 Marks]**
  
- v. Define the following types of software testing: Unit testing, system testing, release testing and performance testing. **[4 Marks]**

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**CSC 4630: Advanced Software Engineering – Exam Questions**

**SECTION B**  
**ANSWER ANY THREE (3) QUESTIONS IN THIS SECTION**

**QUESTION 1 [20 marks]**

Lusaka City Council (LCC) have hired your company to build a bus reservation system for all bus trips taken from Intercity Bus Terminal (IBT).

2. Outline in one paragraph the information you would need to gather in order to perform domain analysis for the LCC IBT bus reservation system.

**[7 marks]**

3. Requirements can be divided into four major types functional, quality, platform and process. Describe quality requirements and give 2 examples of main categories for quality requirements.

**[3 marks]**

4. Classify the following aspects of the LCC IBT bus reservation system into F for functional, Q for quality, PL for platform, PR for process, and X for 'should not be a requirement'. Also indicate the subcategory of requirement. For something that should not be a requirement, explain why not.

- i. What information appears on tickets and reports.
- ii. How fares are calculated.
- iii. The system must be available at all times. Only 2 minutes' downtime a week is to be permitted.
- iv. The system must run on any Linux system.
- v. A merge-sort algorithm must be used to sort the flights by departure time.

**[5 marks]**

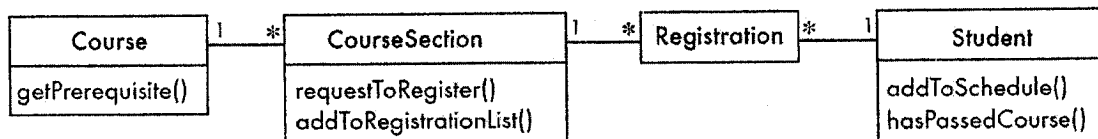
5. In describing *simplified use cases* of the LCC IBT bus reservation system, giving the **name** and **steps** of the use cases is enough, however your project manager insists that you describe *complete use cases*. State 5 other components you would add to the description of the use cases of the LCC IBT bus reservation in order to make them complete. Give a short explanation for each component that you state.

**[5 marks]**

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**CSC 4630: Advanced Software Engineering – Exam Questions**

**QUESTION 2 [20 marks]**

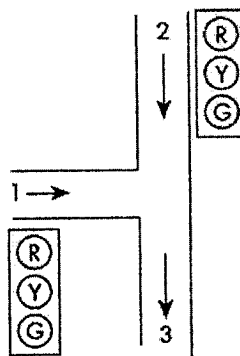
1. The diagram below shows the classes involved in a fictitious Student Registration System (SRS) for the University of Zambia (UNZA). It shows the classes involved when a student attempts to register for a course.



- i. Draw a **simple sequence diagram** based on the given class diagram that shows the interactions that occur in the UNZA SRS when a student attempts to register for a course. [4 marks]
- ii. Assume that a student is only allowed to register for a course if he has passed the course prerequisites. Draw a new **detailed sequence diagram**, by expanding on your previous answer, showing a *GUI* and *Course* object as well as showing an *optional combined fragment* for the prerequisite. [8 marks]
- iii. You can use communication diagrams as opposed to sequence diagrams to show the interactions occurring in the UNZA SRS since both types of diagrams contain much of the same information. Describe 4 situations/reasons that make sequence diagrams the better choice when depicting interaction within a software system diagrammatically. [4 marks]
2. Assume the diagram below represents the road layout when exiting the UNZA Main Campus along Great East Road with a vehicle. Assume movement in the direction from 2 to 3 represents vehicles moving on Great East Road from Arcades roundabout to Manali roundabout. Traffic lights have been installed at this junction as follows:
- The traffic light at point 1 has three colors Green, Yellow and Red. When the system starts up the robot is Red.
  - After startup, the system indefinitely rotates among Green, Yellow and Red. The Red light only stays on for 30 seconds, at which time the Green light comes on.

University of Zambia – Department of Computer Science  
**CSC 4630: Advanced Software Engineering – Exam Questions**

- iii. The Green light stays on for 25 seconds, at which time the system changes to Yellow.
- iv. After five more seconds the Yellow light gives way to the Red light again.
- v. Traffic moving from point 2 to 3 always has a Green light unless a vehicle arrives at point 1 and triggers a sensor.
- vi. When the sensor at point 1 is triggered, the robot their changes to Yellow, but only after the traffic coming from point 2 has had at least 25 seconds of Green light. Without this a steady series of vehicles arriving at point 1 would prevent the light at point 2 from staying green long enough for traffic to flow.



Draw a state diagram for the UNZA traffic light system described above, illustrating elapsed-time transitions.

[4 marks]



University of Zambia – Department of Computer Science  
**CSC 4630: Advanced Software Engineering – Exam Questions**

**QUESTION 3 [20 marks]**

1. A small Zambian publishing company requires a software system to manage customer subscriptions to the journals that it publishes. Below are the basic requirements.  
A journal is published a fixed number of times a year and payment is made in advance. The software system must keep track of all subscriptions for each journal along with the payment details. Payment can be by credit card or using PayPal.  
Once a month the system will be used to check the status of all subscriptions and generate renewal notices for those that will soon expire. Subscriptions that have not been renewed expire. When a new edition of a journal is published, the system must generate address labels for all current subscribers.  
The following details are stored for each customer: name, address, and telephone number. The following details are stored for each journal: name, ISSN, issue date, frequency, and cost.

- i. Model the functional requirements using a use case diagram. Specify one of the use cases in detail. **[10 marks]**
- ii. Create a domain model for this system in a UML Class diagram showing classes, relationships, attributes and multiplicity information. There is no requirement to add details other than what is supplied in the description above. **[10 marks]**

**QUESTION 4 [20 marks]**

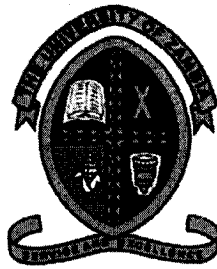
1. When an online exam is taking place, student activity is monitored by a tool, which shows a dynamically updated table of the students taking the exam, with information such as when the most recent backup occurred for each student, and whether any students have attempted to cheat by accessing applications or web pages other than the exam. The tool works by sending HTTP messages to the server, receiving data in response, so to a firewall it looks just like a web browser. In other words, the tool is polling the server at intervals for batches of information, rather than the server providing each piece of information as soon as it's available.
  - i. Explain the notion of a **design pattern**, and why design patterns are important in object-oriented software development. **[4 marks]**
  - ii. In the first version of the tool, there was a 1-1 mapping between exams and monitoring tool instances. It was not possible for one exam to be monitored by many tools, or many exams to be monitored by one tool. Also, we expect in the

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**CSC 4630: Advanced Software Engineering – Exam Questions**

future to have different types of tools for different users, e.g. invigilators in a room vs. managers overseeing the whole exam process. We might even have different types of servers, e.g. local vs. remote. Explain how the **Observer design pattern** can be used to remove these restrictions and provide the basis of future developments. **[4 marks]**

- iii. Draw a UML diagram to illustrate the Observer pattern as applied to this situation **[6 marks]**
- iv. In what way does the method of communication between the tool and the server described above require changes to the standard Observer pattern? **[2 marks]**
- v. Explain another way in which the Observer pattern could be used in the monitoring tool. **[2 marks]**
- vi. Briefly suggest how two other design patterns might be used in the monitoring process. **[2 marks]**

**END OF PAPER**



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**Department of Computer Science**

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**CSC4631 – Software Testing & Maintenance**

**2016/2017 EXAMINATION QUESTION PAPER**

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Date: Thursday 11<sup>th</sup> May 2017  
Venue: B 512  
Time: 14:00 – 17:00 hrs  
Duration: 3 Hours

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**Instructions**

1. This exam has two sections A and B.
2. Answer **ALL** questions in **Section A**.
3. Answer **any four (4)** questions in **Section B**.
4. **Total number of questions answered should be 5.**

**SECTION A**

**QUESTION 1 [20 marks]**

1. Define software maintenance as described by the IEEE software maintenance standard, IEEE STD 1219-1993. **[1 mark]**
2. Give 4 strategic options for legacy system evolution? **[4 marks]**
3. Under what circumstances might an organization decide to scrap a system when the system assessment suggests that it is of high quality and high business value? **[3 marks]**
4. State at least 3 reasons why a software system that is used in a real-world environment must change or become progressively less useful. **[3 marks]**
5. The components of the software maintenance framework are *user, environment, maintenance process, software product* and *maintenance personnel*. Discuss in-brief how the components interrelate. **[6 marks]**
6. One of the reasons why software maintenance is needed is *to facilitate future maintenance work*. Expound on why this can be said, giving an example of what would be involved. **[3 marks]**

## SECTION B

### QUESTION 2 [20 marks]

1. In the course of designing an enhancement to a software system, a software engineer needs to investigate the current system, why? **[3 marks]**
2. As part of the work on a software maintenance project proposal that your team is working on, the team lead asks you to itemize artifacts needed for the implementation and testing phases of the project to help in giving the potential client an indication of the cost of work. Give 2 examples of implementation artifacts and testing artifacts that you would submit? **[4 marks]**
3. Describe at least 2 types of change that a software product may undergo in a software maintenance project, giving rationale for each. **[6 marks]**
4. How does *effective communication* as part of on-going support assist in software maintenance activities? **[3 marks]**
5. From the period 1974 to 1996, Meir Lehman and Laszlo Belady formulated 8 *laws of software evolution*. The laws describe a balance between forces driving new developments on one hand, and forces that slow down progress on the other hand. Describe the *Law of Conservation of Familiarity* and the *Law of Declining Quality*. **[4 marks]**

**QUESTION 3 [20 marks]**

1. Describe briefly the economic implications of modifying software. **[3 marks]**
2. The Quick-Fix model of maintaining software in commercial operations is unreliable. Why though is it still used in such settings? And what would be the correct way to use it? **[4 marks]**
3. What is a baseline in software configuration management? **[2 marks]**
4. Outline the responsibilities of an individual or team handling configuration management in a software maintenance project? **[5 marks]**
5. There are several vendors developing and marketing a wide variety of tools that claim to support software maintenance. Bearing this in mind, describe at least 3 factors you should consider before acquiring a tool for software maintenance work? **[6 marks]**

**QUESTION 4 [20 marks]**

1. What is reverse engineering and what is the motivation behind doing it? **[3 marks]**
2. There are no hard and fast rules as to what criteria a program must fulfil before it may usefully be subject to reverse engineering. There are, however, some indicators which may serve as warning signs. Name at least 6 indicators that may prove helpful along with their corresponding motivations. **[6 marks]**
3. Your co-workers in a software engineering team, Machaka and Shemaiah are arguing about where it is best to begin reverse engineering. Machaka says the architectural design, Shemaiah says the source code. Who is right and why? **[3 marks]**
4. Software system abstraction is achieved by highlighting the important features of the subject system and ignoring the irrelevant ones. Briefly describe the 2 types of abstractions that can be performed on software systems. **[4 marks]**
5. Reverse engineering, in-itself, does not directly lead to modification of a system. The understanding of a system that we obtain through reverse engineering can support the implementation of change. Briefly describe at least 2 techniques that are used to implement changes after performing reverse engineering. **[4 marks]**

**QUESTION 5 [20 marks]**

Your company has been hired for a software maintenance project at Zambia Revenue Authority. The revenue authority's taxing software system is large and complex. It is the responsibility of you and your team to ensure that the software system under maintenance

is of satisfactory quality. You must also make sure that system changes are effected with minimum possible delay at the least possible cost.

1. Briefly describe how can you achieve this. **[4 marks]**
2. As project manager, describe 4 ways you can motivate personnel on your software maintenance team. **[8 marks]**
3. What are the benefits of exposing your team to education and training? **[5 marks]**
4. Why do large and complex software systems present challenges for managers of software maintenance projects? **[3 marks]**

### **QUESTION 6 [20 marks]**

As team lead on the University of Zambia Student Portal System you are putting together a maintenance plan. Part of your plan involves selecting software maintenance measurements.

1. Is software measurement different from software metric? Explain. **[2 marks]**
2. In software measurement, there are 2 types of attributes internal attributes and external attributes. Using examples explain how they differ. **[4 marks]**
3. Give five main reasons, in brief, of why it is important to carry out software maintenance measurement on the student portal system. **[10 marks]**
4. Some guidelines that can prove helpful in selecting suitable maintenance measures are well defined objectives, fitness for purpose, ease of use, low implementation cost and sensitivity. Explain how *well defined objectives* and *ease of use* are helpful? **[4 marks]**

**- END OF QUESTION PAPER -**



**THE UNIVERSITY OF ZAMBIA**  
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Department of Computer Science

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**FINAL EXAMINATION**

**CSC 4642**  
**SOFTWARE QUALITY ASSURANCE**

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Date: 06<sup>TH</sup> SEPT 2017  
Time: 14:00 – 17:00 hrs  
Duration: 3 Hour  
Venue: P206

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**Instructions**

- The question paper has TWO SECTIONS (A and B).
  - Section A comprises FOUR (4) questions. Answer any THREE (3).
  - Section B comprises THREE (3) questions. Answer any TWO (2).
  - Answer FIVE (5) questions in total.
  - Clearly number your answers.
  - Use the marks as a guide to the detail required in your answers while keeping your answers concise and relevant
-

## **SECTION A: ANSWER ANY THREE QUESTIONS [60 Marks]**

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### **Question 1**

- i. Define software error, software fault and software failure. [3 marks]
- ii. Briefly describe any four causes of software errors. [8 marks]
- iii. According to the IEEE definition of SQA, quality control (QC) is not equated with quality assurance (QA).
  - a. In what respects does QC vary from QA? [4 marks]
  - b. Why can QC be considered part of QA? [2 marks]
- iv. It is claimed that no significant SQA activities are expected to take place during the phase of production planning for software products.
  - a. Discuss this claim. [3 marks]

### **Question 2**

- i. What are the three factor categories belonging to McCall's factor model? [3 marks]
- ii. What factors are included in each of the categories? [4 marks]
- iii. Southcottage Inc. is a manufacturer of washing machines and dishwashers. The requirements document for the new control unit included the following specifications:  
(1) The firmware should be suitable for all six variations of model 2002 washing machines  
(2) The water level control module of the washing machine should be suitable for use as a water level control module in the new model 2002 dishwasher.
  - a. To which quality factors do the above requirements belong? Explain your answer. [4 marks]
- iv. Many organisations do not apply their contract review procedures to internal projects even though they perform comprehensive contract reviews for all their external projects.
  - a. List two arguments that support this approach. [3 marks]
  - b. List two arguments that oppose this approach. [3 marks]
  - c. Suggest types of internal projects where omission of a contract review could result in severe damage to the organisation. [3 marks]



### Question 3

- i. “Preparing full-scale development and quality plans for internal projects, and applying regular full customer–supplier relationships for the implementation of internal projects is highly beneficial to both sides”. [8 marks]
  - a. Explain four benefits of these procedures to the developer.
  - b. Explain four benefits to internal customers.
- ii. With respect to verification, validation and qualification:
  - a. Explain the differences among these three aspects of SQA activities. [6 marks]
  - b. Can a project that successfully passed verification and validation reviews but failed part of the qualification review adequately supply users with the information needed? Explain your answer. [6 marks]

### Question 4

- i. Referring to the model for defect removal efficiency and costs:
  - a. Explain the six assumptions that rest at the foundations of the model? [10 marks]
  - b. Which three of the model's data components are based on published survey results? [6 marks]
- ii. Compare the various review techniques. [4 marks]
  - a. In what aspects are design reviews more formal than inspections?
  - b. In what aspects are inspections more formal than walkthroughs?

## **SECTION B: ANSWER ANY TWO QUESTIONS [40 Marks]**

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### Question 5

Consider the following system: Module **M12** is integrated with five lower-level **Modules** and only one upper-level **Module**.

- i. Illustrate and describe both top-down and bottom-up testing of the system. [8 marks]

- ii. Discuss how stubs and drivers are used in top-down and bottom-up testing of the system. [8 marks]
- iii. Based on your discussion in (ii), comment on the resources required to perform each type of testing on the system. [4 marks]

### Question 6

Consider the following program:

```
IF A = 10 THEN
  IF B > C THEN
    A = B
  ELSE
    A = C
  ENDIF
ENDIF
Print A
Print B
Print C
```

- i. Develop the Flow Chart for the program. [5 marks]
- ii. Develop the Program Flow Graph for the program. [5 marks]
- iii. Compute the Cyclomatic Complexity of the program. [2 marks]
- iv. Show the set of paths resulting from your computation in (iii). [5 marks]
- v. Comment on the overall complexity of the program based on the Cyclomatic Complexity you computed. [3 marks]

### Question 7

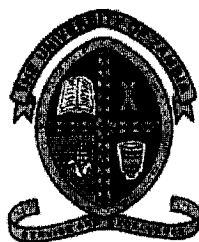
A module that calculates bus ticket prices has been developed for the Lusaka City Council Transport unit. The bus ticket price table is shown below. Peak time = 5.00 am – 9.00 am; off-peak = 9.01 am – 23.45 pm.

	Monday-Friday				Saturday-Sunday			
Mode of Payment	Cash	Cash	Card	Card	Cash	Cash	Card	Card
Time of Travel	Peak	Off-Peak	Peak	Off-Peak	Peak	Off-Peak	Peak	Off-Peak
	Bus Fare - ZMK							

<b>Passenger Years</b>								
Child: 0.00 -13.00	2.00	1.00	1.50	0.50	1.80	0.80	1.30	0.30
Senior Citizen 60.01-120.00	5.00	4.00	4.50	3.50	4.80	3.80	4.30	3.30
Adult: 13.01- 60.00	10.00	8.00	8.50	6.50	9.80	7.80	8.30	6.30
	<b>Special Needs Passengers</b>							
	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00

- i. What are the variables in the bus ticket system? [2 mark]
- ii. List the valid equivalence classes for the module? [4 marks]
- iii. Suggest representational values for each of the equivalence classes from (ii).[4 marks]
- iv. What are the boundary values for valid equivalence classes? [2 marks]
- v. List the invalid equivalence classes for the module? [4 marks]
- vi. Suggest representational values for each of the invalid equivalence classes from (ii). [4 marks]

**END OF EXAM**



**THE UNIVERSITY OF ZAMBIA**  
School of Natural Sciences  
Department of Computer Science

**FINAL EXAMINATION**

**CSC 4722**  
**Distributed Systems**

Date: 12<sup>th</sup> September 2017  
Time: 09:00hrs – ~~14:00hrs~~ 12:00 hrs  
Duration: 3 Hours  
Venue: UPPER D/HALL

**Instructions**

1. There are **two (2) sections** in this exam paper.
2. *Answer all the questions in **Section A** and choose any three (3) questions from **Section B***

## **SECTION A. Short answers (40 marks)**

You are required to answer all questions in this section. Each question carries **4 marks**.

1. What is a distributed system?
2. Give two characteristics of a distributed system?
3. What are the ACID properties of a transaction processing system?
4. What are the differences between relocation, replication and migration?
5. What is false sharing with regard to distributed shared memory systems?
6. What is distribution transparency with regards to distributed system goals?
7. How does a Remote Procedure Call work for messaging passing in a shared nothing environment?
8. Explain four pitfalls of distributed systems?
9. What is hadoop?
10. Give four advantages of cloud computing.

## SECTION B (60 marks)

Answer any three (3) of the five (5) questions.

1.

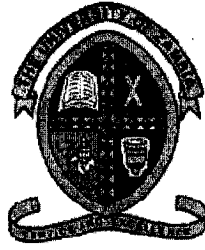
- a. What is cloud computing? [2 marks]
- b. What are the four essential characteristics of cloud computing? [4 marks]
- c. Explain with an illustration the cloud computing stack and the three service models for cloud computing? [7 marks]
- d. Explain with an illustration the four deployment models for cloud computing.  
[7 marks]

2.

- a. What is the major difference between internal and external clock synchronization? [2 marks]
- b. How does Cristian's Algorithm for external clock synchronization work. [5 marks]
- c. Give an example of an internal clock synchronization algorithm. Explain its mechanism. [5 marks]
- d. Machine  $M_a$  has a time  $a$ , machine  $M_b$  has a time  $b$  and machine  $M_c$  has a time  $c$ . Using the Berkeley algorithm deduce and show that the time on the three machines will be synchronized to  $(a + b + c)/3$  and hence generally the average.  
[8 marks]

3. A coordinator is a very important node in most algorithms for distributed systems. Please clarify on the following with regards to election algorithms

- a. How does a bully algorithm pick a winner of the election process? [2 marks]
- b. Explain the ring election algorithm [6 marks]
- c. Suppose that we have four processes arranged in a ring:



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**FINAL EXAMINATION**

**DATA MINING AND DATA WAREHOUSING**  
**CSC 4792**

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Date: 15<sup>th</sup> SEPTEMBER, 2017  
Time: 09:00hrs – 12:00hrs  
Duration: 3 Hours  
Venue: P206

---

**Instructions**

1. Answer *all* the questions in Section A.
2. Choose *any THREE (3)* questions in Section B.

## SECTION A

Answer ALL question in this section. The total weight of this section is 40 Marks.

### Question 1 [20 Marks]

- a. From your understanding, what is *data mining*? In your answer, address the following:
  - i. Is it another technological hype? [2 Marks]
  - ii. Is it a simple transformation of technology developed from databases, statistics, and machine learning? [5 Marks]
  - iii. Explain how the evolution of database technology led to data mining. [5 Marks]
  - iv. Describe the steps involved in data mining when viewed as a process of knowledge discovery. [8 Marks]

### Question 2 [20 Marks]

- b. Based on your answer in Question 1 (a):
  - i. Present an example where data mining is crucial to the success of a business.[4Marks]
  - ii. What data mining functions does this business need? [4 Marks]
  - iii. Can they be performed alternatively by data query processing or simple statistical analysis? [4 Marks]
  - iv. Explain how a data warehouse is different from a database? How are they similar? [8 Marks]



## SECTION B

There are five (5) questions in this section. All of them carry an equal weight of 20 Marks.  
CHOOSE ONLY THREE (3)!

### Question 1 [20 Marks]

- a. Suppose your task as a software engineer at Big-University is to design a data mining system to examine their university course database, which contains the following information: the name, address, and status (e.g., undergraduate or graduate) of each student, the courses taken, and their cumulative grade point average (GPA).
  - i. Describe the architecture you would choose. [10 Marks]
  - ii. What is the purpose of each component of this architecture? [10 Marks]

### Question 2 [20 Marks]

- a. In predictive modeling, what is the difference between “classification” and “regression”? [4 Marks]
- b. Differentiate between “classification” and “clustering” algorithms. [4 Marks]
- c. In question 2 (b), list out at least four main categories of classification algorithms. [8 Marks]
- d. Explain the general approach towards building a classification model? NOTE: Show this by way of a diagram. [4 Marks]

### Question 3 [20 Marks]

- a. For classification, explain how the decision tree algorithm works. [5 Marks]
- b. In decision trees, what is the significance of leaf nodes? [3 marks]
- c. From your description in Question 3 (a), briefly describe three design issues associated with this classification algorithm. [6 Marks]
- d. Explain how the Rule- Based algorithms differ from the decision tree algorithm. [ 6 Marks]

**Question 4 [20 Marks]**

- a. State seven (7) issues that ought to be addressed in data preprocessing stage of the data mining process? [7 Marks]
- b. What is the difference between “binarization” and “discretization”? [4 Marks]
- c. Given that there are  $m$  categorical values of a given variable, show that you need,  $n = \log_2(m)$ , binary digits to represent these  $m$  integers. [5 Marks]
- d. How many binary variables would a categorical variable with five (5) values have after the process of binarization in question 4 (c)? [4 Marks]

**Question 5 [20 Marks]**

- a. For each of the following pairs of data mining functionalities, explain the differences and similarities:
  - i. Discrimination and classification [4 Marks]
  - ii. Characterization and clustering [4 Marks]
  - iii. Classification and prediction [4 Marks]
- b. Give examples of each data mining functionality in Question 5(a), using a real-life database that you are familiar with. [8 Marks]

End of Exam

$P_0 \rightarrow P_1 \rightarrow P_2 \rightarrow P_3 \rightarrow P_4 \rightarrow P_5 \rightarrow P_0 \dots$

$P_5$  which is the coordinator then crashes. Assuming  $P_2$  detects that  $P_5$  is not responding outline with illustrations, the stages of the election that will occur using a ring algorithm. [6 marks]

- d. Illustrate an election process that would be followed if a bully algorithm is used instead of the ring election algorithm. [6 marks]

4.

- a. List and explain the two main categories of mutual exclusion algorithms?

[8 marks]

- b. How are election algorithms related to mutual exclusion algorithms? [2 marks]
- c. With illustrations explain how the token ring based mutual exclusion algorithm works. [4 marks]
- d. Given three processes  $P_0$ ,  $P_1$  and  $P_2$ ;  $P_1$  has timestamp 7 and  $P_2$  has timestamp 13.  $P_1$  and  $P_2$  wish to enter their critical regions. Explain with an illustration how this can be achieved using a timestamp prioritized mechanism. [6 marks]

5.

- a. What is concurrency and why is it important in distributed systems? [4 marks]
- b. A distributed application uses three processes on different machines. Process  $P_1$  starts with event  $a$  (with timestamp 1) and is followed by event  $b$  and then finally  $c$ . Process  $P_2$  starts with event  $d$  (with timestamp 1) which sends a message to event  $c$  of Process  $P_1$ . Event  $d$  is followed by event  $e$  which receives a message from event  $a$  of Process  $P_1$ . Event  $e$  is then followed by event  $f$  and later on event  $g$ . Event  $g$  receives a message from event  $c$  of Process  $P_1$ . Process  $P_3$  starts with event  $h$  (with has timestamp 1) and is followed by event  $i$  which receives a message from event  $g$  of Process  $P_2$ .

a.i. Generate a Lamport timestamp diagram for all the processes. [8 marks]

a.ii. Generate a Vector timestamp diagram for all the processes. [8 marks]

**THE UNIVERSITY OF ZAMBIA  
SCHOOL OF NATURAL SCIENCES**

**2016 ACADEMIC YEAR FINAL EXAMINATIONS**

**GES 1310: INTRODUCTION TO GEOGRAPHY**

**TIME:** Three (3) Hours

**INSTRUCTIONS:** Answer **all** questions in section A and **any other (one)** in section B. Use of an approved calculator is allowed. Candidates are encouraged to use illustrations wherever appropriate.

---

**SECTION A**

1. Write short explanatory notes on **All** of the following:
  - a. Renewable and non-renewable natural resources
  - b. Ubiquitous and Localised raw materials
  - c. Stocks and flows
  - d. Frost weathering
  - e. Vertical and lateral abrasion in a river
  - f. Metamorphism.
2. Using data in Table 1 answer the following:
  - a. Determine if the Kamimaland scenario conforms to the Rank Size Rule (RSR).
  - b. Comment on the city distribution pattern which the actual set of data produces.

**Table 1: Population of nine largest cities in Kamimaland**

City	Population
Apedale	478,000
Beartown	3,673,000
Catville	682,000
Deersdale	19,189,000
Elephantein	3,140,000
Foxdale	1,474,000
Goatsbosch	799,000
Hippopark	671,000
Impalaburg	280,000

Source: Hypothetical data

**SECTION B**

3. With the aid of examples, discuss the key assumptions of political ecology.

4. Describe the components of the formula  $f(CI, O, R, P, T)$  representing the five soil formation factors.
  5. Explain the causes of urbanisation and its socio-economic and environmental implications.
- 

**END OF EXAMINATION**

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**2016 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 wherever appropriate.

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1. What are the socio-economic benefits of Africa's large lakes?
  2. In which ways did the colonial interface contribute to rapid change in terms of modernisation and cultural dynamics in Africa?
  3. Explain how Zambia's Vision 2030, Adesina's 5 Highs of the African Development Bank and the African Union's Agenda 2063 can contribute to job creation, and poverty reduction in Zambia .
  4. Describe the shift in the development path that Tanzania has experienced on her journey to achieve socio-economic development.
  5. Compare and contrast agricultural and rural development policies and strategies followed in Zambia before and after 1991 by the various administrations.
- 

**END OF EXAMINATION**

**THE UNIVERSITY OF ZAMBIA**  
**SCHOOL OF NATURAL SCIENCES**

**2016 ACADEMIC YEAR FINAL EXAMINATIONS**

**GES 2322: FUNDAMENTALS OF NATURAL RESOURCES ECONOMICS**

**TIME:** Three (3) Hours

**INSTRUCTIONS:** Answer any three questions. All questions carry equal marks. Candidates are encouraged to use illustrations wherever appropriate. Use of an approved calculator is allowed.

---

1. Write short explanatory notes on **all** of the following:
  - (a) Normal and inferior goods
  - (b) Substitute and complementary goods
  - (c) The study of natural resource economics
  - (d) Rostow's five stages of economic growth
  - (e) Gross Domestic Product
2. Compare and Contrast monopoly and monopolistic market structures.
3. Explain how inadequate human resources, cultural barriers and rapid population growth can affect the economic development of a country.
4. (a) With the aid of a diagram, illustrate the difference between '*a shift in supply*' and '*a change in quantity supplied*'.  
  
(b) Using any two factors of your choice, explain how they can cause a shift in the supply curve of a good.
5. Study Table 1 and answer the questions that follow:

Table 1 Quantity demanded and price of good X at different periods.

Periods	Quantity demanded	Price (\$)
(a)	150	4
(b)	105	5
(c)	75	8
(d)	70	8.32

Source: hypothetical data

- (a) What is the price elasticity of demand when;
- There is a change from (a) to (b)
  - There is a change from (b) to (c)
  - There is a change from (c) to (d)
  - Describe the elasticity in i, ii and iii above.
- (b) Outline and briefly explain three factors that influence the elasticity of demand of a good.

---

**END OF EXAMINATION**

**FORMULA**

$$\text{price elasticity of demand} = \frac{\text{percentage change in quantity demanded}}{\text{percentage change in price}}$$



**THE UNIVERSITY OF ZAMBIA  
SCHOOL OF NATURAL SCIENCES**

**2016 ACADEMIC YEAR FINAL EXAMINATIONS  
GES 2420: RESEARCH AND STATISTICAL METHODS IN GEOGRAPHY**

**TIME:** Three (3) hours

**INSTRUCTIONS:** Answer any THREE questions  
All questions carry equal marks  
Use of an approved calculator is allowed

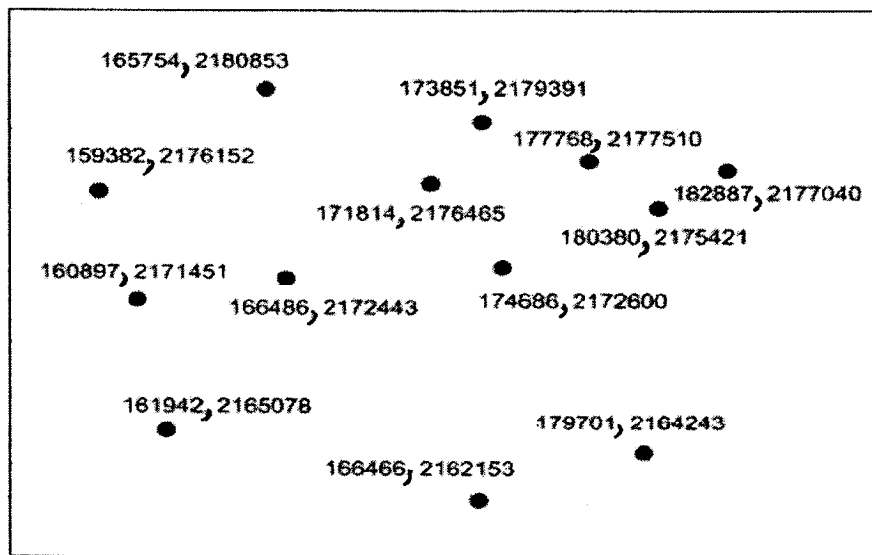
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1. Write short explanatory notes on **ALL** of the following:
  - a) Purpose of conducting research
  - b) Epistemology
  - c) Snowball sampling
  - d) Case study
  - e) Quota sampling
  
2. Too much or little rain can threaten human development in Zambia. A new model of development is called for, one in which strategies to increase human resilience in the face of climate change and the stability of ecosystems is central. You decide to conduct a study on the effects of climate variability on crop production in Chief Chipeco of Southern Province of Zambia:
  - a) Formulate a statement of the problem
  - b) Formulate the aim and three (3) objectives of the study
  - c) Construct a questionnaire for collecting such data

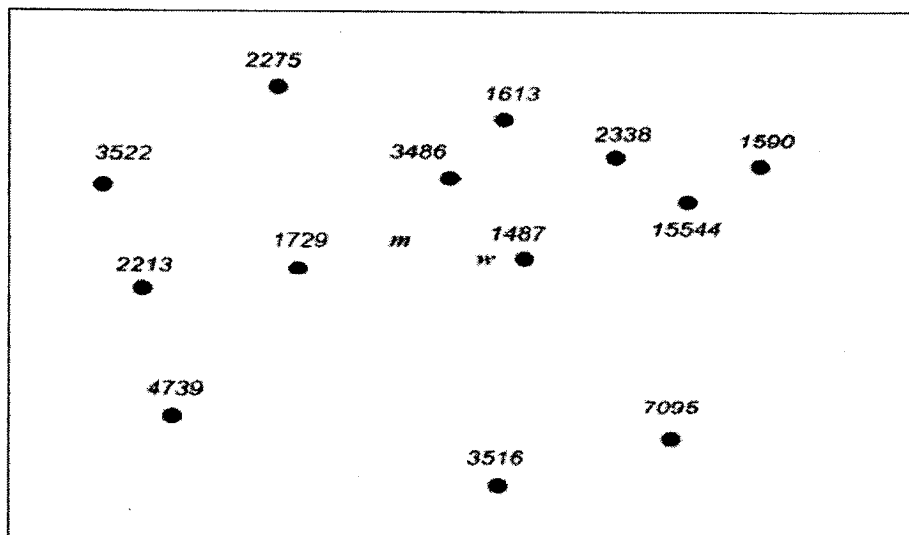
3. For the data given in Figures 1 and 2, calculate and interpret:

- a) The mean centre
- b) The weighted mean centre

**Fig. 1: Location of hypothetical towns**



**Fig. 2: Population of hypothetical towns**



4. High blood pressure is a leading cause of strokes. Medical researchers are consistently seeking ways to treat patients suffering from this condition. A specialist in hypertension claims that regular aerobic exercise can reduce high blood pressure just as successfully as medication. Patients who suffer from high blood pressure were randomly selected to participate in the experiment. For 60 days one sample exercised whilst the other took standard medication. The percentage reduction in blood pressure was recorded, as presented in Table 1. Assuming that the data is normally distributed, can someone conclude that exercise is more effective than medication in reducing hypertension at  $\alpha = 0.01$ ?

**Table 1: Percentage reduction in blood pressure through exercise and use of medication**

Exercise	2.0	1.5	1.22	3.03	1.25	2.86	1.55	2.35	3.33	3.0	4.0	2.64	1.89	2.5
Medication	4.6	5.8	8.4	3.99	4.5	5.55	4.44	3.45	3.85	7.73	4.46	2.86		

Source: *Hypothetical*

5. A company wishes to compare four programmes for training workers to perform a certain manual task. Twenty new employees are randomly assigned to the training programmes, with 5 in each programme. At the end of the training period, a test is conducted to see how quickly trainees can perform the task. The number of times the task is performed per minute is recorded for each trainee, with the results shown in Table 2. What conclusion can you make from this experiment  $\alpha = 0.05$  and assuming that the data are normally distributed?

**Table 2: Training programmes and number of times a task is performed**

Programme	Number of times the task is performed per minute				
1	9	12	14	11	13
2	10	6	9	9	10
3	12	14	11	13	11
4	9	8	11	7	8

Source: *Hypothetical*

---

END OF EXAMINATION

**THE UNIVERSITY OF ZAMBIA**  
**SCHOOL OF NATURAL SCIENCES**  
**2016 ACADEMIC YEAR FINAL EXAMINATIONS**  
**GES 3142: ECONOMIC GEOGRAPHY**

**TIME:** Three hours

**INSTRUCTIONS:** Answer any three questions. All questions carry equal marks. Candidates are encouraged to use illustrations wherever possible.

---

1. Write short explanatory notes on ALL of the following:
  - a) The Location Triangle
  - b) Economies of agglomeration
  - c) Industrial linkages
  - d) Ubiquities and localized materials
  - e) Three key decisions in plant location
2. 'There is a relationship between a road network pattern and optimal spatial organization of economic activities'. Discuss.
3. Analyse Paul Krugman's (1991) assertion that economic geography is a 'branch of economics that is concerned with the where of things in relation to one another'.
4. Compare and contrast any two theories of international trade and highlight how Zambia could adapt any one of the two to develop an effective international trade policy.
5. With the aid of examples, explain how economic, natural, human and political factors are used to determine economic regions.

---

**END OF EXAMINATION**

**THE UNIVERSITY OF ZAMBIA  
SCHOOL OF NATURAL SCIENCES**

**2016 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) Factors that affect the rate of extinction of organisms
    - (b) Criticisms of the theory of Island Biogeography
    - (c) Marsupials
    - (d) Reproductive isolation mechanisms
    - (e) Adaptive radiation
    - (f) Refugia
    - (g) The impact of the shift of Gondwanaland from 60° south to the Equator during the Cretaceous period on both Gondwanaland climate and flora
    - (h) Similarities and differences between *Allopatric* and *Peripatric* types of speciation.
  2. Discuss the use of fire by pre-agricultural people and outline its effects on the local vegetation.
  3. Explain the two alternative approaches that have been used to understand the disjunct distribution patterns of plants and animals and show why antagonisms between supporters of these two approaches are not necessary.
  4. The Linnaean System of classification is described as being “generic, hierarchical, comprehensive, and binomial,” (McKnight, 1984:194). Explain the terminology in relation to the classification using examples from the *Miombo* woodland.
  5. Explain the two views that have been held in Biogeography regarding species’ dispersal across the globe.
- 

**END OF EXAMINATION**

**THE UNIVERSITY OF ZAMBIA**  
**SCHOOL OF NATURAL SCIENCES**  
**2016 ACADEMIC YEAR FINAL EXAMINATIONS**  
**GES 3330: ENVIRONMENT AND DEVELOPMENT**

**TIME:**                      **Three hours**

**INSTRUCTIONS:**    **Answer question 1 and any other TWO questions**

**All questions carry equal marks**

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1. a) State four (4) major effects of overpopulation (4 marks)
  - b) Briefly explain the paradox of plenty (4 marks)
  - c) Explain briefly how greenhouse gases (GHG) influence climate change (5 marks)
  - d) State four environmental hazards that characterise traditional agriculture (4 marks)
  - e) Contrast weak sustainability and strong sustainability (3 marks)
  - f) Describe the concept of 'resource scarcity' and explain any three social responses to it. (6 marks)
  2. Discuss the 5 key risks of climate change in Zambia?
  3. Using examples, explain the persistence of environmental degradation in developing countries despite the high number of ratified and multilateral environmental agreements.
  4. 'Inter-generational equity is widely regarded as being an important aspect of sustainable development'. Discuss
  5. Using the United Nations Development Program (UNDP) definition of poverty, explain how poverty is perpetuating environmental degradation.
- 

**END OF EXAMINATION**

**THE UNIVERSITY OF ZAMBIA**  
**SCHOOL OF NATURAL SCIENCES**

**2016 ACADEMIC YEAR FINAL EXAMINATIONS**

**GES 3342: ENVIRONMENTAL PLANNING AND MANAGEMENT**

**TIME:** Three (3) Hours

**INSTRUCTIONS:** Answer any **three** questions. All questions carry equal marks. Candidates are encouraged to use illustrations wherever appropriate.

---

1. Write short explanatory notes on **ALL** of the following:
    - a) Types of rights in natural resource utilization and management
    - b) Types of natural resources
    - c) Fresh water as a scarce natural resource
    - d) Life Cycle Assessment
    - e) Cumulative Effects Assessment
  2. Describe any five (5) types of environmental pollution.
  3. Explain four management challenges related to the two core attributes of common pool resources.
  4. Using appropriate examples, discuss the challenges and opportunities of decentralized natural resources management in rural Zambia.
  5. Explain the **four** issues to consider in impact prediction.
  6. Discuss the following Environmental Management Principles:
    - a) Social principle
    - b) Human rights principle
    - c) Sustainability principle
- 

**END OF EXAMINATION**

**THE UNIVERSITY OF ZAMBIA  
SCHOOL OF NATURAL SCIENCES**

**2016 ACADEMIC YEAR FINAL EXAMINATIONS**

**GES 4165: MIGRATION, REFUGEES AND ENVIRONMENT**

**TIME:** Three (3) Hours

**INSTRUCTIONS:** Answer **question 1** and **any other two**. Candidates are advised to make use of illustrations wherever appropriate.

---

1. Write short explanatory notes on **ALL** of the following:
    - a) Environmental refugee
    - b) Involuntary migration
    - c) Environmental vulnerability and migration
    - d) Four essential features of Todaro's migration theory
    - e) Any five of Ravenstein's laws of migration
    - f) Remittances.
  2. Morrissey (2012) presents the environmental refugee as a polarising issue. Assess the three major critiques of the environmental refugee 'maximalist' position.
  3. 'Petersen's Typology of migration is too unrealistic to apply to reality'. Discuss.
  4. Evaluate the three 'durable solutions' to the refugee problem in a developing country context.
  5. Discuss the assertion that 'refugees are a problem to the host country'.
- 

**END OF EXAMINATION**



**THE UNIVERSITY OF ZAMBIA  
SCHOOL OF NATURAL SCIENCES**

**2016 ACADEMIC YEAR FINAL EXAMINATIONS**

**GES 4292: HYDRO-GEOMORPHOLOGY OF DRAINAGE BASINS**

**TIME:** Three Hours

**INSTRUCTIONS:** Answer **ALL** questions in section A and any **TWO (2)** in section B. Both sections carry equal marks. Candidates are advised to make use of illustrations and examples wherever appropriate. Use of an approved calculator is allowed.

---

**SECTION A**

1. How can you construct a sediment budget of a drainage basin? [4 marks]
2. Describe three channel patterns. [6 marks]
3. Explain the concept of base level and what happens to the local base level when a reservoir is constructed. [5 marks]
4. Table 1 shows the inflow hydrograph as measured at a cross section of a stream.

Given the Muskingum routing equation as  $Q_{j+1} = C_1 I_{j+1} + C_2 I_j + C_3 Q_j$  and assuming the Muskingum coefficients  $C_1 = 0.35$ , and  $C_2 = 0.48$ .

- a) Determine the coefficient  $C_3$  [4 marks]
- b) Compute the outflow hydrograph at a point five kilometres downstream by completing Table 1 using the Muskingum method. Take initial outflow as 60 ( $\text{m}^3/\text{s}$ ). [21 marks]

Table 1: Inflow hydrograph at the given cross section

Time (hr)	Inflow ( $\text{m}^3/\text{s}$ )	$C_1 I_{j+1}$	$C_2 I_j$	$C_3 Q_j$	Outflow ( $\text{m}^3/\text{s}$ )
1	100				60
2	330				
3	556				
4	660				
5	601				
6	476				
7	340				
8	215				
9	144				
10	100				

*Source: Hypothetical data*

- c) What is the volume (in cubic meters) of channel storage after 2 hours? [6 marks]
- d) Plot the inflow and outflow hydrograph of the downstream point in (b) [4 marks]

### **SECTION B**

- 5. 'A drainage basin is an open system with four elements – inputs, storage, transfers and outputs'. Describe the pathways of water and sediments with reference to the four elements.
- 6. Discuss the effects of deforestation on the hydro-geomorphology of drainage basins in the Zambian context.
- 7. Write short explanatory notes on ALL of the following:
  - a) Channel hydraulic geometry
  - b) Sediment sources
  - c) Sediment delivery ratio
  - d) Variable source area concept
  - e) Hydro-geomorphology as an emerging science.

---

**END OF EXAMINATION**

**THE UNIVERSITY OF ZAMBIA  
SCHOOL OF NATURAL SCIENCES  
2016 ACADEMIC YEAR FINAL EXAMINATION**

**GES 4372: TOURISM, ENVIRONMENT AND DEVELOPMENT**

**TIME:** THREE (3) HOURS

**INSTRUCTIONS:** Answer question 1 and any other TWO questions. Candidates are encouraged to use illustrations wherever appropriate.

---

1. Write short explanatory notes on **ALL** of the following:
    - a) Tourism policy
    - b) Domestic tourism
    - c) Ecotourism
    - d) Travel
    - e) Destination accessibility
  2. Apart from increased leisure, explain the other **six** factors that promote demand for tourism.
  3. Discuss the **five** major economic impacts of tourism.
  4. To what extent can conceptual tools such as Carrying Capacity, Limits of Acceptable Change and Environmental Impact Assessment help us to create sustainable forms of tourism?
  5. Explain the systems approach to tourism planning.
- 

***END OF EXAMINATION***

The University of Zambia  
School of Natural Sciences  
Department of Mathematics and Statistics  
2016 Academic Year Examinations - August 2017  
MAT1100 - Foundation Mathematics

Time allowed : 3 Hours

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**Instructions:** • There are **seven (7)** questions in this examination. Attempt **any five (5)** questions. **All** questions carry **equal** marks.

- Indicate your **Computer Number** and **Tutorial Group (TG)** on all your answer booklets.
- You are required to show all **necessary** steps in your solutions.
- **Calculators** are not allowed for this examination.

*This paper consists of 5 pages of questions.*

---

1. a) (i) Let  $A = [-2, 3]$ ,  $B = (-1, 10]$ ,  $C = \{x \in \mathbb{Z} : -2 \leq x \leq 15\}$  and the universal set be  $\mathbb{R}$ . Find the set  $(A' \cup B) \cap C$  and display your answer on the number line.
- (ii) Given that  $X \subseteq Y$  and  $X \subseteq Z$ , display on a Venn diagram the set  $X' \cap Y \cap Z$ .
- (iii) Given that  $C \cap D = \emptyset$ , simplify the following as much as possible:

$$(C \cup D) \cap (C' \cup D').$$

b) Let  $*$  be a binary operation on  $\mathbb{Z}$  defined by  $a * b = a^2 + 2b$ .

(i) Find  $(-1) * 3$  and  $3 * (-1)$ .

(ii) Is  $*$  commutative on  $\mathbb{Z}$ ? Give reasons for your answer.

(iii) Determine whether or not  $*$  is associative on  $\mathbb{Z}$ .

c) (i) Express

$$\frac{1 - \sqrt{27}}{2 + \sqrt{75}}$$

in the form  $a + b\sqrt{3}$  where  $a$  and  $b$  are rational numbers.

(ii) Find the value of

$$\left| \frac{1}{2+i} + \frac{1}{1-2i} \right|.$$

(iii) Find the complex numbers  $z = x + iy$ ,  $x, y \in \mathbb{R}$  for which  $|z - i| = 2z - 4i$ .

[8, 8, 9]

2. a) (i) Find the domain and range of the function  $g(x) = 2 + \sqrt{3 - x}$ . Hence sketch the graph of the function  $g(x)$ .

(ii) If  $f(x) = 3(x + 4)$  and  $g(x) = \frac{1-x}{3}$ , solve the equation  $(f \circ g)^{-1}(x) = 2$ .

(iii) Sketch the graph of the function

$$f(x) = \frac{x-9}{x-4},$$

indicating all asymptotes and intercepts.

b) Given that  $f(x) = ax^3 + (a+b)x^2 + (a+2b)x + 1$  is exactly divisible by  $(x+1)$ :

(i) Express  $b$  in terms of  $a$ .

(ii) Use synthetic division to find the quotient when  $f(x)$  is divided by  $(x+1)$ .

(iii) If the quotient in part (ii) has no real roots, show that  $a^2 - 6a + 1 < 0$ .

c) Given the quadratic function  $f(x) = -2x^2 + 4x + 9$ :

(i) Complete the square of  $f(x)$ .

(ii) Find the turning point and the  $x$ - and  $y$ - intercepts.

(iii) Sketch the graph of  $y = f(x)$ .

[12, 6, 7]

3. a) Prove each of the following identities:

(i)  $(\operatorname{cosec} A - \sin A)(\sec A - \cos A) = \cos A \sin A$

(ii)  $\frac{\cos \theta}{1 - \tan \theta} + \frac{\sin \theta}{1 - \cot \theta} = \sin \theta + \cos \theta$

b) Given the function  $f(x) = 1 - 3 \sin(2x + \pi)$ :

(i) Find the period and phase shift.

(ii) Sketch the graph of  $f(x)$  for  $-\pi \leq x \leq \pi$ .

c) Solve each of the trigonometric equations for  $0 \leq x \leq 2\pi$ :

(i)  $\cos 2x + 3 \sin x = 2$       (ii)  $4 - 5 \cos x = 2 \sin^2 x$

[10, 5, 10]

4. a) Find the following limits:

(i)  $\lim_{x \rightarrow 4} \frac{2 - \sqrt{x}}{x - 4}$       (ii)  $\lim_{x \rightarrow -\infty} \frac{3x^3 - 2}{1 - 2x - 7x^3}$

b) Let

$$f(x) = \begin{cases} x^2 + 2 & \text{if } x < 1, \\ 2x + 1 & \text{if } x \geq 1. \end{cases}$$

(i) Determine, giving reasons, whether the function is continuous at  $x = 1$ .

(ii) Sketch the graph of  $f(x)$ .

(iii) Find the equation of the tangent to the graph of  $f(x)$  at  $(-1, 3)$ .

c) (i) Find  $\frac{dy}{dx}$  given that:

$$y = \ln \left( \frac{x(x^2 + 1)}{x^2 - 1} \right).$$

(ii) A rocket is fired vertically into the sky and rises at the rate of 6km/s. An observer is standing 4km away from the launching base. How fast is the distance between the observer and rocket changing when the rocket is 3km above the ground surface?

[6, 8, 11]

5. a) (i) Differentiate the function

$$f(x) = \frac{3x - 1}{x}$$

from the first principle.

- (ii) Use implicit differentiation to find  $\frac{dy}{dx}$  given that  $y^3x - \sin y + x^2 = 7$ .

- b) (i) The coefficients of  $x$  and  $x^2$  when

$$\left(a + \frac{x}{b}\right)^6$$

is expanded in ascending powers of  $x$  are  $-64$  and  $\frac{80}{3}$ , respectively. Find the values of  $a$  and  $b$ .

- (ii) Expand  $(1 - 2x)^{\frac{1}{2}}$  in ascending powers of  $x$ , up to and including the term in  $x^3$ .

- (iii) Use your expansion in part (ii) to find the approximate value of  $\sqrt{0.8}$  to three decimal places.

- c) Given that  $f(x) = x^4 + 2x^3 - 2x$ :

- (i) Determine the intervals where the function is concave up and where it is concave down.

- (ii) Sketch the graph of  $f(x)$ .

[6, 11, 8]

6. a) Evaluate each of the following integrals:

$$(i) \int (1 - x^{-1})^5 x^{-2} dx \quad (ii) \int \sin^2 x \cos^3 x dx \quad (iii) \int x^2 \tan^{-1} x dx$$

- b) (i) Find the definite integral

$$\int_0^2 \frac{3}{(x-1)(x+2)} dx$$

- (ii) Compute the area of the region enclosed by the graphs of the functions  $f(x) = x$  and  $g(x) = x^3$ .

- c) (i) Solve the equation  $2^{2x+1} - 17(2^x) + 8 = 0$ .

- (ii) Find the values of  $x$  for which  $\log_3 x - 2\log_x 3 = 1$ .

[9, 8, 8]

7. a) The matrix  $A$  is given by

$$A = \begin{pmatrix} m & 1 & 3 \\ 2 & 1 & -1 \\ 0 & 1 & 2 \end{pmatrix}.$$

(i) Find the value of  $m$  if  $A$  has no inverse.

(ii) Given that

$$B = \begin{pmatrix} -1 & 1 & 3 \\ 2 & 1 & -1 \\ 0 & 1 & 2 \end{pmatrix},$$

find  $B^{-1}$ .

(iii) Hence or otherwise, solve the system of equations:

$$-x + y + 3z = 1$$

$$2x + y - z = 4$$

$$y + 2z = -1$$

b) The matrices  $A$ ,  $B$  and  $C$  are given by

$$A = \begin{pmatrix} 3 \\ 1 \\ 2 \end{pmatrix}, \quad B = \begin{pmatrix} 4 \\ 0 \\ 3 \end{pmatrix}, \quad C = \begin{pmatrix} 2 & 4 & 1 \end{pmatrix}.$$

Find the following:

(i)  $A - 4B$

(ii)  $CA$

c) (i) Find the centre and radius of the circle given by  $x^2 + y^2 - 16x - 12y + 96 = 0$ .

(ii) Find the equation of a circle passing through the points  $(2, 1)$ ,  $(0, 5)$  and  $(-1, 2)$ .

[12, 4, 9]

END!



The University of Zambia  
Department of Mathematics & Statistics  
2016/17 Academic Year, Final Examinations  
MAT 1110 - Foundation Mathematics and Statistics for Social  
Sciences

Time allowed : Three (3) Hours

Full marks : 100

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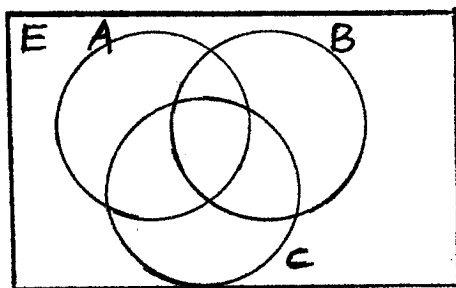
**Instructions:**

1. Answer **any five (5)** questions.
2. All questions carry equal marks.
3. **Full credit** will only be given when **necessary work** is shown.
4. Indicate your **computer number** on all answer booklets.
5. **Calculators** are **not** allowed.

*This paper consists of 4 pages of questions.*

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1. (a) (i) Given that  $A = \{x \in \mathbb{R} \mid -1 \leq x < 2\}$  and  $B = \{x \in \mathbb{R} \mid -3 \leq x < 4\}$ . Find  $A^c \cap B^c$  and illustrate your answer on the real number line.  
(ii) Let  $A$  and  $B$  be subsets of the universal set  $E$ . Simplify  $[A \cap (B \cup B^c)]^c$ .  
(iii) Let  $A, B$  and  $C$  be subsets of the universal set  $E$ . Shade the corresponding set on the following Venn diagram.  $(A \cup B) \cap C^c$ .



4. (a) (i) Solve the equation

$$e^{2x} - 9e^x + 18 = 0.$$

- (ii) Express  $2\log_a x + \log_a(xy^2) - \log_a(3y\sqrt{x})$  as a single logarithm.

- (b) Find the following integrals:

(i)  $\int \frac{2x}{(1+2x^2)^2} dx$

(ii)  $\int xe^{-x} dx$

- (c) For the function  $f(x) = \begin{cases} x^2 + 1 & ; x < 2 \\ 3 - 3x & ; x \geq 2. \end{cases}$

- (i) Find  $f(0)$ .

- (ii) Discuss the continuity of  $f(x)$  at  $x = 2$ .

5. (a) (i) Find the set of values of  $x$  for which  $\frac{1}{x-3} \leq \frac{9}{4x+3}$ .

- (ii) Sketch the curve  $f(x) = x^3 - 3x^2$ .

- (b) The cost in kwacha of producing  $x$  tennis balls is modelled as

$$C(x) = 3000 - 10x + 0.01x^2,$$

where  $x$  is the number of tennis balls produced. Determine how many tennis balls should be produced so that the cost is minimum.

- (c) The following data are marks of 10 students in an examination:

$$60, 59, 60, 58, 62, 56, 63, 63, 55, 54.$$

- (i) Calculate the mean mark of the 10 students.

- (ii) Calculate the variance of the data.

6. (a) The functions  $f$  and  $g$  are defined by  $f(x) = \ln(3 - 2x)$  and  $g(x) = e^{2x} + 1$ . Find

(i)  $g \circ f(x)$ ,

(ii)  $g \circ f(-1)$ ,

(iii)  $f(1)$ .

- (b) Given the equation  $xe^y + \cos y - x^2 = 0$ , find  $\frac{dy}{dx}$  at  $(2, 0)$ .

**THE UNIVERSITY OF ZAMBIA**  
**SCHOOL OF NATURAL SCIENCES**  
**DEPARTMENT OF MATHEMATICS AND STATISTICS**  
2016/2017 ACADEMIC YEAR FINAL EXAMINATION  
MAT2012 – ECONOMICS FOR ACTUARIAL SCIENCE

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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
- 

**Section A [Total 30 Marks] – MULTIPLE CHOICE - Each Question Carries 1½ Marks**

- 1) The main categories of economic resources are:
  - a) natural resources, labour and money.
  - b) labour, money and factories.
  - c) natural resources, capital and factories.
  - d) natural resources, labour and capital.
- 2) Which of the following will NOT cause a shift in the demand curve for Good X?
  - a) a change in the price of Good X.
  - b) a change in the price of other goods.
  - c) a change in consumer incomes.
  - d) a change in consumer tastes.
- 3) A profit maximising monopolist is currently operating at a level of output where marginal revenue is K20 and marginal cost is K12. In order to increase profits the monopolist should:
  - a) increase output and reduce price
  - b) reduce price and output
  - c) increase price and output
  - d) reduce output and increase price
- 4) A perfectly competitive firm is not maximising profit if:
  - a) marginal cost equals price and price is above minimum average total cost
  - b) marginal cost equals average revenue
  - c) marginal cost equals marginal revenue
  - d) total revenue is maximised
- 5) According to the kinked demand curve theory of oligopoly, at the quantity corresponding to the kink the firm's:
  - a) average cost curve is discontinuous
  - b) marginal cost curve is discontinuous
  - c) marginal revenue curve is discontinuous
  - d) average revenue curve is discontinuous
- 6) Diseconomies of scale means:
  - a) short run average total cost falls as output rises.
  - b) long run average total cost falls as output rises.

- c) long run average total cost rises as output rises.
  - d) short run average total cost rises as output rises.
- 7) Total Revenue from the sale of a Good will decrease if:
- a) income increases and the Good is normal
  - b) its price rises and demand is price elastic
  - c) its price rises and demand is price inelastic
  - d) income falls and the Good is inferior
- 8) As a result of an improvement in productivity a profit maximising monopolist is currently operating at a level of output where marginal revenue is greater than marginal cost. The monopolist should:
- a) increase output and reduce price
  - b) reduce price and output
  - c) increase price and output
  - d) reduce output and increase price
- 9) The problem of scarcity in economics:
- a) exists only in economies which rely on the market mechanism.
  - b) could be eliminated if we force prices to fall.
  - c) means that there are shortages of some goods.
  - d) exists because there are insufficient resources to satisfy human wants.
- 10) Monopolies can be considered detrimental to society since they lead to a social cost. This is because they profit maximise at a level of output and price different from the socially optimal output and price. The monopolist produces where:
- a) prices are higher and output lower than the social optimum.
  - b) prices are higher and output higher than the social optimum.
  - c) prices are lower and output lower than the social optimum.
  - d) prices are lower and output higher than the social optimum.
- 11) Which of the following conditions indicates that a firm is operating in a perfectly competitive industry, rather than a monopolistic industry?
- a) output of the firm is where marginal revenue equals marginal cost.
  - b) the cost curves of the firm are U-shaped.
  - c) marginal revenue equals average revenue.
  - d) the marginal cost curve cuts the average cost curve at its minimum point.
- 12) A profit maximising monopolist with positive marginal costs and a downward sloping demand curve will set its price in the region of the demand curve where the price elasticity of demand is:
- a) inelastic.
  - b) elastic.
  - c) equal to unity.
  - d) indeterminate.
- 13) In the long run, a firm operating under conditions of monopolistic competition will produce at an output at which:
- a) average total cost equals average revenue.
  - b) average total cost is less than average revenue.

- c) average total cost is at a minimum.
  - d) marginal cost is equal to average total cost.
- 14) All other things being equal, which one of the following statements is always TRUE?
- a) an appreciation of a country's exchange rate will increase its import expenditure and decrease its export revenues.
  - b) an appreciation of a country's exchange rate will increase its import volumes and decrease its export volumes.
  - c) a depreciation of a country's exchange rate will decrease its import volumes and decrease its export volumes.
  - d) a depreciation of a country's exchange rate will decrease its import expenditure and increase its export revenues.
- 15) During 19XX government expenditure was K350 billion, tax revenue K275 billion, aggregate saving K300 billion and aggregate investment K250 billion. The net exports during that year are equal to a:
- a) surplus of K125 billion.
  - b) deficit of K125 billion.
  - c) surplus of K25 billion.
  - d) deficit of K25 billion.
- 16) The need to employ workers with certain skills may decline even if the industry as a whole is not in decline. This form of unemployment is called:
- a) structural.
  - b) demand-deficient.
  - c) regional.
  - d) technological.
- 17) Which of the following is likely to be the most effective method of reducing the natural rate of unemployment?
- a) increase unemployment benefit
  - b) increase government expenditure
  - c) increase the money supply
  - d) increase information flows on job availability
- 18) Firms can benefit through specialisation and international trade due to:
- a) comparative advantage.
  - b) absolute advantage.
  - c) different factor endowments.
  - d) all of the above.
- 19) To prevent the value of the Kwacha from depreciating against the US dollar, the Bank of Zambia might:
- a) buy the Kwacha in the foreign exchange market and increase its foreign exchange reserves.
  - b) buy the Kwacha in the foreign exchange market and decrease its foreign exchange reserves.
  - c) sell the Kwacha in the foreign exchange market and increase its foreign exchange reserves.

- d) sell the Kwacha in the foreign exchange market and decrease its foreign exchange reserves.

20) For a small open economy the imposition of a tariff on its imports of a good will normally:

- a) reduce the domestic price of the imported good.
- b) increase domestic consumption of the imported good.
- c) increase domestic production of the imported good.
- d) increase the quantity imported of the good.

## **Section B [Total 70 Marks]**

### **Question 21 [Total 10 Marks]**

Based on the history of the Zambia economy and its performance, write short notes, highlighting the benefits and shortcomings to Zambia of any two economic structures of your choice. [10 Marks]

### **Question 22 [Total 10 Marks]**

- (a) Explain the four determinants of market structures [4 Marks]
- (b) Draw two diagrams illustrating the profit maximising price and output of a firm operating under conditions of perfect competition to show:
  - (i) The firm making normal profits. [3 Marks]
  - (ii) The firm making a loss. [3 Marks]

**Hint:** The curves on the diagram should be labelled: MR for Marginal Revenue, AR for Average Revenue, MC for Marginal Cost, AC for Average Cost. Price and Quantity should be labelled  $P_1$  and  $Q_1$  respectively.

### **Question 23 [Total 16 Marks]**

- (a) A company producing a health drink called Boost has plans to carry out a new advertising campaign to publicise Boost's properties of bringing vitality and health to the consumer. Graphically illustrate the following.
  - (i) The effects of advertising on the demand for Boost. [4 Marks]
  - (ii) The four stages of the Boost's product life cycle. [4 Marks]
- (b) Describe appropriate pricing policies during the Boost's product life cycle. [4 Marks]
- (c) Explain how the stages of the life cycle of basic mobile phones may differ from that of Boost. [4 Marks]

**Question 24 [Total 10 Marks]**

- (a) Distinguish between a merger and an acquisition. [2 Marks]
- (b) Outline any two types of mergers and give examples of each. [4 Marks]
- (a) Why do you think governments must regulate mergers and acquisitions. [2 Marks]

**Question 25 [Total 8 Marks]**

(a) Explain with the aid of a diagram the four phases of the business cycle. In your diagram make clear the distinction between the full capacity output trend and the actual trend in economic output. [5 Marks]

(b) The following information is extracted from a country's Central Statistical Office:

	<i>K billions</i>
Wages and salaries	600
Mixed incomes	80
Net income from abroad	50
Gross profit/rent and interest of firms, Government and other institutions	300
Taxes on products	100
Subsidies on products	20
Depreciation	50

- (i) Calculate the Gross Domestic Product at market prices. [1 Mark]
- (ii) Calculate Gross National Income at market prices. [1 Mark]
- (iii) Calculate the Net National Income at market prices. [1 Mark]

**Question 26 [Total 8 Marks]**

- (a) Describe the reasons why countries can gain from free trade. [5 Marks]
- (b) Discuss THREE factors which influence a developing country's economic growth. [3 Marks]

**Question 27 [Total 7 Marks]**

(i) Describe TWO examples of negative externalities and TWO examples of positive externalities which affect the social efficiency of markets. [4 Marks]

(i) Draw a diagram showing the marginal social benefit curve and marginal private benefit curve when a negative externality in consumption exists. Show on your diagram the quantity that would be consumed at the market price P by the private sector as  $Q_1$  and the socially optimal level of production as  $Q_2$ . [3 Marks]

**END OF EXAMINATION**

The University of Zambia  
School of Natural Sciences  
Department of Mathematics & Statistics  
2016/2017 Sessional Examinations - September 21, 2017  
MAT 2100 - Analytic Geometry and Calculus

Time allowed : Three (3) hrs

Full marks : 100

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**Instructions:**

- Indicate your **computer number** on all answer booklets.
- Attempt **any (5) five** questions. All questions carry equal marks.
- **Full credit** will only be given when **necessary work** is shown.

*This paper consists of 4 pages of questions.*

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1. (a) (i) Find the equation of the hyperbola with vertices (0, 6) and (6, 6); foci 10 units apart.

(ii) Sketch the graph of the hyperbola in a(i), showing the equations of the asymptotes, vertices, foci and center.

- (b) Convert the polar equation

$$r = \frac{6 \sec \theta}{2 \sec \theta - 1}$$

to a rectangular equation.

**Turn Over/...**



- (c) Show that  $f_x(0,0)$  and  $f_y(0,0)$  both exist, but the function is not differentiable at  $(0,0)$ , where  $f$  is defined as

$$f(x, y) = \begin{cases} \frac{2x^2y^2}{x^4+y^4} & \text{if } f(x, y) \neq (0, 0) \\ 0 & \text{if } f(x, y) = (0, 0) \end{cases}$$

[8,6,6]

2. (a) Use the  $\epsilon - \delta$  definition to prove that

$$\lim_{x \rightarrow 5} \frac{1}{x-1} = \frac{1}{4}$$

- (b) (i) State Rolle's Theorem.

- (ii) Show that the hypothesis of Rolle's Theorem are satisfied by the function  $f(x) = \cos x$  on the interval  $\left[\frac{\pi}{2}, \frac{3\pi}{2}\right]$ .

- (iii) For the function in b(ii), find the value  $c$  which satisfies Rolle's Theorem.

- (c) Solve the following second order differential equation

$$y'' + 4y = \csc 2x$$

[7,5,8]

3. (a) Solve the following Bernoulli's differential equation

$$\frac{dy}{dx} + y = (xy)^2.$$

- (b) Find the sum of the following convergent series

$$\sum_{k=0}^{\infty} \frac{5}{4^k}.$$

**Turn Over/...**

(c) Let  $z = f(x, y)$ , where  $x = r \cos \theta$  and  $y = r \sin \theta$ . Show that

$$\left(\frac{\partial z}{\partial x}\right)^2 + \left(\frac{\partial z}{\partial y}\right)^2 = \left(\frac{\partial z}{\partial r}\right)^2 + \frac{1}{r^2} \left(\frac{\partial z}{\partial \theta}\right)^2.$$

[7,5,8]

4. (a) Evaluate the following integral

$$\int \frac{x^2}{\sqrt{4-x^2}} dx.$$

(b) Find the arc length of  $y = \frac{1}{3}\sqrt{x}(3-x)$  for  $0 \leq x \leq 3$ .

(c) The differential equation  $y^2 dx + (xy - 1)dy$  is **NOT** exact. Find an integrating factor for this differential equation and **solve it**.

[5,8,7]

5. (a) For the space curve given by

$$x(t) = e^t \cos t, \quad y(t) = e^t \sin t, \quad z(t) = e^t,$$

find

(i) The unit tangent vector  $\mathbf{T}(t)$  at  $t = 0$ .

(ii) The unit normal vector  $\mathbf{N}(t)$  at  $t = 0$ .

(b) Find the volume of the solid generated when the region between the graphs of the equations  $y = 2 + x^2$ ,  $x = 0$ ,  $x = 4$  and  $y = x$  is revolved about the  $x$ -axis.

(c) Find the centroid of the region under the curve

$$y = \sin x, \quad 0 \leq x \leq \pi.$$

[7,7,6] Turn Over/...

6. (a) Let  $f(x, y) = x^3 + y^3 - 3x - 3y$ . Find all critical points for  $f(x, y)$  and determine their nature, that is, whether they are minimum, maximum or saddle points.

- (b) Show that the function

$$f(x, y) = y^4 + x^3 y e^{\frac{y^2}{x^2}}$$

is homogeneous of degree 4.

- (c) (i) State Euler's Theorem on homogeneous functions.

- (ii) Show that the function

$$f(x, y) = y^4 + x^3 y e^{\frac{y^2}{x^2}}$$

satisfies the Euler's Theorem on homogeneous functions.

[8,4,8]

7. (a) Find the first five terms of the Maclaurin series for

$$\int \sqrt{1+x^4} dx.$$

- (b) Find

$$\lim_{x \rightarrow 0^+} (x+1)^{\cot x}.$$

- (c) Let  $u = x^3 y$ . Find  $\frac{du}{dt}$  if  $x^4 + y = t$  and  $x^2 + y^3 = t^2$ .

[6,7,7]

**END!**

THE UNIVERSITY OF ZAMBIA  
SCHOOL OF NATURAL SCIENCES  
DEPARTMENT OF MATHEMATICS & STATISTICS  
MAT2110: Engineering Mathematics I  
Final Examination

2016 Academic Year      Friday, 8<sup>th</sup> September 2017

Total time allowed: **Three (3) hours**

**Instructions:**

- There are **seven (7)** questions in this paper; **attempt any five (5)**.
- Show detailed working to earn full marks.

1. (a) i. Determine the  $xy$ -coordinates of  $(X, Y) = (0, 1)$  if the point is rotated through the angle of  $\frac{\pi}{3}$ . [ 2 marks ]  
ii. Find the  $xy$ -coordinates for vertices of the conic section given by  
$$4x^2 - 4xy + 7y^2 = 24. \quad [10 \text{ marks}]$$
- (b) Show that if  $x + y = xy$ , then  
$$\frac{d^2y}{dx^2} = \frac{2y^3}{x^3}. \quad [4 \text{ marks}]$$
- (c) Find the distance from the point  $S(1, 1, 0)$  to the line  $L : x = 2 - t, y = t$ , and  $z = t - 1$ . [ 4 marks ]
2. (a) Find the center and radius of the sphere given by the equation  
$$x^2 + y^2 + z^2 - 6y + 8z = 0. \quad [3 \text{ marks}]$$
- (b) Find the point where the line with parametric equations  
$$x = 8 + 2t, \quad y = -2t \quad \text{and} \quad z = -1 + t$$
intersects the plane  $3x + 2y + 6z = 6$ . [ 4 marks ]

(c) Find the Maclaurin series expansion of  $f(x) = 2^x$ . [ 4 marks ]

(d) Integrate

$$\int \frac{x^2}{x^3 + 3x^2 + x - 5} dx \quad [9 \text{ marks}]$$

3. (a) i. If  $f(x, y)$  is a function of  $x$  and  $y$ , define the partial derivative of  $f$  with respect to  $x$ . [ 3 marks ]

ii. Given that  $f(x, y) = 3x^2 - 2y$ , use the definition of a partial derivative to find  $f_x(x, y)$ . [ 4 marks ]

Evaluate

$$\int_0^\pi \sqrt{1 - \cos x} \, dx. \quad [5 \text{ marks}]$$

(b) Use the method of Variation of Parameters to find the general solution of the second order Non-homogeneous differential equation  $y'' + y = 3x$ . [ 8 marks ]

4. (a) Define row-equivalence of two matrices. [ 2 marks ]

(b) Use elementary row operations to find the inverse of the matrix

$$A = \begin{pmatrix} 1 & 2 & 3 \\ -2 & 1 & -1 \\ 0 & -6 & -8 \end{pmatrix}$$

if it exists, leaving the entries in the form  $\frac{a}{b}$  where  $a, b \in \mathbb{Z}$ . [ 5 marks ]

(c) Find the particular solution of the homogeneous differential equation

$$x^2 - 3y^2 + 2xy \frac{dy}{dx} = 0,$$

given that  $y = 3$  when  $x = 1$ . [ 6 marks ]

(d) Find the length of the arc from  $x = 1$  to  $x = 2$  on the graph of

$$y = \frac{x^5}{15} + \frac{1}{4x^3}. \quad [7 \text{ marks}]$$

5. (a) State each of the following:

i. Ratio test. [ 3 marks ]

ii. Integral test theorem. [ 3 marks ]

(b) Find the interval of convergence of the power series

$$\sum_{n=2}^{\infty} \frac{x^n}{n(\ln n)^2}. \quad [9 \text{ marks}]$$

- (c) Use the Gauss Elimination method to solve the system of equations below.

$$\begin{aligned} -y + z &= -4 \\ x - y + z &= 4 \\ 3x + 2y - z &= 1 \end{aligned}$$

[ 5 marks ]

6. (a) i. Find the critical points of the function

$$f(x, y) = y^3 + 2xy - \frac{1}{2}x^2 + y + 8.$$

[ 3 marks ]

- ii. Use the Second Partial Derivatives Test to determine whether each critical points found in (i) above is a relative minimum, relative maximum or saddle point.

[ 5 marks ]

- (b) Find the domain of the function  $f(x, y) = y\sqrt{x-1} + y^2\sqrt{8-2x}$  and show it on the number line.

[ 4 marks ]

- (c) Find the volume of the solid formed by revolving the region bounded by the graphs of  $y = \ln(x)$ ,  $y = 0$ ,  $x = 1$ , and  $x = e$  about the  $x$ -axis.

[ 8 marks ]

7. (a) Find the particular solution of the differential equation

$$\frac{dy}{dx} - \cos^3 x \sin^4 x = 0, \text{ given that } y = \frac{72}{35} \text{ when } x = \frac{\pi}{2}. \quad [4 \text{ marks}]$$

- (b) Find the equation for the plane which passes through the points

$$P(4, 0, 0), Q(0, 3, 0) \text{ and } R(0, 0, 2). \quad [6 \text{ marks}]$$

- (c) Find the area of the surface formed by revolving the graph of  $y = x^3$  on the interval  $[0, 1]$  about the  $x$ -axis.

[ 4 marks ]

- (d) Estimate the error when  $\sqrt{e} = e^{\frac{1}{2}}$  is approximated by the third Maclaurin polynomial of  $f(x) = e^x$ .

[ 6 marks ]

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA  
DEPARTMENT OF MATHEMATICS AND STATISTICS  
END OF YEAR EXAMINATIONS - 2016/2017 ACADEMIC YEAR  
MAT 2300 INTRODUCTION TO 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.
- 

1. (a) Define the following terms:

- i. A positive class in a field.
- ii. A Dedekind cut.

(b) Prove the following:

- i. If  $x$  and  $y$  are real numbers and if  $y > 0$ , then there exists a natural number  $n$  such that  $ny > x$ .
- ii. If  $\mathbb{F}$  is an ordered field with a positive class  $\mathbb{P}$ , then  $|x + y| \leq |x| + |y|$  for all  $x, y \in \mathbb{F}$ .

(c) i. Prove that the set  $\alpha = \{p \in \mathbb{Q} : p < 0\} \cup \{p \in \mathbb{Q} : p \geq 0 \text{ and } p^2 < 2\}$  is a cut in  $\mathbb{Q}$ .

ii. Show that the set  $\mathbb{P} = \{\frac{m}{n} : m, n \in \mathbb{N}\}$  forms a positive class in the field  $\mathbb{Q}$  of rational numbers.

2. (a) What is meant by the following:

- i. The image of a set  $A$  under a function  $f$ .
- ii. The inverse image of a set  $B$  under a function  $g$ .

(b) Let  $f$  be a function on  $\mathbb{R}$  and suppose that  $A, B$  are subsets of  $\mathbb{R}$ . Prove the following:

- i.  $f(A \cup B) = f(A) \cup f(B)$
- ii.  $f^{-1}(A - B) = f^{-1}(A) - f^{-1}(B)$

(c) Consider the function defined by  $f(x) = \frac{3}{1 - 2x}$  and let  $A = [0, 1]$ ,  $B = (-1, 3]$ . Find

- i.  $f(A)$
- ii.  $f^{-1}(B)$

3. (a) Define the following:
  - i. A convergent sequence of real numbers.
  - ii. A Cauchy sequence of real numbers
- (b) State and prove the Bolzano-Weierstrass Theorem.
- (c) Verify the following:
  - i. The sequence  $\frac{2n}{n+1}$  is convergent.
  - ii. The sequence  $\frac{1}{n} - \frac{1}{n+1}$  is Cauchy.
4. (a) What is meant by the following:
  - i. An absolutely convergent series.
  - ii. An alternating series.
- (b) State and prove
  - i. The ratio test for convergence of series.
  - ii. The root test for convergence of series.
- (c) Discuss convergence of the following series:
  - i.  $\sum_{n=1}^{\infty} \frac{3n+1}{n^2+2}$
  - ii.  $\sum_{n=1}^{\infty} \frac{2^n}{n!}$
  - iii.  $\sum_{n=1}^{\infty} \frac{\log n}{n^n}$
5. (a) What is meant by the following:
  - i.  $\lim_{x \rightarrow -\infty} f(x) = L$
  - ii. A real-valued function  $f$  is continuous at a point  $x_0$ .
- (b) If  $f$  and  $g$  are continuous functions at a point  $x_0$ , prove that the following functions are also continuous at  $x_0$ .
  - i.  $f + g$
  - ii.  $fg$
- (c) Discuss the continuity of the function
  - i.  $f(x) = \frac{x}{1-|x|}$
  - ii.  $f(x) = \frac{x^2-1}{x^2-3x+2}$



6. (a) Define the following terms:
- i. A uniformly continuous function.
  - ii. A differentiable function.
- (b) i. Prove that if a function  $f$  is differentiable at  $x_0$ , then it is continuous there.
- ii. State and prove the Inverse Function Theorem.
- (c) i. Discuss the differentiability of the function  $f(x) = \frac{1}{|x| - 1}$ .
- ii. Show that the function  $f(x) = x^2 - 1$  is uniformly continuous on any closed interval  $[a, b]$  of  $\mathbb{R}$ .

**THE UNIVERSITY OF ZAMBIA  
SCHOOL OF NATURAL SCIENCES**

**2016 ACADEMIC YEAR  
FINAL EXAMINATIONS**

**MAT2602 INTRODUCTION TO STATISTICS**

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Time Allowed: Three (3) Hours

- Instructions:
1. There are Six (6) Questions in this paper. Answer any **Five (5)** Questions.
  2. Show All Essential Working.
  3. Statistical Tables are provided.
  4. Calculators are Allowed.
- 

1. (a) Define the following:
  - (i) inferential statistics.
  - (ii) random sample.
- (b) The distribution table below shows the speeds of 50 cars passing a police checkpoint:

speed (km/h)	20 – 30	30 – 40	40 – 50	50 – 60	60 – 70
frequency	5	20	16	7	2

- (i) Construct a histogram for the data.
  - (ii) Describe the distribution of the data.
  - (iii) Prepare a cumulative frequency distribution table.
  - (iv) Prepare a frequency polygon.
- (c) The math scores of students admitted to a certain university are normally distributed with a mean of 70 and a standard deviation of 8.
  - (i) The probability that a randomly chosen student has a score greater than  $k$  is 0.2743. Find the value of  $k$ .
  - (ii) Find the probability that the mean score of 10 randomly chosen students lies between 64 and 68.
  - (iii) Find the probability that the combined score of 20 randomly chosen students exceeds 1350.

2. (a) Define the following:
- (i) probability sample.
  - (ii) sampling distribution.
- (b) A company that produces water bottles claims that the mean content of the water bottles produced the company is 500ml with a standard deviation of 15ml. To test the claim, it is decided that a random sample of 35 bottles would be taken and the claim rejected if  $\bar{x} < 495$  or  $\bar{x} > 505$ .
- (i) Explain how one can commit a type II error in this context.
  - (ii) Find the probability of committing a type I error if the claim is true.
  - (iii) Find the probability of committing a type II error if the true mean value is 496.5ml.
- (c) A random sample of 10 workers was obtained from the University of Zambia and the number of hours worked during a certain week recorded as follows:
- 42 36 26 30 48 40 35 41 38 29
- Assume that the number of hours follows a normal distribution.
- (i) Construct a 98% confidence interval for the mean number of hours worked during the week.
  - (ii) Is the mean number of hours worked during the week significantly different from 40? Explain.
  - (iii) Is the standard deviation of the number of hours worked during the week more than 6? Test at the 10% level of significance.
3. (a) State the following:
- (i) central limit theorem.
  - (ii) two properties of the correlation coefficient  $r$ .
- (b) A study was conducted to compare the performance of mission and government schools. Out of 200 students randomly chosen from mission schools 150 obtained full Grade 12 certificates compared to 180 out of 300 students randomly chosen from government schools.
- (i) Construct a 90% confidence interval for the difference in the proportion of students who obtain full Grade 12 certificates.
  - (ii) Test whether mission schools are better than government schools. Use a 1% level of significance.
  - (iii) How large a sample is required in order to be 97% confident that the estimate of the proportion of students who obtain full Grade 12 certificates from government schools is within 0.1 units of the true value.

- (c) The following data represent the number of hours of relief provided by 4 different brands of headache tablets to 20 patients suffering from headache.

	Brand				
	A	B	C	D	Total
	5	9	3	2	
	4	7	5	3	
	8	8	2	4	
	6	6	3	1	
	3	9	7	4	
Total	26	39	20	14	99

(Additionally:  $\sum_i \sum_j y_{ij}^2 = 603$  )

- (i) What design was used in the experiment?
- (ii) Is there a significant difference among the brands? Test at the 5% level of significance.
4. (a) Define the following
- (i) type II error.
- (ii) stratified sample.
- (b) A official from the Ministry of Education claims that girls perform better in single-sex classes than in mixed classes. To test the claim random samples were drawn from the two types of classes and a maths test was administered. The following results were obtained:

	sample size	mean	sample standard deviation
Single-sex classes	16	85	5
Mixed classes	10	78	7

Assume that the results are normally distributed.

- (i) Test whether the claim is valid at the 5% level of significance. Assume that the population variances are equal.
- (ii) Is the assumption of equal population variances made in (i) valid? Use  $\alpha = 0.01$ .
- (c) The following are data on 150 chickens divided according to breed and yield of eggs:

	Yield		
	High	Medium	Low
Breed A	45	29	28
Breed B	27	13	8

Does the type of breed affect yield? Test at the 10% level of significance.

5. (a) Define the following:
- correlation coefficient.
  - response bias.
- (b) The following data give jumping distance (y) in metres and take-off error (x) in metres for 10 randomly chosen long jumpers at the Summer Olympics:

	Take-off error (x)	Jumping distance (y)
	0.09	5.30
	0.17	5.55
	0.19	5.47
	0.24	5.45
	0.16	5.07
	0.22	5.32
	0.09	6.15
	0.12	4.70
	0.09	5.22
	0.09	5.77
Total	1.46	54

(Additionally :  $\sum_i x_i^2 = 0.2434$ ,  $\sum_i y_i^2 = 292.977$ ,  $\sum_i x_i y_i = 7.856$  )

- Find the estimated linear regression equation.
- Explain the meaning of the estimated regression coefficients in (i) above.
- Copy and complete the following ANOVA table:

Source	SS	df	MS	F*
Regression				
Error			0.16889	
Total				

- Determine if there is a significant linear relationship between jumping distance and take-off error. Use a 10% level of significance.
- Compute the value of  $R^2$ .
- Find the correlation coefficient.
- Compute a 90% confidence interval for the slope parameter.

6. (a) Given a fitted regression equation  $\hat{y}_i = \hat{\alpha} + \hat{\beta} x_i$ ,  $i = 1, 2, 3, \dots, n$ . Show that the least squares estimators  $\hat{\alpha}$  and  $\hat{\beta}$  for  $\alpha$  and  $\beta$  are respectively given by

$$\hat{\alpha} = \bar{y} - \hat{\beta} \bar{x}$$

$$\hat{\beta} = \frac{\sum_{i=1}^n x_i y_i - n \bar{x} \bar{y}}{\sum_{i=1}^n x_i^2 - n \bar{x}^2}$$

- (b) Three cards were drawn from an ordinary deck of playing cards and the number  $X$  of spades recorded. After repeating the experiment 64 times, the following outcomes were recorded:

$x$	0	1	2 or more
frequency	21	31	12

Using a 5% level of significance, test if the recorded data follows the

binomial distribution  $P(X = x) = \binom{3}{x} \left(\frac{1}{4}\right)^x \left(\frac{3}{4}\right)^{3-x}$ ,  $x = 0, 1, 2, 3$

- (c) Nine patients suffering from Alzheimer's disease were given a test on word pronunciation and the number of pronunciation errors counted. A year later the same patients were given the same test and the number of pronunciation errors counted again. The following results were obtained:

First time	0	1	1	2	5	0	5	7	6
Second time	3	3	1	1	6	9	8	11	3

- Compute a 90% confidence interval for the difference in the mean number of pronunciation errors.
- Is there a significant difference in the number of pronunciation errors over the one-year period? Explain
- What assumption(s) are needed for (i) and (ii) to be valid?

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA  
SCHOOL OF NATURAL SCIENCES  
DEPARTMENT OF MATHEMATICS & STATISTICS

2016/2017 Academic Year Final Examinations  
MAT 3100      ADVANCED CALCULUS

AUGUST, 2017

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Total time allowed: Three (3) hours

Instructions:

- This question paper comprises seven (7) questions. **Answer any five (5) questions.**
  - Show detailed working to earn full marks.
- 

1. (a) (i) Sketch the surface  $9x^2 + y^2 - z^2 = 1$ .  
(ii) Obtain the first partial derivatives of the function

$$\sin(xyz) = 3x + y + 3z$$

at  $(\frac{\pi}{2}, 1, 1)$  given that  $z = f(x, y)$ .

- (b) Find the general solution of

$$\frac{d\bar{y}}{dt} = \begin{bmatrix} 1 & 2 \\ -1 & 4 \end{bmatrix} \bar{y} + \begin{bmatrix} e^t \\ -2 \end{bmatrix}$$

- (c) (i) Show that the two functions  $u(x, y) = \cos(2x^2 + 2y^2 - t)$  and  $v(x, y) = \sin(2x^2 - t + 2y^2)$ , where  $t$  is some constant, are functionally dependent in their domain of definition.

- (ii) Find a functional relation for the functions in part c(i).

2. (a) (i) Find the gradient of the function  $f(x, y, z) = \frac{x-y}{x+y} + z^2$  at the point  $(2, 1, 1)$ .

- (ii) For the function  $f(x, y) = x^2 + 4y^2$ , find all directions  $\vec{u}$  in which  $D_{\vec{u}}(f)(2, 1) = 8$ . In which direction is the derivative increasing rapidly, decreasing rapidly and zero.

- (b) Solve the following integral equation using the Laplace transform method and the idea of convolution  $y(t) + 2e^{2t} \int_0^t y(u)e^{-u} du = te^t$ .

- (c) (i) Show that the following vector field is conservative, hence find the potential function

$$\mathbf{F}(x, y, z) = y^2 \cos z \mathbf{i} + 2xy \cos z \mathbf{j} - xy^2 \sin z \mathbf{k}.$$

- (ii) Find the parametric equations of the tangent line at the point indicated

$$x^2 + y^2 + z^2 = 9, \quad x^2 + y^2 - 8z^2 = 0, \quad (2, 2, 1).$$

3. (a) (i) With the help of a sketch of the solid, find the volume in the first octant bounded by the cylinder  $z = 4 - y^2$  and the plane  $x = 3$ .  
(ii) Sketch the region whose area is given by the integral and evaluate the integral

$$\int_0^\pi \int_0^{3 \cos \theta} r \, dr d\theta.$$

- (b) (i) Evaluate  $\int \int \int_E y \, dV$  given that  $E$  is bounded by the paraboloid  $y = 9x^2 + 9z^2$  and the plane  $y = 9$ .  
(ii) Apply the Wronskian to show that the following functions are linearly independent for all  $x$ ;  $f_1(x) = xe^x$ ,  $f_2(x) = e^x$  and  $f_3(x) = \sinh x$ .

- (c) Evaluate the line integral  $\int_C xy^2 \, dx + 2yx^2 \, dy$  given that  $C$  consists of the arc  $C_1$  of the parabola  $y = x^2$  from  $(0, 0)$  to  $(2, 4)$  followed by the following; a vertical line segment  $C_2$  from  $(2, 4)$  to  $(2, 6)$ , a horizontal line segment  $C_3$  from  $(2, 6)$  to  $(0, 6)$  and a vertical line segment  $C_4$  from  $(0, 6)$  to  $(0, 0)$ .

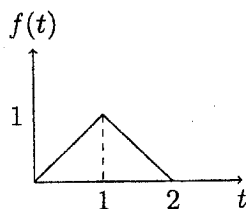
4. (a) Evaluate  $\int_C \mathbf{F} \cdot d\mathbf{r}$  along the line segment from  $(1, 0, -2)$  to  $(4, 6, 3)$ , given that  $\mathbf{F}(x, y, z) = yz\mathbf{i} + xz\mathbf{j} + (xy + 2z)\mathbf{k}$ .  
(b) Find the surface integral  $\int \int_S y \, dS$  where  $S$  is the part of the paraboloid  $y = x^2 + z^2$  that lies inside the cylinder  $x^2 + z^2 = 4$ .  
(c) Use the Laplace transform method to solve the following initial value problem  $y_1' = -2y_2$ ,  $y_2' = -y_1 + 2[1 - u(t - 2\pi)] \cos t$ ,  $y_1(0) = 1$ ,  $y_2(0) = 0$ .



5. (a) Find the flux of  $\mathbf{F}$  across the surface  $S$  given that  $\mathbf{F}(x, y, z) = xze^y\mathbf{i} - xze^y\mathbf{j} + z\mathbf{k}$  and  $S$  is the part of the plane  $x + y + z = 1$  in the first octant with downward orientation.
- (b) Suppose that  $\mathbf{r} = x\mathbf{i} + y\mathbf{j} + z\mathbf{k}$  and  $r = \sqrt{x^2 + y^2 + z^2}$ , prove that  $\nabla\left(\frac{2}{r}\right) = \frac{-2\mathbf{r}}{r^3}$ .
- (c) Obtain the odd periodic extension of the given function and sketch, in the interval  $-3\pi \leq x \leq 3\pi$ , the corresponding periodic extension for the function

$$f(x) = \begin{cases} \pi - 2x & \text{if } 0 < x < \frac{\pi}{2}, \\ 0 & \text{if } \frac{\pi}{2} < x < \pi. \end{cases}$$

6. (a) Find the Laplace transform of the following function



- (b) Use Lagrange multipliers to find the maximum and minimum values of the function subject to the given constraint  $f(x, y) = x^2 - y^2$ ,  $x^2 + y^2 = 1$ .
- (c) Obtain the Fourier series of the function  $f(t) = t^2$ ,  $-\pi \leq t \leq \pi$ , hence or otherwise prove that  $\frac{\pi^2}{12} = 1 - \frac{1}{2^2} + \frac{1}{3^2} - \frac{1}{4^2} + \dots$ .
7. (a) (i) Find the Fourier transform of the function

$$f(x) = \begin{cases} e^{-x} & \text{if } x > 0, \\ e^{5x} & \text{if } x < 0. \end{cases}$$

- (ii). Obtain the first partial derivatives of the function

$$f(x, y) = \int_{2y+1}^{x^2} \ln(s^2 + 1) ds.$$

- (b) (i) Find the Jacobian matrix for the following mapping

$$v(x, y, z) = x^3 + 2y^2 - z.$$

- (ii) Let  $z = 5x^3y$ , find  $\frac{dz}{dt}$  given that  $x^5 + y = t$  and  $x^2 + y^3 = t^2$ .
- (c) Apply the power series method to find the general solution of  $(1+x)y' = y$ .

**END OF EXAM!**

UNIVERSITY OF ZAMBIA  
DEPARTMENT OF MATHEMATICS AND STATISTICS

END OF ACADEMIC YEAR EXAMINATION 2016/17

MAT 3110– Engineering Mathematics II

September 11, 2017.

TIME ALLOWED: 3 HOURS

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INSTRUCTIONS TO CANDIDATES

1. Do not open this booklet until you are told to do so.
2. This examination paper contains **SEVEN (7)** questions and comprises **SEVEN (7)** printed pages.
3. Attempt any **FIVE (5)** questions. Each question carries 20 marks.
4. Candidates may use calculators. However, they should write down systematically the steps in the workings and also give exact answers without approximating and rounding off.
5. A standard normal table is attached at the end of this booklet.
6. Candidates must ensure that they fill in their details on the attendance slip that will be provided and also sign the attendance register before leaving the exam room.

**Question 1**

- (a) Find the power series solution of the ordinary differential equation

$$y'' - y = x^2.$$

(7 marks)

- (b) Let

$$f(x) = \pi - |x| \text{ for } -\pi \leq x \leq \pi \text{ and } f(x + 2\pi) = f(x)$$

- (i) Find the Fourier series of  $f(x)$ .  
 (ii) Using the Fourier series of  $f(x)$ , show that

$$\frac{\pi^2}{8} = 1 + \frac{1}{3^2} + \frac{1}{5^2} + \frac{1}{7^2} + \cdots$$

(7 marks)

- (c) (i) Find the inverse Laplace transform of

$$\frac{e^{-2s} - e^{-4s}}{s^2}$$

- (ii) Sketch the function
- $\mathcal{L}^{-1} \left[ \frac{e^{-2s} - e^{-4s}}{s^2} \right]$

(6 marks)

Total: 20 marks

**Question 2**

- (a) (i) 30 random observations are taken from a binomially distributed population,  $X \sim B(9, 0.5)$ . Find the probability that the sample mean exceeds 5.  
 (ii) A random variable  $X$  has probability density function

$$f(x) = \frac{1}{4}(4 - x), \quad 1 \leq x \leq 2.$$

Find the variance of the distribution.

(7 marks)

- (b) For every real number  $r$ , the equation

$$x^2 + y^2 - (r - 1)z^2 = r$$

is a quadratic surface. For each real number  $r$ , determine what quadratic surface the equation represents.

(6 marks)

- (c) Use the divergence theorem to evaluate

$$\int_S \mathbf{F} \cdot d\mathbf{S}$$

where  $\mathbf{F}(x, y, z) = xy \mathbf{i} - \frac{1}{2}y^2 \mathbf{j} + z \mathbf{k}$  and the surface  $S$  consists of the three surfaces, the elliptic paraboloid  $z = 4 - 3x^2 - 3y^2$ ,  $1 \leq z \leq 4$  on the top, the cylinder  $x^2 + y^2 = 1$ ,  $0 \leq z \leq 1$  on the sides and  $z = 0$  on the bottom.

(7 marks)

Total: 20 marks

### Question 3

- (a) (i) State (without proof) Green's theorem.  
 (ii) Using Green's theorem, evaluate the line integral

$$\int_C \mathbf{F} \cdot d\mathbf{r}$$

where  $\mathbf{F} = 2xy\mathbf{i} + (e^x + x^2)\mathbf{j}$  and  $C$  is the boundary of the triangle with vertices  $(0, 0)$ ,  $(1, 0)$  and  $(1, 1)$  with counter clockwise orientation.

(7 marks)

- (b) Find the general solution of the Euler equation

$$x^2 y'' + xy' - 4y = 0.$$

(6 marks)

- (c) (i) The random variable  $X$  is distributed uniformly where  $6 \leq x \leq 9$ . Find  $P(7.2 \leq X \leq 8.4)$ .

- (ii) The lengths of metal strips produced by a machine are normally distributed with mean length of 150cm and standard deviation of 10cm. Find the probability that the length of a randomly selected strip is within 5cm of the mean.

(7 marks)

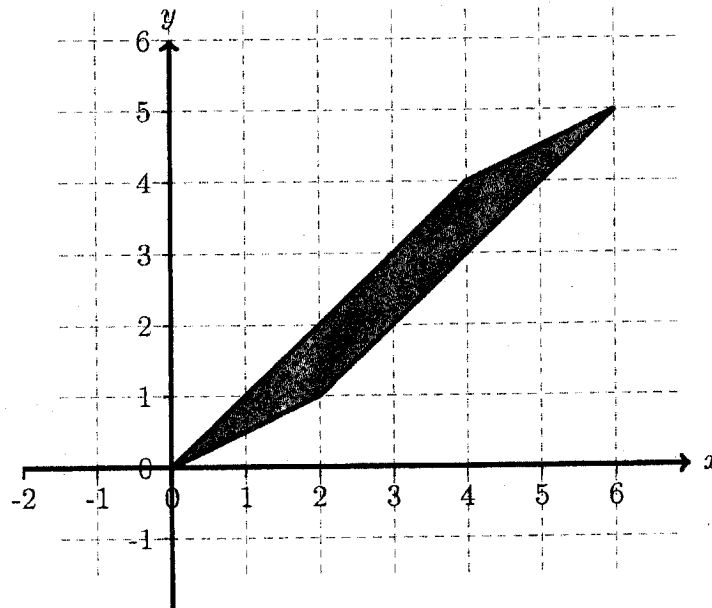
**Question 4**

- (a) Use Laplace transforms to solve the initial value problem

$$y'' - y' - 2y = e^{2t}, \quad y(0) = 0, \quad y'(0) = 1.$$

(8 marks)

- (b) Using double integrals, find the area of the parallelogram shown below.



(7 marks)

- (c) Identify and sketch the quadratic surface  $x = 4 - 5y^2 - 9z^2$ . (5 marks)

Total: 20 marks

Question 5

- (a) The height (in metres) of a random sample of 6 policemen from a particular station are as follows:

1.80, 1.36, 1.99, 1.81, 1.83, 1.79

Assuming that the heights of policemen from the station are normally distributed with mean  $\mu$ .

- (i) Calculate a 95% confidence interval for  $\mu$ .  
 (ii) State the width of this interval.

(7 marks)

- (b) Let  $F(x, y, z) = z^2 \mathbf{i} + y^2 \mathbf{j} + x \mathbf{k}$ .

(i) Find curl  $F$ .

(ii) Evaluate

$$\int_C \mathbf{F} \cdot d\mathbf{r}$$

where  $C$  is the triangle with vertices  $(1, 0, 0)$ ,  $(0, 1, 0)$  and  $(0, 0, 1)$  with counter-clockwise orientation.

(7 marks)

- (c) Find the Fourier transform of the function

$$f(x) = \begin{cases} e^x, & \text{if } x < 0 \\ e^{-x}, & \text{if } x > 0. \end{cases}$$

(6 marks)

Total: 20 marks

**Question 6**

- (a) Find the volume of the solid that lies within the sphere  $x^2 + y^2 + z^2 = 1$ , above the  $xy$ -plane, and below the cone  $z = \sqrt{x^2 + y^2}$ . (7 marks)

- (b) (i) Find all the eigenvalues and corresponding eigenvectors of the matrix

$$\begin{pmatrix} 2 & -5 \\ 1 & -2 \end{pmatrix}.$$

- (ii) Find the solution of the following  $2 \times 2$  system of first order linear differential equations

$$x'_1 = 2x_1 - 5x_2$$

$$x'_2 = x_1 - 2x_2$$

(7 marks)

- (c) The discrete random variable  $X$  has probability density function given below.

x	1	2	3	4	5
P(X = x)	0.2	0.25	0.4	a	0.05

Find

- (i) Find  $P(2 < X < 5)$   
 (ii)  $E[X]$   
 (iii)  $\text{Var}[X]$

(6 marks)

Total: 20 marks

**Question 7**

- (a) Let  $\mathbf{F}(x, y) = (2x^3y^4 + x) \mathbf{i} + (2x^4y^3 + y) \mathbf{j}$

- (i) Show that  $\mathbf{F}$  is a conservative vector field.  
 (ii) Find the potential function of  $\mathbf{F}$ .



(iii) Evaluate

$$\int_C \mathbf{F} \cdot d\mathbf{r}$$

where  $C$  is given by

$$\mathbf{r}(t) = (t \cos(\pi t) - 1) \mathbf{i} + \sin\left(\frac{\pi t}{2}\right) \mathbf{j}, \quad 0 \leq t \leq 1.$$

(7 marks)

(b) Let  $a$  be a real constant, show that

$$\mathcal{L}(\sinh at \sin at) = \frac{2a^2 s}{s^4 + 4a^4}.$$

(6 marks)

(c) Evaluate the surface integral

$$\iint_S \frac{1}{\sqrt{x^2 + y^2 + z^2}} dS$$

where  $S$  is the surface of the cylinder  $x^2 + y^2 = 1$  from  $z = 0$  to  $z = 5$ .

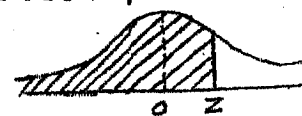
(7 marks)

Total: 20 marks

**END OF PAPER**

Standard normal cumulative distribution function  $\Phi(z)$  and  $100 \times \gamma$ th percentiles  $z_\gamma$

$$\Phi(z) = \int_{-\infty}^z \frac{1}{\sqrt{2\pi}} e^{-t^2/2} dt$$



$z$	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
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	0.8314	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
$\gamma$	0.90	0.95	0.975	0.99	0.995	0.999	0.9995	0.99995	0.999995	
$z_\gamma$	1.282	1.645	1.960	2.326	2.576	3.090	3.291	3.891	4.417	

**The University of Zambia  
School of Natural Sciences  
Department of Mathematics & Statistics**

**2016 ACADEMIC YEAR FINAL EXAMINATIONS**

**MAT3300 – REAL ANALYSIS**

**8<sup>th</sup> September, 2017**

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**INSTRUCTIONS:** 1. There are seven questions. Answer any **Five (5)** questions only.  
2. All questions carry equal marks.  
3. Indicate the number of each question attempted on the cover of the main answer book.

**TIME ALLOWED: Three (3) hours.**

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1. (a) Let  $\mathbb{R}$  be the set of real numbers. Give the definition of each of the following:
- (i) Open set in  $\mathbb{R}$
  - (ii) Limit point of a set
  - (iii) Closed set in  $\mathbb{R}$
- [6]
- (b) Let  $A$  and  $G$  be two subsets of  $\mathbb{R}$ . If  $A$  is closed and  $G$  is open, prove that
- (i)  $(G - A)$  is open
  - (ii)  $A$  is closed if and only if  $A^c$  is open.
- [8]
- (c) State and prove Bolzano-Weiestrass theorem for sets.
- [6]

2. (a) Define each of the following:
- (i) Two separated sets
  - (ii) A disconnected set
  - (iii) Continuity of a real valued function at a point
- [6]
- (b) Prove each of the following:
- (iii) If an open set  $O$  is a union of two separated sets  $A$  and  $B$ , then  $A$  and  $B$  are open.
  - (ii) If two connected sets are not separated, then their union is connected.
- [8]
- (c) Prove that a real value function  $f$  defined on an interval  $I \subseteq \mathbb{R}$  is continuous at a point  $p \in I$  if and only if for every sequence  $\{x_n\}_{n=1}^{\infty}$  in  $I$  which converges to  $p$ , the sequence  $\{f(x_n)\}_{n=1}^{\infty}$  converges to  $f(p)$ .
- [6]
3. (a) Let  $\mathbb{R}$  be a set of all real numbers. Define
- (ii) open covering of a subset of  $\mathbb{R}$
  - (ii) compact subset of  $\mathbb{R}$
- [4]
- (b) (i) State and prove the Cantor's intersection theorem.
- (ii) Prove that  $A = (0,1)$  is not compact.
- [10]
- (c) Suppose  $f$  is a continuous function from a compact set  $X (\subseteq \mathbb{R})$  into  $Y (\subseteq \mathbb{R})$ . Prove that  $f(X)$  is compact.
- [6]

4. (a) Give the definition of each of the following:
- (i) A uniformly continuous function
  - (ii) A function of bounded variation
  - (iii) If  $f$  is of bounded variation, define its total variation function. [6]
- (b) (i) Prove that if a real valued function  $f : I \rightarrow \mathbb{R}$  is uniformly continuous on an interval  $I$ , then it is continuous on  $I$ .
- (ii) Show that the function defined by  $f(x) = \sin x$ ,  $x \in (0, \infty)$  is uniformly continuous on  $(0, \infty)$ . [8]
- (c) Prove that if  $f$  is a function of bounded variation on  $[a, b]$ , then its variation function  $v(x)$  is continuous at a point  $c \in [a, b]$  if and only if  $f$  is continuous at  $c \in [a, b]$ . [6]
5. (a) Let  $I$  be an interval and  $f : I \rightarrow \mathbb{R}$  a real valued function.
- (i) When is  $f$  said to have a derivative at a point  $c \in I$ ?
  - (ii) When is  $f$  said to have a relative maximum at a point  $c \in I \subset \mathbb{R}$ ?
  - (iii) State Rolle's theorem. [6]
- (b) (i) Let  $I$  be an interval and,  $f : I \rightarrow \mathbb{R}$  and  $g : I \rightarrow \mathbb{R}$  be functions that are differentiable at  $c \in I$ . Prove that the function  $fg$  is differentiable at  $c$ , and
- $$(fg)'(c) = f'(c)g(c) + f(c)g'(c).$$
- (ii) If  $f$  has the derivative at every point of the closed interval  $[a, b]$ , then  $f'$  takes on every value between  $f'(a)$  and  $f'(b)$ . [8]
- (c) State and prove the Generalized Mean value theorem (or Cauchy's Mean Value theorem). [6]

6. (a) Let  $f : [a, b] \rightarrow \mathbb{R}$  be a bounded function. Define what is meant by

(i)  $P$  is a partition of an interval  $[a, b]$

(ii) the upper and lower sums,  $U(P, f)$  and  $L(P, f)$  respectively

(iii) the upper and lower integrals,  $\overline{\int_a^b f}$  and  $\underline{\int_a^b f}$  respectively

(iv)  $f$  is Riemann integrable over an interval  $[a, b]$ .

[6]

(b) Consider the function  $f : [0, 1] \rightarrow \mathbb{R}$  defined by

$$f(x) = \begin{cases} 0, & 0 \leq x < 1/2 \\ 1, & 1/2 \leq x \leq 1. \end{cases}$$

If  $\alpha = x^2$ , prove that for the partition  $P = \{0, 3/5, 1\}$  of  $[0, 1]$ ,

$$U(P, f, \alpha) - L(P, f, \alpha) < \frac{2}{5}.$$

[5]

(c) (i) Suppose  $f$  is continuous and nonnegative on  $[0, 1]$ ,  $0 \leq x_0 \leq 1$ , and

$f(x_0) > 0$ . Prove that  $f$  is integrable on  $[0, 1]$ , and that  $\int_0^1 f dx > 0$

(ii) Construct a nonnegative function  $f$  on  $[0, 1]$  with  $f(\frac{1}{2}) > 0$  but  $\int_0^1 f dx = 0$ .

[8]

7. (a) State and prove the Integral test for convergence of series.

[6]

(b) Suppose  $f$  is a real continuously differentiable function on  $[a, b]$  and

$f(a) = f(b) = 0$ , and  $\int_a^b f^2(x) dx = 1$ . Prove that

$$\int_a^b x f(x) f'(x) dx < 0 \text{ and that } \int_a^b [f'(x)]^2 dx \cdot \int_a^b x^2 f^2(x) dx > 0. \quad [6]$$

(c) Consider the improper integral  $\int_0^\infty \frac{\sin x}{x} dx$ .

(i) Prove that the integral converge.

(ii) Does the integral converge absolutely?

(Hint:  $|\cos x| \leq 1$  and  $\int_1^\infty \frac{1}{x^2} dx$  is convergent.)

[8]

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**END OF EXAMINATION**

**The University of Zambia**  
**School of Natural Sciences**  
**Department of Mathematics and Statistics**

**2016 ACADEMIC YEAR**  
**END OF YEAR FINAL EXAMINATIONS**

**MAT3902: PROBABILITY THEORY**

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**TIME ALLOWED :** Three (3) Hours

**INSTRUCTIONS :** Answer any four (4) questions. Full credit will only be given when all the necessary work is shown.

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1.
  - a) Let  $X_1, X_2,$  and  $X_3$  be independent standard normal random variables. Define  $Y_1 = X_1 + X_2 + X_3$ ,  $Y_2 = X_1 - X_2$  and  $Y_3 = X_1 - X_3$ . Find the joint pdf for  $Y_1, Y_2$  and  $Y_3$ .
  - b)
    - (i) Let  $X$  be a Geometric random variable with parameter  $P$  and suppose that the conditional distribution of  $Y$  given that  $X = n$  is gamma with parameters  $n$  and  $\lambda$  i.e.  $Y|_{X=n} \sim g(n, \lambda)$ . Find the conditional probability mass function of  $X$  given that  $Y = y$ .
    - (ii) An Urn contains  $2N$  cards, two of them marked 1, two marked 2, two marked 3 and so on. If  $M$  cards are drawn at random, what is the expected number of pairs that still remain in the urn?
  - c) Let  $X$  and  $Y$  be random variables with joint pdf
$$f_{X,Y}(x,y) = \frac{1}{y} e^{-\frac{(x+1)}{y}}, \quad 0 < x < \infty, \quad 0 < y < \infty.$$
 Find the following;
    - (i)  $P(X > 1 | Y=1)$
    - (ii) Mgf of  $X$  given  $Y = 1$
    - (iii) Mean and Variance of  $X$  given  $Y = 1$ .
2.
  - a)
    - (i) State and prove the weak law of large numbers.
    - (ii) 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  $Y = \sum_{i=1}^N X_i$   
Prove that  $\text{Var}(Y) = \text{Var}(X) E(N) + \text{Var}(N)(E(X))^2$

- b) Let  $Y_1, Y_2, \dots, Y_n$  be a random sample from an exponential distribution with pdf given by  $f_Y(y, \lambda) = \lambda e^{-\lambda y}$ . Define  $X_k = \sum_{i=1}^k Y_i$ ,  $k = 1, 2, \dots, n$ . Find the following;
- Joint probability density function for  $X_1, X_2, \dots, X_n$
  - Marginal probability function of  $X_n$ .
- c) Suppose that people immigrate into a certain country at a Poisson rate 1.5 per day. Find the following;
- Expected time until the tenth immigrant arrives
  - Probability that the elapsed time between the tenth and eleventh arrival exceeds three days.
  - Probability that 9 immigrated in three weeks, given that 5 had immigrated in one week.

3. a) Define each of the following;

- Stochastic Counting Process
- Poisson Process
- Markov Chain

b) Consider a Markov Chain on state space  $\{0, 1, 2, 3, 4\}$  having transition matrix

$$P = \begin{pmatrix} 0 & 1 & 2 & 3 & 4 \\ 0 & \frac{1}{3} & \frac{2}{3} & 0 & 0 \\ 0 & 0 & 0 & \frac{1}{4} & \frac{3}{4} \\ 0 & 0 & 0 & \frac{1}{4} & \frac{3}{4} \\ 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \end{pmatrix}$$

- Show that the Chain is irreducible.
- Find the period.
- Find the stationary distribution



- c) (i) Derive the Chapman-Kolmogorov equations  
(ii) Prove that a Counting Process  $\{N(t), t \geq 0\}$  is a Poisson Process having rate  $\lambda$ ,  $\lambda > 0$  if
- $N(0) = 0$
  - Process has stationary and independent increments
  - $P(N(h) = 1) = \lambda h + o(h)$
  - $P(N(h) \geq 2) = o(h)$

4. a) The weather in a certain region can be characterized as being Sunny ( $E_0$ ), Cloudy ( $E_1$ ) or Rainy ( $E_2$ ) on any particular day. The probability of any type of weather on one day depends only on the state of weather on previous day. The transition matrix

$$P = \begin{matrix} & \begin{matrix} E_0 & E_1 & E_2 \end{matrix} \\ \begin{pmatrix} \frac{1}{2} & \frac{1}{2} & 0 \\ \frac{1}{2} & \frac{1}{4} & \frac{1}{4} \\ 0 & \frac{1}{2} & \frac{1}{2} \end{pmatrix} \end{matrix}$$

- (i) Sketch the transition paths for this Markov Process  
(ii) Is the Markov Chain with this transition matrix irreducible? Justify your answer.  
(iii) Find the probability that if it is Sunny today it will be Rainy in four days time.  
(iv) Find the limiting distribution for this Markov Chain if it exists.
- b) Let  $X_1, X_2, \dots, X_n$  be a random sample from a distribution with pdf

$$f_X(x, \beta) = 2\beta x e^{-\beta x^2}, \quad x > 0, \beta > 0$$

Find the following;

- (i) Probability density function for  $X_{(1)}$   
(ii) Probability density function for  $X_{(n)}$   
(iii) Joint Probability density function of  $X_{(1)}$  and  $X_{(n)}$ .
- c) (i) State the strong – law of large numbers theorem  
(ii) Prove the strong – law of large numbers theorem.

5. a) Define each of the following;

- (i) Recurrent state  
(ii) Transient state  
(iii) Ergodic Markov chain.

- b) (i) Let  $X$  and  $Y$  be random variables with some joint distribution. Show that  $\text{Var}(X) = E(\text{Var}(X/Y)) + \text{Var}(E(X/Y))$ .
- (ii) If  $X$  and  $Y$  are independent Binomial random variables each with parameters  $(n, p)$ . Find the conditional expectation of  $Y$  given that  $X + Y = K$ .
- c) (i) If  $X$  is a Poisson random variable with parameter  $\mu$ , then its moment generating function is  $e^{\mu(e^t - 1)}$ . Find the best Chernoff bound on  $P(X \geq K)$ .
- (ii) State and prove one – sided Chebyshev's inequality.
- (iii) State and prove Jensen's inequality.

-----End of Examination-----

The University of Zambia  
School of Natural Sciences  
Department of Mathematics and Statistics  
2016 Academic Year Examinations - September 2017  
MAT4119 - Engineering Mathematics III

Time allowed : 3 Hours

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**Instructions:** • There are **six (6)** questions in this paper. Attempt **any five (5)** questions.

All questions carry **equal** marks.

- **Full credit** will only be given when **necessary work** is shown.
- Indicate your **computer number** on all answer booklets.
- **Calculators** are allowed for this examination.

*This paper consists of 4 pages of questions.*

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1. a) Given equally spaced points  $x_0, x_1$  and  $x_2$ , use the Lagrange interpolation polynomial to derive a 3 three point formula for  $f'(x_0)$ .
- b) Let  $f(x) = \sin x$ .
  - (i) Find a third-order polynomial that interpolates  $f(x)$  at the points  $[0, \pi/2, \pi, 3\pi/2]$ .  
The corresponding function values are  $[0, 1, 0, -1]$ .
  - (ii) Approximate  $P_3(0.75)$ .
  - (iii) Find a bound for the error.
- c) Experiments with a periodic process  $y(t)$  is believed to fit the model  $y = a \cos t + b$ .  
Derive the normal equations.

[7, 6, 7]

2. a) Give one advantage and one disadvantage of each of the following methods:-

(i) Bisection Method

(ii) Newton-Raphson Method

(iii) Secant Method

(iv) Fixed point Method

b) Use the Newton-Raphson method to find correct to five decimal places, the smallest root of the equation  $e^{-x} - \sin x = 0$ .

c) Given the equation  $3x - \sqrt{1 + \sin x} = 0$

(i) Determine the number of iterations necessary to find the root of the equation which lies between 0 and 1, with accuracy  $10^{-2}$ , using the Bisection method.

(ii) Hence approximate the root of the equation which lies between 0 and 1, with accuracy of  $10^{-2}$ .

[4, 7, 9]

3. a) Given the linear system of equations

$$10x_1 - 2x_2 - x_3 - x_4 = 3$$

$$-2x_1 + 10x_2 - x_3 - x_4 = 15$$

$$-x_1 - x_2 + 10x_3 - 2x_4 = 27$$

$$-x_1 - x_2 - 2x_3 + 10x_4 = -9$$

(i) Use the Jacobi Method to compute the first two iterations given that the initial approximation is  $\mathbf{x}^{(0)} = (0.3, 1.5, 2.7, -0.9)$ .

(ii) Use the Gauss-Seidel Method to compute the first two iterations given that the initial approximation is  $\mathbf{x}^{(0)} = (0.3, 1.5, 2.7, -0.9)$ .

b) Compute the  $\|x\|_\infty$  and  $\|x\|_2$  norms for each of the approximate solutions in a).

c) The matrix  $A$  is given as

$$A = \begin{pmatrix} -1 & 1 & 3 \\ 2 & 1 & -1 \\ 0 & 1 & 2 \end{pmatrix}$$

(i) Use Gaussian elimination method to find the inverse of  $A$ .

(ii) Hence, solve the system of equations:

$$-x + y + 3z = 1$$

$$2x + y - z = 4$$

$$y + 2z = -1$$

[10, 4, 6]

4. a) Consider the data:

$x$	1.0	1.01	1.06	1.10
$f(x)$	1.682940	1.7732994	1.8188014	1.9103448

Approximate  $f'(1.08)$  using the centred difference formula.

b) Given the approximation formula

$$f'''(x_0) = \frac{1}{2h^3} [f(x_0 + 2h) - f(x_0 - 2h) - 2f(x_0 + h) + 2f(x_0 - h)] - \frac{h^2}{4} f^{(5)}(c).$$

(i) Approximate  $f'''(2.0)$  where  $f(x) = xe^x$  and  $h = 0.05$ .

(ii) Find a bound for the error which is due to approximation of  $f'''(2.0)$  in (i) and compare with the actual error, given that  $f'''(2.0) = 36.94528$ .

c) Given the forward difference formula

$$f'(x_0) = \frac{1}{h} [f(x_0 + h) - f(x_0)] - \frac{h}{2} f''(x_0) - \frac{h^2}{6} f'''(x_0) + \mathcal{O}(h^3).$$

(i) Use Richardson's extrapolation to derive  $N_3(h)$ , an  $\mathcal{O}(h^3)$  formula for approximating  $f'(x_0)$ .

(ii) Given that  $f(x) = \ln x$  and  $h = 0.4$ , use the formula derived in (i) to approximate  $f'(1.0)$ .

[3, 7, 10]

5. a) (i) Use Simpson's rule to approximate the integral

$$\int_{\frac{\pi}{2}}^{\frac{3\pi}{4}} \cot x dx,$$

and compare the approximate value to the actual value.

- (ii) Find a bound for the error in (i).

- b) Use the composite Trapezoidal rule to approximate

$$\int_1^3 \frac{dx}{x} \quad \text{with } n = 4.$$

- c) Show that  $u = x^2 - y^2 - y$  is harmonic in the whole complex plane and find a conjugate harmonic function  $v$  of  $u$ .

[9, 5, 6]

6. a) Show that the initial value problem,

$$y' = -\frac{2}{t}y + t^2e^t, \quad 1 \leq t \leq 2, \quad y(1) = \sqrt{2}e,$$

has a unique solution.

- b) Given the initial value problem

$$y' = -y + t + 1, \quad 0 \leq t \leq 2, \quad y(0) = 1,$$

with exact solution  $y(t) = e^{-t} + t$ .

- (i) Approximate  $y(0.4)$  using Euler's method with  $h = 0.2$ .

- (ii) Suppose that the error in (i) is minimum when  $h = \sqrt{\frac{2\delta}{M}}$  where  $M = \max_{0 \leq t \leq 2} |y''|$ .

Determine the optimal value of  $h$  to use in computing  $y(0.4)$ , assuming that

$$\delta = 10^{-6}.$$

- c) Use Taylor's method of order two to approximate the solution to the initial value problem

$$y' = t + y, \quad 0 \leq t \leq 1, \quad y(0) = 1, \quad h = 0.25.$$

[4, 8, 8]

END!

The University of Zambia  
Department of Mathematics & Statistics  
2016 Academic Year Examinations  
MAT4212 - Module and Field theory

Time allowed : Three (3) hrs

Full marks : 100

- 
- Instructions:**
- Attempt **any five (5)** questions. All questions carry equal marks.
  - **Full credit** will only be given when **full understanding** is demonstrated.
  - Indicate your **computer number** on all answer booklets.

*This paper consists of 3 pages of questions.*

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1. a) Define the following:
  - i) a left  $R$ -module [2 marks]
  - ii) a left  $R$ -module homomorphism. [2 marks]
- b) i) Let  $G$  be an abelian group and let  $g \in G$ . For  $n \in \mathbb{Z}$ , define scalar multiplication  $ng$  by
$$ng = \begin{cases} g + g + \cdots + g & (\text{n times}) \text{ if } n > 0 \\ 0 & \text{if } n = 0 \\ (-g) + (-g) + \cdots + (-g) & (-\text{n times}) \text{ if } n < 0 \end{cases}$$
Show that  $G$  is a  $\mathbb{Z}$ -module. [6 marks]
  - ii) Define a map  $\theta : M \rightarrow M/N$  by  $\theta(m) = m + N$ . Show that  $\theta$  is a left  $R$ -module homomorphism. [3 marks]
- c) i) Show that  $\text{Ker } \psi$ , where  $\psi : M \rightarrow N$  is a left  $R$ -module homomorphism, is a submodule of  $M$ . [3 marks]
  - ii) Prove that if  $M_1$  and  $M_2$  are irreducible  $R$ -modules, then any non-zero  $R$ -module homomorphism  $\varphi : M_1 \rightarrow M_2$  is an isomorphism. [4 marks]

2. a) Define the following:

- i) a finitely generated module; [2 marks]
  - ii) a torsion element of a module  $M$ . [2 marks]
- b) i) Suppose that  $N$  is a submodule of an  $R$ -module  $M$ . If  $N$  and  $M/N$  are finitely generated, prove that  $M$  is also finitely generated and  $\mu(M) \leq \mu(N) + \mu(M/N)$ , where  $\mu(M)$  is the rank of  $M$ . [5 marks]
- ii) Define an exact sequence; and give conditions for which the sequences

$$0 \longrightarrow M_1 \xrightarrow{f} M \text{ and } M \xrightarrow{g} M_2 \longrightarrow 0$$

will be exact. [2+1+1 marks]

c) Let  $R$  be an integral domain and let  $M$  be an  $R$ -module. Show that

- i) if  $M$  is a free module then  $M$  is torsion free. [4 marks]
  - ii) if  $M_\tau$  is a set of torsion elements of  $M$  then  $M/M_\tau$  is torsion free. [3 marks]
3. a) Define the following:
- i) a Galois group; [2 marks]
  - ii) the degree of a field extension. [2 marks]
- b) Find
- i) the degree of the extension  $\mathbb{Q}(\sqrt[4]{3}, \sqrt{-1}) : \mathbb{Q}$ . [3 marks]
  - ii) the Galois group of  $x^4 - 2$  over  $\mathbb{Q}$ . [5 marks]
- c) i) Let  $\mathbb{F}$  be a field,  $G$  be a group of automorphisms of  $\mathbb{F}$  and  $\mathbb{E} = \text{Fix}(G)$ . Show that  $\mathbb{F} : \mathbb{E}$  is finite, normal and separable. [5 marks]
- ii) Let  $f(x) \in \mathbb{E}[x]$  with root  $\alpha$ . Show that  $\alpha$  is a multiple root if and only if  $f'(\alpha) = 0$ , where  $f'$  is the first derivative of  $f$ . [3 marks]
4. a) Give meaning to the following:
- i) a splitting field of a polynomial  $f(x) \in \mathbb{E}[x]$ ; [2 marks]
  - ii) a Galois extension. [2 marks]
- b) Obtain the splitting field of
- i)  $x^3 - 1$  over  $\mathbb{Q}$ . [3 marks]
  - ii)  $x^2 - 1$  over  $\mathbb{Q}$ . [2 marks]
- c) i) State the Fundamental Theorem of Galois Theory. [3 marks]
- ii) Hence, prove the one to one correspondence statement between intermediate fields and subgroups. [8 marks]



5. a) Give meaning to the following:
- i) a radical extension; [2 marks]
  - ii) a polynomial  $f(x) \in \mathbb{E}[x]$  is solvable by radicals. [2 marks]
- b) i) Let  $f(x) \in \mathbb{E}[x]$  and let  $\mathbb{F} : \mathbb{E}$  be a field extension. Prove that the Galois group of  $f(x)$  over  $\mathbb{F}$  is isomorphic to a subgroup of a Galois group of  $f(x)$  over  $\mathbb{E}$ . [3 marks]
- ii) Suppose that the Galois group  $G_f$  of  $f(x) \in \mathbb{E}[x]$  is solvable, show that  $f(x) = 0$  is solvable by radicals. [5 marks]
- c) Determine whether or not the following are solvable by radicals:
- i)  $x^3 - 5 \in \mathbb{Q}[x]$ . [4 marks]
  - ii)  $x^5 - 4x + 2 \in \mathbb{Q}[x]$ . (Hint: Use the fact that  $G_f = S_p$  if  $f$  has prime degree  $p$ ) [4 marks]
6. a) What is the meaning of the following:
- i) a primitive polynomial; [2 marks]
  - ii) a normal basis of a field extension. [2 marks]
- b) i) Let  $\mathbb{E}$  be a field of characteristic  $p$ . If  $\mathbb{E} : \mathbb{F}_p$  is Galois, show that  $G(\mathbb{E} : \mathbb{F}_p)$  is cyclic and is generated by  $\sigma(x) = x^p$ ,  $x \in \mathbb{E}$ . [3 marks]
- ii) Given that  $g(x) = x^4 + x + 1$  is an irreducible factor of  $x^{16} + x$  over  $\mathbb{F}_2$ . Show that  $g(x)$  is a primitive polynomial. [4 marks]
- c) i) Let  $\mathbb{F} : \mathbb{E}$  be a Galois extension. If  $G(\mathbb{F} : \mathbb{E})$  is cyclic, show that  $\mathbb{F}$  has a normal basis. [5 marks]
- ii) Let  $\mathbb{F} : \mathbb{E}$  be a Galois extension of degree  $n$  and let  $\sigma_1, \sigma_2, \dots, \sigma_n$  be the elements of  $G(\mathbb{F} : \mathbb{E})$ . Show that  $\{\alpha_1, \alpha_2, \dots, \alpha_n\}$  is a basis for  $\mathbb{F}$  if and only if the matrix  $A = (\alpha_{ij})$ , where  $\alpha_{ij} = \sigma_i(\alpha_j)$  is non singular. [4 marks]

End of Examination!

**THE UNIVERSITY OF ZAMBIA**  
**SCHOOL OF NATURAL SCIENCES**  
**DEPARTMENT OF MATHEMATICS & STATISTICS**  
**END OF 2016/2017 ACADEMIC YEAR EXAMINATIONS**  
**1<sup>st</sup> SEPTEMBER 2017**

**MAT 4300 - ELEMENTS OF FUNCTIONAL ANALYSIS**

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**INSTRUCTIONS:**

1. Answer any **five(5)** questions.
2. All questions carry equal marks.

**TIME ALLOWED:** Three (3) hours

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[TURN OVER]

1. (a) Let  $(X, d)$  be a metric space and  $\{x_n\}_{n=1}^{\infty}$  a sequence in  $X$ .
    - (i) When is  $\{x_n\}_{n=1}^{\infty}$  said to be a Cauchy sequence? [2]
    - (ii) When is  $X$  said to be complete? [2]
  - (b) The usual metric on  $\mathbb{R}$  is  $d : \mathbb{R} \times \mathbb{R} \rightarrow \mathbb{R}$  defined by  $d(a, b) = |a - b|$ . Prove that  $\mathbb{R}$  is a complete metric space. [5]
  - (c) State and prove the infinite form of Hölder's inequality. [6]
  - (d) Prove that the space  $C[a, b]$  of continuous functions on the interval  $[a, b]$  is separable. [5]
- 
2. (a) Let  $X$  and  $Y$  be linear spaces over a field  $\mathbb{F}$ . Define the following:
    - (i) a norm on  $X$ . [2]
    - (ii) an isometry  $f : (X, d_1) \rightarrow (Y, d_2)$  for some metric  $d_1$  and  $d_2$  on  $X$  and  $Y$  respectively. [2]
  - (b) (i) Let  $X$  be a linear space. Let  $\|\cdot\| : X \times X \rightarrow \mathbb{R}$  be a norm on  $X$ . Prove that  $|\|x\| - \|y\|| \leq \|x - y\|$  for all  $x, y \in X$ . [3]
  - (ii) Prove that the norm function  $\|\cdot\| : X \rightarrow \mathbb{R}$  from  $X$  onto  $\mathbb{R}$  is continuous. [3]
  - (c) Show that every normed space is a metric space but the converse is not always true. [5]
  - (d) Let  $X = C[0, 1]$ , Prove that  $\|f\| = \max_{0 \leq x \leq 1} |f(x)|$  defines a norm on  $X$ . [5]

[TURN OVER]

3. (a) Define the following:
- (i) a Banach space. [2]
  - (ii) an operator on a normed linear space  $X$ . [2]
- (b) Let  $X$  and  $Y$  be normed linear spaces and  $T$  a linear transformation of  $X$  onto  $Y$ . Prove that the following are equivalent.
- (i)  $T$  is continuous.
  - (ii)  $T$  is continuous at the origin.
  - (iii) there exists a real number  $K \geq 0$  such that  $\|T(x)\| \leq K\|x\|, \forall x \in X$ .
  - (iv) If  $B = \{x : \|x\| \leq 1\}$  is a closed unit ball in  $X$ , then the image  $T(B)$  is a bounded set in  $Y$ . [5]
- (c) Prove that a subspace  $Y$  of a Banach space  $X$  is complete if and only if the set  $Y$  is closed in  $X$ . [5]
- (d) Let  $X$  be the normed space of all polynomials on  $[0, 1]$  with norm given by  $\|x\| = \max\{|x(t)| : t \in [0, 1]\}$ . Define the differentiation transformation  $T$  on  $X$  by  $Tx(t) = x'(t)$ . Prove that this transformation is linear but not bounded. [6]

4. (a) Let  $X$  and  $Y$  be normed linear spaces and  $T \in \mathcal{B}(X, Y)$ . Let

$$\begin{aligned} N &= \inf\{M \in \mathbb{R} : \|T(x)\| \leq M\|x\|, x \in X\}, \\ P &= \sup\{\|T(x)\| : x \in X, \|x\| \leq 1\} \text{ and} \\ S &= \sup\{\|T(x)\| : x \in X, \|x\| = 1\} \end{aligned}$$

Prove that  $\|T\| = N = P = S$ . [6]

- (b) Let  $X$  and  $Y$  be normed linear spaces. Further, let  $\|T\| = \sup\{\|T(x)\| : \|x\| \leq 1\}$  be the norm on  $\mathcal{B}(X, Y)$ . Prove that if  $Y$  is a Banach space, then so is  $\mathcal{B}(X, Y)$ . [6]
- (c) Show that  $l_2$  with an inner product of two vectors defined by
- $$\langle x, y \rangle = \sum_{i=1}^{\infty} x_i \bar{y}_i \text{ is an inner product space.} \quad [4]$$
- (d) Suppose that  $x, y \in l_2$ , define  $\langle x, y \rangle = \sum_{n=1}^{\infty} x_n \bar{y}_n$ .
- Evaluate  $\|x\|$  given that  $x_n = 2^{-\frac{n}{2}}$ . [4]

[TURN OVER]

5. (a) Let  $X$  be a normed linear space over a field  $\mathbb{F}$ . Define the following:
- (i) the conjugate space  $X^*$  of  $X$ . [2]
  - (ii) a bounded linear functional  $f$  on  $X$ . [2]
- (b) Prove that a linear functional  $f$  defined on a normed linear space  $X$  is bounded if and only if it is continuous. [5]
- (c) Prove that the space  $(l_p^n)^*$  is isometrically isomorphic to  $l_q^n$ , where  $\frac{1}{p} + \frac{1}{q} = 1$ . [5]
- (d) State and prove Hahn Banach theorem. [6]
- 
6. (a) Define the following:
- (i) a Hilbert space  $H$ . [2]
  - (ii) an orthonormal set  $S$  in a Hilbert space  $H$  [2]
- (b) (i) Let  $X$  be an inner product space. Let  $x \in X$ , prove that  $\{x\}^\perp$  is a closed subspace of  $X$ . [3]
- (ii) Let  $H$  be an inner product space. Prove that  $\|x\|^2 = \sum |\langle x, e_i \rangle|^2$  for all  $x \in H$  implies that  $\{e_i\}$  is a complete orthonormal subset in  $H$ . [3]
- (c) Prove that an orthonormal set in a Hilbert space is linearly independent. [4]
- (d) If  $M$  is a proper closed linear subspace of a Hilbert space  $H$ , prove that there exists a non zero vector  $z_0$  in  $H$  such that  $z_0 \perp M$ . [6]

# THE UNIVERSITY OF ZAMBIA

## SCHOOL OF NATURAL SCIENCES

2016/17 ACADEMIC YEAR FINAL EXAMINATION

MAT 4622: CATEGORICAL DATA ANALYSIS

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**TIME:** THREE ( 3 ) HOURS

**INSTRUCTIONS:**

1. Answer ANY five (5) questions
  2. Show all your work to earn full credit.
  3. All questions carry equal marks.
  4. You may use calculators and tables where provided.
- 

**Question 1**

A state in the USA asked business entities to indicate the approximate amount of transportation costs incurred for shipping goods and products to and from their facility.

In the questionnaire the business entities were requested to check one range for inbound and one range for outbound shipment, the results are shown below.

DIRECTION	COST OF SHIPMENT ( in dollars)					
	Under \$100,000	\$100,000 - \$500,000	\$500,000 - \$1 million	\$1 million - \$5 million	\$5 million \$10 million	
Inbound	39	86	31	41	20	217
Outbound	32	68	33	57	27	217
	71	154	64	98	47	434

- ( a ) ( i ) State the measurement scale for each variable; *Cost* and *Direction*.
- ( ii ) Show that the *inbound* and *outbound* shipments are stochastically ordered with respect to their distribution on cost of shipment.
- ( iii ) On the same diagram, provide a sketch of the distributions of the *cost of inbound shipment* and *cost of outbound shipment*.
- ( vii ) If 300 companies were interviewed, how many would declare their inbound costs to be a \$1 million or lower?
- ( b ) ( i ) If we consider *Cost* as a response variable and *Direction* as a fixed classification variable, state the distribution of  $\{n_{ij}\}_{i=1, j=1}^{2, 5}$ , the set of cell counts.
- ( ii ) Test whether the cost of shipment and the direction of shipment are independent using the Chi-square statistic at  $\alpha = 0.05$ .

## Question 2

- ( a ) ( i ) Suppose X and Y are categorical variables each with two levels as depicted in the table below.

X	Y	
	Yes	No
Yes	$n_{11}$	$n_{12}$
No	$n_{21}$	$n_{22}$

State, in probability terms, what is meant by the odds of Y given a value of X.

- ( ii ) Let  $\theta_{ac \times bd}^{XY} = \frac{\pi_{ac}\pi_{bd}}{\pi_{bc}\pi_{ad}}$  be the odds ratio in an  $I \times J$  table for X and Y but limiting the odds ratio to rows "a" and "b" and columns "c" and "d".

Further, define:

$$\theta_{ij} = \theta_{ij \times i+1, j+1} = \frac{\pi_{ij}\pi_{i+1, j+1}}{\pi_{ij+1}\pi_{i+1, j}} \quad i = 1, 2, \dots, I-1 \text{ and } j = 1, 2, \dots, J-1 \text{ as the set of local odds-ratios.}$$

Show that  $\theta_{11 \times 24}^{XY} = \frac{\pi_{11}\pi_{42}}{\pi_{41}\pi_{12}}$  can be expressed in terms of local odds ratios in an  $I \times 2$  table.

- ( iii ) State another set of minimal odds ratio other than local odds ratios and write down the expression.

- ( b ) The table below lists age in years (AGE), and presence or absence of evidence of significant coronary heart disease (CHD) for 100 subjects selected to participate in a study.

AGE	CHD Status	
	Present	Absent
55 - 64	21	6
45 - 54	11	10
35 - 44	8	19
20 - 34	3	22

- ( i ) Obtain all local odds ratios for the table of age and CHD data.
- ( ii ) Collapse age into two categories; age  $\leq 44$  and  $44 < \text{age}$  and create a  $2 \times 2$  table of the data above.
- ( iii ) Calculate the odds ratio and interpret.
- ( iv ) Using the value in (iii) find the 95% confidence interval for the odds ratio.

### Question 3

- (a) Suppose that  $X$  and  $Y$  are ordinal variables for which  $(X_a, Y_a)$  and  $(X_b, Y_b)$  are pairs of measurements from the joint distribution of  $X$  and  $Y$ .
- (i) Define what is meant by  $(X_a, Y_a)$  and  $(X_b, Y_b)$  are concordant pairs.
- (ii) Define what is meant by  $(X_a, Y_a)$  and  $(X_b, Y_b)$  are discordant pairs.
- (b) The data in the table below show the distribution of spouse pairs by educational level of husband and wife.

Husband's Education	Wife's Education			
	College Graduate	High School Graduate	Less than High School graduate	
College Graduate	296	478	14	788
High School Graduate	108	604	60	772
Less than High School graduate	8	95	35	138
	412	1177	109	1698

- (i) Other than Gamma, mention two other measures you would use to explore the relationship between husband's level of education to that of a wife.
- (ii) Calculate the probability estimates of a concordant and discordant pair.
- (iii) Calculate the estimate of the Gamma statistic.
- (iv) Interpret the result in (iii).
- (v) What is the probability that if a husband has a high school certificate or lower, the wife will also have a high school certificate or lower?
- (vi) Display the distribution of a wife's education conditional on the husband's education level,  $\{\pi_{j/i}\}$ , for  $i, j = 1, 2, 3$ . All values to 3 decimal places.

### Question 4

- (a) (i) Briefly describe any two of the following studies; *cross-sectional*, *cohort* or *case-control* study.
- (ii) Give an example of each of the studies selected in (i), using students at UNZA as a study population.
- (b) Assume that the government decides to introduce mandatory testing of citizens for a health condition in order to have a full knowledge of the burden of the condition. Assume that 13 males and 12 females are randomly asked to state whether they approve of such a measure and results turn out as depicted in the table below.



Gender	Do you approve mandatory testing?		
	Yes	No	
Female	10	2	12
Male	5	8	13
	15	10	25

We would like to find out whether there is any association, if any, between approval of mandatory testing and the gender of an individual, fixing the significance level at 5% , i.e.,  $\alpha = 0.05$ .

- ( i ) Give reasons why using Pearson Chi-square might not be ideal in this case.
- ( ii ) Test whether there is any association between approval of mandatory testing and gender using Fisher's exact test at  $\alpha = 0.05$ .
- ( iii ) Let  $\pi_{1/1} = \Pr(\text{Approval} = \text{yes}/\text{female respondent})$  and  
 $\pi_{1/2} = \Pr(\text{Approval} = \text{yes}/\text{male respondent})$

Assume  $n_{i1} \sim \text{Bin}(n_{i+}, \pi_{1/i})$ , the binomial distribution where  $i = 1, 2$  and that the responses of males and females are independent.

Write down the expression for  $\Pr(n_{11}, n_{21})$ , the probability of observing the the pair  $(n_{11}, n_{21})$

- ( iv ) If  $\pi_{1/1} = \pi_{1/2} = \phi$  in ( iii), find the maximum likelihood estimator of  $\phi$ .
- ( v ) Estimate  $\phi$  using the data in the table above.

### Question 5

A newspaper publisher trying to pinpoint her market's characteristics, wondered whether newspaper readership in the city is related to reader's education level. In a survey she asked adults in the area on the level of education and their frequency of readership. The results are shown in the table.

Readership \* Education Cross tabulation

		Education				Total
		Postgraduate	Graduate	High school	Primary	
Readership	Always	28	19	6	13	66
	Weekend edition	35	38	16	7	96
	Sometimes	12	23	8	5	48
	Never	10	17	11	21	59
	Total	85	97	41	46	269

- (a) You are employed to carry out a test of association of the factors at  $\alpha = 0.05$ .
- State the null and alternative hypotheses.
  - If the Likelihood ratio test yields the value  $G^2 = 32.507$ , carry out the test.
  - How would you advise the publisher in view of the result in (ii)?
- (b) (i) You are given the following partial partition of the likelihood ratio statistic:
- High school* versus *Primary* yields a  $G^2_1$  of 9.847.
- Calculate  $G^2_3$ , the likelihood ratio statistic of *Postgraduate* versus (*Graduate* or *lower*).
- Using the values of  $G^2$  in (a) (ii),  $G^2_1$  and  $G^2_3$  obtain the value of  $G^2_2$ , the likelihood ratio statistic of *Graduate* versus (*High school* or *lower*).
  - Verify the degrees of freedom

### Question 6

- (a) Suppose that  $\underline{n} = (n_1, n_2, \dots, n_K)' \sim \text{Mult}(n, \underline{\pi})$ , the multinomial distribution where we assume  $\underline{\pi} = \{\pi_1, \pi_2, \dots, \pi_K\}$  is  $\underline{\pi} \in \Omega$  and  $n = \sum_{j=1}^K n_j$ .
- Write down the constraint imposed on  $\{\pi_1, \pi_2, \dots, \pi_K\}$ .
  - Write down the likelihood function  $f(\underline{n})$ .
  - Using the log function of  $f(\underline{n})$  derive the maximum likelihood estimates of  $\underline{\pi}$ , be sure to show all the steps clearly.
- (b) The results of a probability course taken by students at UNZA in 2013 are shown below.

Grade	B+	B	C+	C	D+	D	NE	Total
Frequency ( $O_j$ )	5	18	22	38	13	11	14	121

We wish to test whether the fixed point model  $\underline{\pi}_0 \in W_0$  applies to the data above.

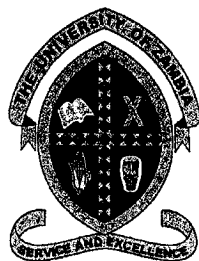
Assume the grades have the distribution  $\underline{\pi}_0$  as shown in the table below.

Grade	B+	B	C+	C	D+	D	NE
Pr(Grade)	$\pi_1$	$\pi_2$	$\pi_3$	$\pi_4$	$\pi_5$	$\pi_6$	$\pi_7$
$\underline{\pi}_0$	0.06	0.13	0.2	0.29	0.07	0.2	0.05

Test whether the data fits the model well at  $\alpha = 0.05$  using the alternative Chi-square

given by  $\chi^2 = \sum_{i=1}^k \frac{(O_i - E_i)^2}{E_i} = n \left( \sum_{j=1}^k \frac{(\hat{p}_j)^2}{\pi_j} - 1 \right) \sim \chi^2(k-1)$ , where  $\hat{p}_j = \frac{O_j}{n}$ .

**END OF EXAMINATION PAPER**



***The University of Zambia***  
***Department of Physics***  
***University Examinations 2016-17***  
***PHY1010: Introductory Physics***

**Time: Three hours.**

**Maximum marks = 100.**

**All questions carry equal marks. The marks are shown in brackets.  
Question 1 is compulsory. You must use the blank answer sheet provided for Question 1.**

**Attempt only four more questions. Clearly indicate on the cover page of the answer script which questions you have attempted.**

**Show your working clearly. Omission of essential work will lead to loss of marks.**

**Write clearly only your computer number on the answer book as well as on the answer sheet for Question 1. Tie them together. Organize the answer script properly.**

**Question 1:** For each correct answer, 2 marks will be given. For each wrong answer, 0.67 marks will be deducted. For no answer, zero mark will be given. The minimum total mark for Question 1 is zero. [20]

(A) A person moves 20 m East and then 30 m North. The magnitude of the resultant displacement is

- (a) 50 m
- (b) -10 m
- (c) 10 m
- (d) None of the above

(B) A bullet hits and gets embedded in a solid block resting on a horizontal frictionless table. What is conserved?

- (a) kinetic energy alone
- (b) momentum alone
- (c) momentum and kinetic energy both
- (d) none of these.

(C) A man in a lift will appear to weigh more when:

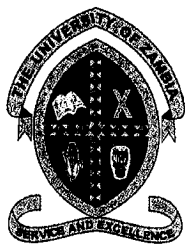
- (a) the lift accelerates downward
- (b) the lift descends freely
- (c) the lift is slowing down while going up
- (d) the lift accelerates upward

(D) If a particle moves in a circle describing equal angles in equal times, its velocity vector:

- (a) changes both in direction and magnitude
- (b) remains constant
- (c) changes in direction only
- (d) changes in magnitude only

(E) The rate at which heat flows through a slab of some material does not depend on:

- (a) the area of the slab
- (b) the specific heat capacity of the material
- (c) the temperature difference between the slabs
- (d) the thickness of the slab



**The University of Zambia  
Department of Physics  
University Examinations 2016/2017  
PHY1010 Introductory Physics**

**Answer sheet for Question 1**

**Computer Number only .....**

**Q1. Put a cross (x) or tick mark (✓) in the appropriate box.**

**If it is on the dividing line, it will not be counted.**

	a	b	c	d
A				
B				
C				
D				
E				
F				
G				
H				
I				
J				

**Do NOT write here.  
For official use only:**

	Number of parts N	Factor f	Marks f × N
Correct		2	
Wrong		-(0.67)	
Net Marks:			

**Attach this sheet firmly with the main answer book. If you lose this sheet, you will lose the marks for Question 1!!**

(F) When stretched beyond its elastic limit, a metal rod such as steel:

- (a) becomes elastic
- (b) becomes plastic
- (c) obeys Hooke's law
- (d) becomes colder.

(G) The area enclosed by the  $P$ - $V$  graph of a complete heat engine cycle equals:

- (a) the work done by the engine per cycle
- (b) the heat intake per cycle
- (c) the heat output per cycle
- (d) the work done on the engine per cycle.

(H) A given mass of an ideal gas is at a pressure  $P$ , a volume  $V$  and temperature  $100\text{ }^{\circ}\text{C}$ . If the temperature of the gas is raised to  $200\text{ }^{\circ}\text{C}$  keeping the volume constant, the pressure would be

- (a)  $P$
- (b)  $2P$
- (c)  $\frac{1}{2}P$
- (d)  $1.27P$

(I) The total amount of work that must be done to compress a spring against the restoring force represents the

- (a) kinetic energy of the spring
- (b) potential energy of the spring
- (c) force constant
- (d) none of the above.

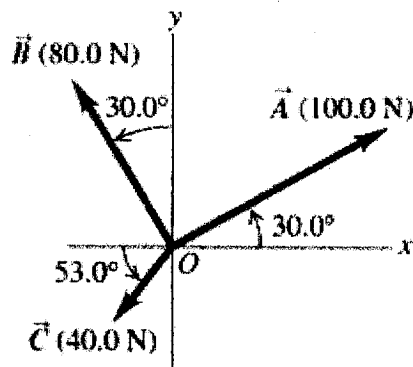
(J) In simple harmonic motion, there is always a constant ratio between the displacement of the mass and its:

- (a) speed
- (b) mass
- (c) acceleration
- (d) period.

**Attempt any four (4) questions from the following:**

**Q2(a)** Three horizontal ropes pull on a large stone lying on the ground, producing the vector forces  $\vec{A}$ ,  $\vec{B}$ , and  $\vec{C}$ .

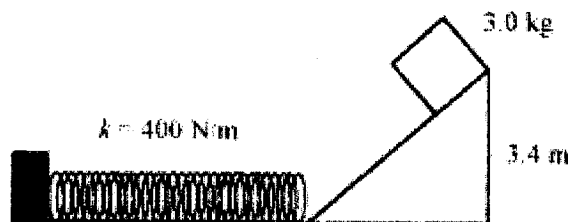
Find the magnitude and direction of a fourth force on the stone that will make the vector sum of the four forces zero. [9]



**(b)** Place a 3 kg block at the top of a 3.4 m high frictionless incline.

(i) At the bottom of the incline, the block encounters a spring with a constant of 400 N/m on a horizontal surface. No energy is lost due to friction. How far is the spring compressed?

(ii) Now add a coefficient of friction 0.20 for the horizontal surface. How far does the block slide on the horizontal surface while compressing the spring? [11]



*Kay leyens*

**Q3(a)** A man stands on the roof of a building 50 m high and throws a stone with a speed of 60 m/s at an angle of  $37^\circ$  above the horizontal.

Calculate

- (i) the maximum height above the roof reached by the rock
- (ii) the magnitude of the downward velocity of the rock just before it strikes the ground.
- (iii) the horizontal distance from the base of the building to the point where the stone strikes the ground.

[11]

**(b)** A string with a mass per unit length of 0.008 kg/m is stretched by the application of 320 N between two fixed points.

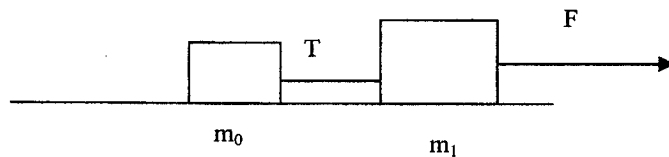
- (i) What length of the string will be required to produce a fundamental frequency of 500 Hz?
- (ii) What tension is required to give this string a fundamental frequency of 750 Hz? [9]

**Q4(a)** In the figure shown, the two blocks of masses  $m_0 = 2 \text{ kg}$  and  $m_1 = 5 \text{ kg}$  are connected on a horizontal frictionless table and pulled to the right with a force  $F = 40 \text{ N}$ .

Calculate the acceleration of the masses and the tension  $T$  in the cord connecting  $m_0$  and  $m_1$  :

- (i) if the table is frictionless.
- (ii) if the coefficient of kinetic friction between the masses and the surface is 0.40.

[11]



**4(b)** An engine operates between a high temperature of  $200^\circ\text{C}$  and a surrounding low temperature of  $20^\circ\text{C}$ . It is operating at 40% of its ideal Carnot efficiency.

The engine does a work of 8000 J each cycle. Calculate

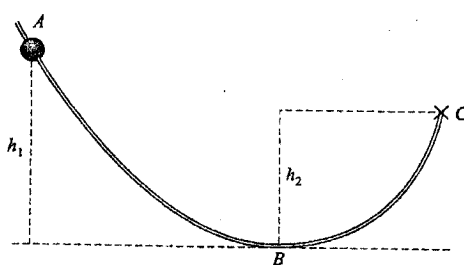
- (i) the actual efficiency of the engine.
- (ii) the amount of thermal energy absorbed per cycle at the high temperature reservoir.
- (iii) the amount of exhaust thermal energy to the surrounding during each cycle. [9]



**Q5(a)** In the figure,  $h_1 = 200$  cm and  $h_2 = 170$  cm, and at  $A$  the 3 g bead has a downward speed along the wire of 800 cm/s.

- (i) How fast is the bead moving as it passes point  $B$  if friction is negligible?
- (ii) How much energy did the bead lose due to work done against friction if it rises to a height of 20 cm above  $C$  after it leaves the wire?

[10]



**(b)** One mole of a gas is isothermally expanded at  $27^\circ\text{C}$  till the volume is doubled.

Then it is adiabatically compressed to its original volume. Find the total work done.

Given  $\gamma = 1.4$ ,  $R = 8.315$  J/mol.K

[10]

Work done in an isothermal expansion  $W_{\text{isotherm}} = nRT \ln \frac{V_2}{V_1}$ .

Work done in an adiabatic process  $W_{\text{adiabatic}} = \frac{1}{\gamma - 1} (P_1 V_1 - P_2 V_2)$

**Q6(a)** A gun of mass 4 kg recoils with a speed of 0.5 m/s when it fires a bullet of mass 10 g horizontally.

- (i) Find the speed with which the bullet is fired.
- (ii) If the bullet embeds itself in a 1.990 kg block of wood at rest on a horizontal table, with what velocity do the block and bullet begin to move?
- (iii) If the block-and-bullet stop after 10 cm, calculate the coefficient of sliding friction between the block and the table.

[10]

(b) The heat necessary to raise the temperature of 10 moles of an ideal gas at a constant pressure of  $1.0 \times 10^5$  Pa through 10 degrees is 2100 J.

What is

- (i) the volume change
- (ii) the specific heat capacity at constant pressure, and
- (iii) the specific heat capacity at constant volume?

[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.

- (i) How long will it take for the grindstone to come to a halt?
- (ii) How many revolutions has the grindstone made during this period?

[9]

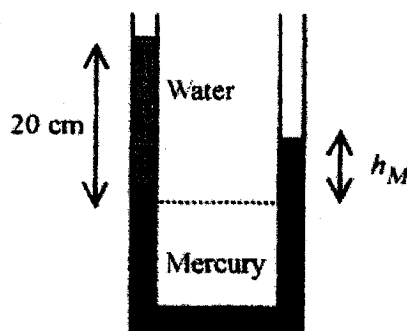
[  $I = (\frac{1}{2})MR^2$  ]

(b) A U-tube originally containing mercury has water added to one arm to a depth of 20 cm.

- (i) What is the pressure at the water-mercury interface?
- (ii) What is the height of the mercury column as measured from the water-mercury level?

[density of mercury,  $\rho_{\text{mercury}} = 14 \times 10^3 \text{ kg/m}^3$  ]

[8]



(c) State the second law of thermodynamics in terms of

- (i) the direction of heat transfer between systems at different temperatures, and
- (ii) the entropy of the system.

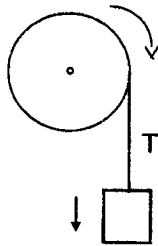
[3]

**Q8(a)** A wheel of radius 6 cm is mounted so as to rotate about a horizontal axis through its centre as shown in the figure. A string of negligible mass wrapped round its circumference carries a mass of 200 g attached to its free end. When allowed to fall, the mass descends through 100 cm in 5 seconds.

Calculate

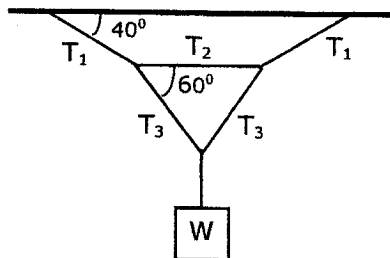
- (i) the angular acceleration of the wheel,
- (ii) the moment of inertia of the wheel,
- (iii) tension in the cord.

[12]



- (b)** The system in the figure is in equilibrium. If the tension  $T_1$  is 60 N, find the value of  $T_2$ ,  $T_3$  and  $W$ . Assume the ropes to be massless.

[8]



==End of PHY1010 2017 Exam==

## Some Useful Equations

### Uniformly accelerated motion:

$$x = \bar{v}t \quad \bar{v} = \frac{1}{2}(v_f + v_i) \quad v_f = v_i + at \quad v_f^2 = v_i^2 + 2ax \quad x = v_i t + \frac{1}{2}at^2$$

### Projectile motion:

$$v_x = v_i \cos \theta_i = \text{constant} \quad v_y = v_i \sin \theta_i - gt \quad y = (v_i \sin \theta_i)t - \frac{1}{2}gt^2$$
$$y = (\tan \theta_i)x - \left[ \frac{g}{2v_i^2 (\cos^2 \theta_i)} \right] x^2 \quad R = \frac{v_i^2}{g} \sin 2\theta \quad t = \frac{2v_i \sin \theta}{g}$$

### Force and motion:

$$F = ma \quad w = mg \quad F_{AB} = -F_{BA} \quad F_f = \mu F_N$$

### Work and Energy:

$$PE = wh = mgh \quad KE = \frac{1}{2}mv^2 \quad W = Fx \cos \theta \quad P = \frac{W}{t} = Fv \cos \theta$$

**Linear momentum:**  $p = mv$   $F\Delta t = \Delta mv = m(v_f - v_0)$

### Circular motion and gravitation:

$$T = \frac{2\pi r}{v} \quad a_c = \frac{v^2}{r} \quad F_c = \frac{mv^2}{r} \quad F_{grav} = G \frac{m_A m_B}{r^2} \quad 1 \text{ rev} = 360^\circ = 2\pi \text{ rad}$$

$$v_T = \frac{(2\pi r)}{T} : \tan \theta = \frac{v^2}{rg}$$

### Rotational motion and angular momentum:

$$\theta = \frac{s}{r} = \left( \frac{\omega_i + \omega_f}{2} \right) t \quad \omega = \frac{\theta}{t} \quad \theta = \omega_i t + \frac{1}{2}\alpha t^2 \quad \omega_f = \omega_i + \alpha t \quad v = \omega r$$

$$I = mk^2 \quad \omega_f^2 = \omega_i^2 + 2\alpha\theta \quad \alpha = \frac{\Delta\omega}{\Delta t} = \frac{a_T}{r} \quad I = \sum mr^2 \quad KE_{rot} = \frac{1}{2}I\omega^2$$

$$\tau = FL = I\alpha \quad W = \tau\theta \quad P = \tau\omega \quad L = I\omega \quad KE_{total} = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$$

### Properties of matter:

$$\rho = \frac{m}{V} \quad F = -kx \quad \frac{\Delta L}{L_i} = \frac{1}{Y} \frac{F}{A} \quad \phi = \frac{s}{d} = \frac{1}{s} \frac{F}{A} \quad B = -\frac{\Delta P}{\Delta V / V_0}$$

$$W_{app} = W \left( 1 - \frac{\rho_{fluid}}{\rho} \right) \quad F_B = \rho V g, \text{ (submerged object)} \quad F_B = Mg \text{ (floating } M)$$

### Thermal Properties of matter:

$$PV = nRT : \Delta Q = mc\Delta T = nC\Delta T : \Delta L = \alpha L\Delta T : L_t = L_0(1 + \alpha t) : \Delta V = \gamma V\Delta T :$$

$$W = P\Delta V \quad (\Delta Q / \Delta t) = (kA\Delta T) / \Delta L \quad : m = V \times \rho \quad \frac{Q}{t} = eA\sigma T^4 \quad C_p = C_v + R$$

$$Q = n.C.\Delta T = \frac{3}{2}n.R.\Delta T \text{ for isobaric and iso-volumetric processes}$$

### Thermodynamics:

$$\Delta Q = \Delta U + \Delta W : W = p.\Delta V \quad PV = nRT \quad n = \frac{m}{M} \quad P_1V_1^\gamma = P_2V_2^\gamma \quad T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$$

$$COP_{ref} = \frac{Q_C}{W} \quad COP_{heat\ pump} = \frac{Q_H}{W} \quad W_{isothermal} = nRT \ln \frac{V_2}{V_1} \quad W_{adiabatic} = \frac{1}{\gamma-1}(P_1V_1 - P_2V_2) :$$

$$COP_{max-refr} = \frac{T_C}{W} \quad COP_{max-heat\ pump} = \frac{T_H}{W} \quad e = 1 - \frac{T_c}{T_h} = \frac{\text{work done}}{\text{input heat at high temp}}$$

### Waves and Sound:

$$f = \frac{1}{\tau} \quad v = \pm \sqrt{\frac{k}{m}(x_0^2 - x^2)} \quad v = \sqrt{\frac{T}{m/L}} \quad \tau = \frac{1}{f} = 2\pi\sqrt{\frac{m}{k}} \quad a = -\left(\frac{k}{m}\right)x \quad v = \sqrt{\frac{Y}{\rho}}$$

$$v = \sqrt{\frac{B}{\rho}} \quad f' = f \frac{v \pm v_L}{v \mp v_s} \quad (\text{dB}) = 10 \cdot \log \frac{I}{I_0} : \text{velocity of sound} = 331.45 + 0.61t (^{\circ}\text{C})$$

$$\tau = \frac{2\pi x_0}{v_0} = 2\pi \left( \frac{x_0}{v_0} \right) = \frac{2\pi}{\omega} \quad f = \frac{1}{2L} \sqrt{\frac{T}{m}} \quad x = x_0 \cos(\omega t) \quad I_0 = 10^{-12} \text{ W/m}^2$$

### Wherever necessary use:

$$g = 9.8 \text{ m/s}^2 : \text{pascal} = 1 \text{ N/m}^2 : \rho_{\text{water}} = 1000 \text{ kg/m}^3 : 1 \text{ hp} = 746 \text{ watts} :$$

$$1 \text{ metric ton} = 1000 \text{ kg} : P_{\text{atm}} = 1.013 \times 10^5 \text{ pascals} : 1 \text{ cal} = 4.184 \text{ J} : M = 4 \text{ for helium} ;$$

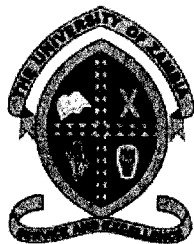
$$R = 8.315 \text{ J/mol.K} : \text{Volume of a sphere} = (4/3)\pi r^3 ; 1 \text{ litre} = 1 \times 10^{-3} \text{ m}^3$$

$$\text{Surface area of a sphere} = 4\pi r^2, H_f = 80 \text{ cal/g}, H_v = 539 \text{ cal/g}.$$

$$\text{Surface area of a cylinder} = 2\pi rL ; G = 6.67 \times 10^{-11} \text{ N.m}^2/\text{kg}^2 : 1 \text{ litre} = 1 \times 10^{-3} \text{ m}^3$$

$$\text{specific heat of H}_2\text{O} = 4184 \text{ J/kg.}^{\circ}\text{C} : \text{s.t.p.} = 0^{\circ}\text{C and 1 atmospheric pressure}$$

$$c_{\text{ice}} = 0.5 \text{ cal/g.}^{\circ}\text{C}, c_{\text{steam}} = 0.46 \text{ cal/g.}^{\circ}\text{C} = 1920 \text{ J/kg.}^{\circ}\text{C (at } 100^{\circ}\text{C, constant volume)}$$



# The University of Zambia

## School of Natural Sciences

Department of Physics  
2016-17 Academic Year

End of Year University Examinations  
PHY2112: Atomic and Modern Physics

Time: Three hours.

[Maximum Marks : 100 ]

1. Attempt any five questions. All questions carry equal marks.
2. Write clearly your computer number on each answer booklet.
3. Show all essential working

Below is a table of constants that might be useful.

Electron mass $m_e = 9.11 \times 10^{-31} \text{kg}$	Avogadro's number $N_A = 6.023 \times 10^{23} \text{ per mole}$	Permeability of free space $\mu_0 = 4\pi \times 10^{-7} \text{ T.m/A}$
electron charge $e = -1.6 \times 10^{-19} \text{C}$	Electron volt $1\text{eV} = 1.6 \times 10^{-19} \text{J}$	Permittivity of free space $\epsilon_0 = 8.85 \times 10^{-12} \text{C}^2/\text{N.m}^2$
Stefan's constant $\sigma = 5.67 \times 10^{-8} \text{Wm}^{-2}\text{K}^{-4}$	Planck's constant $h = 6.63 \times 10^{-34} \text{ J.s}$	Boltzmann constant $\kappa = 1.38 \times 10^{-23} \text{J.K}^{-1}$
Wien's constant $b = 2.9 \times 10^{-3} \text{m.K}$	Rydberg constant $R = 1.0974 \times 10^7 \text{m}^{-1}$	Angstroms to meters $1\text{\AA} = 10^{-10} \text{ m.}$

**Below is a list of formulas that might be helpful.**

converting year to second :  $1yr = 31557600 \approx 3.16 \times 10^7 s$

Magnetic field inside a solenoid:  $B = \frac{\mu_0 NI}{l}$

Magnetic energy density:  $U^* = \frac{U}{V} = \frac{1}{2\mu_0} B^2$

Decay law:  $N = N_0 e^{-\lambda t}$ . The decay rate or activity :  $A = \frac{dN}{dt} = -\lambda N$

Energy of a photon  $E = \frac{hc}{\lambda}$  , and momentum of a photon  $p = \frac{h}{\lambda}$

Transmitted intensity  $I = I_0 e^{-\mu x}$

Photoelectric equation:  $\frac{1}{2}mv^2 = h\nu - \varphi$

Compton scattering equation:  $\Delta\lambda = \lambda' - \lambda = \frac{h}{m_0 c} (1 - \cos \theta)$

Moseley's law:  $\sqrt{\nu} = a(Z - b)$

Wien's displacement law:  $\lambda_{max} T = 0.2898 \times 10^{-2} \text{ m.K}$

De Broglie wavelength:  $\lambda = \frac{h}{mv}$

Total energy of a planetary electron:  $E = E_k + E_p = \frac{1}{2}mv^2 - \frac{Ze^2}{4\pi\epsilon_0 r}$

Permitted radii in Bohr atom:  $r = \frac{\epsilon_0 h^2 n^2}{\pi m_e Z e^2}$

Planck's radiation law:  $E(\lambda) = \frac{8\pi hc}{\lambda^5} \frac{1}{e^{\frac{ch}{\lambda kT}} - 1}$

Number of atoms in sample :  $N = \frac{\text{mass(g)} \times \text{Avogadro's number}}{\text{Molar mass}}$

- Q1 (a) (i) State Faraday's and Ampere's laws. [3]  
 (ii) Distinguish between free currents and Amperian currents [2]  
 (iii) Briefly discuss the implication of Gauss's law for magnetic flux  
 $\oint \mathbf{B} \cdot d\mathbf{s} = 0$ . [2]  
 (iv) Differentiate between paramagnetics and diamagnetics. [3]
- (b) An iron ring of radius 5 cm has a cross-sectional area of 2 cm<sup>2</sup>. Its permeability is  $1000\mu_0$ . It is wound with 1500 turns of insulated wire carrying 5 A current. Calculate
- (i) the magnetic field intensity  $H$  [2]  
 (ii) the solenoidal current density of the coil [2]  
 (iii) the magnetization  $M$  of the coil [4]  
 (iv) the induced Amperian current density [2]
- Q2 (a) Show that Planck's radiation law reduces to Wien's displacement law at maximum wavelength, i.e. ,

$$\lambda_{\max} \times T = 2.898 \times 10^{-3} \text{ m.K}$$

(Hint: At  $\lambda_{\max}$  energy density  $\frac{dE_\lambda}{d\lambda} = 0$ ) Note: the equation  $\frac{x}{5} + e^{-x} = 1$  has a single root given by  $x = 4.965$  [10]

- (b) A temperature of a blackbody is increased from 500K to 1900K. By what factor does the total power radiated per unit area increase? [3]
- (c) Photoelectrons are liberated by ultraviolet light of wavelength 3000Å from a metallic surface for which the photoelectric threshold is 4000Å. Calculate the de Broglie wavelength of electrons emitted with maximum kinetic energy. [7]
- Q3 (a) What are stationary states in the Bohr atom and how do they differ from the classical states? [3]
- (b) A particle of mass  $m$  moves in a circular orbit of radius  $r$  under the influence of a force given by  $F = Kr$  directed toward the center ( $K$  is a constant). Assuming that Bohr's postulates apply to this system, derive the equation for the radii of the permissible orbits. [7]



- (c) The radius of the first orbit, known as the Bohr radius, for the hydrogen atom is  $0.53 \times 10^{-10}\text{m}$ .
- (i) Assuming that the Coulomb force between the electron and the proton provides the centripetal force for the circulating electron, calculate the linear speed of the electron in the first Bohr orbit of the hydrogen atom. [4]
  - (ii) Using the value of the velocity calculated above, find the frequency of revolution of the electron in this first orbit. [2]
  - (iii) Using the frequency calculated above, find the magnitude of the circulating current  $i$  due to the motion of the electron. [2]
  - (iv) Finally, compute the magnetic moment  $\mu$  due to the current. [2]
- Q4 (a) A certain metal has a threshold wavelength of 600 nm. Find the stopping potentials when metal is irradiated with
- (i) monochromatic light of wavelength 400 nm, [3]
  - (ii) light having twice the frequency of that in (i), [3]
  - (iii) light having three times the intensity of that in (i). [2]
- (b) Bragg's spectrometer is set for the first order reflection to be received by the detector at glancing angle of  $10^\circ$ . Calculate the angle through which the detector is rotated to receive the second order reflection from the same face of the crystal. [6]
- (c) A certain radioactive element has a half life of 20 days.
- (i) How long will it take for  $\frac{3}{4}$  of the atoms originally present to disintegrate? [2]
  - (ii) How long will it take only  $\frac{1}{8}$  of the atoms originally present to remain unchanged? [2]
  - (iii) What are the disintegration constant and the average life of this element? [2]

- Q5 (a) State the de Broglie hypothesis [2]
- (b) Explain the macroscopic absorption coefficient (linear attenuation coefficient) and the half-value layer (hvl) of a material for X-ray absorption. [2+2]
- (c) What percentage of the X-ray beam is absorbed when it passes through 0.1 mm of liquid mercury for which the linear absorption coefficient is  $\mu = 0.22 \text{ mm}^{-1}$ ? [4]
- (d) A photon of energy  $E$  undergoes a Compton collision with a free particle of rest mass  $m_0$ . Show that the maximum recoil kinetic energy of the particle is

$$E_{k_{max}} = \frac{E^2}{E + \frac{m_0 c^2}{2}}$$

[10 marks]

- Q6 (a) Explain briefly the nature and properties of radiations  $\alpha$ ,  $\beta$  and  $\gamma$ -rays emitted by radioactive atoms. [6]
- (b) An X-ray line of wavelength  $0.53832 \text{ \AA}$  is found to be emitted from an X-ray tube with a zinc ( $Z=30$ ) target in addition to the characteristic  $K_\alpha$  of zinc of wavelength of  $1.43603 \text{ \AA}$ . If the unknown line is due to an impurity in the target, obtain the atomic number of the impurity. [4]
- (c) State the law of radioactivity decay and define the terms disintegration constant and half-life. [3]
- (d) A 50 gram sample of carbon is taken from the pelvis bone of a skeleton and is found to have a  $^{14}\text{C}$  decay rate of 200 decays/minute. Given that carbon from a living organism has a decay rate of 15 decays per minute per gram of the substance, and that  $^{14}\text{C}$  has a half-life of 5730 years, find the age of the skeleton. [7]

- Q7 (a) State and explain the three mechanisms of  $\gamma$ -ray absorption. [6]
- (b) An alpha particle is ejected from the nucleus of a radium atom with 5.78MeV of kinetic energy. Determine the De Broglie wavelengths of this particle? [4]
- (c) The K absorption edge of tungsten is  $0.178\text{\AA}$  and the average wavelength of the K-series lines are  $K_\alpha = 0.210\text{\AA}$ ,  $K_\beta = 0.184\text{\AA}$  and  $K_\gamma = 0.179\text{\AA}$ . Construct the X-ray energy level diagram for tungsten. [10]

=====End of PHY2112 Examination=====



**THE UNIVERSITY OF ZAMBIA  
SCHOOL OF NATURAL SCIENCES  
DEPARTMENT OF PHYSICS**

**2016/17 ACADEMIC YEAR**

**END YEAR UNIVERSITY EXAMINATIONS**

**PHY-2522: ANALYTICAL MECHANICS AND SPECIAL THEORY OF  
RELATIVITY**

**Time allowed: 3 Hours**

**Instructions**

- This examination paper contains 7 questions. Each question carries 20 marks. Attempt any 5 questions out of the 7 questions given.
- This paper has a total of 100 marks. All questions carry equal marks
- Show all your working clearly. Omission of essential work will result in loss of marks
- Write your computer number clearly on the answer sheets

**Where necessary, you may use the following:**

In plane polar coordinates

$$x = r \cos \theta, \quad y = r \sin \theta, \quad \vec{v} = \dot{r} \hat{r} + r \dot{\theta} \hat{\theta} \quad \vec{a} = (\ddot{r} - r \dot{\theta}^2) \hat{r} + (r \ddot{\theta} + 2\dot{r} \dot{\theta}) \hat{\theta}$$

$$\frac{d}{dt} \left( \frac{\partial L}{\partial \dot{q}_k} \right) - \frac{\partial L}{\partial q_k} = Q_k, \quad \dot{q}_k = \frac{\partial H}{\partial p_k}, \quad \frac{\partial H}{\partial t} = - \frac{\partial L}{\partial t}, \quad -\dot{p}_k = \frac{\partial H}{\partial q_k}, \quad p_k = \frac{\partial L}{\partial \dot{q}_k} \quad x' = \gamma(x - vt),$$

$$t' = \gamma \left( t - \frac{Vx}{c^2} \right), \quad y' = y, \quad z' = z, \quad \gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}, \text{ speed of light } c = 3 \times 10^8 \text{ m/s}, \quad T = \gamma T_0, \quad L_0 = \gamma L,$$

$$\frac{\partial^2 u(x,t)}{\partial t^2} = \frac{T}{\mu} \frac{\partial^2 u(x,t)}{\partial x^2}, \quad I_{\text{sphere}} = \frac{2}{5} Ma^2$$

$$A_n = \frac{2}{L} \int_0^L u_0(x) \sin\left(\frac{n\pi x}{L}\right) dx, \quad B_n = \int_0^L \dot{u}_0(x) \sin\left(\frac{n\pi x}{L}\right) dx$$

$$u(x,t) = \sum_{n=1}^{\infty} \left[ A_n \sin\left(\frac{n\pi x}{L}\right) \cos(\omega_n t) + B_n \sin\left(\frac{n\pi x}{L}\right) \sin(\omega_n t) \right], \quad \omega_n = \frac{n\pi v}{L}$$

- Q1** A particle of mass  $m$  is attracted toward a given point by a force of magnitude

$$|\vec{F}(r)| = \frac{b}{r^2}$$

where  $b$  is a positive constant. Using Cartesian coordinates,

- (a) show that the Hamiltonian is

$$H(x, y, p_x, p_y) = \frac{1}{2}m \left( \frac{p_x^2}{m^2} + \frac{p_y^2}{m^2} \right) + \frac{b}{\sqrt{x^2 + y^2}}, \quad [12 \text{ marks}]$$

and

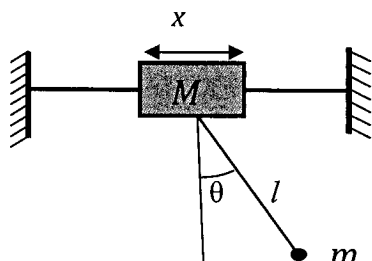
- (b) that the equations of motion are

$$m\ddot{x} + \frac{bx}{(x^2 + y^2)^{3/2}} = 0 \quad [4 \text{ marks}]$$

and

$$m\ddot{y} + \frac{by}{(x^2 + y^2)^{3/2}} = 0 \quad [4 \text{ marks}]$$

- Q2** A mass  $M$  is free to slide along a frictionless rail. A pendulum of length  $l$  and mass  $m$  hangs from  $M$  as shown in the figure below.



- (a) How many degrees of freedom does the system have? [1 marks]
- (b) Obtain the expression for the Lagrangian of the system [8 marks]
- (c) Find the equations of motion using the Lagrangian formalism [5+5 marks]
- (d) State the ignorable coordinate of the system [1 marks]
- Q3(a)** Consider projectile motion under gravity in two dimensions. If the projectile is fired at an angle  $\theta$  to the horizontal, show that by the use of Lagrange's formalism, the resulting equations of motion are:

$$\ddot{r} - r\dot{\theta}^2 + g \sin \theta = 0 \quad \text{and} \quad \ddot{\theta} + 2\dot{r}\dot{\theta} + g \cos \theta = 0 \quad [6+6 \text{ marks}]$$

- (b) One of a pair of identical twins sets off on a voyage at the age of 30 years and his ship travels at 90% the speed of light. He comes back home and tells his brother that he is 36 years old. How old will his brother say he is? [4 marks]
- (c) In a stationary laboratory the length of a meter rule moving longitudinally along its length is found to be 0.64 m. How fast in terms of  $c$  is the meter rule moving relative to the observer in the laboratory. (Take the speed of light  $c = 3.0 \times 10^8$  m/s). [4 marks]

**Q4** A sinusoidal travelling wave represented by

$$\psi_i = A' \cos(\omega t - kz + \phi')$$

coming from the left reaches a fixed end at  $z = 0$ .

- (i) Show that after reflection, the resulting standing wave is given by

$$\psi = A \sin kz \cos(\omega t + \phi)$$

where  $A = 2A'$  and  $\phi = \phi' - \frac{1}{2}\pi$ . [8 marks]

- (ii) Describe what happens at the points on the string for which

$$kz = m\pi \quad (m = 0, \pm 1, \pm 2, \pm 3, \dots) \quad [3 \text{ marks}]$$

- (iii) In terms of wavelength, how far apart are the points in (ii) above. [2 marks]

- (iv) What are the points midway along the string at which condition in (ii) holds called? [1 marks]

- (v) Show that  $u = \sin(2x)\cos(vt)$  is not a solution of the wave equation

$$\frac{\partial^2 u(x,t)}{\partial x^2} - \frac{1}{v^2} \frac{\partial^2 u(x,t)}{\partial t^2} = 0 \quad [6 \text{ marks}]$$

**Q5(a)** Using the Galilean transformations

$$x'_1 = x_1 - vt, \quad x'_2 = x_2, \quad x'_3 = x_3, \quad t' = t,$$

show that Newton's second law of motion for a particle of mass  $m$  is invariant in a stationary inertial frame  $S$  and an inertial frame  $S'$  moving with a constant velocity  $v$  with respect to  $S$ . [8 marks]

(b) The relativistic equation of kinetic energy is given by

$$T = mc^2 - m_0c^2.$$

Show that the equation reduces to the classical one at speeds much less than that of light.

[6 marks]

(c) The trajectory of a particle moving parallel to  $O_x$  with a uniform velocity  $v$  in the stationary inertial reference frame  $S$  is given by

$$x = x_0 + vt$$

Show that in the reference frame  $S'$  in standard configuration with  $S$  and moving with a velocity  $V$  relative to  $S$ , the trajectory of the particle is given by

$$x' = \frac{x_0}{\gamma\left(1 - \frac{vV}{c^2}\right)} + \frac{(v - V)t'}{\left(1 - \frac{vV}{c^2}\right)} \quad [6 \text{ marks}]$$

**Q6** A wave in a string has its displacement  $y$  in meters represented by

$$y(x, t) = 0.1 \cos\left[\left(\frac{\pi}{2}\right)x - (100\pi)t\right].$$

(a) Obtain

(i) the wavelength  $\lambda$  of the waves on the string, [3 marks]

(ii) the frequency  $f$  of the waves on the string and [3 marks]

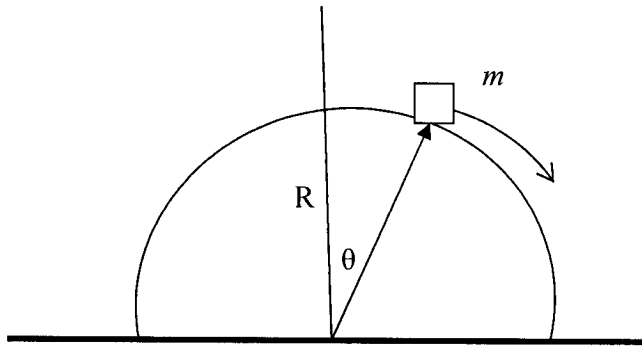
(iii) the velocity of the wave motion. [2 marks]

(b) Make a sketch of the displacement showing how the string looks for two ( $2\lambda$ ) wavelengths. [4 marks]

(c) Calculate the value of  $y$  when  $x = 5$  m and  $t = 5$  sec and clearly mark it on your graph [4+2 marks]

(d) How many wavelengths does the wave travel in 1 sec? [2 marks]

Q7(a)



A particle of mass  $m$  sliding off a fixed frictionless hemisphere of radius  $R$  as shown in the figure above. The particle is therefore subject to a steep potential  $V(r)$  due to the hemisphere. Assuming that in the real world the radius  $r$  is not constrained to  $R$ , then the Lagrangian of the system is given by

$$L = \frac{1}{2}m(\dot{r}^2 + r^2\dot{\theta}^2) - mgr \cos \theta - V(r).$$

Show that the resulting equation of motion for  $\theta$  resembles that of the equation of motion for a simple pendulum. **[8 marks]**

- (b) A solid sphere of mass  $m$  and radius  $R$  rolls down an inclined plane without slipping. Assuming that the plane is inclined at an angle  $\theta$ , show that the Hamiltonian of the sphere is

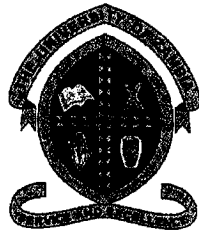
$$H = \frac{5}{14} \frac{p_x^2}{m} - mgx \sin \theta \quad \textbf{[10 marks]}$$

where direction down the plane is taken to be  $x$ .

- (c) State one major difference between the Lagrangian and the Hamiltonian formalism in terms of the generalized coordinates. **[2 marks]**

\*\*\*\*\*END OF EXAMINATION\*\*\*\*\*





# **The University of Zambia**

**School of Natural Sciences**

**Department of Physics**

**2016/2017 Academic Year**

**End of 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

$$e = 1.602 \times 10^{-19} \text{ C}$$

$$m_e = 1.6 \times 10^{-27} \text{ kg}$$

$$m_p = 9.11 \times 10^{-31} \text{ kg}$$

$$\epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2 \text{N}^{-1} \text{m}^{-2}$$

$$h = 6.63 \times 10^{-34} \text{ J s}$$

$$\mu_0 = 4\pi \times 10^{-7} \text{ N s}^2 \text{C}^{-2}$$

$$c \cong 3.0 \times 10^8 \text{ m/s}$$

$$1 \text{ \AA} = 0.1 \text{ nm}$$

$$n_{\text{water}} = 1.33$$

$$n_{\text{glass}} = 1.5$$

$$n_{\text{air}} = 1$$

# FORMULAE THAT MAY BE USEFUL

$n_1 \sin \theta_1 = n_2 \sin \theta_2$	$\frac{1}{f} = \frac{1}{s_o} + \frac{1}{s_i}$	$\frac{n_1}{s_o} + \frac{n_2}{s_i} = \frac{n_2 - n_1}{R}$
$\frac{1}{f} = \left( \frac{n_2}{n_1} - 1 \right) \left( \frac{1}{R_1} - \frac{1}{R_2} \right)$	$M_T = \frac{y_i}{y_o}$	$D = P = \frac{1}{f}$
$u_E = \frac{1}{2} \epsilon_o E^2$	$u_B = \frac{1}{2 \mu_o} B^2$	$l_o n_1 + l_i n_2 = \text{const.} = s_o n_1 + s_i n_2$
$\psi(x, t) = A \sin k(x - vt)$	$v = \frac{1}{\sqrt{\mu_o \epsilon_o}}$	$M_T = \frac{-s_i}{s_o}$
$M_T = \frac{-x_i}{f} = -\frac{f}{x_o}$	$n = \frac{\sin \theta_i}{\sin \theta_r}$	$M_T = \frac{f_1 s_i}{d(s_o - f_1) - s_o f_1}$
$f_o = \frac{n_1}{n_2 - n_1} R$	$M_T = M_{T1} M_{T2}$	$s_i = \frac{f_2 d - [f_1 f_2 s_o / (s_o - f_1)]}{d - f_2 - [f_1 s_o / (s_o - f_1)]}$
$x_i x_o = f^2$	$k = \frac{2\pi}{\lambda}$	$n \equiv \frac{c}{v} = \sqrt{\frac{\epsilon \mu}{\epsilon_o \mu_o}}$
$v = v \lambda$	$\omega = kv = ck = 2\pi v$	$\frac{1}{v^2} \frac{\partial^2 \psi(x, t)}{\partial t^2} = \frac{\partial^2 \psi(x, t)}{\partial t^2}$
$\psi(x, t) = A \sin(kx - \omega t + \xi)$	$v = \frac{1}{\sqrt{\mu_o \epsilon_o}}$	$E_o = \frac{1}{\sqrt{\mu_o \epsilon_o}} B_o$
$\frac{\partial E_z}{\partial y} = -\frac{\partial B_x}{\partial t}$	$\frac{\partial B_x}{\partial y} = -\mu_o \epsilon_o \frac{\partial E_z}{\partial t}$	$\mu_o \epsilon_o \frac{\partial^2 E_z}{\partial t^2} = \frac{\partial^2 E_z}{\partial y^2}$
$\mu_o \epsilon_o \frac{\partial^2 B_x}{\partial t^2} = \frac{\partial^2 B_x}{\partial y^2}$	$E_z(y, t) = E_o \sin(ky \pm \omega t)$	$B_x(y, t) = B_o \sin(ky \pm \omega t)$
$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$	$D = D_1 + D_2$	$b.f.l. = \frac{f_2(d - f_1)}{[d - (f_1 + f_2)]}$
$\text{O.P.L.} = \int_s^p n(s) ds$	$\sin \theta_c = n_{ii}$	$f.f.l. = \frac{f_1(d - f_2)}{[d - (f_1 + f_2)]}$

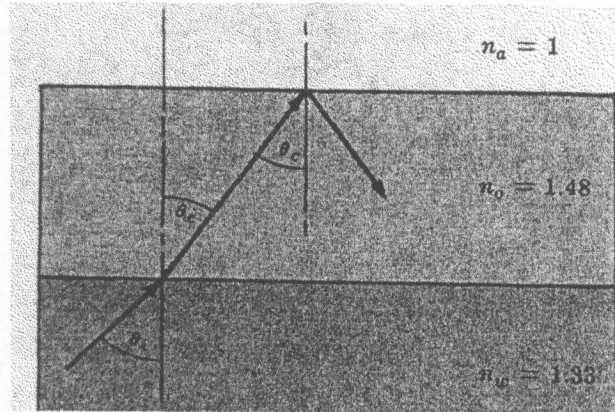
$f_i = \frac{n_2}{n_2 - n_1} R$	$h_1 = -\frac{f(n_1 - 1)d}{R_2 n_1}$	$b.f.l. = f + h_2$
$f.f.l. = f + h_1$	$h_2 = -\frac{f(n_1 - 1)d}{R_1 n_1}$	$\frac{1}{f} = (n - 1) \left[ \frac{1}{R_1} - \frac{1}{R_2} + \frac{(n_1 - 1)d}{n_1 R_1 R_2} \right]$

## Question 1

(a) What is the wavefunction?

[ 1 ]

(b) A tank of water ( $n_w = 1.33$ ) is covered with a 2-cm thick layer of oil ( $n_o = 1.48$ ) above which is air ( $n_a = 1.00$ ) as shown in the figure below. What angle must a beam of light, originating in the tank, make at the water-oil interface if no light is to escape? [ 3 ]



(c) The solutions to Maxwell's equations for electromagnetic radiation in free space for an oscillating electric field in the  $yz$ -plane and an oscillating magnetic field in the  $xy$ -plane satisfy the following two equations

$$\frac{\partial E_z}{\partial y} = -\frac{\partial B_x}{\partial t} \quad , \quad \frac{\partial B_x}{\partial y} = -\mu_0 \epsilon_0 \frac{\partial E_z}{\partial t} \quad .$$

(i) Use these equations to derive the wave equations for the electric and magnetic fields

$$\mu_0 \epsilon_0 \frac{\partial^2 E_z}{\partial t^2} = \frac{\partial^2 E_z}{\partial y^2} \quad , \quad \mu_0 \epsilon_0 \frac{\partial^2 B_x}{\partial t^2} = \frac{\partial^2 B_x}{\partial y^2}$$

[ 8 ]

(ii) Show that  $E_z(y, t) = E_o \sin(ky - \omega t)$  is a solution to the electric field vector wave equation and

[ 3 ]

(iii)  $B_x(y, t) = B_o \sin(ky - \omega t)$  is a solution to the magnetic field vector wave equation.

[ 3 ]

- (d) Consider an interface between two regions, one of glass ( $n_g = 1.50$ ) and the other of water ( $n_w = 1.33$ ). A ray travelling in the glass impinges on the interface at  $43^\circ$  and refracts into water. What is the transmission angle? [ 2 ]

## Question 2

- (a) What kind of thick lens made of glass immersed in air will have a focal length which is independent of its thickness? [ 1 ]

- (b) Given that the wavefunction (in SI units) for a light wave to be

$$\psi(x, t) = 10^2 \sin[\pi(3 \times 10^6 x - 9 \times 10^{14} t)]$$

Determine the

- (i) speed, [ 2 ]
  - (ii) wavelength, [ 2 ]
  - (iii) frequency, [ 1 ]
  - (iv) period, [ 1 ]
  - (v) and amplitude. [ 1 ]
- (c) Light from a sodium lamp ( $\lambda_0 = 589 \text{ nm}$ ) passes through a tank of glycerine (of refractive index 1.47) 20 m long in a time  $t_1$ . If it takes a time  $t_2$  to traverse the same tank when filled with carbon disulphide (of refractive index 1.63), determine the difference  $t_2 - t_1$ . [ 4 ]
- (d) 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) Describe the relationship between  $\theta_i$  and  $\theta_r$  both when  $n_i > n_r$  and  $n_i < n_r$ . [ 8 ]
- (b) Write an expression for the particular Cartesian ovoid whose object and image distances are 9 cm and 10 cm, respectively. Assume it to be made of glass ( $n_g = 1.5$ )

and surrounded by air ( $n_a = 1$ ). Sketch the interface showing  $l_o$  values of 10 and 11 clearly. [ 7 ]

- (c) Suppose that a glass rod ( $n_g = 1.50$ ) is immersed in water ( $n_w = 1.33$ ) with the left end ground to a convex hemisphere of 2 cm radius. If the point source is located 6 cm to the left vertex of the hemisphere, where will its image appear? Will the resulting image be real or virtual? [ 5 ]

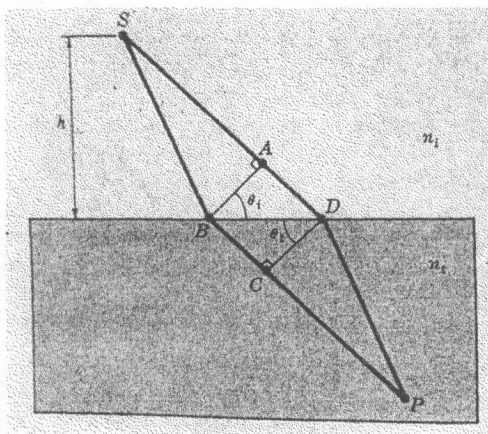
## Question 4

- (a) Writing the wave function as

$$\psi = Ae^{i\varphi}$$

where  $A$  is the amplitude of the wave, show that it is unchanged when its phase is increased or reduced by  $2\pi$ . [ 4 ]

- (b) Use the alternative statement of Fermat's principle to arrive at Snell's law of refraction without calculus. Consider the following diagram which shows refraction at an interface for your derivation.



[ 9 ]

- (c) A point source ( $S$ ) is located on the axis of, and 30 cm from, a plano-concave thin lens. Suppose that the glass lens is immersed in air ( $n_{lm} = 1.5$ ) and that it has a radius of

5 cm. Determine the location of the image

- (i) When the flat surface is toward  $S$  and [ 4 ]

- (ii) When the curved surface is toward  $S$ . [ 3 ]

### Question 5

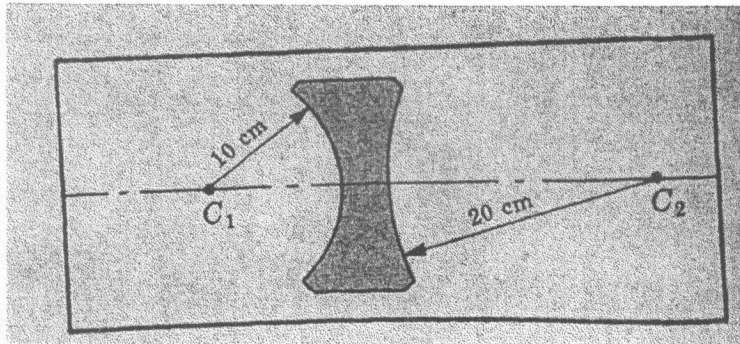
- (a) Distinguish between optical and geometrical path. [ 1 ]
- (b) Use Fermat's principle (calculus version) to arrive at the law of reflection. Show an associated diagram representing the derivation. [ 9 ]
- (c) A double convex lens has radii of 5 cm, a thickness of 2 cm and an index of refraction of 1.5.
- (i) Locate the focal length referenced from each of the principal planes [ 2 ]
  - (ii) Determine the principal points distance,  $h_1$  and  $h_2$ , from each vertex [ 4 ]
  - (iii) Compute the image distance for an object 16.5 cm in front of  $V_1$  [ 2 ]
  - (iv) Determine the values of the front focal length and the back focal length.

[ 2 ]

### Question 6

- (a) (i) Why doesn't the frequency of light change during refraction? [ 1 ]
- (ii) In what instance and why would the colour of light change when the wave propagates from one medium into another medium? [ 2 ]
- (b) The velocity of light in air is  $3.0 \times 10^8$  m/s. Find the velocity and wavelength of sodium light in glass of refractive index 1.658. The wavelength of sodium light in air is 5893 Å. [ 7 ]
- (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 ( $n_m = 1.63$ ).
- (ii) Is the resultant lens' effect diverging or converging the rays impinging on it from its left side?





[ 3 ]

(d) The amplitude coefficients of reflection and transmission are given by

$$r_{\parallel} = \frac{n_i \cos \theta_i - n_t \cos \theta_t}{n_i \cos \theta_i + n_t \cos \theta_t}, \quad r_{\perp} = \frac{n_i \cos \theta_i - n_t \cos \theta_t}{n_i \cos \theta_i + n_t \cos \theta_t}$$

and

$$t_{\parallel} = \frac{2n_i \cos \theta_i}{n_i \cos \theta_i + n_t \cos \theta_t}, \quad t_{\perp} = \frac{2n_i \cos \theta_i}{n_i \cos \theta_i + n_t \cos \theta_t}$$

respectively for the cases arising when the **E**-field is parallel and perpendicular to the plane of incidence.

(i) Derive expressions for each of these amplitude coefficients at normal incident (where  $\theta_i \approx \theta_t \approx 0$ ) and compute their numerical values at an air-glass interface where  $n_t = 1.5$ . [ 5 ]

(ii) In a case where  $n_i > n_t$ , what happens to the light impinging on the interface when  $\theta_i > \theta_c$  (the critical angle)? [ 2 ]

## Question 7

(a) What is the photon energy in joules corresponding to a 50-Hz wave emitted from an electric power line? How does this compare with the energy range for light, i.e.,  $3.8 \times 10^{14}$  to  $7.7 \times 10^{14}$  Hz? [ 5 ]

(b) A beam of collimated light travelling in air makes an angle of  $30^\circ$  to the normal to the glass plate. If the refractive index of the glass is 1.50, determine the direction of the transmitted beam within the plate. Draw a diagram to illustrate the situation. [ 4 ]

- (c) It is required that a real image twice the size of the object be formed by a thin plano-convex lens. If the lens has a radius of curvature of 50 cm and a refractive index of  $n_{lm} = 1.50$ , determine the locations of the object and image with respect to the lens by use of the
- (i) Newtonian formulation and [ 8 ]
  - (ii) Gaussian formulation. [ 3 ]

**End of PHY 2712 Examination**



# The University of Zambia

School of Natural Sciences

Department of Physics

2016/17 Academic Year

End of Year University Examinations

**PHY3032: Computational Physics I**

Answer **any four** 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.

=====

## Physical Constants

Standard atmosphere, 1 atm = 101325 Pa	Density of water at 20°C, $\rho_{\text{water}} = 1000 \text{ kg/m}^3$
Specific heat capacity of oil is 1450 J/kg.K	Elementary charge $q = 1.602176462 \times 10^{-19} \text{ C}$
Density of mercury at 20°C, $\rho_{\text{mercury}} = 13600 \text{ kg/m}^3$	Universal gas constant $R = 8.314472 \text{ J mol}^{-1} \text{ K}^{-1}$
Planck constant $h = 6.62606876 \times 10^{-34} \text{ J.s}$	Boltzmann's constant $k = 1.3806503 \times 10^{-23} \text{ J K}^{-1}$
Reduced Planck constant $\hbar = h/2\pi = 1.054571800 \times 10^{-34} \text{ J.s/rad}$	Acceleration due to gravity $g = 9.80665 \text{ m.s}^{-2}$
Stefan-Boltzmann constant $\sigma = 5.6704 \times 10^{-8} \text{ Wm}^{-2}\text{K}^{-4}$	Specific heat capacity of water $c_w = 4184 \text{ J/kg.K}$
Speed of light in vacuum $c = 2.99792 \times 10^8 \text{ m/s}$	Proton mass, $m_p = 1.67262158 \times 10^{-27} \text{ kg}$
Gravitation constant $G = 6.67384 \times 10^{-11} \text{ Nm}^2\text{kg}^{-2}$	Electron mass, $m_e = 9.1093888 \text{ kg}$
Avogadro constant $N_A = 6.02214199 \times 10^{23} \text{ mol}^{-1}$	Magnetic constant $\mu_0 = 4\pi \times 10^{-7} \text{ NA}^{-2}$

## **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  $n^{\text{th}}$  derivative of  $f(x)$ .

### **2. LAGRANGE INTERPOLATION**

Consider a set of  $n+1$  data points  $(x_0, y_0), (x_1, y_1), (x_2, y_2), \dots, (x_n, y_n)$ . 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  $k=0, 1, 2, \dots, n$ ,

$$\text{or } L_k(x) = \frac{[x - x_0][x - x_1][x - x_2] \dots [x - x_{k-1}][x - x_{k+1}] \dots [x - x_n]}{[x_k - x_0][x_k - x_1][x_k - x_2] \dots [x_k - x_{k-1}][x_k - x_{k+1}] \dots [x_k - x_n]}.$$

### **3. Linear Least Squares Fitting**

Consider a set of  $N$ -data points  $[(x_i, y_i) | i=1, 2, 3, \dots, N]$ . Assuming a straight line model of the form  $y = a_0 + a_1 x$  is fitted to the data, then the best-fit straight line is obtained if the

intercept is given by  $a_0 = \frac{S_{xx}S_y - S_xS_{xy}}{NS_{xx} - S_x^2},$

and the gradient by  $a_1 = \frac{NS_{xy} - S_xS_y}{NS_{xx} - S_x^2},$

where  $N = \sum_{i=1}^N 1$ ,  $S_x = \sum_{i=1}^N x_i$ ,  $S_y = \sum_{i=1}^N y_i$ ,  $S_{xx} = \sum_{i=1}^N x_i^2$ ,  $S_{xy} = \sum_{i=1}^N x_i y_i$  and  $S_{yy} = \sum_{i=1}^N y_i^2$ .

4. **ALGORITHM BISECTION METHOD**  $[f, a, b, \varepsilon, N_{\max}]$

**INPUT:**  $a, b$  and  $\varepsilon > 0$ .

**OUTPUT:** Approximate solution  $x_m$  ( $n \leq N_{\max}$ ) or message of failure.

**For**  $n = 1, 2, 3, \dots, N_{\max}$  **do:**

Compute  $f_1 = f(a)$ ,  $f_2 = f(b)$  and  $g = f_1 f_2$ .

**IF**  $g > 0$ , **THEN**

**OUTPUT:** "No root between  $a$  and  $b$ . Initial are Wrong".

**GOTO** 200

**ELSEIF**  $g < 0$  **THEN**

100      Compute  $x_m = \frac{a+b}{2}$  and  $f(x_m)$

**IF**  $|f(x_m)| \leq \varepsilon$  **THEN**

**OUTPUT:** Solution  $x_m$  obtained. **GOTO** 200

**ELSE**  $h = f(x_m)$  and  $g_1 = f_1 h$

**IF**  $g_1 > 0$  **THEN**  $a = x_m$  and  $f_1 = h$

**ELSE**  $b = x_m$  and  $f_2 = h$

**GOTO** 100

**OUTPUT:** "Failure: Procedure completed unsuccessfully after  $N_{\max}$  iterations"

200      **STOP**

**END BISECTION**

5. **ALGORITHM**      NEWTON RAPHSON ( $f, f', x_0, \varepsilon, N_{\max}$ )

**INPUT:**  $x_0, \varepsilon > 0$  and  $N_{\max}$ .

**OUTPUT:** Approximate solution of  $x_i$  where  $i \leq N_{\max}$  or message of failure

**For**  $i = 1, 2, 3, 4, \dots, N_{\max}$ .

Compute  $f'(x)$ . IF  $f'(x) = 0$  then OUTPUT "Failure". STOP. [Procedure unsuccessful due to zero first derivative]

ELSE Compute  $u_{0,i} = \frac{f(x)}{f'(x)}$  and  $x_{i+1} = x_i - u_{0,i}$ ,

IF  $|x_{i+1} - x_i| \leq \varepsilon$  then OUTPUT  $x_{i+1}$ . Stop [Procedure successful after  $i + 1$  iterations]

OUTPUT "Failure". Stop [Procedure unsuccessful after  $N_{\max}$  iterations]

**END NEWTON RAPHSON**

6. **ALGORITHM**      HALLEY'S ALGORITHM ( $f, f', f'', x_0, \varepsilon, N_{\max}$ )

**INPUT:**  $x_0, \varepsilon > 0$  and  $N_{\max}$ .

**OUTPUT:** Approximate solution of  $x_i$  where  $i \leq N_{\max}$  or message of failure

**For**  $i = 1, 2, 3, 4, \dots, N_{\max}$ .

Compute  $f'(x_0)$ . IF  $f'(x_0) = 0$  then OUTPUT "Failure". STOP. [Procedure unsuccessful due to zero first derivative]

ELSE Compute  $f''(x_0)$ ,  $u_{0,i} = \frac{f(x)}{f'(x)}$ ,  $u_{2,i} = \frac{f''(x_0)}{f'(x_0)}$  and  $x_{i+1} = x_i - u_{0,i} - \frac{1}{2} [u_{0,i}]^2 u_{2,i}$ .

IF  $|x_{i+1} - x_i| \leq \varepsilon$  then OUTPUT  $x_{i+1}$ . Stop [Procedure successful after  $i + 1$  iterations]

OUTPUT "Failure". Stop [Procedure unsuccessful after  $N_{\max}$  iterations]

**END HALLEY'S ALGORITHM**

7. **ALGORITHM: COMPOSITE TRAPEZOIDAL RULE** ( $x_i, f_i, i = 0, 1, 2, \dots, n$ )

INPUT:  $a, b$  and  $n > 0$ . OUTPUT: Approximate Integral  $G$

$$h = \frac{b-a}{n}, V = f(a) + f(b) \text{ and } W = 0.$$

For  $i = 1, 2, 3, \dots, N-1$ , set

$$x = a + ih \text{ and } W = W + f(x)$$

$$\text{Compute } G = \frac{h}{2}[V + 2W]$$

**END COMPOSITE TRAPEZOIDAL RULE**

8. **ALGORITHM COMPOSITE SIMPSON RULE** ( $x_i, f_i, i = 0, 1, 2, \dots, n$ )

INPUT:  $a, b$ ;  $m \geq 1$  with  $n = 2m$ . OUTPUT: Approximate Integral to  $G$ .

$$h = \frac{b-a}{n}, \text{ where } n = 2m, U = f(a) + f(b), V = 0, \text{ and } W = 0.$$

For  $i = 1, 2, 3, 4, \dots, n-1$ , set  $x = a + ih$

If  $i$  is even then set  $V = V + f(x)$  ELSE  $W = W + f(x)$ .

$$\text{Set } G = \frac{h}{3}[U + 2V + 4W]. \quad \text{OUTPUT } [G]$$

**END COMPOSITE SIMPSON RULE**

9. **ALGORITHM EULER-CAUCHY** ( $f, x_0, y_0, h, N$ )

INPUT:  $x_0, y_0, h$  and  $N$ . OUTPUT: Approximation  $y_{i+1}$

For  $i = 0, 1, 2, 3, \dots, N-1$ ,  $x_{i+1} = x_i + h$  and  $y_{i+1} = y_i + hf(x_i, y_i)$

OUTPUT  $x_{i+1}, y_{i+1}$

**End**

**END EULER-CAUCHY**

10. **ALGORITHM RUNGE-KUTTA**  $(f, x_0, y_0, h, N)$

**INPUT:**  $x_0, y_0, h$  and  $N$

**OUTPUT:** Approximation  $y_{i+1}$

**For**  $i=0,1,2,3,\dots,N-1$  **do:**

$$k_1 = hf(x_i, y_i), k_2 = hf\left(x_i + \frac{1}{2}h, y_i + \frac{1}{2}k_1\right), k_3 = hf\left(x_i + \frac{1}{2}h, y_i + \frac{1}{2}k_2\right)$$

$$k_4 = hf(x_i + h, y_i + k_3), x_{i+1} = x_i + h, y_{i+1} = y_i + \frac{1}{6}[k_1 + 2k_2 + 2k_3 + k_4]$$

**OUTPUT**  $x_{i+1}, y_{i+1}$

**END RUNGE-KUTTA**

11. **ALGORITHM RUNGE – KUTTA – NYSTRÖM**  $(f, x_0, y_0, y'_0, h, N)$

**INPUT:**  $x_0, y_0, y'_0$  step size  $h$  and number of steps  $N$ .

**OUTPUT:** Approximation  $y_{i+1}$ .

**For**  $i=0,1,2,3,\dots,N-1$  **set**

$$k_1 = \frac{1}{2}hf(x_i, y_i, y'_i), M = \frac{1}{2}h\left[y'_i + \frac{1}{2}k_1\right], k_2 = \frac{1}{2}hf\left(x_i + \frac{1}{2}h, y_i + M, y' + k_1\right),$$

$$k_3 = \frac{1}{2}hf\left(x_i + \frac{1}{2}h, y_i + M, y'_i + k_2\right), L = h\left[y'_i + k_3\right], k_4 = \frac{1}{2}hf(x_i + h, y_i + L, y'_i + 2k_3),$$

$$x_{i+1} = x_i + h, y_{i+1} = y_i + h\left[y'_i + \frac{1}{3}[k_1 + k_2 + k_3]\right].$$

**OUTPUT**  $x_{i+1}, y_{i+1}$

$$y'_{i+1} = y'_i + \frac{1}{3}[k_1 + 2k_2 + 2k_3 + k_4]$$

**END RUNGE – KUTTA – NYSTRÖM**



- 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) RANK of a Fortran array and SIZE of a Fortran array. [4]
- (b) Show that an unformatted computer storage device with a rating of 1Terabyte has 976562500 kibibytes. [5]

- Q2. (a) Consider the following Fortran 90 code:

```

IMPLICIT NONE
REAL :: y
REAL (KIND = 8) :: h, p, t
DOUBLE PRECISION :: x = 1.0d0 , w
INTEGER :: J, k = 9, m = 3
INTEGER(Kind = 8) :: n = 2, L = 7, f, s
COMPLEX :: z

w = n/K           ;    y = real(m)*real(k)
f = INT(y)        ;    J = mod(f,n)
h = dble(L/m)     ;    z = cmplx(h,J)
p = n**10         ;    s = int(imag(z))
t = dble(L)/dble(m)+ n - dble(J)*k

PRINT*, w, y, f
PRINT*, j, h, z
PRINT*, p, s, t

END PROGRAM

```

What numerical values [including appropriate number of decimal points whenever necessary] for w, y, f, j, h, z, p, s and t [in this order] would be displayed on a computer screen after program execution? [10]

- (b) The van der Waals equation of state is given by

$$\left[ P + \frac{a}{v^2} \right] [v - b] - RT = 0,$$

or  $f(P, v, T, a, b) = 0$ , where  $f(P, v, T, a, b) = \left[ P + \frac{a}{v^2} \right] [v - b] - RT$ ,

such that  $P$  is the gas pressure,  $v = V/n$  is its volume  $V$  per unit mole  $n$ ,  $T$  is absolute temperature,  $R = 0.0820578$  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

$$f(v) = \left[ P + \frac{a}{v^2} \right] [v - b] - RT.$$

Consider a sample of Oxygen gas at 5.0 atm pressure and temperature of 27°C. In the case of oxygen,  $a = 1.36$  litres<sup>2</sup>-atm/mol<sup>2</sup> and  $b = 0.003183$  litres/mol. Starting with initial guess 6.0 litres/mol and a tolerance of 0.0001, use the Halley's algorithm to estimate  $v$ . [15]

- Q3. (a) In order to determine how the time  $t$  for the energy exchange depends on the separation of two coupled pendulums, an experiment was set up as in Figure 1.

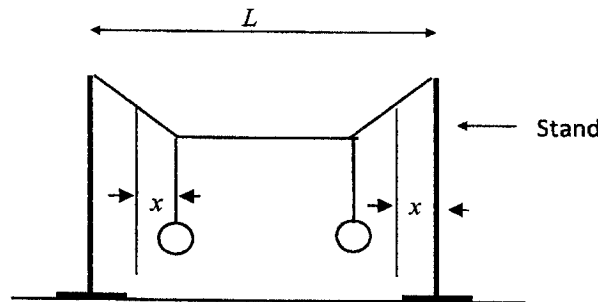


Figure 1 : Energy Exchange in Coupled Pendulums

The relation between the energy exchange time  $t$  and the distance  $x$  [see Figure 1] is assumed to be a power law of the form

$$t = \beta x^\alpha,$$

where  $\alpha$  and  $\beta$  are constants. This relation can be linearized as

$$\ln(t) = \ln(\beta x^\alpha) = \ln(\beta) + \alpha \ln(x),$$

suggesting that the constants  $\alpha$  and  $\beta$  can, respectively, be obtained from gradient and intercept of the linear relation of the graph of  $\ln(t)$  against  $\ln(x)$ .

The experimental data collected is shown in table 1. This data, together with headings, were saved in a text file called “**input.txt**”.

**Table 1: Data collected for the energy exchange in a coupled pendulum**

Distance $x$ [m]	Average time, $t$ [s]	$\log_e(x)$	$\log_e(t)$
0.17	6.94	-1.77	1.94
0.18	5.19	-1.71	1.65
0.19	4.21	-1.66	1.44
0.20	3.63	-1.61	1.29
0.21	2.95	-1.56	1.08
0.22	2.70	-1.51	0.99
0.23	2.12	-1.47	0.78
0.24	2.03	-1.43	0.71
0.25	1.89	-1.39	0.64
0.26	1.87	-1.35	0.63
0.27	1.74	-1.31	0.55

Write a Fortran 90 code that

- (i) uses the IOSTAT command in the READ statement, in a driver program, in order to automatically count the number  $n$  of data points in the file **input.txt**, [4]
- (ii) can identify an error in the data file [including the location of the error] if a non-numeric entry is included in **input.txt**. [2]
- (iii) implements linear least squares algorithm, through a subroutine called “LinearReg ( $n, a_0, a_1$ )”, taking the number counted data point  $N$  from the driver program in (i) and returns the gradient  $a_1$  and intercept  $a_0$  for the graph of  $\ln(t)$  against  $\ln(x)$ . Values of  $a_1$  and  $a_0$  should be written to screen in the driver program correct to 2 decimal places. [13]
- (iv) includes appropriate comments describing sections of code. [2]

- (b) Write a **gnuplot** script for plotting the graph  $t$  against  $x$  using data saved in the file **input.txt**. The graph should have axes labels, units and a title. [4]

- Q4. (a) In a classical mechanics experiment to determine the moment of inertia of a wheel, a student obtained data in Table 2.

Table 2: Table of mass against angular acceleration

$m$ [kg]	$\ddot{\theta} = a/r$ [rad/s <sup>2</sup> ]
0.50	14.30
0.70	23.60
0.80	28.80

Use the Quadratic Lagrange Interpolation to estimate the value of  $\ddot{\theta}$  when  $m = 0.60$  kg correct to 2 decimal places. [5].

- (b) A student modeled the time dependent alternating voltage  $v(t)$  in a system as

$$v(t) = V_0 \sin(100\pi t + \pi/3),$$

where  $t$  is time and  $V_0 = 350$  volts. In order to get numerical values of  $v(t)$  against  $t$  correct to 3 decimal places in time steps of 0.001s for  $0 \leq t \leq 10$ s, the student wrote the following code. However, this Fortran 90 code could be compiled due to errors. Identify the 10 errors in the code and write correct code without changing the general format of the given code.

```

PROGRAM driver
IMPLICIT NONE
REAL (kind=4) :: t, tmax, dt=0.001
OPEN(1,file="volt.txt")
DO WHILE (t.gt.tmax)
    write(2,*) t, v(t)
    t= t + 1
ENDDO
1000 FORMAT (2f10.7)
END PROGRAM driver
REAL FUNCTION v(t)
IMPLICIT NONE
REAL (KIND=4 ):: pi =4.0d0*atan(1.d0),Vo=350
REAL (KIND=4 ) :: phase, t
V(t)=Vo*sin(wf*t + phase)
RETURN
END FUNCTION

```

[10]

- (c) The velocity of a particle moving in a straight line is given by

$$\frac{dx}{dt} = 1 - 2e^{-0.5t}; \quad x(t_0) = 1.0 \text{ m}, \quad t_0 = 0.$$

Apply the Euler – Cauchy algorithm to the above initial value problem, choosing a step size of  $\Delta t = 0.1$  s, and show that the position of the particle after 0.5 s is about  $x = 0.5371$  m. **Note:**  $t = t_0 + n\Delta t$  for  $n = 0, 1, 2, 3, 4, 5, \dots$ . [10]

- Q5. (a) Numerical approximation of values needed in the construction of a Cornu spiral in Fresnel diffraction involves, in part, evaluation of the Fresnel Cosine integral, namely

$$C(u) = \int_0^u \cos\left(\frac{\pi}{2}x^2\right)dx.$$

Use the Simpsons rule, with 10 subintervals, to show that

$$C(1) \approx 0.779911. \quad [13]$$

- (b) Prove that the Newton-Raphson algorithm has a second order convergence. [5]

- (c) The factorial of any positive integer  $n$  is given by

$$n! = n[n-1][n-2][n-3] \dots \times 4 \times 3 \times 2 \times 1$$

and  $0! = 1$ .

Use the “INTEGER (KIND = 8)” to write a Fortran 90 code that can evaluate  $n!$  for  $n \leq 20$  supplied via a computer keyboard. [7]

- Q6. The differential equation of motion governing torsional vibrations of a disc attached to an elastic wire is given by

$$I_0 \frac{d^2\theta}{dt^2} = -\gamma \frac{d\theta}{dt} - C\theta,$$

where  $I_0$  is the polar moment of inertia of the wheel about its centre,  $C$  is the torsional stiffness [i.e. twisting couple per unit twist or torsional rigidity] of the wire,  $\theta$  is the angle measured from the state of equilibrium,  $t$  is time while  $\gamma \geq 0$  is the damping constant. This differential equation can be expressed as

$$\frac{d^2\theta}{dt^2} = -\alpha \frac{d\theta}{dt} - \omega^2\theta$$

or  $\ddot{\theta} = -\alpha\dot{\theta} - \omega^2\theta$

where  $\alpha = \gamma/I_0$ ,  $\omega = \sqrt{C/I_0}$ ,  $\dot{\theta} = d\theta/dt$  and  $\ddot{\theta} = d^2\theta/dt^2$ .

In the special case when  $\alpha$  and  $\omega$  are constants, the differential equation of motion with initial conditions  $\theta_0 = \theta(t=0)$  and  $\dot{\theta}_0 = \dot{\theta}(t=0)$  can be expressed as

$$\ddot{\theta} = \ddot{\theta}(t, \theta, \dot{\theta}); \text{ with } \theta_0 = \theta(t=0) \text{ and } \dot{\theta}_0 = \dot{\theta}(t=0).$$

Consider a torsion pendulum for which  $\omega^2 = C/I_0 = 13.69 \text{ s}^{-1}$  and  $\alpha = \gamma/I_0 = 0.5$ , with initial displacement  $\theta(t=0) = 0.2618 \text{ rad}$  and initial velocity  $\dot{\theta}(t=0) = 0.1745 \text{ rad/s}$ .

Write a Fortran 90 code that implements the Runge – Kutta – Nyström algorithm to this initial value problem in time steps of 0.001 s to

- (i) estimate values of  $\dot{\theta}$  and  $\theta$  for  $0 \leq t \leq 20\text{s}$  [22]
- (ii) write values of  $\dot{\theta}$  and  $\theta$  as  $0 \leq t \leq 20\text{s}$  to a file called "RKN.txt" with all entries given correct to 10 decimal places. [3]

**– END OF PHY3032 EXAMINATION –**

UNIVERSITY OF ZAMBIA  
DEPARTMENT OF PHYSICS  
UNIVERSITY EXAMINATIONS  
2016/17  
**PHY3531: INTRODUCTION TO QUANTUM MECHANICS**

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TIME: THREE HOURS  
ANSWER: ANY FOUR QUESTIONS  
ALL QUESTIONS CARRY EQUAL MARKS  
TOTAL MARKS: 100

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Useful information

$$j = \frac{\hbar}{2mi} (\Psi^* \frac{d}{dx} \Psi - \Psi \frac{d}{dx} \Psi^*), \quad \int_{-\infty}^{\infty} e^{-x^2} dx = \sqrt{\pi}$$

$$[AB, C] = A[B, C] + [A, C]B$$

$$[A, BC] = B[A, C] + [A, B]C$$

$$[L_i, L_j] = i\hbar L_k \text{ with } i, j \text{ and } k \text{ taken in cyclical order}$$

1. (a) (i) Interpret the wave function  $\Psi(x, t)$ . [2 marks]

Hence explain why the wave function must have the following properties

(ii)  $\Psi(x, t)$  is single-valued [2 marks]

(iii)  $\Psi(x, t)$  is continuous [2 marks]

(iv)  $\Psi(x, t) \rightarrow 0$  as  $x \rightarrow \pm\infty$ . [2 marks]

(b) (i) Show 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

$$\Psi(\mathbf{r}, t) = \psi(\mathbf{r})e^{-i\omega t}$$

[2 marks]

(iii) Show that for such a potential, the probability density is time-independent. [1 mark]

(iv) Show that the probability current density of the particle is not a function of the time. [3 marks]

(c) If the force acting on a particle is given by  $F(x) = -kx^{-2}$ , where  $k$  is a constant, write down the Schroedinger equation for the particle. [[4 marks]]

2. (a) Determine which of the operators defined below are Hermitian.

(i)  $A\psi(x) = \sqrt{\psi(x)}$  [2 marks]

(ii)  $A\psi(x) = -\frac{\hbar^2}{2m}\frac{d^2}{dx^2}\psi(x)$  [5 marks]

(iii)  $A\psi(x) = \psi(x)^*$ . [2 marks]

Note that the operators act on functions which vanish at infinity.

(b) The Hamiltonian of the one-dimensional harmonic oscillator is

$$H = -\frac{\hbar^2}{2m}\frac{d^2}{dx^2} + \frac{1}{2}m\omega^2x^2$$

while the ground-state wave function is

$$\psi(x, t) = A \exp(-bx^2) \exp(-i\omega t)$$



- (i) Explain why this wave function is acceptable over the range of motion  $-\infty < x < \infty$ . [2 marks]  
(ii) Calculate the normalisation constant  $A$ . [5 marks]  
(iii) Determine the ground-state energy if  $b = m\omega/2\hbar$  [9 marks]

**3.** A system consists of two particles, each of mass  $m$ , moving independently in the potential well

$$V(x) = \begin{cases} \infty & \text{for } x \leq 0, \ x \geq L, \\ 0 & \text{for } 0 \leq x \leq L \end{cases}$$

Using  $x_1$  for the coordinate of one particle and  $x_2$  for the coordinate of the other, the Hamiltonian for the system is

$$H(x_1, x_2) = \frac{\hbar^2}{2m} \left( \frac{\partial^2}{\partial x_1^2} + \frac{\partial^2}{\partial x_2^2} \right)$$

(i) Show that the time-independent Schroedinger equation of the system separates into the ordinary differential equations

$$\frac{\hbar^2}{2m} \frac{d^2}{dx_1^2} \psi_1(x_1) = E_1 \psi_1(x_1)$$

and

$$\frac{\hbar^2}{2m} \frac{d^2}{dx_2^2} \psi_2(x_2) = E_2 \psi_2(x_2)$$

[6 marks]

(ii) Hence show that the eigenfunctions of the system are given by

$$\Psi_{n_1, n_2}(x_1, x_2) = \frac{2}{L} \sin \left( \frac{n_1 \pi x_1}{L} \right) \sin \left( \frac{n_2 \pi x_2}{L} \right), \quad n_1, n_2 = 1, 2, 3, \dots$$

[12 marks]

while the energy eigenvalues are given by

$$E_{n_1, n_2} = \frac{\hbar^2 \pi^2}{2mL^2} (n_1^2 + n_2^2), \quad n_1, n_2 = 1, 2, 3, \dots$$

[2 marks]

(iii) Obtain the total wave function of the system. [2 marks]

(iv) Obtain the energy, the degree of degeneracy and the eigenfunctions for the two lowest energy states of the system. [3 marks]

4.(a) A particle of mass  $m$  is incident from the left on a potential of the form

$$\begin{aligned} V(x) &= 0, \quad x \leq 0 \quad (\text{Region I}) \\ &= V_1, \quad 0 < x < a \quad (\text{Region II}) \\ &= V_2, \quad x > a \quad (\text{Region III}) \end{aligned}$$

The energy of the particle is such that  $E > V_2$  while  $V_2 > V_1$ .

(i) Show that in the three regions the eigenfunction takes the following forms:

$$\psi_I(x) = Ae^{ikx} + Be^{-ikx}, \quad k = \sqrt{\frac{2mE}{\hbar^2}} \quad (\text{Region I})$$

$$\psi_{II}(x) = Ce^{iqx} + De^{-iqx}, \quad q = \sqrt{\frac{2m(E - V_1)}{\hbar^2}} \quad (\text{Region II})$$

$$\psi_{III}(x) = Fe^{i\lambda x}, \quad \lambda = \sqrt{\frac{2m(E - V_2)}{\hbar^2}} \quad (\text{Region III})$$

[10 marks]

(ii) Interpret each of the terms in the expressions above. [3 marks]

(ii) Show that the reflection and transmission coefficients  $R$  and  $T$  are given by

$$R = \frac{q}{k} \left| \frac{B}{A} \right|^2 \quad \text{and} \quad T = \frac{\lambda}{k} \left| \frac{F}{A} \right|^2$$

[6 marks]

(iii) Justify and write down the equations that would be used to determine  $B$  and  $F$  in terms of  $A$ . [3 marks]

(b) Obtain the angles between the angular momentum vector and the  $z$  axis for all allowed orientations for  $l = 1$ . [3 marks]

5. (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

$$[L_i, L_j] = i\hbar L_k, \quad (i, j, k) \text{ in cyclical order}$$

show that  $[L^2, L_z] = 0$ . [5 marks]

(iii) Explain the importance of the result in (ii). [2 marks]

(b) The components of the angular momentum  $\mathbf{L}$  in spherical polar coordinates are

$$L_x = i\hbar \left( \sin \varphi \frac{\partial}{\partial \theta} + \cot \theta \cos \varphi \frac{\partial}{\partial \varphi} \right),$$

$$L_y = i\hbar \left( -\cos \varphi \frac{\partial}{\partial \theta} + \cot \theta \sin \varphi \frac{\partial}{\partial \varphi} \right)$$

and

$$L_z = -i\hbar \frac{\partial}{\partial \varphi}.$$

You are also given that for  $l = 1$ ,  $Y_{11}(\theta, \phi) = A_1 \sin \theta e^{i\phi}$

(i) Show that the ladder operators are

$$L_{\pm} = \hbar e^{\pm i\varphi} \left( \pm \frac{\partial}{\partial \theta} + i \cot \theta \frac{\partial}{\partial \varphi} \right)$$

[7 marks]

(ii) Prove that the unnormalised forms of  $Y_{10}(\theta, \phi)$  and  $Y_{1-1}(\theta, \phi)$  are

$$Y_{10}(\theta, \phi) = A_0 \cos \theta$$

and

$$Y_{1-1}(\theta, \phi) = A_{-1} \sin \theta e^{-i\phi}$$

[4 marks]

(iii) Prove that the three functions are the correct eigenfunctions of  $L_z$  [3 marks]

**6. (a)** The wave function of a certain particle whose motion is confined to the negative  $x$  axis is  $\Psi(x, t) = C e^{ip_0 x / \hbar + i x a} e^{-i\omega t}$  where  $C$  is a normalisation constant.

(i) Obtain the position probability density of the particle. [2 marks]

(ii) Determine the constant  $C$ . [4 marks]

(iii) Obtain the probability that a measurement of the position of the particle finds a value lying between  $x = -5$  and  $x = 0$ . [4 marks]

(iv) Obtain the probability that a measurement of the position of the particle finds the particle between  $x = -10 - 10^{-12}$  and  $x = -10$ . [2 marks]

(v) Obtain the expectation value of the position [3 marks]

- (vi) Obtain the probability current density of the particle. [4 marks]
- (b) A particle is incident from the left on a square potential barrier of height  $V_0$  with edges at  $x = 0$  and  $x = L$ . If the particle energy is  $E < V_0$ ,
- (i) Show that according to quantum mechanics the particle can tunnel to the other side of the barrier. [2 marks]
- (ii) Contrast this behaviour with the classical behaviour. [2 marks]
- (iii) Give one phenomenon explained by means of this behaviour. [2 marks]



## The University of Zambia

### Department of Physics

#### Fundamentals of Medical Physics, PHY 4242

#### Final Examination Academic Year 2016/17

**All questions carry equal marks. The marks are shown in brackets.**

**Time: 3 hours.**

**Maximum marks = 100**

#### **Instructions:**

Attempt any 4 questions, all questions carry equal marks

#### **Useful Equations:**

$$SI = \frac{4500}{\left(\frac{v}{c}\right)^2} \quad \frac{\text{Radiation energy loss}}{\text{Ionisation energy loss}} = \frac{E_k Z}{820} \quad I = I_0 e^{-\mu x} \quad HVL = \frac{\ln 2}{\mu}$$

$$\mu_{en} = \mu \frac{E_a}{h\nu} \quad \lambda = \frac{1.24}{h\nu} \text{ (nm)} \quad \Delta\lambda = 0.00243(1 - \cos\phi) \quad E_{\max} = h\nu_{\max} = \frac{hc}{\lambda_{\min}}$$

$$\Phi = \frac{N}{A} \quad \phi = \frac{\Phi}{t} = \frac{N}{At} \quad \Psi = \Phi E = \frac{NE}{A} \quad I = \psi = \phi E = \frac{NE}{At}$$

$$I = \psi = \sum_{i=1}^m f_i \phi E_i \quad X = \frac{Q}{m}, \quad \frac{\Phi}{X} = \frac{2.11 \times 10^{14}}{h\nu(\mu_{en})_m} \quad D(\text{Gy}) = \frac{E/m}{1\text{J/kg}}$$

$$DE(\text{Sv}) = D(\text{Gy}) \times QF \quad ED(\text{mSv}) = D(\text{mGy}) \times W_R \quad E = JW$$

$$\Psi = \frac{JW}{\rho(\mu_{en})_m} \quad \frac{V}{X} = \frac{1.29v}{C + C_e}$$

#### **Constants:**

W = 33.85eV : Avagadro's number =  $6.023 \times 10^{23}$ /mol : 1R =  $2.58 \times 10^{-4}$ C/kg-air  
 1 R = 1electrostatic unit (ESU)/0.001293 g air = 1 ESU/cm<sup>3</sup> air at STP

- Q 1**      **a)** A mono-energetic narrow beam of  $\gamma$ -rays is attenuated by copper in the manner shown below. Plot the data semi-logarithmically and determine the HVL and total linear coefficient of the beam.

Cpm	6000	1800	545	166	49
Thickness, cm	0	1	2	3	4

[6]

- b)** Explain the term half-value layer (HVL) and how it relates to the beam of radiation. [3]

- c)** A narrow mono-energetic beam containing 12,000 photons is reduced to 6000 photons by a slab of aluminium 2 mm thick. What is the total linear attenuation coefficient of aluminium for the photons? [5]

- d)** Give a brief description, with the aid of a diagram, of how a radiation calorimeter is used to measure dose. [6]

- e)** A dose of 40 Gy is delivered uniformly to a 200 g mass of water. How much energy in joules is absorbed by each gram of water and by the entire mass? [5]

- Q 2**      **a)** Explain with the aid of diagrams what is meant by good geometry and bad geometry in relation to a radiation beam. [6]

- b)** A focal spot of apparent size 1.2 mm is projected from an X-ray tube. The true focal spot is 6 mm.

- i)** What is the target angle? [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)** Calculate the specific ionization (SI) and LET of 0.15 MeV electrons in air ( $v/c = 0.548$ ) by using an average W-quantity for electrons of 33.85 eV/IP. [4]

- d)** A thimble chamber with an air-equivalent wall receives an exposure of 0.02 C/kg in one minute. The volume of the chamber is 0.50 cm<sup>3</sup>. What is the ionization current from the chamber? [5]

- Q 3**      **a)** An abdominal X-ray beam uses  $10^{17}$  photons to expose film with an area of 30 cm x 40 cm for 0.2 second. Assume all photons have energy of 90 keV. Find:

- i)** The photon fluence

- ii) The photon flux
- iii) The energy fluence, and
- iv) The intensity I. [8]

**b)** Describe in detail the operation of a thimble chamber and state its advantages in comparison to the Free-air ionization chamber. [8]

**c)** Give a brief explanation of the principles on which the following dosimetry systems are based:

i) Photographic

ii) Chemical

iii) Solid-state [9]

**Q 4 a)** Copper has a density of  $8.9 \text{ g/cm}^3$  and a molecular mass of 63.56. The total attenuation of copper is  $9.10 \times 10^{-24} \text{ cm}^2/\text{atom}$  for 400 keV photons. What thickness (in cm) of copper is required to attenuate 50 keV photons to a quarter of the original number? [7]

**b)** A 180 keV photon is scattered at an angle of  $70^\circ$  during a Compton interaction. What is the energy of the scattered photon? [6]

**c)** 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 will be used as shielding material. How many half-value layers are required? How many centimeters of lead are required given that  $(\mu_{en})_{Pb} = 0.431 \text{ cm}^{-1}$ . [7]

**d)** Give a brief description of a basic CT scanner, including the basic operating principles and its advantage over conventional diagnostic X-ray radiographs. [5]

**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  $0.46 \text{ cm}^3$ . The capacitance is six times the capacitance of the charger-reader. What is the capacitance of the chamber? [10]

**c)** What is meant by term dose equivalent (DE)? Explain the relationship between the sievert and the rem. [3]

**d)** What is a gray (Gy) and how is it related to the rad? [2]

**Q 6 a)** Draw a well labelled diagram of a simplified X-ray tube with a rotating anode and heated filament. [10]

**b)** The tenth-value layer is the thickness of slab of matter necessary to attenuate the beam of X-rays or  $\gamma$ -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  $2.30/\mu$ , where  $\mu$  is the total linear attenuation coefficient. [5]

**c) i)** What is the purpose of a simulator?

**ii)** Why are multiple radiation beams often used for radiotherapy?

**iii)** In radiotherapy, what is a phantom? [5]

**d)** Explain the terms elastic and inelastic interactions and give examples of each interaction. [5]

**End of Exam**





**THE UNIVERSITY OF ZAMBIA  
SCHOOL OF NATURAL SCIENCES  
DEPARTMENT OF PHYSICS**

**2016/17 ACADEMIC YEAR FINAL EXAMINATION**

**PHY4442: DIGITAL ELECTRONICS II**

**TIME: THREE HOURS**

**MAXIMUM MARKS : 100**

**Attempt ANY FOUR questions  
All questions carry equal marks.  
The marks are shown in brackets.**

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## 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	02	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) What are microprocessor initiated operations?

[7]

(b) Explain with a figure the bus organization of the 8085 microprocessor. Discuss the function of each bus.

[9]

(c) Simplify the following function using the Karnaugh map technique.

[9]

$$F = \sum m(0, 1, 2, 3, 4, 6, 8, 9, 10, 11, 12, 13, 14, 15)$$

Q2. (a) (i) Write an assembly language program using the 8085 instruction set to find the two's complement of a 16-bit number. The number to be complemented is placed in memory locations 801AH and 801BH. The result is to be stored in memory locations 8020H and 8021H.

[7]

(ii) Write short notes on Cache memory.

[5]

(b) (i) Define memory map.

[1]

(ii) Illustrate the memory map of a 4K(4096) memory with a figure.

[5]

(iii) Explain how this memory chip is selected by the microprocessor for reading and writing data.

[7]

Q3. A system is designed to monitor the temperature of a furnace. Temperature readings are recorded in 16-bits and stored in memory locations starting at 8060H as shown in Figure 1.

8060H	05
8061H	81
8062H	05
8063H	95
8064H	05
8065H	78
8066H	05
8067H	7A
8068H	05
8069H	98

Figure 1

The higher order byte is stored first and the lower order byte is stored in the next consecutive memory location. However, the higher order byte (05H) of all the temperature readings is constant.

Write a program and flowchart to transfer low order temperature readings to consecutive memory locations starting at 8080H and discard the higher order bytes as shown in Figure 2. [25]

Temperature (H): 0581, 0595, 0578, 057A, 0598

81	8080H
95	8081H
78	8082H
7A	8083H
98	8084H

Figure 2

**Q4.** (a) Design a circuit and write a program 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. [12]

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	

(b) Modify the program to keep the air conditioner ON continuously without affecting the functions of the other appliances, even if someone turns off the switch. [6]

(c) Explain the instructions LHLD and XCHG with an example. [7]

**Q5. (a)** Using connection abbreviations, implement the following functions on a Field Programmable Logic Array (FPLA) circuit. [10]

$$X = \overline{B} (C \overline{D} + \overline{A} D) + \overline{B} \overline{C} (A + \overline{A} \overline{D})$$

$$Y = \overline{(\overline{A} + \overline{D}) \cdot (\overline{B} + \overline{D})}$$

$$Z = \overline{AB}$$

(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) Draw the shared Karnaugh map for the following multiple output functions and simplify it. [6]

$$F_1 = \pi M(3,4,5,7,11,13,15). d(6,8,10,12)$$

$$F_2 = \pi M(2,7,9,10,11,12,14,15). d(0,4,6,8)$$

Q6. (a) Perform the following hexadecimal arithmetic operations. [4]

(i)  $A7C5 + 2DA8$

(ii)  $A05C - 24CA$

(b) Change the following expression into standard SOP form. [9]

$$X = ABC + AB + \bar{A} B \bar{C} + CD + B \bar{D}$$

(c) Write short notes on

(i) word length of a computer [3]

(ii) don't care conditions in Karnaugh map techniques [3]

(iii) minterms and maxterms in Boolean expressions [3]

(iv) Programmable logic devices [3]

END OF EXAMINATION



**UNIVERSITY OF ZAMBIA**  
**SCHOOL OF NATURAL SCIENCES**  
**DEPARTMENT OF PHYSICS**  
**END-OF-YEAR UNIVERSITY EXAMINATIONS**  
**2016/2017 ACADEMIC YEAR**

**BSc PHYSICS**  
**PHY4535**  
**QUANTUM MECHANICS II**

<b>DURATION:</b>	Three hours.
<b>INSTRUCTIONS:</b>	Answer four questions from the six given. <i>Each question carries 25 marks with marks indicated in brackets.</i>
<b>MAXIMUM MARKS:</b>	100
<b>DATE:</b>	Monday 28 <sup>th</sup> August 2017

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**Included items:**

1. Table of Clebsch-Gordan coefficients.
- 

**Formulae that may be needed**

All symbols used have their usual meaning.

1. The harmonic oscillator ladder operators are defined as

$$a = \left(\frac{m\omega_c}{2\hbar}\right)^{1/2} x + i \left(\frac{1}{2m\hbar\omega_c}\right)^{1/2} p, \quad \text{and} \quad a^\dagger = \left(\frac{m\omega_c}{2\hbar}\right)^{1/2} x - i \left(\frac{1}{2m\hbar\omega_c}\right)^{1/2} p$$

2.  $[\hat{a}, \hat{a}^\dagger] = 1, \quad [x, p] = i\hbar$

3.  $\hat{H} = \left(\hat{a}^\dagger \hat{a} + \frac{1}{2}\right) \hbar\omega$

4.  $\hat{H}|n\rangle = \left(n + \frac{1}{2}\right) \hbar\omega_c |n\rangle, \quad \hat{a}|n\rangle = \sqrt{n}|n-1\rangle, \quad \hat{a}^\dagger|n\rangle = \sqrt{n+1}|n+1\rangle$

5.

$$\begin{aligned} (H_0 - W^{(0)}) v^{(0)} &= 0, \\ (H_0 - W^{(0)}) v^{(1)} + (H' - W^{(1)}) v^{(0)} &= 0, \\ (H_0 - W^{(0)}) v^{(2)} + (H' - W^{(1)}) v^{(1)} - W^{(2)} v^{(0)} &= 0 \end{aligned}$$

6.

$$W^{(1)} = H'_{mm} = \langle u_m | H' | u_m \rangle, \quad W^{(2)} = - \sum_{n=0}' \frac{|H'_{nm}|^2}{E_n - E_m}$$

7.

$$a_f^{(1)}(t) = \frac{1}{i\hbar} \int_0^t e^{i\omega_{fi}t'} H'_{fi}(t') dt'$$

8.

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

9.

$$\int_0^\infty \frac{\sin^2 nx}{x^2} dx = \frac{\pi}{2} |n|$$

10.

$$\hat{J}_+ = \hat{J}_x + i\hat{J}_y, \text{ and } \hat{J}_- = \hat{J}_x - i\hat{J}_y$$

11.

$$\begin{aligned} J_z |j, m\rangle &= m\hbar |jm_j\rangle, \quad J^2 |jm_j\rangle = j(j+1)\hbar^2 |jm_j\rangle, \\ J_\pm |jm_j\rangle &= \hbar [j(j+1) - m(m \pm 1)]^{\frac{1}{2}} |jm_j \pm 1\rangle, \end{aligned}$$

12.

$$\int \frac{1}{x} dx = \ln x$$

13.

$$[J_x, J_y] = i\hbar J_z, \quad [J_y, J_z] = i\hbar J_x, \quad [J_z, J_x] = i\hbar J_y, \quad [J^2, J_x] = [J^2, J_y] = [J^2, J_z] = 0$$

14.

$$\hat{\mathbf{n}} = \sin\theta\cos\phi\hat{\mathbf{i}} + \sin\theta\sin\phi\hat{\mathbf{j}} + \cos\theta\hat{\mathbf{k}}$$

15.

$$\hat{S}_x = \frac{\hbar}{2} \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}, \quad \hat{S}_y = \frac{\hbar}{2} \begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix}, \quad \hat{S}_z = \frac{\hbar}{2} \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}$$

16.

$$|\chi_{n+}\rangle = \begin{pmatrix} \cos \frac{\theta}{2} \\ e^{i\phi} \sin \frac{\theta}{2} \end{pmatrix}, \quad |\chi_{n-}\rangle = \begin{pmatrix} \sin \frac{\theta}{2} \\ -e^{i\phi} \cos \frac{\theta}{2} \end{pmatrix}$$



## QUESTION 1

- (i) Using Dirac notation, derive the closure property

$$\sum_n |n\rangle\langle n| = I$$

(9 marks)

- (ii) Derive the following properties

(a)

$$(A^\dagger)^\dagger = A,$$

(4 marks)

(b)

$$(AB)^\dagger = B^\dagger A^\dagger.$$

(4 marks)

(c)

$$(A + B)^\dagger = A^\dagger + B^\dagger,$$

(4 marks)

- (iii) Use Dirac notation to define the Hermitian conjugate of a linear operator  $A$  and define a Hermitian operator. Prove that a linear operator (whether or not Hermitian) can act forwards or backwards. (4 marks)

## QUESTION 2

- (i) Determine what the following commutators are equal to:  $[\hat{a}^\dagger \hat{a}, \hat{a}^\dagger]$  and  $[\hat{a}^\dagger \hat{a}, \hat{a}]$ . (4 marks)
- (ii) For the harmonic oscillator potential determine the eigenvalues of the number operator and hence the energy eigenvalues of the harmonic oscillator Hamiltonian  $\hat{H}_0 = (\hat{a}^\dagger \hat{a} + 1)\hbar\omega_c$ . First find the spacing between the eigenvalues, then show how the eigenvalue spectrum can be fixed. (16 marks)
- (iii) Find the matrix representing the raising operator  $\hat{a}^\dagger$  in the harmonic oscillator representation. (5 marks)

### QUESTION 3

- (i) Determine the expectation value of the operator  $\hat{S}_y$  in the eigenstate  $|\chi_{n+}\rangle$  of the arbitrary spin- $\frac{1}{2}$  operator  $\hat{S} = \hat{\mathbf{S}} \cdot \hat{\mathbf{n}}$ . (6 marks)

- (ii) By acting with  $\hat{J}_+$  on the eigen-equation

$$\hat{J}_z |jm_j\rangle = m_j \hbar |jm_j\rangle,$$

and by using the commutator  $[\hat{J}_z, \hat{J}_+] = \hbar \hat{J}_+$ , determine the action of  $\hat{J}_+$  on  $|jm_j\rangle$  and describe your answer in words. (8 marks)

- (iii) For  $\hat{J}^2 = \hat{J}_1^2 + \hat{J}_2^2$ , where  $\hat{J}_1$  commutes  $\hat{J}_2$ , determine the commutators  $[\hat{J}_1^2, \hat{J}_z]$  and  $[\hat{J}_{1z}, \hat{J}_z]$ . (4 marks)

- (iv) Consider two spin- $\frac{1}{2}$  electrons. Express the total state  $|s_1 s_2 s m_s\rangle = |\frac{1}{2}, \frac{1}{2}, 1, 0\rangle$  in terms of the state  $|\frac{1}{2}, m_1\rangle$  of electron 1 and state  $|\frac{1}{2}, m_2\rangle$  of electron 2. (7 marks)]

### QUESTION 4

Consider time-independent perturbation theory for the case of two-fold degeneracy. Note that all symbols have their usual meaning.

- (i) Write down the solutions of the zeroth order equation, i.e., write down the eigenvalue and the corresponding eigenfunction. (5 marks)
- (ii) Using the results from part (i), and beginning with the first order equation derive the following equation:

$$\begin{pmatrix} (h_{11} - W^{(1)}) & h_{12} \\ h_{21} & (h_{22} - W^{(1)}) \end{pmatrix} \begin{pmatrix} a_1^{(0)} \\ a_2^{(0)} \end{pmatrix} = 0.$$

(15 marks)

- (iii) Without calculation, state what kind of solutions are expected for  $W^{(1)}$ , and describe the physical consequences. (5 marks)

### QUESTION 5

Derive the Fermi-Golden rule, and give its meaning beginning with the formula for the first-order coefficient of time-dependent perturbation theory for a constant perturbation

$$|a_f^{(1)}(t)|^2 = \frac{|H'_{fi}|^2}{\hbar^2} \frac{4 \sin^2(\omega_{fi}t/2)}{\omega_{fi}^2}.$$

Clearly state any assumptions used.

(25 marks)

### QUESTION 6

(1) Consider the variation method.

- (a) In what year and by who was this method developed? What problems was the method originally applied to and to which quantum mechanical problems is it most useful?

(3 marks)

(b) Prove that

$$W = \int \psi^* \hat{H} \psi \, dx \geq E_0,$$

where  $E_0$  is the ground state energy, i.e., the lowest eigenvalue of the Hamiltonian operator  $\hat{H}$ , and  $\psi$  is an arbitrary wave function.

(7 marks)

- (c) On what idea is the variation method based? Describe in general terms how the method is used to obtain an approximation.

(7 marks)

- (ii) By substituting  $\psi(x) = Ae^{iS(x)/\hbar}$  into the one-dimensional time-independent Schrödinger equation,

$$-\frac{\hbar^2}{2m} \frac{d^2\psi(x)}{dx^2} + V(x)\psi(x) = E\psi(x),$$

derive the zeroth and first-order differential equations of the WKB approximation.

(8 marks)

————— END —————

# The University of Zambia

## Department of Physics

### 2016/2017 University Examinations

#### PHY 4815: Physics of Renewable Energy Resources

**Duration:** Three (3) Hours

**Total Marks:** 100

#### Instructions

- This paper has five questions. Attempt **any four (4)** questions
- Show all your work clearly
- All questions carry equal marks and are indicated in brackets [ ]

**Table 1: Some Physical Constants you may find useful**

Radius of the Sun, $R_s = 6.96 \times 10^8 \text{ m}$	Mass of the Sun, $M_s = 1.99 \times 10^{30} \text{ kg}$
Radius of the Earth, $R_e = 6.38 \times 10^6 \text{ m}$	Mass of the Earth, $M_e = 5.97 \times 10^{24} \text{ kg}$
1 Astronomical Unit, $1AU = 1.496 \times 10^{11} \text{ m}$	Sun's average surface temperature = 5777 K
Solar Constant $I_{sc} = 1367 \text{ Wm}^{-2}$	Boltzmann constant, $k = 1.38 \times 10^{-23} \text{ JK}^{-1}$
Universal gas constant, $R = 8.314 \text{ J/mol.K}$	Stefan-Boltzmann constant, $\sigma = 5.67 \times 10^{-8} \text{ W.m}^{-2}\text{K}^{-4}$
Mean molecular mass of air, $\bar{M} = 29.0 \text{ amu}$	Planck's constant, $h = 6.63 \times 10^{-34} \text{ J.s}$
Speed of light (vacuum), $c = 2.9979 \times 10^8 \text{ m.s}^{-1}$	Electron charge, $e = 1.6 \times 10^{-19} \text{ C}$
Specific heat of water, $c_w = 4.186 \text{ kJ/kg.K}$	Wien's Law: $\lambda_{max}T = 2898 \text{ }\mu\text{.mK}$

**Table 2: The Equation of Time in Minutes**

Day of Month	1	4	7	10	13	16	19	22	25	28
January	-4	-5	-6	-8	-9	-10	-11	-12	-12	-13
February	-14	-14	-14	-14	-14	-14	-14	-14	-13	-3
March	-13	-12	-11	-10	-10	-9	-8	-7	-6	-5
April	-4	-3	-2	-1	-1	0	+1	+1	+2	+2
May	+3	+3	+3	+4	+4	+4	+4	+4	+3	+3
June	+2	+2	+2	+1	0	0	-1	-2	-2	-3
July	-3	-4	-5	-5	-6	-6	-6	-6	-6	-6
August	-6	-6	-6	-5	-5	-4	-4	-3	-2	-1
September	0	+1	+2	+3	+4	+5	+6	+7	+8	+9

October	+10	+11	+12	+13	+14	+14	+15	+15	+16	+16
November	+16	+16	+16	+16	+16	+15	+15	+14	+13	+12
December	+11	+10	+9	+7	+6	+4	+3	+2	0	-2

**Table 3: Values of  $f(x) = 1/\sigma \left( \int_0^x \left( a / \left( x^5 \left( e^{(b/x)} - 1 \right) \right) \right) dx \right)$  for different  $x$ .**

$x$ ( $\mu\text{m-K}$ )	$f(x)$	$x$ ( $\mu\text{m-K}$ )	$f(x)$	$x$ ( $\mu\text{m-K}$ )	$f(x)$
1100	0.0001	4600	0.580	8100	0.860
1200	0.0002	4700	0.594	8200	0.864
1300	0.0004	4800	0.608	8300	0.868
1400	0.0008	4900	0.521	8400	0.871
1500	0.0013	5000	0.634	8500	0.875
1600	0.0020	5100	0.646	8600	0.878
1700	0.0029	5200	0.658	8700	0.881
1800	0.0040	5300	0.669	8800	0.884
1900	0.0052	5400	0.680	8900	0.887
2000	0.0067	5500	0.691	9000	0.890
2100	0.0083	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

$\delta = 23.45 \sin \left[ \frac{365}{360} (n + 284) \right]$	$n_t = \sqrt{n_g}$
$J = \varepsilon \sigma T^4$	$\alpha = \exp \left( - \frac{\sqrt{n_z^2 - \sin^2 \theta'_1}}{n_{ks}} \right)$
$\text{Solar time} = \text{standard time} + 4(L_{loc} - L_{st}) + EOT$	$R = Nk$
$P_{dlr} = I_{sc} \cos \theta \exp \left( - \frac{\cos \theta_z}{\tau} \right)$	$\omega = 15 \left[ (ST - 12) + \frac{MM}{60} \right]$
$\cos \gamma_s = \frac{\sin \alpha \sin \phi - \sin \delta \cos \alpha \cos \phi}{\cos \gamma_s}$	

Table 4: Some formulae you may find useful

4500	0.564	8000	0.856	
4400	0.549	7900	0.852	
4300	0.533	7800	0.848	50000
4200	0.516	7700	0.844	40000
4100	0.499	7600	0.840	30000
4000	0.483	7500	0.834	20000
3900	0.462	7400	0.830	19000
3800	0.443	7300	0.824	18000
3700	0.424	7200	0.819	17000
3600	0.404	7100	0.814	16000
3500	0.383	7000	0.808	15000
3400	0.362	6900	0.802	14000
3300	0.340	6800	0.796	13000
3200	0.318	6700	0.790	12000
3100	0.296	6600	0.783	11000
3000	0.273	6500	0.776	10000

$\omega_s = \cos^{-1}(-\tan\phi\tan\delta)$	$T_{f,e} = T_B - (T_B - T_{f,i})\exp\left[-\frac{U_L L}{\dot{m} C_f}\right]$
$d_f = \frac{m\lambda_0}{4n_f}, \quad m = 1, 3, 5, \dots$	$N = \frac{2}{15} \omega_s$
$r_{11} = \left[ \frac{n_r^2 \cos\theta_i - n_i \sqrt{n_r^2 - n_i^2 \sin^2\theta_i}}{n_r^2 \cos\theta_i + n_i \sqrt{n_r^2 - n_i^2 \sin^2\theta_i}} \right]^2$	$r_{\perp} = \left[ \frac{n_i^2 \cos\theta_i - \sqrt{n_r^2 - n_i^2 \sin^2\theta_i}}{n_i^2 \cos\theta_i + \sqrt{n_r^2 - n_i^2 \sin^2\theta_i}} \right]^2$
$R = r \left[ 1 + \frac{\alpha^2 (1-r)^2}{1 - \alpha^2 r^2} \right]$	$T = \frac{\alpha (1-r)^2}{1 - \alpha^2 r^2}$

$$\begin{aligned} \cos\theta_i = & \sin\delta [\sin\phi \cos\beta - \cos\phi \sin\beta \cos\gamma] \\ & + \cos\delta \cos\omega [\cos\phi \cos\beta + \sin\phi \sin\beta \cos\gamma] \\ & + \cos\delta \sin\beta \sin\gamma \sin\omega, \end{aligned}$$

**Q1. (a)** The tungsten filament of a clear 150 W bulb operates at a temperature of 2700°C. The filament's average emissivity at this temperature is 0.4.

- Estimate the surface area of the filament if it is assumed that all the energy leaves via radiation. [4]
- Repeat part (i) above for a filament of 60 W bulb operating at 2700°C. [4]
- What conclusion do you draw from the results in (i) and (ii) above? [3]
- Find the characteristic wavelength for the emitted spectrum of the 60 W bulb operating at full power. [3]

**(b)** Find the solar constants of

- Venus at its mean distance from the Sun, given that its radius is  $1.08 \times 10^8$  km. [4]
- Mars at its mean distance from the Sun, given that its radius is  $2.28 \times 10^8$  km. [4]
- What conclusion do you draw from the two calculations above? [3]

**Q2. (a)** A single glazing panel has the following specifications;

Efficiency of the panel = 0.7

Absorber plate absorptance = 0.9

Extinction coefficient for the glazing =  $0.1 \text{ cm}^{-1}$

Thickness of the glazing = 0.5 cm

Index of refraction of the glazing = 1.5

Surface reflectance of the glazing = 0.04

If a direct solar beam is incident at an angle of  $30^\circ$  on the panel, calculate

- (i) the bulk transmittivity of the glazing (i.e, the fraction reaching the lower interface), [3]
- (ii) the overall transmittance of the glazing, [3]
- (iii) the overall reflectance of the glazing, [3]
- (iv) the optical efficiency of the glazing-absorber system, [2]
- (v) the overall efficiency of the heating panel. [2]

(b) A solar heating panel is located in Lusaka with the following coordinates: Latitude  $15^\circ\text{S}$  and longitude  $28^\circ\text{E}$ . On 10<sup>th</sup> February ( $n = 41$ ) at 10:00, the average optical thickness of the atmosphere is 0.2. Find

- (i) the solar declination, [1]
- (ii) the solar time, [2]
- (iii) the hour angle, [2]
- (iv) the angle of incidence of the solar beam, [2]
- (v) the direct radiation flux incident on the panel and [3]
- (vi) the day length on 10<sup>th</sup> February. [2]

**Q3. (a)** The total solar intensity arriving at the ground at an angle of incidence  $\theta$  from the entire atmosphere is obtained by integrating the expression

$$I_{\lambda}^{thermal} = \frac{1}{\pi\mu} \int_0^{\tau_{\lambda}} B_{\lambda}(T) \exp\left(-\frac{\tau_{\lambda}-t_{\lambda}}{\mu}\right) dt_{\lambda},$$

where  $\mu = \cos\theta$  and  $(\tau_{\lambda} - t_{\lambda})$  is the optical thickness of the air between the emitted layer and the ground. Since  $T$  is a function of the altitude, the integration can be performed only after the temperature profile is known. If the atmosphere is assumed to be isothermal, i.e.,  $T = T_o$ , show that the above expression reduces to

$$I_{\lambda}^{thermal} = \frac{B_{\lambda}(T_o)}{\pi} \left[1 - \exp\left(-\frac{\tau_{\lambda}}{\mu}\right)\right]. \quad [15]$$



(b) An absorber plate in a flat plate collector is operating at a temperature of  $T = 80^\circ\text{C}$  and rests on 15 cm of fiberglass insulation ( $K_f = 0.05 \text{ W/m}^\circ\text{C}$ ), which is itself supported by a plywood ( $K_w = 0.08 \text{ W/m}^\circ\text{C}$ ) sheet of thickness 1.25 cm. If the temperature of the exterior face of the plywood is observed to be  $25^\circ\text{C}$ , find the heat flux rate conducted through the back face of the collector.

[10]

**Q4.** A flat-plate solar heating panel contains two glazings. In the steady state, the plate temperature is  $T_p = 120^\circ\text{C}$  and the sky temperature is  $T_{\text{sky}} = T_a = 20^\circ\text{C}$ . The coefficients for heat transfer from the plate to the inner glazings are  $U_{d,1}^{(c)} = 3.0 \text{ W/m}^2\text{C}$  and  $U_{d,1}^{(r)} = 5.0 \text{ W/m}^2\text{C}$ . Those for heat transfer from one glazing to the other are  $U_{d,2}^{(c)} = 5.0 \text{ W/m}^2\text{C}$  and  $U_{d,2}^{(r)} = 7.0 \text{ W/m}^2\text{C}$ . The coefficients for heat transfer from the outer glazing are  $U_{\infty}^{(c)} = 8.0 \text{ W/m}^2\text{C}$  and  $U_{\infty}^{(r)} = 7.0 \text{ W/m}^2\text{C}$ .

- (a) Draw the resistor equivalent network for the system [8]
- (b) Calculate the heat transfer coefficients  $\bar{U}_{d,1}$ ,  $\bar{U}_{d,2}$ , and  $\bar{U}_{\infty}$ . [4]
- (c) Calculate the overall heat transfer coefficient  $\bar{U}_c$  [4]
- (d) Find the flux loss from the absorber [3]
- (e) Find the temperature of the glazings. [6]

**Q5. (a)** (i) What are selective absorber coatings? Explain the use of selective absorber coatings.  
(ii) Explain the greenhouse effect as it applies to the solar heating panels. [3+3]

(b) Consider an absorber plate suspended in space above the atmosphere. The plate is blackened and oriented towards the Sun. Assuming no convective losses and no back surface losses,

- (i) Show that the steady-state absorber plate temperature is about  $121^\circ\text{C}$ . [6]
- (ii) Show that the steady-state absorber plate temperature is about  $196^\circ\text{C}$  when a glazing is placed in front of the absorber. (Assume further that  $a_\lambda = \epsilon_\lambda = 1$  in both cases) [5]
- (c) If the absorber plate in **Q5 (b)** (i) is coated on the front part with an ideal selective coating with cut-off wavelength  $\lambda_c = 4\mu\text{m}$ , estimate the steady-state temperature of the absorber plate.

[8]

=====End of PHY 4815 Examination=====