

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

**2018 ACADEMIC YEAR
FINAL EXAMINATIONS**

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

TIME: THREE HOURS

INSTRUCTIONS

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

1. Choose the statement which is true.
 1. After replication, half the daughter DNA contains two new strands.
 2. In their experiment, Meselson and Stahl proved that DNA replication is conservative.
 3. Meselson and Stahl initially grew *E. coli* cells in a medium containing nitrogen 15 isotope for many generations.
 4. Meselson and Stahl initially grew *E. coli* cells in a medium containing nitrogen 14 isotope for one generation.
 5. Meselson and Stahl analysed DNA samples using caesium chloride preparative centrifugation.
 6. I do not know.

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

3. The Meselson-Stahl experiment to study DNA replication had three layers settled in the centrifuge tubes according to their weight. Which layer had the nitrogen 14 isotope?
 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.

4. The normal replication of DNA involves ...
 1. A pairing with G.
 2. leading stranding and lagging strand synthesis.
 3. daughter DNA having one old strand and one new strand.
 4. A paring with U.
 5. parental DNA having one old strand and one new strand.
 6. I do not know.

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

6. Which of the following contains the genetic information for the synthesis of one specific protein?
1. messenger RNA.
 2. transfer RNA.
 3. ribosomal RNA.
 4. messenger RNA and transfer RNA.
 5. DNA.
 6. I don't know.

7. During DNA replication, new nucleotides are added to the ...
1. phosphate group of carbon 5 of the deoxyribose
 2. OH group of carbon 3 of the deoxyribose
 3. phosphate group of carbon 5 of the ribose
 4. OH group of carbon 3 of the ribose
 5. phosphate group on the 3' end of the RNA primer.
 6. I do not know.

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

9. At the end of the lagging strand DNA synthesis, ...
1. phosphodiester bonds between adjacent nucleotides break.
 2. bonds between the nitrogen base and deoxyribose sugar break.
 3. a number of Okazaki fragments are produced.
 4. hydrogen bonds between the nucleotides of the two strands break. α
 5. helicase catalyses the sealing of the gap between adjacent DNA fragments. α
 6. I do not know.

10. Choose the enzyme which is **correctly** matched with its function.

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

11. Which reaction in DNA replication is catalysed by helicase?
1. Addition of new nucleotides to the lagging strand.
 2. Separation of the strands of DNA double helix.
 3. Addition of new nucleotides to the leading strand.
 4. Base pairing of the template and the newly formed DNA strand.
 5. Synthesis of a short RNA primer complementary to DNA.
 6. I do not know.

12. During DNA replication, separation of DNA strands requires ...

1. hydrolysis of phosphodiester bonds.
2. DNA ligase activity.
3. hydrolysis of GC and AT bonds.
4. complementary base-pairing. \times
5. topoisomerase activity.
6. I do not know

13. If the sequence of bases on a non-template DNA is 5'- TAGT - 3', then the corresponding sequence of bases in the transcribed RNA will be...

1. 5'- ATCG- 3'.
2. 5'-TAGC- 3'.
3. 3'-UAGC-5'.
4. 3'-AUGC- 5'.
5. 3'-UAGU- 5'.
6. I do not know.

AUCA
ATCA AUCA
UAGU

14. Which of the following occurs in both eukaryotic and bacterial transcription?

1. 5' capping
2. Poly A tail
3. Nucleolus
4. Splicing
5. RNA synthesis
6. I do not know.

15. Which of the following is not part of RNA processing in eukaryotes?

1. Addition of a 5' cap. ✓
2. Lagging strand synthesis
3. Addition of poly A tail ✓
4. Intron removal. ✓
5. Joining exons together. ✓
6. I do not know

16. Choose the statement which represents the universality of the genetic code.
1. The genetic code is very unstable.
 2. The genetic code is the same for all organisms.
 3. Two or more codons may specify one amino acid.
 4. Two or more amino acids may be specified by one codon.
 5. Each codon consists of three nucleotides.
 6. I do not know.
17. Which position(s) of a codon is(are) said to wobble?
1. First and second
 2. Second and third
 3. First
 4. Second
 5. Third
 6. I do not know.
18. Which of the following is **not** a property of the genetic code?
1. Triplet
 2. Degenerate
 3. Overlapping
 4. Universal
 5. Unpunctuated
 6. I do not know.
19. The total number of possible codons of the genetic code is ⁶⁴ out of which ³ are stop codons.
1. 20, 3
 2. 21, 3
 3. 64, 21
 4. 64, 3
 5. 64, 20
 6. I do not know.
20. During the process of translation, the ...
1. first amino acid binds to the A site and the second amino acid binds to the P site.
 2. first amino acid binds to formyl methionine.
 3. first amino acid binds to the P site and the second amino acid binds to the A site.
 4. last amino acid binds to the stop codon.
 5. last amino acid binds to the release factor.
 6. I do not know.

21. Identify the complex that is formed when mRNA binds to a ribosomal subunit.
1. Aminoacyl synthetase
 2. Aminoacyl tRNA complex
 3. 70S initiation complex
 4. 30S initiation complex
 5. 40S initiation complex
 6. I do not know.
22. A messenger RNA is 300 nucleotides long, excluding the start and stop codons. The number of amino acids in the protein translated from this mRNA is
1. 98
 2. 100
 3. 300
 4. 30
 5. 302
 6. I do not know
23. Identify the role of the enzyme peptidyl transferase during translation.
1. Transfer of peptide from the P site to the A site.
 2. Transfer of peptide from the A site to the P site.
 3. Breakdown of peptide bonds between neighbouring amino acids.
 4. Synthesis of tRNA.
 5. Formation of peptide bonds between neighbouring amino acids
 6. I do not know.
24. The nucleolus is the site where ...
1. mRNA poly A tail is added. *no*
 2. rRNA is synthesised in prokaryotes. *no*
 3. mRNA is synthesised in prokaryotes. *no*
 4. mRNA is translated. *no*
 5. rRNA is synthesised in eukaryotes. *no*
 6. I do not know
25. The poly-A tail is added to the ...
1. 3' end of tRNA. *no*
 2. 5' end of mRNA. *no*
 3. 5' end of any RNA. *no*
 4. 3' end of any RNA. *no*
 5. 3' end of mRNA. *no*
 6. I do not know

26. During RNA processing ...

1. exons are removed and hydrolysed. ✗
2. RNA molecules are converted to DNA. ✗
3. mRNA molecule is translated into a protein molecule. ✗
4. the different types of RNA are synthesised from the DNA template. ✗
5. the different RNA primary transcripts are converted to mature RNA. ✓
6. I do not know

27. Which one of the following molecules contains introns?

1. Primary mRNA transcript of prokaryotic cells.
2. Primary mRNA transcript of eukaryotic cells.
3. Primary tRNA transcript of eukaryotic cells.
4. Primary rRNA transcript of prokaryotic cells.
5. Processed prokaryotic mRNA. ✗
6. I do not know

28. Because there are more codons than amino acids, ...

1. each amino acid is specified by more than one codon.
2. some codons specify more than one amino acid.
3. some codons do not specify any amino acid.
4. some amino acids do not have matching codons.
5. Both 1 and 3 above are correct.
6. I do not know

29. Given the DNA sequence CAT-AAG-GGC, AAG-GGC-CAT which of the following polypeptides would be the result?

1. Val-Phe-Pro
2. Gln-Asn-Gly
3. Val-Ser-Pro
4. Phe-Pro-Val
5. Gly-Leu-Pro
6. I do not know.

GUA - UUA - CCG
UUC - CCA - GUA

30. All the following materials are required in translation except ...

1. all the types of RNA.
2. amino acids.
3. the RNA primer.
4. elongation factors.
5. ribosomes.
6. I do not know

31. Identify the sequence on the amino acid attachment arm of t-RNA.
1. 3' CAC 5'^α
 2. 3' CCA 5'
 3. 5' CCA 3'
 4. 3' ACA 5'^α
 5. 3' ACC 5'^α
 6. I do not know
32. The end of translation is signalled by a/an ... which binds a protein called the ...
1. anticodon, initiation factor
 2. stop codon, release factor
 3. start codon, initiation factor
 4. stop codon, stop factor
 5. stop codon, nonsense codon.
 6. I do not know.
33. During the process of translation ...
1. all incoming tRNA molecules must first bind to the P-site.^α
 2. initiation begins with the binding of the ribosome to the start anticodon. ✓
 3. the message on mRNA is translated into a polypeptide. ✓
 4. termination is achieved by the binding of methionine to the stop codon.
 5. the growing polypeptide is passed from the A-site to the P-site.
 6. I do not know.
- ^α 34. The role of messenger mRNA is to ...
1. act as a catalyst during protein synthesis.
 2. help in the assembly of the ribosome.
 3. provide the genetic information for protein synthesis
 4. translate the genetic code into other tRNA molecules.
 5. modify tRNA molecules before protein synthesis.
 6. I do not know.
35. During prokaryotic translation the start codon specifies the amino acid...
1. methionine.
 2. valine.
 3. glycine.
 4. formyl methionine.
 5. tryptophan.
 6. I do not know.

36. The enzyme amino acyl-tRNA synthetase....

1. attaches an amino acid to the 30s ribosomal subunit.
2. attaches an amino acid to its tRNA.
3. removes tRNA from its amino acid.
4. attaches an amino acid to its mRNA.
5. helps tRNA synthesize amino acids.
6. I do not know.

37. The ribosome reads the message on ...

1. mRNA in the 5' to 3' direction.
2. mRNA in the 3' to 5' direction.
3. mRNA in both directions.
4. tRNA in the 5' to 3' direction.
5. tRNA in the 3' to 5' direction.
6. I do not know

38. Which one of the following sequences does **not** belong to the genetic code?

1. AAA GGC AAG CAC
2. CCC GGG AAA GCA
3. AUA GGC AUG CAC
4. GGT CCC GCC GTG
5. CAA UGA ACA CCA
6. I do not know.

39. If the sequence of bases on template DNA is ATCG, then the sequences of bases on the RNA transcript will be ...

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

UAGC

TAGC

AUCG

40. The stages of translation arranged in chronological order are ...

1. Initiation, elongation, activation, termination.
2. Initiation, activation, elongation, termination.
3. Elongation, initiation, activation, termination.
4. Activation, initiation, elongation, termination.
5. Activation, elongation, initiation, termination.
6. I do not know.

41. Choose the type(s) of RNA involved in translation.

1. tRNA
2. mRNA
3. rRNA
4. tRNA and mRNA
5. all the three types of RNA.
6. I do not know

42. The codon, anticodon and DNA sequence for methionine are, and respectively.

1. UAG, AUC, ATC
2. AUG, AUC, ATC
3. UAG, UAC, TAC
4. AUG, AUC, CTA
5. AUG, UAC, TAC
6. I do not know

- AUG
- UAC
- TAC

43. The *Lac* operon is a group of genes involved in the metabolism of ...

1. galactose.
2. lactose
3. permease.
4. glucose.
5. lactase.
6. I do not know.

44. The *Lac* operon is switched on when ...

1. the repressor molecule binds the operator.
2. glucose is present.
3. lactose is absent.
4. RNA polymerase binds to the operator site.
5. glucose is absent.
6. I do not know.

45. What is the function of the permease enzyme in the *lac* operon?

1. Hydrolysis of lactose
2. Attachment of lactose to the lac repressor protein
3. Breakdown of lactose
4. Entry of lactose into the cell
5. Exit of lactose from the cell
6. I do not know.

46. The *Lac* repressor dissociates from the operator site when it binds to ...
1. lactose.
 2. the operator.
 3. the repressor.
 4. glucose.
 5. the regulator gene.
 6. I do not know.
47. In an operon, the function of the promoter is to ...
1. code for the repressor protein.
 2. bind to the repressor.
 3. code for the regulator gene.
 4. bind with RNA polymerase.
 5. All of the above are correct.
 6. I do not know
48. Choose the item which is **not** part of the lac operon.
1. Inducer.
 2. Regulator.
 3. Operator.
 4. Promoter.
 5. Structural genes.
 6. I do not know.
49. What is the function of β -galactosidase enzyme in the *lac* operon?
1. Entry of lactose into the cell.
 2. Synthesis of lactose.
 3. Attachment of lactose to the lac repressor protein.
 4. Breakdown of lactose.
 5. Exit of lactose from the cell.
 6. I do not know.
50. The repressor becomes inactive when it binds to ...
1. the promoter.
 2. the operator.
 3. the regulator.
 4. glucose.
 5. lactose.
 6. I do not know.

51. What is an operon?

1. A part of ribosome.
2. A part of RNA.
3. A unit made up of linked genes that code for proteins needed to do a specific task.
4. A special gene used in regulation of gene expression.
5. A set of unrelated genes located close by on a chromosome.
6. I don't know.

52. Proteins responsible for compact packaging of chromosomal DNA are called ...

1. haemoglobin.
2. histones.
3. myoglobin.
4. collagen.
5. glycoprotein.
6. I don't know

53. What is the name of the sequence of DNA that determines one specific form of a trait?

1. Allele
2. Genotype
3. Centromere
4. Phenotype
5. RNA
6. I don't know

∞ 54. The number of pairs of autosomal chromosomes in humans are

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

55. What happens during the G₂-phase of the cell cycle?

1. Cell rests and does not need to divide.
2. Cell grows and synthesizes enzymes and other proteins.
3. Cell grows and synthesizes organelles in preparation for division.
4. DNA is replicated.
5. The whole cell divides.
6. I do not know.

56. Cytoplasmic division of a cell is called...

1. S-phase
2. Cytokinesis
3. Mitosis
4. Synapsis
5. G-phase
6. I don't know

57. What is the role of the centromere during mitosis?

1. It makes the chromosomes visible.
2. It holds chromosomes in place.
3. It holds non-sister chromatids together.
4. It duplicates DNA.
5. It holds sister chromatids together.
6. I do not know

58. During the process of _____, two daughter cells will be produced with identical DNA.

1. Mitosis
2. Protein Synthesis
3. Meiosis
4. DNA Replication
5. Interphase
6. I don't know.

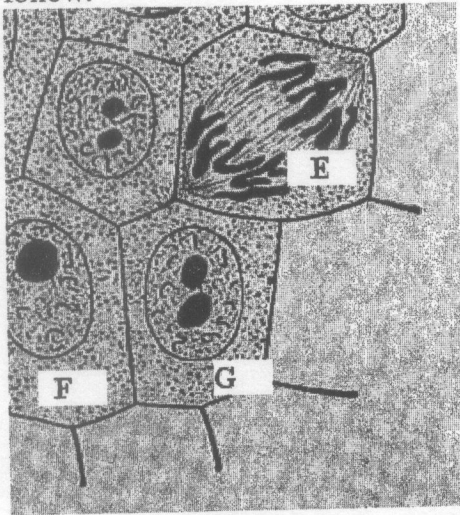
59. Choose the **false** statement.

1. Meiosis is a reductional division.
2. Synapsis takes place during meiosis II.
3. Meiosis produces four haploid daughter cells.
4. Meiosis is a source of genetic variation.
5. Through meiosis daughter cells with recombinant chromosomes may be produced.
6. I do not know.

60. Which of the following is **not** a characteristic of meiosis?

1. Chromosomes arrange themselves in pairs.
2. Daughter cells with half the normal number of chromosomes produced.
3. One cell undergoing two cell divisions, one after the other.
4. Division of diploid mother cells.
5. Recombination of alleles during prophase II. α
6. I do not know.

Study the diagrams below which show some stages of mitosis and answer the questions that follow.



61. Identify the stage labelled E.

1. Interphase.
2. Prophase.
3. Metaphase.
4. Anaphase.
5. Telophase.
6. I do not know.

62. Differentiate between F and G.

1. F is metaphase while G is prophase.
2. F is interphase while G is metaphase.
3. F is interphase while G is telophase.
4. F is interphase while G is prophase.
5. F is prophase while G is metaphase.
6. I do not know.

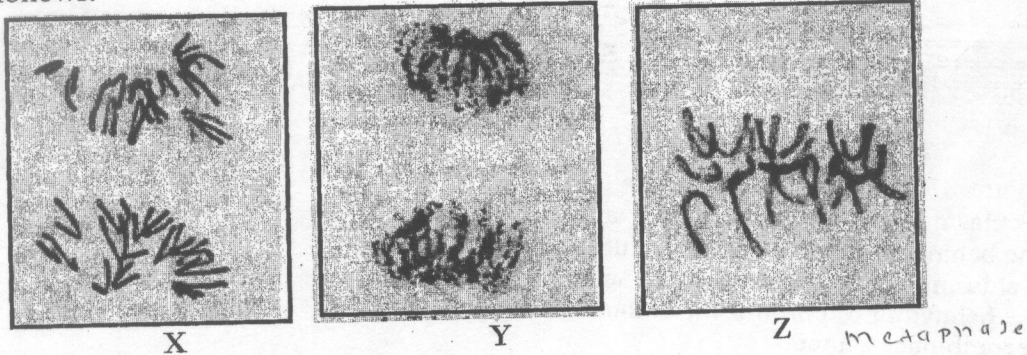
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63. The exchange of segments of 2 non-homologous pair of chromosomes is called...

1. Recombination
2. Linkage
3. Chiasma
4. Metaphase
5. Telophase
6. I don't know.

64. During which of these stages do chromatids separate and move to the poles of the spindle?
1. Metaphase of mitosis and metaphase 1 of meiosis.
 2. Anaphase of mitosis and anaphase 2 of meiosis.
 3. Telophase 1 and 2 of meiosis.
 4. Prophase of mitosis only.
 5. Cytokinesis.
 6. I don't know.

Study the diagrams below which show some stages of mitosis and answer the question that follows.

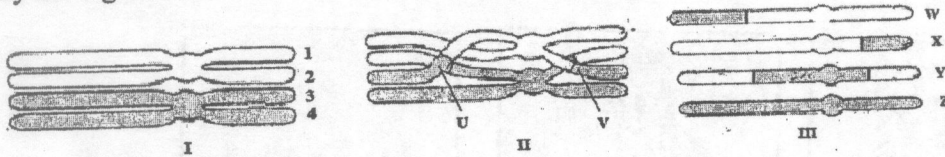


65. Identify the stages labelled X, Y and Z.
1. X is anaphase, Y is telophase, Z is metaphase
 2. X is telophase, Y is interphase, Z is prophase \times
 3. X is prophase, Y is telophase, Z is anaphase \times
 4. X is anaphase, Y is interphase, Z is metaphase α
 5. X is interphase, Y is telophase, Z is metaphase
 6. I do not know.
66. Crossing over between chromatids takes place during ...
1. interphase of meiosis.
 2. prophase II of meiosis.
 3. prophase of mitosis.
 4. metaphase of mitosis.
 5. prophase I of meiosis.
 6. I do not know.
67. Synapsis is a process ...
1. during mitosis whereby chromosomes exchange their material.
 2. during meiosis whereby sister chromatids exchange their material.
 3. whereby daughter cells with half the genetic material of the parent cell are produced.
 4. whereby homologous chromosomes separate and migrate to opposite poles.
 5. homologous chromosomes become closely associated.
 6. I don't know.

68. Crossing-over occurs during

1. prophase
2. interphase
3. prophase I
4. prophase II
5. metaphase I.
6. I do not know

Study the figure below and answer the question that follows.



69. The letter U in diagram II represents ...

1. a chiasma between chromatids 1 and 2.
2. the behaviour of chromosomes during metaphase.
3. a chiasma between chromatids 1 and 3.
4. the behaviour of chromosomes during anaphase.
5. recombinant gametes.
6. I do not know.

70. The structures in diagram III represent...

1. a chiasma between chromatids 1 and 2. ✗
2. the behaviour of chromosomes during metaphase. ✗
3. a chiasma between chromatids 1 and 3.
4. the behaviour of chromosomes during anaphase.
5. recombinant gametes.
6. I do not know.

71. Which one of the following statements is **not** a characteristic of homologous chromosomes?

1. They have the same length. ✓
2. They have the same centromere position. ✓
3. They carry genes that control any given trait at the same location. ✗
4. They always have the same type of alleles that code for the exact same type of a trait.
5. They pair up during meiosis I. ✓
6. I do not know.

72. Choose the **correct** statement.

1. The genotype is the physical appearance of an individual. α
2. The phenotype is the allelic combination of an individual. α
3. An allele contains two or more genes. α
4. A dominant allele is one expressed only in a homozygous individual. α
5. Codominant alleles are both expressed in a heterozygous individual. \checkmark
6. I do not know.

73. Which alleles are responsible for the A and O blood groups?

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

74. Choose the statement which is **not true** about an individual that is homozygous for an allele?

1. The individual is true-breeding with respect to that allele.
2. Each of the individual's cells possesses two copies of that allele.
3. The parents of the individual have to be homozygous for that allele.
4. Each of individual's gametes contains one copy of that allele.
5. The allele can be passed to the individual's offspring.
6. I do not know.

75. Alternative forms of a gene occupying the same position on a pair of homologous chromosomes are known as ...

1. double strands.
2. templates.
3. nucleosomes.
4. alleles.
5. histones.
6. I do not know.

76. The allelic combination of an individual is described as the ...

1. phenotype.
2. genotype.
3. nucleus.
4. chromosomes.
5. genes.
6. I do not know.

77. A test cross is a cross between ...

1. two F₁ individuals.
2. two recessive phenotypes
3. a dominant phenotype and a recessive phenotype.
4. two dominant phenotypes.
5. a dominant genotype and a recessive genotype.
6. I do not know

78. Mendel's second law states that ...

1. alleles of different genes assort independently.
2. genes of different alleles assort independently.
3. alleles of a gene segregate in equal numbers.
4. genes of an allele segregate in equal numbers.
5. genes of an allele segregate in unequal numbers.
6. I do not know

79. If two organisms are crossed and the trait being studied displays incomplete dominance, one may expect the following monohybrid phenotypic ratio in the offspring:

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

80. In a monohybrid cross the ...

1. dominant phenotype disappears in the F₁ generation.
2. dominant phenotype disappears in the F₂ generation.
3. recessive phenotype re-appears in the F₁ generation.
4. recessive phenotype re-appears in the F₂ generation.
5. co-dominant phenotype disappears in the F₁ generation.
6. I do not know.

81. In a cross between red-flowered and white-flowered parental plants, the offspring had red flowers with white spots, indicating that the alleles for flower colour exhibit...

1. complete dominance. ✗
2. recessive behaviour. ✗
3. incomplete dominance.
4. codominance.
5. dominant and recessive behaviour. ✗
6. I do not know.

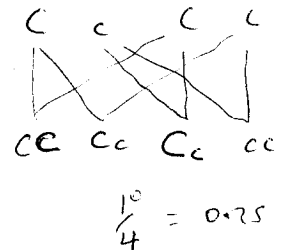
82. In monohybrid inheritance ...

1. two characters, controlled by two alleles are considered.
2. one character, controlled by one allele is considered.
3. two characters, controlled by one gene are considered.
4. one character, controlled by two alleles is considered.
5. two characters, controlled by two genes are considered.
6. I do not know.

Human albinism is determined by homozygosity for the recessive allele *c* while normal pigmentation is determined by the dominant allele *C*. If a normally pigment couple, each of whom has an albino parent are married and have two children, answer the questions that follow.

83. What is the probability that one of the children will be an albino child?

1. $\frac{1}{2}$
2. $\frac{1}{3}$
3. $\frac{1}{4}$
4. $\frac{1}{8}$
5. $\frac{1}{16}$
6. I do not know.



84. What is the probability that both the children will be albino?

1. $\frac{1}{2}$
2. $\frac{1}{3}$
3. $\frac{1}{4}$
4. $\frac{1}{8}$
5. $\frac{1}{16}$
6. I do not know.

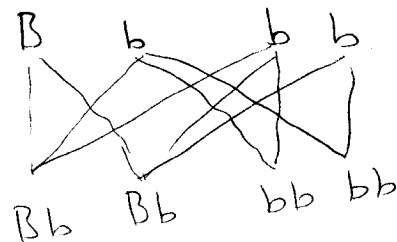
cc

85. Choose the option which best represents a monohybrid testcross.

1. *TT/tt* x *TT*
2. *Tt/TT* x *Tt*
3. *TT/Tt* x *TT*
4. *TT/Tt* x *tt*
5. *TT/tt* x *Tt*
6. I do not know

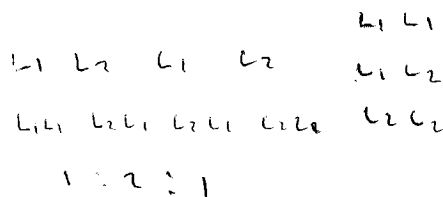
86. In guinea pigs black coat is a dominant trait and white is a recessive trait. When a heterozygous black guinea pig is crossed to a white one, what fraction of the F_2 is expected to be heterozygous?

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.



87. Root shape in radishes is a result of two alleles in which L_1L_1 produces long roots. L_1L_2 produces oval root shape and L_2L_2 produces round root shape. What genotypic ratio would you expect in the F_2 generation?

1. 1:1
2. 3:1
3. 9:3:3:1
4. 1:2:1
5. 3:0
6. I do not know

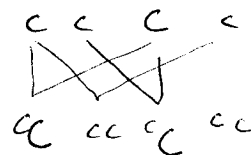


88. A cross between a pure breeding red-flowered plant and a pure breeding white-flowered plant gave a progeny of pink-flowered variety only. This example illustrates ...

1. incomplete dominance.
2. polygenic inheritance.
3. co-dominance.
4. multiple alleles.
5. complete dominance.
6. I do not know

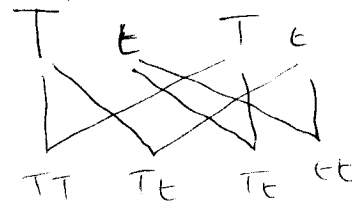
89. Albinism is due to a recessive allele. If an albino male is married to a heterozygous normal female, the children produced will be ...

1. 100% normal homozygous
2. 100% normal heterozygous
3. 50% albino: 50% normal heterozygous
4. 50% normal homozygous: 50% heterozygous
5. None of the above
6. I do not know.



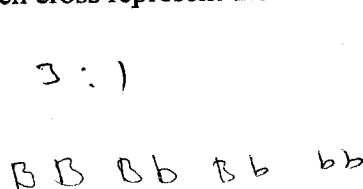
90. In pea plants, axial flowers are dominant over terminal flowers. What phenotypic ratios would you expect in offspring from a cross between two heterozygous axial-flowered plants?

1. 3 axial: 1 terminal
2. 3 terminal: 1 axial
3. 1 axial: 1 terminal
4. All axial.
5. All terminal.
6. I do not know



91. Several black guinea pigs were crossed among themselves and they produced a mixture of 151 black and 49 white offspring. Which cross represent these results?

1. $BB \times BB$
2. $BB \times Bb$
3. $bb \times bb$
4. $BB \times bb$
5. $Bb \times Bb$
6. I do not know



3 axial 1

One type of red flower colour in pea plants is controlled by two alleles **R** and **r**. The dominant allele **R** is responsible for red colour while the recessive allele **r** is responsible for white colour. A cross was carried out between two heterozygous red plants. The progeny plants consisted of 166 red flowered plants and 34 white flowered plants. A chi-squared test was carried out on the results of the progeny phenotypes. Use the information below to answer questions that follow.

92. The expected Mendelian progeny phenotypic ratio of this cross is ...
1. 1:1
 2. 4:1
 3. 1:2:1
 4. 9:3:3:1
 5. 3:1
 6. I do not know.
93. The calculated χ^2 value is ...
1. 1.71
 2. 5.12
 3. 3.8
 4. 6.8
 5. 5.0
 6. I do not know.
94. The tabulated χ^2 value at 0.05 probability is ...
1. 1.7
 2. 5.1
 3. 3.8
 4. 6.8
 5. 5.0
 6. I do not know.
95. From the results of the chi-squared test it can be concluded that ...
1. the calculated χ^2 value is not significant.
 2. the difference between the observed ratio and the expected ratio is not significant.
 3. there are 2 degrees of freedom.
 4. the progeny phenotypes are in the expected Mendelian monohybrid ratio.
 5. the progeny phenotypes are not in the expected Mendelian monohybrid ratio.
 6. I do not know.

96. Short hair in rabbits is governed by a dominant gene (L) and long 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 are the expected genotypic ratios from the cross LLBb x llbb?
1. 1:2
 2. 3:1
 3. 1:1:1:1
 4. 1:1:2:2
 5. 9:3:3:1
 6. I do not know.

Use the information below to answer the questions that follow.

A cross was carried out between two plants; YyRr (yellow, round seeds) x yyrr (green, wrinkled seeds). Out of 500 progeny, the following results were obtained:

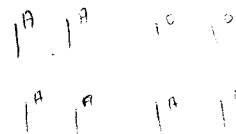
Yellow round	200
Yellow wrinkled	49
Green round	51
Green wrinkled	200

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

97. The calculated chi-squared value is...
1. 45
 2. 46.2
 3. 180.
 4. 43.8.
 5. 7.8.
 6. I do not know.
98. The degrees of freedom are...
1. 2.
 2. 3.
 3. 4.
 4. 9.
 5. 16.
 6. I do not know.
99. The results of this cross suggest that...
1. The gene with alleles R, r and the gene for Y, y are on different chromosome.
 2. The four genes are on different chromosomes.
 3. The two genes are linked.
 4. The three genes are on the same chromosomes.
 5. The three genes are controlled by multiple alleles.
 6. I do not know.

100. If the blood group of a child is A, which of the following couples could not be biological parents of the child?

1. Mother group A and father group B. ✓
2. Both mother and father group A. ✓
3. Mother group AB and father group O. ✓
4. Mother group B and father group O. ✓
5. Mother group A and father group O. ✓
6. I do not know.



CHI-SQUARED TABLE FOR UP TO FOUR DEGREES OF FREEDOM

		Probability							
		0.01	0.05	0.10	0.20	0.5	0.7	0.8	0.9
Degrees of freedom	1	6.6	3.8	2.7	1.6	0.5	0.2	0.06	0.02
	2	9.2	6.0	4.6	3.2	1.4	0.7	0.5	0.2
	3	16.3	7.8	6.3	4.6	2.4	1.4	1.0	0.6
	4	13.3	9.5	9.2	7.3	4.4	3.0	2.3	1.6

 END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
2018 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. Discuss the significance of the microbial growth curve in determining soil fertility.
2. State five methods of sterilization and discuss the sterilization of septrin (Co-trimoxazole) tablets at the point of manufacturing.
3. State four methods used for measuring the effectiveness of anti-microbial agents and describe two of them in detail.
4. (a) Summarise the classification of bacteria and fungi.
(b) Describe in detail how you would prepare 105 culture plates of nutrient agar, each holding 8mls of the agar (35g = 1litre)

SECTION B

5. Describe methods used for quantification of animal and bacterial viruses.
6. Discuss the following in relation to tobacco mosaic virus (TMV).
 - (a) Virus structure.
 - (b) Viral symptoms.
 - (c) Viral transmission methods.
7. Discuss the consequences of virus infection in bacterial cells.
8. Summarise four of the following:
 - (a) Viroid structure.
 - (b) Viral envelope.
 - (c) Viral symmetry.
 - (d) Genomic diversity among viruses.
 - (e) Features of the retroviral genome.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2018 ACADEMIC YEAR
DEFERRED FINAL EXAMINATIONS

BIO 3011: BIOLOGICAL DATA ANALYSIS AND EXPERIMENTAL DESIGN
THEORY PAPER

TIME: THREE HOURS

INSTRUCTIONS: ANSWER **FIVE** QUESTIONS

1. Two Biostatistics classes comprising 10 students each were given a lab test and the scores out of 10 are presented in Table 1.

Table 1. Results of lab tests for two Biostatistics classes.

Class A: 4.00	9.50	6.30	4.50	7.00	7.00	2.00	9.50	6.50	8.00
Class B: 3.50	4.00	7.50	4.00	5.25	6.25	2.00	5.50	5.25	6.00

- (a) Determine the location and scatter of the scores of each class.
(b) Test the null hypothesis that there was no significant difference in the performance of the two classes in the lab test.
2. Table 2 shows the number of years women spent on higher education and the number of children they had. Test whether or not there was a correlation between the number of years spent on higher education and the number of children they had.

Number of years spent on higher education	Number of Children
0	4
9	1
5	0
2	2
4	3
1	5

TURN OVER

3. The results of a Randomized Block Design experiment are set out in Table 3.

Table 3. Results of a Randomized Block Design experiment in centimeters.

Block	Treatments			
	1	2	3	4
1	8.460	27.000	21.000	11.430
2	18.000	39.965	25.000	23.000
3	10.000	26.000	22.000	14.000

Conduct an ANOVA of the results and if the null hypothesis is rejected, separate the means using LSD statistics.

4. The Energy Regulation Board of Zambia tested four different blends of petrol for fuel efficiency according to a Latin Square Design in order to control variability of four different drivers and four different models of cars. Fuel efficiency was measured as kilometers per liter after driving cars over a standard course. The data are given in Table 4.

Table 4. Fuel efficiency test results (in kilometers per liter) for four blends of petrol using four car models by the Energy Regulation Board of Zambia.

Driver	Car Model			
	I	II	III	IV
1	D = 15.50	B = 33.90	C = 13.20	A = 29.00
2	B = 16.30	C = 26.60	A = 19.40	D = 22.80
3	C = 10.80	A = 31.10	D = 17.10	B = 30.30
4	A = 14.70	D = 34.00	B = 19.70	C = 21.60

Test the Null hypothesis that there are no significant differences in fuel efficiency among the four blends of petrol tested.

5. A scientist studied the effect of auxin concentration (gm^{-2}) measured after 10 days exposure on growth media, on root length on two genotypes, **A** and **B** of *Arabidopsis thaliana*. The raw data is as presented in Table 5.

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Table 5. Effect of Auxin on root length of *Arabidopsis thaliana* genotypes.

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

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

6. Measurements of the length (mm) of the prothorax and the diameter of the compound eye of 10 adult females of the armoured ground cricket, *Acanthopplus speiseri* Brancsik, collected from the surroundings of the university of Zambia's Samora Machelo School of Veterinary Medicine are presented in Table 6.

Table 6. Prothorax length and compound eye diameter of adult armoured ground cricket females.

Prothorax length:	13.20	14.00	14.00	13.00	13.00	12.60	13.00	12.50	13.30	11.45
Compound eye diameter:	1.75	1.70	1.85	1.70	1.80	1.80	1.80	1.70	1.70	1.90

- (a) Calculate the product moment correlation coefficient for these two measurements.
 (b) Test the significance of the association.
7. Two samples of the Kafue weed, with 6 plants each, were collected from two locations on the Kafue River between Mazabuka and Kafue Gorge Dam. The lengths of the root systems of the plants (in cm) are given in Table 7.

TURN OVER

Table 7. Lengths of the root systems (cm) of the Kafue weed plants collected between Mazabuka and Kafue Gorge Dam.

SAMPLE 1	SAMPLE 2
97	88
104	101
17	87
101	67
31	65
98	43

- (a) Examine the significance of the difference between the mean root lengths, assuming that population variances are equal.
- (b) Indicate what your conclusion would be regarding the difference between the mean root lengths, if population variances were unequal.
8. The results of a survey in a rural area in Central Africa to compare the prevalence of infection of *Schistosoma mansoni*, a bilharzia parasite, among different occupations are presented in a 2x4 contingency Table 8. Test the Null hypothesis that there was no association between risk of infection and occupation.

Table 8. Risk of infection with *Schistosoma mansoni*, a bilharzia parasite in different occupations in a rural area in Central Africa.

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

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2018 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 3412: GENETICS
THEORY PAPER

TIME: THREE HOURS

INSTRUCTIONS: ANSWER FIVE QUESTIONS; TWO FROM EACH SECTION AND THE FIFTH FROM EITHER SECTION. ILLUSTRATE YOUR ANSWER WHERE NECESSARY. USE SEPARATE ANSWER BOOKS FOR EACH SECTION. A CHI-SQUARED TABLE IS PROVIDED.

SECTION A

1. (a) Explain conjugation in bacteria.
(b) Explain how Hfr bacteria are formed.
(c) Explain how can interrupted conjugation be used to create a genetic map in bacteria?
2. (a) Explain with the help of a diagram, the processes of transduction and transformation.
(b) Explain briefly, the major steps involved in the process of binary fission.
3. (a) Explain either the lytic or lysogenic life cycle in bacteriophage with the help of a diagram.
(b) Explain the factors which determine the transition of a bacteriophage from lysogenic to lytic cycle.
(c) Explain briefly how we can experimentally study recombination in bacteriophages.
4. (a) Differentiate auto-polyploidy from allo-polyploidy and aneuploidy.
(b) Summarise each of the following:
 - (i) Klinefelter syndrome.
 - (ii) Huntington's chorea.
 - (iii) Down syndrome.

SECTION B

5. (a) Explain how you can differentiate unlinked genes from completely linked and partially linked genes using a triple test cross.
(b) Describe the mapping function which relates RF to chiasma frequency.
(c) Demonstrate how the mapping function in 5(b) above can be used to estimate genetic distance between two genes in centimorgans.

TURN OVER

6. A survey was carried out on a human population in order to study its genetic structure based on the albinism trait in which the recessive allele c causes albinism while the dominant allele C produces a normal skin pigmentation. Out of a sample of 1, 500 participants, 30 of them were albino.
- Calculate the genotype frequencies.
 - Calculate the allele frequencies.
 - Estimate the number of individuals who are carriers of the albinism allele in this population.
 - Calculate the probability that a 'normal' couple from this population may have an albino child.
7. A population which was known to be in Hardy-Weinberg equilibrium (HWE) was monitored over a period of time. Table 1 shows the initial and the final genetic structures of the population, based on one gene with two alleles 'A' and 'a'.

Table 1. Results of a study of the genetic structure of a population monitored over a period of time

Population description	Number of AA individuals	Number of Aa individuals	Number of aa individuals
Initial generation (in HWE)	25	49	26
Final generation	40	54	6

For this population:

- Calculate the allele and genotype frequencies
 - Determine whether the final generation of the population is also in HWE.
 - Discuss the results in 7(b) above.
8. A sample of 400 randomly mating humans has allele frequencies $I^B = 0.45$ and $I^O = 0.18$ at the ABO blood group locus.
- Calculate the number of person expected to have each of the following blood groups:
 - A.
 - B.
 - AB.
 - O.
 - Suggest how the knowledge of the ABO blood group distribution in a population can be used by the local hospital blood bank.

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CHI SQUARED TABLE

DEGREES OF FREEDOM	PROBABILITIES										
	0.01	0.05	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
1	6.6	3.8	2.7	1.6	1.1	0.71	0.45	0.27	0.15	0.064	0.016
2	9.2	6.0	4.6	3.2	2.4	1.83	1.19	1.02	0.71	0.446	0.211
3	11.3	7.8	6.3	4.6	3.7	2.95	2.37	1.87	1.42	1.005	0.584
4	13.3	9.5	7.8	6.0	4.9	4.04	3.36	2.75	2.19	1.649	1.064
5	15.1	11.1	9.2	7.3	6.1	5.13	4.35	3.66	3.00	2.343	1.610
6	16.8	12.6	10.6	8.6	7.2	6.21	5.35	4.57	3.83	3.070	2.204
7	18.5	14.1	12.0	9.8	8.4	7.28	6.35	5.49	4.67	3.822	2.833
8	20.1	15.5	13.4	11.0	9.5	8.35	7.34	6.42	5.53	4.594	3.490
9	21.7	16.9	14.7	12.2	10.7	9.41	8.34	7.36	6.39	5.380	4.168

END OF EXAMINATION

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

2018 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 3132: COMMUNITY ECOLOGY
THEORY PAPER

TIME: THREE HOURS

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

1. Predators and prey in a given ecosystem are involved in a long-term evolutionary arms race to survive and reproduce. Provide evidence of strategies both have evolved to support the arms race concept.
2. Summarise each of the following:
 - (a) Species diversity.
 - (b) Trophic cascades.
 - (c) Herbivory.
 - (d) Food web.
3. Discuss a model of an ecosystem after a major disturbance.
4. Savanna ecosystems have an evolutionary history with fires, which means fires are ~~an~~ a common occurrence in such systems. Discuss the effect of fires on plant and animal communities in Miombo woodland.
5. Citing examples, discuss the Intermediate Disturbance Hypothesis (IDH).
6. Summarise each of the following:
 - (a) Facilitation Model.
 - (b) Sigmoid functional response.
 - (c) Community stability.
 - (d) Competition.
6. Compare and contrast natural ecosystems and agro-ecosystems.
8. Aquatic biomes are known to have low Net Primary Production (NPP) in comparison to Terrestrial ones and yet have a proportionately higher biomass of animals. Discuss the validity of this statement.

END OF EXAMINATION

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

**2018/2019 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. Please be reminded that it is your responsibility to **ENSURE** that you have nine (9) printed pages containing questions A1 to A10 and B1 to B5.

ADDITIONAL INFORMATION TO THE CANDIDATES:

Useful data is provided on page 10.
Periodic Table of Elements is on last page.

Please Turn Over

SECTION A
ANSWER ALL QUESTIONS IN THIS SECTION IN THE MAIN BOOKLET

Question A1

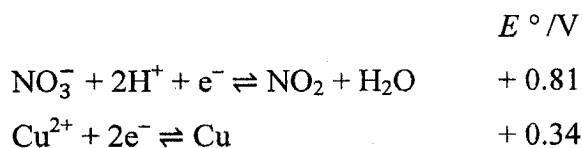
Hemoglobin is the protein that transports oxygen through the blood from the lungs. In doing so, each molecule of haemoglobin combines with four molecules of oxygen. If 1.00 g of haemoglobin combines with $1.53 \times 10^{-6} \text{ m}^3$ of O_2 at 310 K and 99059 Pa, what is the molar mass of haemoglobin? **[4 Marks]**

Question A2

- (a) Two factors can determine the size (radius) of an atom. State any one of them and explain in *three lines or less*, how it influences the size of an atom.
- (b) Is it more difficult to remove a valence electron from a magnesium atom or a chlorine atom? Explain in *three lines or less*.

[4 Marks]**Question A3**

The following standard electrode potentials are needed for this question:



Calculate the standard cell emf for the reaction between copper and nitric acid and derive the balanced reaction equation. **[4 Marks]**

Question A4

Consider the reaction known to be zero order in A and have a rate constant of $5.0 \times 10^{-2} \text{ M s}^{-1}$ at 25 °C. An experiment was run at 25 °C, where $[\text{A}]_0 = 1.0 \times 10^{-3} \text{ M}$.

- (a) Write the integrated rate law for this reaction.
- (b) Calculate the half-life for this reaction.
- (c) Find the concentration after $1.0 \times 10^{-3} \text{ s}$ has elapsed.

[4 Marks]**Question A5**

A solution contains $1.0 \times 10^{-5} \text{ mol dm}^{-3}$ of Na_3PO_4 . What is the required concentration of AgNO_3 that would cause precipitation of Ag_3PO_4 ($K_{\text{sp}} = 1.8 \times 10^{-18}$)?

[4 Marks]**Please Turn Over**

Question A6

- (a) The enthalpy of formation of NH_3 is -46 kJ/mol . Calculate the enthalpy change for the reaction $2\text{NH}_3(\text{g}) \rightarrow \text{N}_2(\text{g}) + 3\text{H}_2(\text{g})$
- (b) When 285 J of heat is added to 33.6 g of hexane, (M_r 86.06 g/mol), the temperature increases by 3.74°C . Calculate the molar heat capacity of hexane.

[4 Marks]**Question A7**

- (a) The vapor pressure above a solution of a nonvolatile solute at 25.0°C is 19.3 mm Hg . What is the mole fraction of the solute? (The vapor pressure of pure water is 23.8 torr at 25.0°C .)
- (b) List the following molecules in order of increasing surface tension: C_3H_8 , CH_4 , CH_3COOH and C_2H_6 .
- (c) Which substance has the higher vapor pressure: $\text{C}_{20}\text{H}_{42}$ or $\text{C}_{30}\text{H}_{62}$?

[4 Marks]**Question A8**

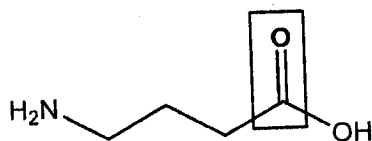
- (a) Identify the strongest intermolecular force present in the following molecules:
- $\text{CH}_3\text{CH}_2\text{OH}$
 - $\text{CH}_3\text{CH}_2\text{Cl}$
- (b) Predict which will have the higher boiling point: ICl or Br_2 . Explain your answer in not more than two lines.

[4 Marks]**Question A9**

- (a) For compound A, 5-isopropyl-2,3-dimethyloct-2-ene:

- Draw a line-bond formula.
- Give molecular formula.
- State the number of allylic hydrogens in A.

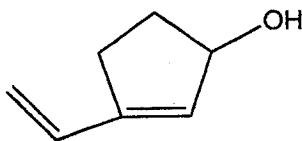
- (b) Classify the molecule shown below and describe the bonding of the group in the box.

**[4 Marks]**

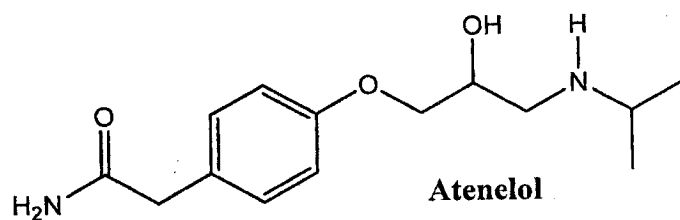
Please Turn Over

Question A10

(a) Give the **IUPAC** name for the molecule shown below:



(b) Identify all functional groups in the drug atenolol, used for treatment of hypertension (high blood pressure), shown below:



[4 Marks]

Please Turn Over

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

Question B1

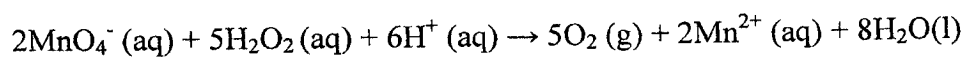
A CHE1000 Student, Lydia, trying to determine the concentration of HCl by titrating it with $0.525 \text{ mol dm}^{-3}$ NaOH. It takes 83 mL of a $0.525 \text{ mol dm}^{-3}$ NaOH solution to neutralize 235 mL of an HCl solution.

- (a) Another student, Joseph, carefully pipettes 10.0 mL of $0.525 \text{ mol dm}^{-3}$ NaOH into a test tube. He places the test tube into a small beaker and then pipettes 7.50 mL of $0.355 \text{ mol dm}^{-3}$ HCl into another test tube. He accidentally knocked the test tubes, while placing, contents combined in the beaker.
- (i) Is the solution formed from the contents of the two test tubes acidic or basic?
- (ii) If he added few drops of Methyl Orange indicator what would be the colour of the solution? (7 marks)
- (b) You are carrying out an acid base titration to determine the concentration of the acid. The endpoint of the neutralization is reached but the stopcock on the burette sticks slightly and allows a few more drops of acid to fall into the solution. Will this small amount of ~~base~~^{acid} have any effect on the determined value for the concentration of the acid? If so, how is it affected (*Not more than 4 lines*)? (4 marks)
- (c) A few small drops of water are left in a burette that is then used to titrate a base into an acid solution to determine the concentration of the acid. Will this small amount of water have any effect on the determined value for the concentration of the acid? If so, how is it affected (*Not more than 4 lines*)? (4 marks)

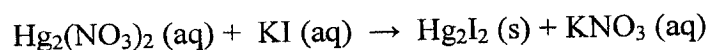
[TOTAL: 15 Marks]

Question B2

- (a) The active agent in many hair bleaches is hydrogen peroxide. The amount of hydrogen peroxide in 15.8 g hair bleach was determined by titration with a standard potassium permanganate solution:



- (i) How many moles of MnO_4^- were required for the titration if 43.2 ml of 0.015 M KMnO_4 was needed to reach the end point? (1 mark)
- (ii) How many moles of H_2O_2 were present in the 15.8 g of hair bleach? (2 marks)
- (iii) How many grams of H_2O_2 were present in the hair bleach? (1 mark)
- (iv) What is the mass percent H_2O_2 in the hair bleach? (2 marks)
- (v) What is the reducing agent in the redox reaction? (1 mark)
- (b) Consider the following precipitation reaction:



- (i) Balance the reaction. (2 marks)
- (ii) Write the **net** ionic reaction. (2 marks)
- (iii) Identify the spectator ions. (2 marks)
- (c) Determine the oxidation number of the underline atom in each of the following:



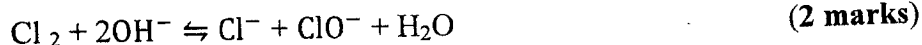
(2 marks)

[TOTAL: 15 Marks]

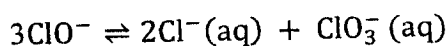
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Question B3

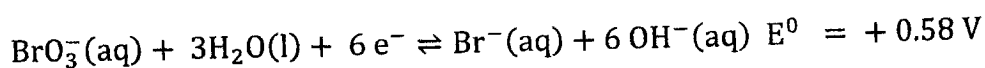
- (a) Use standard electrode potential, E° , data to calculate the cell potential for the following reaction:



- (b) The chlorate(I) ion is unstable and decomposes when heated as shown.



- (i) Calculate the oxidation number of chlorine in each species. (3 marks)
- (ii) In terms of electron transfer, state what happens to chlorine in the reaction. (1 marks)
- (c) A half-equation involving bromate(V) ions, BrO_3^- , and bromide ions is shown.



- (i) An alkaline solution of chlorate (I), ClO^- , can be used to oxidise bromide ions to bromate (V) ions. Write the equation for the spontaneous reaction. (2 marks)
- (ii) Draw a cell in which this reaction will occur and label all the parts. (5 marks)
- (iii) Write the shorthand notation for the cell. (2 marks)

[TOTAL: 15 Marks]

Question B4

- (a) Calculate the maximum Kinetic Energy (in joules) and velocity (3 significant figures) of an electron ejected from zinc by a 275 nm photon. The threshold energy or work function for Zn = 4.31 eV. (3 marks)
- (b) (i) The nitrogen atom in ammonium ion is sp^3 hybridized. Use a suitable hybridization scheme to show the hybridization on the nitrogen atom. (3 marks)
- (ii) Show using a sketch diagram that NH_3 is a polar molecule. (3 marks)

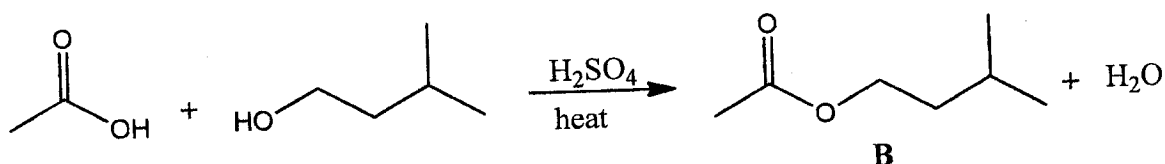
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- (c) Ethene is a planar shaped molecule. Draw a fully labelled diagram showing the bonding (σ - sigma and π - pie) in the molecule. (3 marks)
- (d) (i) How would you expect the first ionization energy to change as you go across a period in the periodic table. (1 mark)
- (ii) State any two factors that influence the ease of removing an electron from an element. (2 marks)

[TOTAL: 15 Marks]

Question B5

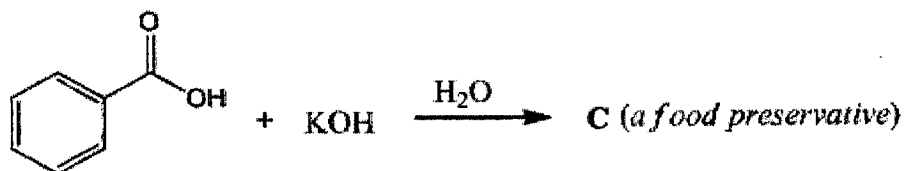
- (a) Several constitutional isomers can be written for molecular formula C_4H_7OCl .
- (i) Calculate the IHD and state all possible interpretations. (2 marks)
- (ii) Draw line-bond formula and give IUPAC name for an isomer that is a straight chain acyl chloride (acid chloride). (3 marks)
- (iii) Draw line-bond formulae for two (2) isomers with cyclobutane as parent chain and state their isomeric relationship as chain, positional or functional isomers. (3 marks)
- (iv) One of the isomers decolorizes bromine water. Interpret this result and state two (2) other functional groups that could be present in this isomer. (2 marks)
- (b) Esters are pleasant sweet-fruity smelling substances frequently used in perfumery and food industry. One common banana flavor **B** used for candy products is prepared by the reaction shown below:



- (i) Name the type of reaction. (1 mark)
- (ii) Give the IUPAC name for B. (2 marks)

Please Turn Over

(c) A frequently used food preservative, C, is prepared as shown below:



Identify C (line-bond structure) and circle the most electrophilic center on its structure.

(2 marks)

[TOTAL: 15 Marks]

END OF EXAMINATION

Please Turn Over

USEFUL DATA**Physical constants**

Avogadro constant, N_A	$6.022 \times 10^{23} \text{ mol}^{-1}$
Acceleration due to gravity	9.8 m s^{-2}
Faraday's constant, F	96485 C mol^{-1}
Mass of electron, m_e	$9.11 \times 10^{-31} \text{ kg}$
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

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

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

Other conversion factors

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

	$E^\circ(\text{V})$
$\text{Cl}_2 + 2 \text{ e}^- \rightleftharpoons 2 \text{ Cl}^-(\text{aq})$	+1.36
$\text{ClO}^-(\text{aq}) + \text{H}_2\text{O}(\text{l}) + 2 \text{ e}^- \rightleftharpoons \text{Cl}^-(\text{aq}) + 2 \text{ OH}^-$	+0.89

UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2018 ACADEMIC YEAR

FINAL DEFERRED EXAMS

CHE 2001: AGRICULTURAL AND VETERINARY CHEMISTRY

INSTRUCTIONS TO THE CANDIDATES

Time: Three (3) hours

All questions carry equal marks (20 marks EACH)

Answer **Any Five (5)** questions

Write your computer number on all Answer booklets

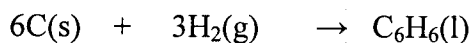
This examination consists of six (6) questions and **FOUR (4)** printed pages and the
DATA sheet.

QUESTION 1

- a) The rate law for the decomposition of N_2O_5 is $\text{Rate} = k[\text{N}_2\text{O}_5]$, where $k = 5.0 \times 10^{-4} \text{ s}^{-1}$. What is the concentration of N_2O_5 after 1900s, if the initial concentration is 0.56 M? **(6 marks)**
- b) The first order reaction, $\text{SO}_2\text{Cl}_2 \rightarrow \text{SO}_2 + \text{Cl}_2$, has a rate constant of 0.17 h^{-1} . If the initial concentration of SO_2Cl_2 is $1.25 \times 10^{-3} \text{ M}$, how many seconds does it take for the concentration to drop to $0.31 \times 10^{-3} \text{ M}$? **(6 marks)**
- c) Cobalt-60 is a radioisotope that decays by first-order kinetics and has a half-life of 5.26 years. The Cobalt-60 in a radiotherapy unit must be replaced when the concentration of Co decreases to 75.0% of its initial value. When does this occur? **(8 marks)**

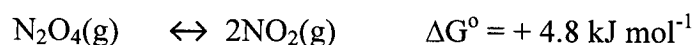
QUESTION 2

- (a) Calculate the enthalpy of formation of benzene, C_6H_6 from the following data: **(6 marks)**



$$\begin{aligned}\Delta H_c^\circ(\text{C}_6\text{H}_6) &= -3267.6 \text{ kJmol}^{-1} \\ \Delta H_f^\circ(\text{H}_2\text{O}) &= -285.9 \text{ kJmol}^{-1} \\ \Delta H_f^\circ(\text{CO}_2) &= -393.5 \text{ kJmol}^{-1}\end{aligned}$$

- (b) Consider the following reaction below:



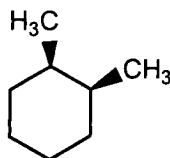
- (i) Write an expression for the equilibrium constant for the reaction. **(2 marks)**
- (ii) What is the value of the equilibrium constant, K_p , at 298 K, ($R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$) **(5 marks)**
- (iii) Which gas is mainly present at equilibrium? **(2 marks)**
- (c) How much energy is required to heat 80 g of water from 26°C to 48°C . The specific heat capacity of water is $4.184 \text{ J/g }^\circ\text{C}$. **(5 marks)**

QUESTION 3

(a) For each of the following molecules; give the IUPAC name, write the bond-line formula and identify the functional group. **(9 marks)**

- (i) $(\text{CH}_3)_2\text{CHCH}_2\text{CH}_3$
- (ii) $(\text{CH}_3)_2\text{CHCH}_2\text{CH}_2\text{OH}$
- (iii) $\text{CH}_3\text{COCH}_2\text{CH}_2\text{CH}_2\text{CH}_3$

(b) Consider *cis*-1,2-dimethylcyclohexane, shown below. It has two possible chair conformations and these are possible through the bond rotations that constitute a ring flip.



***Cis*-1,2-dimethylcyclohexane**

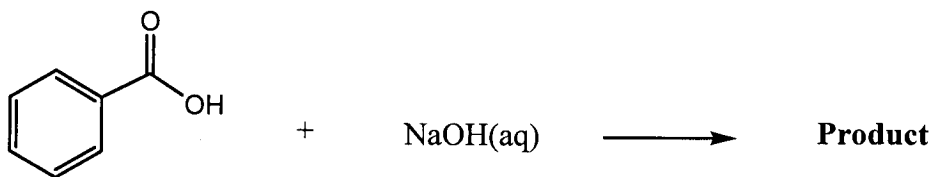
- i) Draw the two chair conformations of *cis*-1,2-dimethylcyclohexane. **(2 marks)**
- ii) Label the bonds where the substituents are as axial or equatorial. **(1 marks)**
- iii) Show the position of equilibrium between the two chair conformers in terms of stability in energy. (*No calculations needed, just use the equilibrium arrows to show this*) **(1 marks)**
- iv) Compare the stability of the conformers and state which one is more stable and explain why. **(1 marks)**

(c) Consider the following molecular formula, $\text{C}_4\text{H}_7\text{OCl}$.

- (i) Draw six isomers with this molecular formula. **(6 marks)**

QUESTION 4

(a) A common food preservative is prepared according to the following reaction:



- (i) Name the type of reaction. **(2 marks)**
- (ii) Draw the structure of the product. **(3 marks)**
- (iii) The product above has an electrophilic carbon, draw a circle to show that. **(2 marks)**

b) Butanoic acid reacts with ethanol in the presence of catalytic amounts of concentrated sulphuric acid to give an **ester** as the product.

- (i) Write an equation to represent this reaction. **(4 marks)**
- (ii) Name the ester produced. **(2 marks)**
- (iii) Give a detailed mechanism for the reaction. **(7 marks)**

QUESTION 5

(a) Calculate the percent dissociation of acetic acid ($K_a = 1.85 \times 10^{-5}$) in each of the following solutions: **(18 marks)**

- i) 1.00 M CH_3COOH
- ii) 0.100 M CH_3COOH

(b) Comment on the calculated percent dissociation values at two different concentrations **(2 marks)**

QUESTION 6

(a) Calculate the pH of the following solutions:

- (i) 0.1000 M HCl **(3 marks)**
- (ii) 0.1000 M NaOH **(3 marks)**
- (iii) 0.1000 M CH_3COOH , $K_a(\text{CH}_3\text{COOH}) = 1.8 \times 10^{-5}$ **(7 marks)**
- (iv) 0.1000 M NH_3 , $K_b(\text{NH}_3) = 1.8 \times 10^{-5}$ **(7 marks)**

1	H	Hydrogen	1.00794	2	He	Helium	4.003
3	Li	Lithium	6.941	4	Be	Beryllium	9.012182
11	Na	Sodium	22.989770	12	Mg	Magnesium	24.3050
19	K	Potassium	39.0983	20	Ca	Calcium	40.078
37	Rb	Rubidium	85.4678	38	Sr	Strontium	87.62
55	Cs	Cesium	132.90545	56	Ba	Barium	137.327
87	Fr	Francium	(223)	88	Ra	Radium	(226)
21	Sc	Scandium	44.955910	22	Ti	Titanium	47.867
23	V	Vanadium	50.9415	24	Cr	Chromium	51.9961
25	Mn	Manganese	54.938049	26	Fe	Iron	55.845
27	Co	Cobalt	58.933200	28	Ni	Nickel	58.6934
29	Cu	Copper	63.546	30	Zn	Zinc	65.39
31	Ga	Gallium	69.723	32	Ge	Germanium	72.61
33	As	Arsenic	74.92160	34	Se	Selenium	78.96
35	Br	Bromine	79.904	36	Kr	Krypton	83.80
37	Rb	Rubidium	85.4678	38	Sr	Strontium	87.62
39	Y	Yttrium	88.90585	40	Zr	Zirconium	91.224
41	Nb	Niobium	92.90638	42	Mo	Molybdenum	95.94
43	Tc	Technetium	(98)	44	Ru	Ruthenium	101.07
45	Rh	Rhodium	102.90550	46	Pd	Palladium	106.42
47	Ag	Silver	107.8682	48	Cd	Cadmium	112.411
49	In	Indium	114.818	50	Sn	Tin	118.710
51	Sb	Antimony	121.760	52	Te	Tellurium	127.60
53	I	Iodine	126.90447	54	Xe	Xenon	131.29
55	Cs	Cesium	132.90545	56	Ba	Barium	137.327
57	La	Lanthanum	138.9055	58	Ce	Cerium	140.116
59	Pr	Praseodymium	140.90765	60	Nd	Neodymium	144.24
61	Pm	Promethium	(145)	62	Sm	Samarium	150.36
63	Eu	Europium	151.964	64	Gd	Gadolinium	157.25
65	Tb	Terbium	158.92534	66	Dy	Dysprosium	162.50
67	Ho	Holmium	164.93032	68	Er	Erbium	167.26
69	Tm	Thulium	168.93421	70	Yb	Ytterbium	173.04
71	Lu	Lutetium	174.967	72	Hf	Hafnium	178.49
73	Ta	Tantalum	180.9479	74	W	Tungsten	183.84
75	Re	Rhenium	186.207	76	Os	Osmium	190.23
77	Ir	Iridium	192.217	78	Pt	Platinum	195.078
79	Au	Gold	196.96655	80	Hg	Mercury	200.59
81	Tl	Thallium	204.3833	82	Pb	Lead	207.2
83	Bi	Bismuth	208.98038	84	Po	Polonium	(209)
85	At	Astatine	(210)	86	Rn	Radon	(222)
87	Fr	Francium	(223)	88	Ra	Radium	(226)
89	Ac	Actinium	(227)	90	Th	Thorium	232.0381
91	Pa	Protactinium	231.03588	92	U	Uranium	238.0289
93	Np	Neptunium	(237)	94	Pu	Plutonium	(244)
95	Am	Americium	(243)	96	Cm	Curium	(247)
97	Bk	Berkelium	(247)	98	Cf	Californium	(251)
99	Es	Einsteinium	(252)	100	Fm	Fermium	(257)
101	Md	Mendelevium	(258)	102	No	Nobelium	(259)
103	Lr	Livermorium	(262)	104	Rf	Rutherfordium	(261)
105	Db	Dubnium	(262)	106	Sg	Seaborgium	(263)
107	Bh	Borhrium	(262)	108	Hs	Hassium	(265)
109	Mt	Moscovium	(266)	110	Ds	Darmstadtium	(269)
111	Uu	Ununium	(272)	112	Cn	Unbinilium	(277)
113	Uth	Untrium	(279)	114	Fl	Unquadium	(285)
115	Uuq	Unquadium	(288)	116	Lv	Unsextium	(293)
117	Uuq	Unseptium	(294)	118	Og	Oganesson	(294)

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

1995 IUPAC nomenclature and approved names from <http://www.chem.qmul.ac.uk/iupac/ATW/>
 updates for 197-111 from CERN, March 13, 1995, p. 35
 112 from <http://www.sci.de/12a.html>

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2018/2019 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 SEVEN (7) printed pages

Question 1

- a) By way of a clear **calculation** (an brief explanation, if any), **show** how you would prepare a 1 litre 0.45 M phosphate buffer at pH 7.4 given that you have at your disposal H_3PO_4 , KH_2PO_4 , K_2HPO_4 and K_3PO_4 (Rel. Mol. Mass: $\text{H}_3\text{PO}_4 = 97.994 \text{ g}\cdot\text{mol}^{-1}$, $\text{KH}_2\text{PO}_4 = 136.1 \text{ g}\cdot\text{mol}^{-1}$, $\text{K}_2\text{HPO}_4 = 174.2 \text{ g}\cdot\text{mol}^{-1}$ and $\text{K}_3\text{PO}_4 = 196.2 \text{ g}\cdot\text{mol}^{-1}$). For additional information, see the last page. **[10 marks]**
- b) **Draw** the structure of histidine, and briefly **explain** why it is an appropriate buffer at pH = 6.0. [useful information on the last page of this examination paper] **[5 marks]**
- c) **Why** is histidine an inappropriate (not effective) buffer at pH 12.0? **ONE SHORT SENTENCE ANSWER. [5 marks]**

Question 2

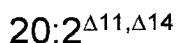
- a) Secondary structure in proteins include α -helix and β -pleated sheets.
- i) In point form **describe** salient features of β -pleated sheets. **[5 marks]**
- ii) **Calculate** the axial length of an α -helix containing 78 amino acyl residues. How long would the polypeptide chain be if it were fully extended? **[10 marks]**
- b) In what order will the following amino acids elute from a chromatographic column packed with Dowex-50 at pH 3.2? ala (pI=6.02), arg(pI=10.76), glu (pI=3.22), ser (pI=5.68) and try (pI=5.88) **[5 marks]**

Question 3

a) On hydrolysis a compound X gave the following products: glycerol, palmitic acid, palmitoleic acid and inorganic phosphate and a disaccharide. The compound X, which was extractable into a hexane/methanol mixture, was also observed to be optically active. Draw the possible structure(s) of compound X. **[6 marks]**

b) The disaccharide in part a was subjected to acid hydrolysis and the two sugars were found to be linked by an α linkage. Exhaustive methylation of the disaccharide produced equal amounts of 2,3,4,6-tetramethylgalactose and 2,4,6-trimethylglucose. Using Haworth formulas draw the structure of the disaccharide suggested by the above information and show clearly the link between the sugars. **[10 marks]**

c) Draw skeleton structure of the following fatty acid including its IUPAC name:



[4 marks]

Question 4

- a) Assume that a fragment of B-DNA occurs as a double helix with a total diameter of 20 Å and on average the molecular weight of deoxynucleotide pairs is 618 Daltons.
- i) Calculate the length of the double stranded DNA molecule of MW 3×10^7 . **[8 marks]**
 - ii) What is the volume occupied by one molecule of this DNA assuming it's a perfect cylinder? **[4 marks]**
 - iii) How many helical turns does a molecule of this DNA contain? **[4 marks]**
- b) A sample of DNA purified from *Mycobacterium tuberculosis* contains 15.1% adenine on a molar basis. What are the percentages of other bases present? **[4 marks]**

Question 5

a) **Define** the following terms.

i) Entropy. [1 mark]

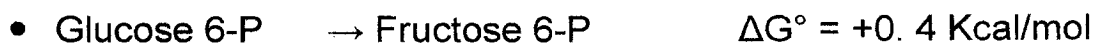
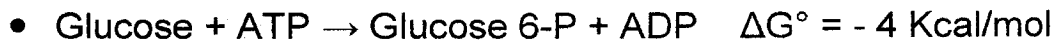
ii) Gibbs free energy [1 mark]

b) i) **State** the second law of thermodynamics. [1 mark]

iii) **Use** the second law of thermodynamics to **derive** the Gibbs - Helmholtz's equation [3 marks]

c) **Using** mathematical expressions **explain** how ΔG° is related to the spontaneity of a biological reaction. [5 marks]

d) Given the following reactions



Calculate the standard Gibbs free energy, ΔG° for the reaction below



e) i) Draw the detailed structure of adenosine triphosphate [3 marks]

ii) Explain why it is a high energy compound [5 marks]

Question 6

a) Define the following terms.

i) Apoenzyme. [1 mark]

ii) Coenzyme. [1 mark]

b) Name one coenzyme that you know and draw its chemical structure. [4 marks].

c) Derive the Michealis-Menten equation stating clearly the important assumptions you make. [3 marks]

d) Using the mathematical expression state how k_m may be found using the V_o versus S_o plot when $V_o = \text{half of } V_{max}$. [3 marks].

e) State two uses of Michealis-Menten plot. [2 marks].

f) Given the following data for an enzymatic reaction estimate the value of k_m and V_{max} without plotting

S/N	Substrate concentration S_o (mol/litre)	Velocity of the reaction V_o (nanomole/minute)
1	0.00000625	15.0
2	0.0000750	56.25
3	0.00010	60.0
4	0.0010	74.9
5	0.010	75.0

[6 marks]

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

**2018 ACADEMIC YEAR
UNIVERSITY DEFERRED EXAMINATIONS**

CHE 2522: FUNCTIONAL GROUP AND ARENE CHEMISTRY

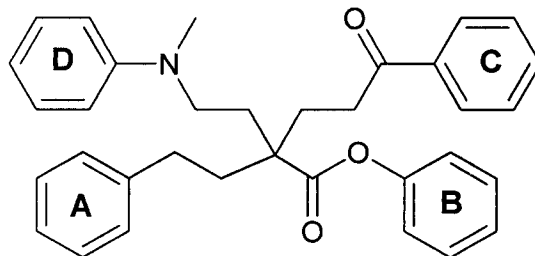
TIME ALLOWED: THREE (3) HOURS

INSTRUCTIONS:

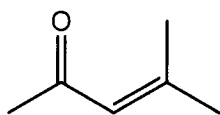
1. Answer any **four (4)** questions.
3. Questions carry equal marks (25).
4. Write your TG number (example: TG 5) on the cover page of each answer booklet.
5. Present your answers in a logical manner.
5. Please ensure that you have six (6) printed pages and five (5) questions.

QUESTION ONE

- (a) The following compound has four aromatic rings, **A** – **D**. Rank them in terms of increasing reactivity toward electrophilic aromatic substitution. **(3 marks)**

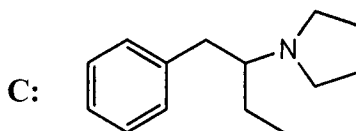


- (b) Upon treatment with hydrogen chloride, acetone gives 4-methylpent-3-en-2-one. Provide the most likely mechanism for this reaction, show all steps clearly. **(11 marks)**



4-Methylpent-3-en-2-one

- (c) Suggest a synthesis of an antidepressant drug **A**, shown below, by reductive amination. Do not write reaction mechanisms. **(4 marks)**

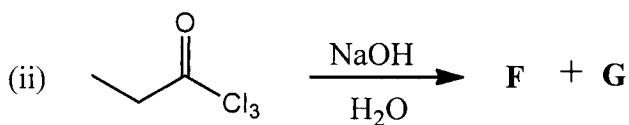
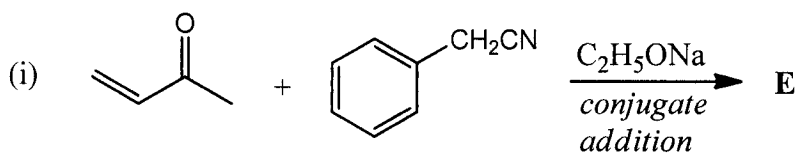


- (d) An unknown compound **D**, $C_5H_{10}O$, gives positive Brady's test, negative Tollen's test and positive iodoform test.

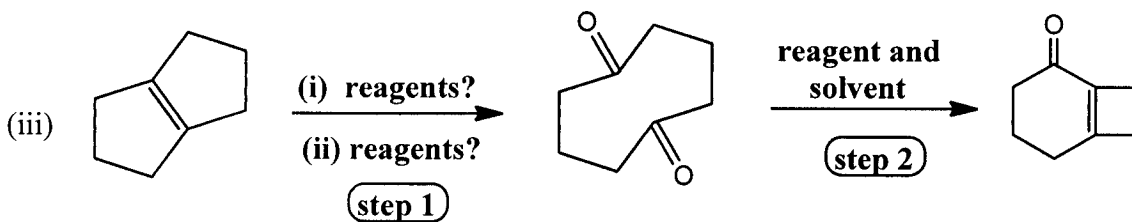
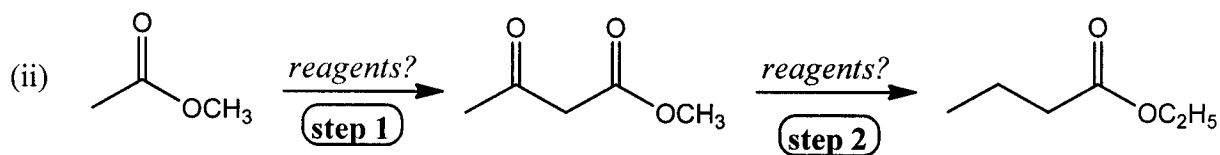
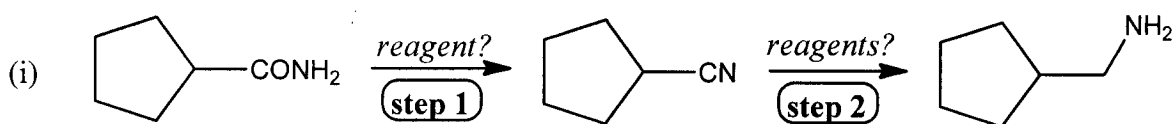
- Calculate IHD for **D** and interpret it. **(2 marks)**
- Interpret the results of all qualitative tests. **(3 marks)**
- Propose possible structure(s) for **D** that are consistent with the given data. **(2 marks)**

QUESTION TWO

(a) Predict the products and give plausible mechanisms of the following reactions: (13 marks)

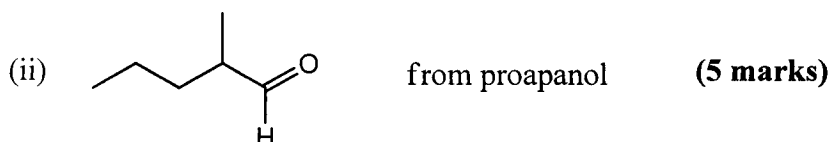
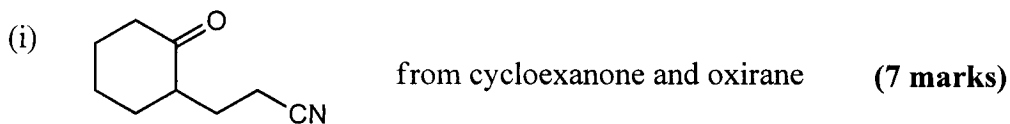


(b) Provide the reagents for the following transformations: (12 marks)



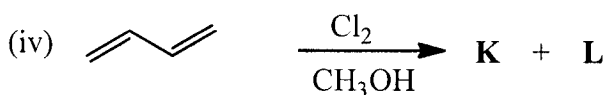
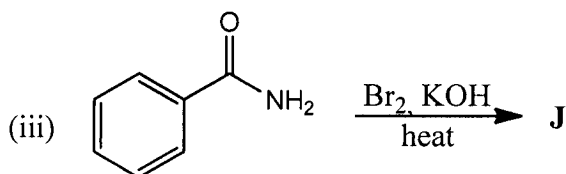
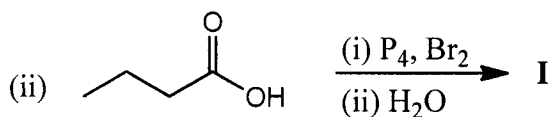
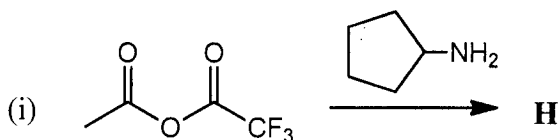
QUESTION THREE

(a) Suggest an efficient synthesis for the following target molecules from indicated materials. Show all steps, including the intermediates, clearly. Assume that all needed reagents are available. *Please do not write reaction mechanisms.*

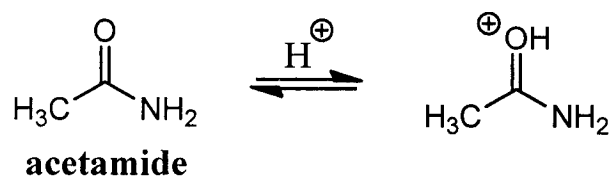


(b) Predict the product of the following reactions:

(10 marks)



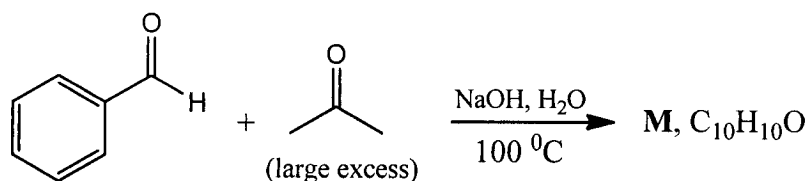
(c) Protonation of acetamide occurs on oxygen rather than on nitrogen. Briefly explain this observation, illustrating your answer with appropriate resonance structures. **(3 marks)**



QUESTION 4

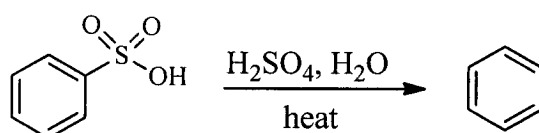
(a) Identify the product and give mechanism of the Claisen-Schmidt reaction shown below:

(9 marks)



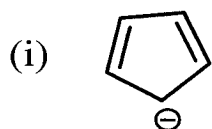
(b) Assuming that you were provided with three (3) amines: ethylamine, diethylamine and triethylamine. Give the name of a laboratory test you would carry out to distinguish the three amines from each other. Write all the reactions involved in the test and clearly show evidence for distinguishing the three amines. Indicate the starting materials, the reagents and the intermediates. (10 marks)

(c) Sulfonation is a reversible reaction. Propose a plausible mechanism for the hydrolysis of benzenesulfonic acid. (6 marks)



QUESTION 5

(a) Determine whether each of the following is aromatic, non-aromatic, or anti-aromatic. Show your working. (3 marks)



UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
FINAL EXAMINATIONS 2018/2019 ACADEMIC YEAR,
CHE2615: BASIC PHYSICAL CHEMISTRY

Duration: Three (3) Hour

Instructions:

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

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

All questions carry equal marks. **(25 Marks)**

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

Useful Information and Constants:

R = 8.314 J mol⁻¹ K⁻¹, Molar volume of gas at STP = 22.4 dm³ mol⁻¹, STP = 273 K and 1 atm,
1 atm = 1 bar = 101325 Pa. Avogadro's constant = 6.02 x 10²³ mol⁻¹, 1 F = 96485 C mol⁻¹

Question 1

- (a) State the assumptions of the kinetic theory of gases? **[4 Marks]**
- (b) (i) Show that the square root of the average of the squares of speeds of all molecules in a sample is given by the equation:

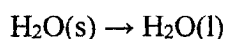
$$u_{rms} = \sqrt{\frac{3RT}{M}} \quad \mathbf{[4 Marks]}$$

- (ii) Draw a sketch diagram showing Maxwell-Boltzmann distribution of molecular speeds **[4 Marks]**
- (c) A gas exerts a pressure of 0.892 atm in a 5.00 L container at 15 °C. The density of the gas is 1.22 g/L. What is the molecular weight of the gas? **[5 Marks]**
- (d) (i) Explain the term *ideal gas behaviour*. **[3 Marks]**
- (ii) Draw a sketch diagram illustrating deviation from ideal gas behaviour. **[5 Marks]**

Question 2

- (a) The properties of a closed system change following the relation between pressure and volume as $pV = 3.0$ where p is in bar and V is in m^3 . Calculate the work done when pressure increases from 1.5 bar to 7.5 bar. [7 Marks]

- (b) The entropy change for the process



is 22.1 J/K and requires that the surroundings transfer 6.00 kJ of heat to the system. Determine whether melting is spontaneous at;

- (i) $+10.00 \text{ }^\circ\text{C}$ [3 Marks]

- (ii) $-10.00 \text{ }^\circ\text{C}$? [3 Marks]

- (c) The process of heat transfer from hot to cold is an irreversible process is spontaneous. Calculate the total change in entropy if 4000 J of heat transfer occurs from a hot reservoir at $327 \text{ }^\circ\text{C}$ to a cold reservoir at $-23 \text{ }^\circ\text{C}$ assuming there is no temperature change in either reservoir. [7 Marks]

- (d) Suppose that water is boiling at its boiling point is maintained in a cylinder that has a frictionless piston. For equilibrium to be established, the pressure that must be applied to the piston is 1 atm (101.325 kPa). Suppose that we now reduce the external pressure by an infinitesimal amount in order to have a reversible expansion. If the piston sweeps out a volume of 2.00 dm^3 , what is the work done by the system? [5 Marks]

Question 3

- (a) The initial rate of reaction between ester A and aqueous sodium hydroxide was measured in a series of experiments at a constant temperature. The data obtained are shown below.

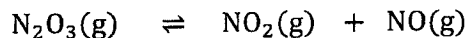
Experiment	Initial concentration of NaOH / mol dm^{-3}	Initial concentration of A / mol dm^{-3}	Initial rate / $\text{mol dm}^{-3} \text{ s}^{-1}$
1	0.040	0.030	4.0×10^{-1}
2	0.040	0.045	6.0×10^{-1}
3	0.060	0.045	9.0×10^{-1}
4	0.120	0.060	to be calculated

Use the data in the table to deduce the order of reaction with respect to A and the order of reaction with respect to NaOH. Hence, calculate the initial rate of reaction in Experiment 4. **[6 Marks]**

- (b) In a further experiment at a different temperature, the initial rate of reaction was found to be $9.0 \times 10^{-3} \text{ mol dm}^{-3} \text{ s}^{-1}$ when the initial concentration of A was $0.020 \text{ mol dm}^{-3}$ and the initial concentration of NaOH was 2.00 mol dm^{-3} . Under these new conditions with the much higher concentration of sodium hydroxide, the reaction is first order with respect to A and appears to be zero order with respect to sodium hydroxide.
- (i) Calculate a value for the rate constant under these new conditions and state its units. **[4 Marks]**
- (ii) Suggest why the order of reaction with respect to sodium hydroxide appears to be zero under these new conditions. **[4 Marks]**
- (c) The milk at 37°C lactobacillus acidophilus has a generation time of 75 minutes. Calculate the population relative to initial value at 90 minutes. **[6 Marks]**
- (d) The rate equation for the decomposition of a compound N has a rate constant with the unit s^{-1} . The rate constant is $4.31 \times 10^3 \text{ s}^{-1}$ at 700 K and $1.78 \times 10^4 \text{ s}^{-1}$ at a temperature T . Use this information to deduce the overall order of reaction and whether temperature T is greater or smaller than 700 K. **[5 Marks]**

Question 4

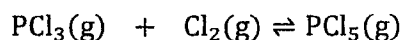
- (a) Nitrogen trioxide dissociates according to the reaction



When one mole of $\text{N}_2\text{O}_3(\text{g})$ is held at 25°C and 1 bar total pressure until equilibrium is reached, the extent of reaction is 0.30. Calculate K_p . **[10 Marks]**

- (b) Given that for the same reaction K_p is equal to 0.15 at 30°C
- (i) What is $\Delta_r G^\circ$ for this reaction at this temperature? **[3 Marks]**
- (ii) What will be the extent of the reaction that will cause a 10 % conversion of N_2O_3 to products. **[4 Marks]**

- (c) Given that $\Delta_r H^\circ$ has an average value of $-69.8 \text{ kJ mol}^{-1}$ over the temperature range 500 K to 700 K for the reaction

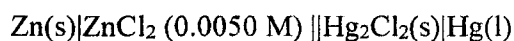


Estimate K_p at 700 K given that $K_p = 0.0408$ at 500 K

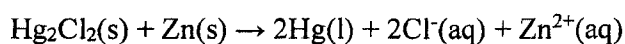
[8 Marks]

Question 5

Consider the cell at 25°C:



for which the cell reaction is



Given that

$$E^\circ(\text{Zn}^{2+}, \text{Zn}) = -0.7628 \text{ V}$$

$$E^\circ(\text{Hg}_2\text{Cl}_2, \text{Hg}) = +0.2676 \text{ V}$$

- (a) Write the Nernst equation for the cell. [4 Marks]
- (b) Determine the mean ionic activity coefficient of ZnCl_2 from the Debye–Hückel limiting. [4 Marks]
- (c) Determine E_{cell}° and E_{cell} . [5 Marks]
- (d) Determine $\Delta_r G^\circ$, $\Delta_r G^\circ$, and K for the cell reaction. [7 Marks]
- (e) Given that $(\partial E_{\text{cell}} / \partial T)_p = -4.52 \times 10^{-4} \text{ V K}^{-1}$, calculate $\Delta_r S$ and $\Delta_r H$. [5 Marks]

END OF EXAM

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

2018/19 ACADEMIC YEAR FINAL-YEAR EXAMINATIONS

CHE3122: ENERGY TRANSDUCTION SYSTEMS

INSTRUCTIONS:

TIME: THREE HOURS

1. Answer any **FOUR (4)** questions
2. All questions carry **EQUAL MARKS** (25 marks each question)
3. There are **FOUR (4)** printed pages in this examination

P.T.O

Question 1

- a) **Describe** a detailed **microscopic** structure of a skeletal muscle. [10 marks]
- b) **Explain** in detail the mechanism of **skeletal** muscle contraction. [15 marks]

Question 2

- a) **What** is meant by the term oxidative phosphorylation? [2.5 marks]
- b) **List** all components of the ATPase protein complex. [10 marks]
- c) **Explain** in detail how ATP is formed by the ATPase in (ii) [10 marks]
- d) **List** two substance that would uncouple oxidative phosphorylation [2.5 marks]

Question 3

- a) **Explain** how the term 'fluid mosaic model' is used to describe the structure of the plasma membrane. [5 marks]
- b) When transport across the plasma membrane is disrupted, serious medical conditions can develop. For each of the medical conditions below, **indicate** the defect and discuss the consequence as well as the main symptoms associated with the condition.
- i) Cystic fibrosis [3 marks]
- ii) Multiple sclerosis [4 marks]
- iii) Familial hypercholesterolemia [3 marks]

P.T.O

c) **Discuss** the biochemical mechanisms by which the following substances disrupt neuronal signalling:

- i) Botulinus toxin [3 marks]
- ii) Scorpion venom [3 marks]
- iii) Prozac [4 marks]

Question 4

- a) **Explain** cyclic photophosphorylation using a neat diagram. [10 marks]
- b) Assuming a light source has speed of $2.998 \times 10^8 \text{ ms}^{-1}$, Planks constant of $6.626 \times 10^{-34} \text{ J.s}$ and Avogadro's number of $6.022 \times 10^{23} \text{ mol}^{-1}$:
 - i) **How** many moles of ATP can be synthesized at 100% efficiency by a photosynthetic organism upon absorption of 1 mol of photons of red light of 700 nm? [8 marks]
 - ii) **How** many molecules of ATP can be produced from 1 photon? [1 mark]
 - iii) **Calculate** the overall efficiency of energy conversion if 1 mole of ATP is formed per 2 equivalents of electrons excited by red light (i.e per 2 mol photons). ΔG° for ATP synthesis is $+30.5 \text{ kJ mol}^{-1}$ [6 marks]

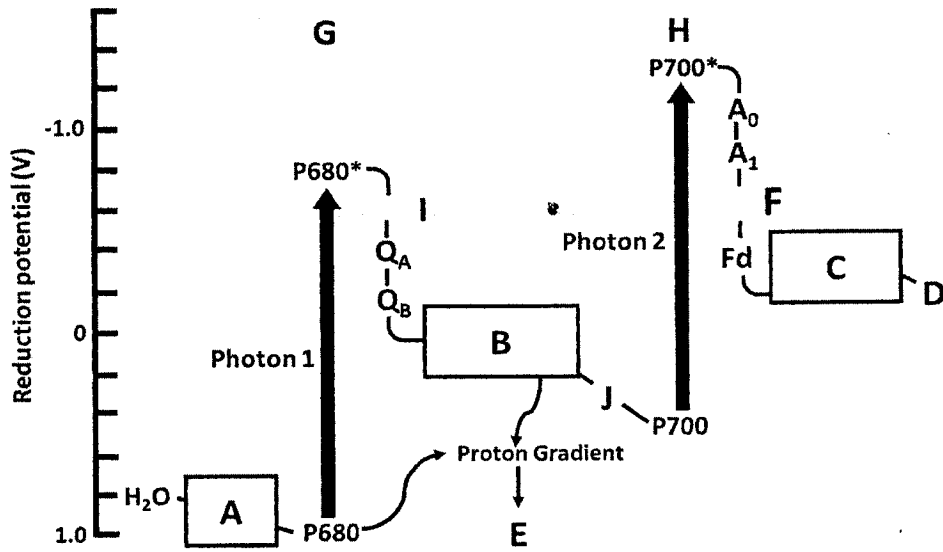
Question 5

- a) **Explain** the first three Calvin cycle reactions with clear chemical structures. [10 marks]
- b) **True or False**
 - i) Atrazine inhibits PS II by blocking the transfer of electrons to QH_2 [1 mark]
 - ii) Dark reactions occur in the stroma [1 mark]
 - iii) The catalytic efficiency of rubisco is ^{is} low [1 mark]
 - iv) 2-carboxyarabinitol-1-phosphate is a regulator of PSII [2 marks]

P.T.O

c) Identify the species or process in the diagram labelled A to J [10 marks]

[10 marks]



END OF FINAL EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
DEPARTMENT OF CHEMISTRY
2018/2019 ACADEMIC YEAR FINAL EXAMINATION

CHE3222 INSTRUMENTAL METHODS OF CHEMICAL ANALYSIS

DURATION: THREE HOURS

INSTRUCTIONS

1. Indicate your student ID number on each of the provided answer booklets.
 2. There are **five** questions in this examination paper; Answer any **four** questions.
 3. All questions carry equal marks.
 4. There are **five printed papers** for the questions; the periodic table is attached also.
 5. Show your reasoning and/ or calculations clearly.
-

Question 1

- (a) Both fluorescence and phosphorescence are spontaneous emissions of electromagnetic radiation. What is the difference between them?
- (b) X-ray spectroscopy (XRF) spectroscopy is an important analytical technique for elemental analysis.
 - (i) Describe in 6 lines or less the fundamental principle of XRF spectroscopy.
 - (ii) One main source of primary x-rays used in XRF spectroscopy is an X-ray tube. With the aid of a well labeled schematic diagram, describe how X-rays are generated in an X-ray tube.
 - (iii) Electrons play a critical role in the production of X-rays in the X-ray tube. State and describe the method used to produce electrons in the X-ray tube.
- (c) Define K_{α} emission, L_{β} emission, and $K_{\alpha 2}$ emission.
- (d) Mention the four key components of an XRF machine.

Question 2

- (a) Describe the principle in chromatographic technique.
- (b) Define the following terms:
 - (i) Elution
 - (ii) Eluent
 - (iii) Eluate
 - (iv) Adsorption
- (c) What is the difference between a symmetric peak and a non-symmetric peak in chromatography? Use diagrams to explain your answer.
- (d) There are two related terms used as quantitative measures of chromatographic efficiency in High Performance Liquid Chromatography (HPLC): Number of 'theoretical plates' N and Plate height H .
 - (i) What do N and H mean?
 - (ii) Write the formula for determining N if you know $W/2$ which is equal to the width of the peak at half its maximum height.

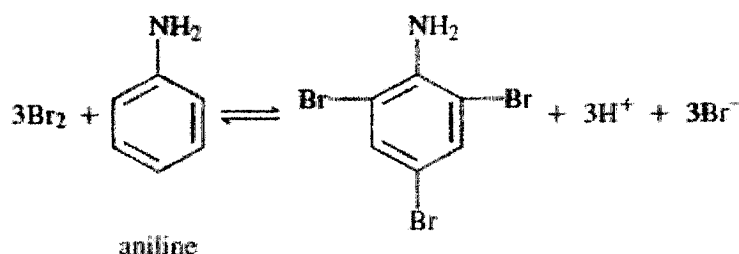
- (iii) Calculate the number of theoretical plates N and the plate height H , when the retention time is 20.40 minutes, half of the base width (given in minutes) is 0.65 minutes and the column length is 30 cm.
- (iv) Draw a chromatogram and label it with retention time (t_R), width at half height ($W_{1/2}$) and width of the peak (W).

Question 3.

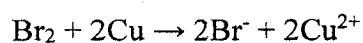
(a) Briefly differentiate between;

- (i) indicator electrode and reference electrode.
- (ii) electrode of the first kind and electrode of the second kind.

(b) Traces of aniline, $C_6H_5NH_2$, in drinking water can be determined by reaction with an excess of electrolytically generated Br_2 :



The polarity of the working electrode is then reversed, and the excess Br_2 is determined by a coulometric titration involving the generation of $Cu(I)$:



Suitable quantities of KBr and $CuSO_4$ were added to a 25.0 mL sample containing aniline.

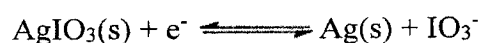
Calculate the number of micrograms of $C_6H_5NH_2$ in the sample from the data:

Working Electrode Functioning As	Generation Time with Constant Current of 1.51 mA, min
Anode	3.76
Cathode	0.270

- (c) The CN^- concentration of 10.0 mL of a plating solution was determined by titration with electrogenerated hydrogen ion to a methyl orange end point. A colour change occurred after 4 min and 11 s with a current of 55.6 mA.
- Calculate the number of grams of NaCN per liter of solution.
 - Calculate the concentration in ppm of NaCN in the solution.
- (d) In four (4) lines or less, describe the principle involved in
- potentiometry.
 - Coulometry

Question 4

- Glass/calomel electrode system has several sources of uncertainty when employed in pH measurements. List at least 4 uncertainties.
- Describe the alkaline error in the measurement of pH. Under what circumstances is this error appreciable? How are pH data affected by alkaline error?
- E°_{Ag} for the process is 0.799 V;



- Calculate E^0 for the process.
 - Use the shorthand notation to describe a cell consisting of a saturated calomel reference electrode and a silver indicator electrode that could be used to measure pIO_3 .
 - Develop an equation that relates the potential of the cell in (b) to pIO_3 .
 - Calculate pIO_3 if the cell in (b) has a potential of 0.306 V
- (d) In order to determine K_1 and K_2 for H_3PO_4 from titration data, careful pH measurements are made after 0.5 and 1.5 mol of base is added for each mole of acid. It is then assumed

PERIODIC TABLE OF ELEMENTS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
hydrogen 1 H 1.00794	helium 2 He 4.002602																
lithium 3 Li 6.941	beryllium 4 Be 9.012182											boron 5 B 10.811	carbon 6 C 12.0107	nitrogen 7 N 14.00674	oxygen 8 O 15.9994	fluorine 9 F 18.9984	neon 10 Ne 20.1797
sodium 11 Na 22.98977	magnesium 12 Mg 24.3050											aluminum 13 Al 26.981538	silicon 14 Si 28.0855	phosphorus 15 P 30.97376	sulphur 16 S 32.065	chlorine 17 Cl 35.453	argon 18 Ar 39.984
potassium 19 K 39.0983	calcium 20 Ca 40.078	scandium 21 Sc 44.95591	titanium 22 Ti 47.867	vanadium 23 V 50.9415	chromium 24 Cr 51.9961	manganese 25 Mn 54.93805	iron 26 Fe 55.845	cobalt 27 Co 58.9332	nickel 28 Ni 58.6934	copper 29 Cu 63.546	zinc 30 Zn 65.409	gallium 31 Ga 69.723	germanium 32 Ge 72.64	arsenic 33 As 74.9216	selenium 34 Se 78.96	bromine 35 Br 79.904	krypton 36 Kr 83.798
rubidium 37 Rb 85.4678	strontium 38 Sr 87.62	yttrium 39 Y 88.90585	zirconium 40 Zr 91.225	niobium 41 Nb 92.90638	molybdenum 42 Mo 95.94	technetium 43 Tc [98]	ruthenium 44 Ru 101.07	rhodium 45 Rh 102.9055	palladium 46 Pd 106.42	silver 47 Ag 107.8682	cadmium 48 Cd 112.411	indium 49 In 114.818	tin 50 Sn 118.710	antimony 51 Sb 121.760	tellurium 52 Te 127.60	iodine 53 I 126.9045	xenon 54 Xe 131.293
caesium 55 Cs 132.90545	barium 56 Ba 137.327	lutetium 71 Lu 174.967	hafnium 72 Hf 178.49	tantalum 73 Ta 180.9479	tungsten 74 W 183.84	rhenium 75 Re 186.207	osmium 76 Os 190.23	iridium 77 Ir 192.217	platinum 78 Pt 195.078	gold 79 Au 196.96655	mercury 80 Hg 200.59	thallium 81 Tl 204.3833	lead 82 Pb 207.2	bismuth 83 Bi 208.980	polonium 84 Po [209]	astatine 85 At [210]	radon 86 Rn [222]
francium 87 Fr [223]	radium 88 Ra [226]	lawrencium 103 Lr [262]	rutherfordium 104 Rf [261]	dubnium 105 Db [262]	seaborgium 106 Sg [266]	bohrium 107 Bh [264]	hassium 108 Hs [269]	meitnerium 109 Mt [268]	darmstadtium 110 Ds [271]	roentgenium 111 Rg [272]	ununbium 112 Uub [285]	ununtrium 113 Uuq [289]	ununquadium 114 [289]				
		lanthanum 57 La 138.9055	cerium 58 Ce 140.116	praseodymium 59 Pr 140.90765	neodymium 60 Nd 144.24	promethium 61 Pm [145]	samarium 62 Sm 150.36	europium 63 Eu 151.964	gadolinium 64 Gd 157.25	terbium 65 Tb 158.9253	dysprosium 66 Dy 162.50	holmium 67 Ho 164.930	erbium 68 Er 167.259	thulium 69 Tm 168.934	ytterbium 70 Yb 173.04		
		actinium 89 Ac [227]	thorium 90 Th 232.038	protactinium 91 Pa 231.0359	uranium 92 U 238.0289	neptunium 93 Np [237]	plutonium 94 Pu [244]	americium 95 Am [243]	curium 96 Cm [247]	berkelium 97 Bk [247]	californium 98 Cf [251]	einsteinium 99 Es [252]	fermium 100 Fm [257]	mendelevium 101 Md [258]	nobelium 102 No [259]		

key
 element name
 atomic number
 symbol
 atomic mass

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

Department of Chemistry

2018 Academic year Term 2 Final Exam

CHE3422

Organometallics and Reaction Mechanism

Instructions: Answer any four questions

All questions carry equal marks

Duration: 3 hours

Answer EACH question on a fresh page.

QUESTION 1

- (a) A sample of Uranium mineral was found to contain 0.214 gm of lead-206 for every gram of Uranium. Calculate the time when the mineral was formed in the earth's crust? The $t^{1/2}$ of U-238 is 4.5×10^9 years.
- (b) (i) Give the product of the nuclear reaction
- $${}_{98}\text{Cf}^{250} + {}_5\text{B}^{11} \rightarrow ? + 4 {}_0\text{n}^1$$
- (ii) ${}_{12}\text{Mg}^{24}$ (d, α)
- (c) When a positron and an electron collide, they are annihilated and two gamma photons of equal energy are emitted. Calculate the wavelength corresponding to their gamma emission. [Mass of electron = 9.11×10^{-31} kg, Speed of light = 2.9979×10^8 m/s and Plancks constant = 6.62×10^{-34} J.s

QUESTION 2

- (a) Comment on the behaviour of HNO_3 in solvents (i) liquid NH_3 (ii) H_2SO_4
- (b) Give balanced equations for a reaction between (i) SOCl_2 and CS_2SO_3 (ii) SOCl_2 and KBr
- (c) What is a polar aprotic solvent? Give two examples.

QUESTION 3

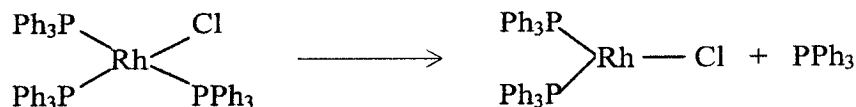
- (a) Describe how do you separate lanthanide ions from a solution containing a mixture of $\text{Ln}(\text{NO}_3)_3$, if you are provided with hydroxyl ion solution? Explain the principle involved.
- (b) Explain that (i) Ce^{3+} is more basic than Ce^{4+} (ii) La^{3+} is colorless but Lu^{4+} is orange red.
- (c) Actinides form oxocations but lanthanides don't. Elaborate the statement.

QUESTION 4

- (a) What properties or characteristics or features of an atom or ligand enhance Electron-richness and Electron-deficiency as used in organometallic chemistry?
- (b) Which compound in each group is more electron-rich and why?
(i) $\text{Ti}(+2) d^2$ or $\text{Pt}(+2) d^8$
(ii) $\text{Al}(\text{CH}_3)_3$ or $\text{N}(\text{CH}_3)_3$
(iii) Which of these two compounds PMe_3 and $\text{P}(\text{OMe})_3$ will be electron-rich and which will be electron deficient? Explain your answer.
- (c) (i) Comment on the observation that the $\nu(\text{CO})$ band in $[\text{Fe}(\text{CO})_6]^{2+}$ appears at 2203 cm^{-1} whilst in free CO it's at 2143 cm^{-1} .
(ii) Given $\text{V}(\text{CO})_6$ and $[\text{V}(\text{CO})_6]^+$, which one will have a shorter C-O bond length and which one will have a shorter V-C bond length? Justify your answer.

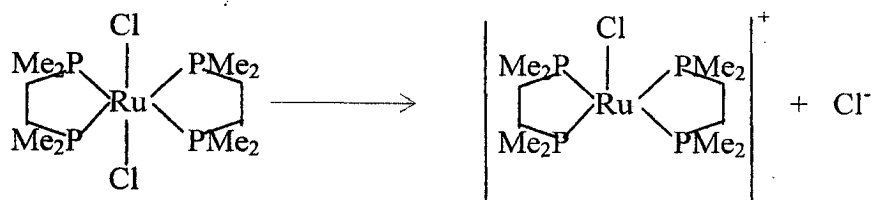
QUESTION 5

(a) Reaction I

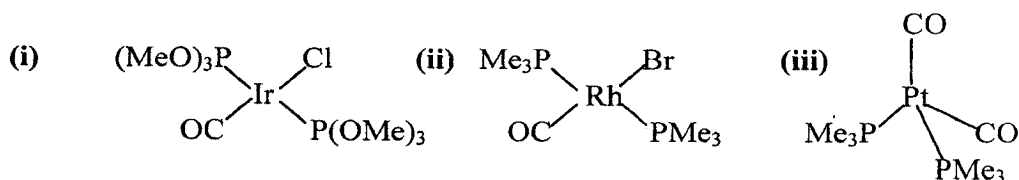


- (i) Name the reactant organometallic reagent in Reaction I above and state its most important usage.
- (ii) What type of organometallic reaction does reaction I above represent?
- (iii) Briefly define the reaction type you suggested in (b) above.
- (iv) In reaction I above, why does the PPh_3 ligand fall off instead of the Cl^- ligand?

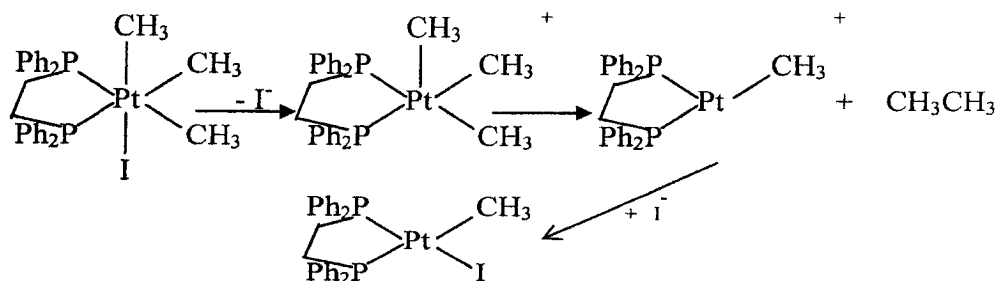
(b) Reaction II



- (i) What type of organometallic reaction does reaction II above represent?
 (ii) Explain why in reaction II the Cl⁻ ion ligand falls off whereas in reaction I it is the triphenylphosphine ligand that falls off.
 (iii) to which of the following complexes will H₂ undergo oxidative addition most readily and why?



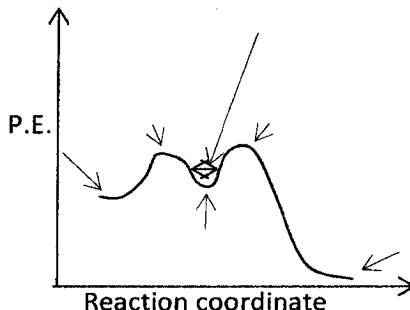
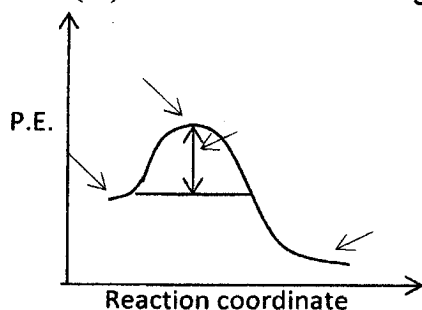
(c) Reaction III



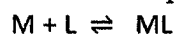
- (i) Explain reaction (III) above.
 (ii) We see in reaction (III) above that CH₃CH₃ falls off instead of CH₃I. Propose the reasons why.

QUESTION 6

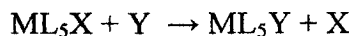
- (a) (i) What is meant by the term 'reaction mechanism'?
 (ii) What is meant by the term 'Rate Law'?
 (iii) Consider the following reaction profiles:



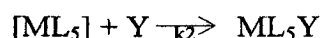
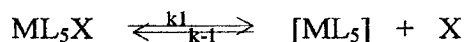
Label these profiles for the reaction represented by the following equation:



(b) Consider the following ligand substitution reaction in Octahedral complexes



where X is the leaving group and Y is the entering group, proceeding by the following mechanism



(i) What mechanism pathway does this reaction present?

(ii) What is the rate determining step in this reaction?

(iii) State the factors that affect the rate at which rate determining step of this reaction proceeds.

(c) (i) What is a labile complex?

(ii) Give an example of a useful labile complex reaction.

(iii) Lability is generally a function of the metal ion, not the ligands. Illustrate with an example.

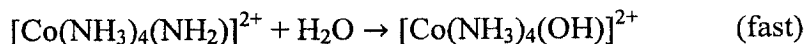
(iv) In aquo complexes, rate of substitution of aquo ligand does not depend on the nature of the incoming ligand and exchange of aquo ligand by another ligand is always faster than substitution of one ligand by another. Explain why.

(v) The Conjugate Base Mechanism (S_N1CB) of Substitution mechanism requires a

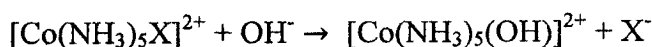
a. deprotonatable ligand on the complex e.g. NH_3 , H_2O and

b. presence of hydroxide OH^- in aqueous solutions.

The mechanism using the $[Co(NH_3)_5X]^{2+}$ complex proceeds as follows:



Overall reaction



Explain the necessity of a deprotonable ligand

END OF EXAMINATION

PERIODIC TABLE OF ELEMENTS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
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1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18		
hydrogen 1 H 1.00794	beryllium 4 Be 9.012182																helium 2 He 4.002602		
lithium 3 Li 6.941	sodium 11 Na 22.98977	potassium 19 K 39.0983	calcium 20 Ca 40.078	scandium 21 Sc 44.95591	titanium 22 Ti 47.867	vanadium 23 V 50.9415	chromium 24 Cr 51.9961	manganese 25 Mn 54.93805	iron 26 Fe 55.845	cobalt 27 Co 58.9332	nickel 28 Ni 58.6934	copper 29 Cu 63.546	zinc 30 Zn 65.409	gallium 31 Ga 69.723	germanium 32 Ge 72.64	arsenic 33 As 74.9216	selenium 34 Se 78.96	bromine 35 Br 79.904	krpton 36 Kr 83.798
	magnesium 12 Mg 24.3050	strontium 38 Sr 87.62	yttrium 39 Y 88.90585	zirconium 40 Zr 91.224	niobium 41 Nb 92.90638	molybdenum 42 Mo 95.94	technetium 43 Tc [98]	ruthenium 44 Ru 101.07	rodium 45 Rh 102.9055	rhodium 46 Pd 106.42	silver 47 Ag 107.8682	cadmium 48 Cd 112.411	indium 49 In 114.818	tin 50 Sn 118.710	antimony 51 Sb 121.760	tellurium 52 Te 127.60	iodine 53 I 126.9045	xenon 54 Xe 131.293	radon 86 Rn [222]
	barium 56 Ba 137.327	lanthanum 57 La 138.9055	cerium 58 Ce 140.116	praseodymium 59 Pr 140.90765	neodymium 60 Nd 144.24	promethium 61 Pm [145]	samarium 62 Sm 150.36	europium 63 Eu 151.964	gadolinium 64 Gd 157.25	terbium 65 Tb 158.9253	ytterbium 70 Yb 173.04	holmium 67 Ho 164.930	erbium 68 Er 167.259	thulium 69 Tm 188.934	ytterbium 70 Yb 173.04	lutetium 71 Lu 174.967	hafnium 72 Hf 178.49	tantalum 73 Ta 180.9479	tungsten 74 W 183.84
	radium 88 Ra [226]	actinium 89 Ac [227]	thorium 90 Th 232.038	protactinium 91 Pa [231.0369]	uranium 92 U 238.0289	neptunium 93 Np [237]	plutonium 94 Pu [244]	americium 95 Am [243]	curium 96 Cm [247]	berkelium 97 Bk [247]	californium 98 Cf [251]	einsteinium 99 Es [252]	fermium 100 Fm [257]	mendelevium 101 Md [258]	nobelium 102 No [259]	lawrencium 103 Lr [261]	rutherfordium 104 Rf [261]	dubnium 105 Db [262]	seaborgium 106 Sg [266]

key
 element name
 atomic number
 symbol
 atomic mass

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

**2018 ACADEMIC YEAR
FINAL EXAMINATIONS**

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

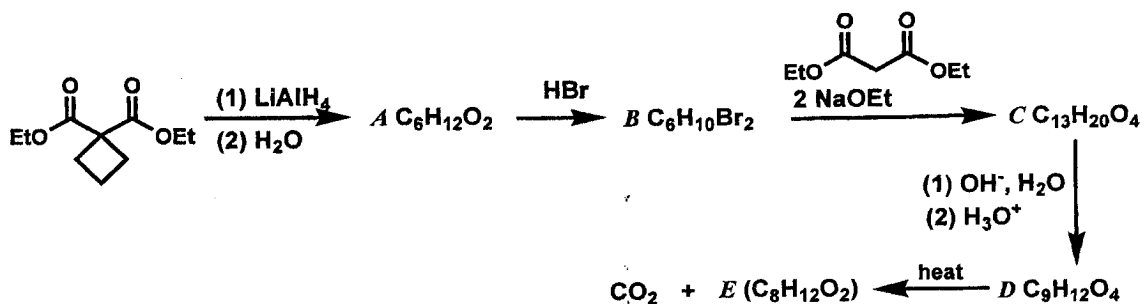
TIME: THREE (3) HOURS

INSTRUCTIONS:

1. ANSWER ANY FOUR (4) QUESTIONS.
2. EACH QUESTION CARRIES 25 MARKS.
3. PRESENT YOUR ANSWERS IN A LOGICAL MANNER.
4. ENSURE THAT YOU HAVE 5 PRINTED PAGES AND FIVE (5) QUESTIONS.

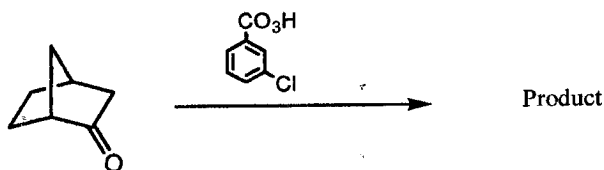
QUESTION 1

- (a) Compound *E*, a compound with two four-membered rings, has been synthesized by the following route. Deduce the structures of this compound and those of the intermediates *A-D*. (10 marks)



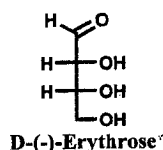
- (b) Show how periodic acid could be used to distinguish between an aldohexose and a ketohexose. What products would you obtain from each, and how many molar equivalents of HIO_4 would be consumed? (8 marks)

- (b) Identify the product and propose a plausible mechanism for the following reaction: (7 marks)



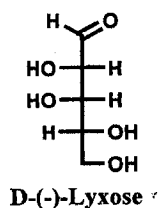
QUESTION 2

- (a) Outline a Kiliani–Fischer synthesis of epimeric aldopentoses starting with D-(-)-erythrose (structure shown below) (use Fischer projections). (10 marks)

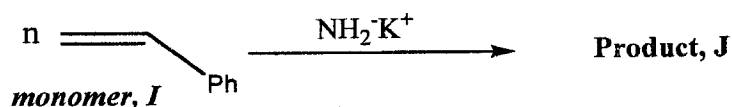


(b) The two epimeric aldopentoses that one obtains are **F** and **G**. Nitric acid oxidation of **G** yields an optically inactive aldaric acid, whereas similar oxidation of **F** yields an optically active product. On the basis of this information alone, which Fischer projection represents **F** and which one represents **G**? (2 marks)

(c) When the aldohexose **H** is treated with nitric acid, it yields an optically inactive aldaric acid. When **H** is subjected to Ruff degradation, it yields D-(-)-lyxose (see structure below). Using only these data, write the Fischer projection formula for **H**. Show your reasoning. (5 marks)



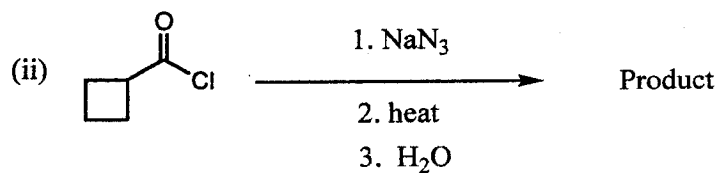
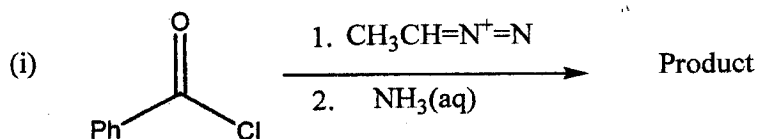
(d) Product, **J** shown below produced by polymerisation of monomer, **I**:



- (i) Name this type of polymerisation (1 mark)
- (ii) Draw the structure of the product, **D** (2 marks)
- (iii) Write the mechanism for this polymerization (5 marks)

QUESTION 3

(a) Identify the product and propose a plausible mechanism for the following reactions: (17 marks)



(b) Give appropriate structural formulas to illustrate each of the following: **(8 marks)**

- (i) An aldopentose (straight chain Fischer projection formula)
- (ii) A non-reducing sugar (cyclic form)
- (iii) Anomers (cyclic form)
- (iv) Epimers (straight chain Fischer projection formula)

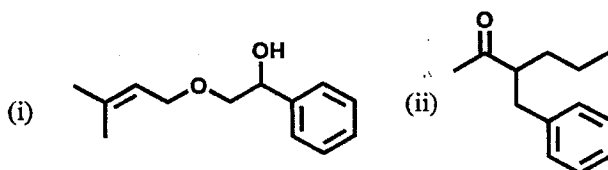
QUESTION 4

(a) Draw the structure of the product expected from the killing of living polystyrene (resulting from anionic polymerization of styrene) by each of the following reagents: **(7 marks)**

- (i) water
- (ii) carbon dioxide then water
- (iii) a small amount of ethylene oxide then water

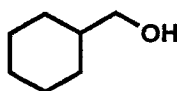
(b) Outline a retrosynthetic analysis for the following molecules. In each case, outline the corresponding synthesis clearly showing reagents and reaction conditions for each step.

Assume starting materials containing ≤ 6 carbon atoms are readily available. **(18 marks)**

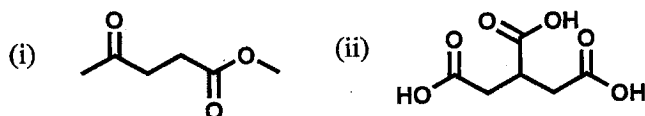


QUESTION 5

(a) Propose a synthetic approach for the following compound from diethyl malonate and any other organic and inorganic reagents. *Assume starting materials containing ≤ 6 carbon atoms are readily available.* **(11 marks)**

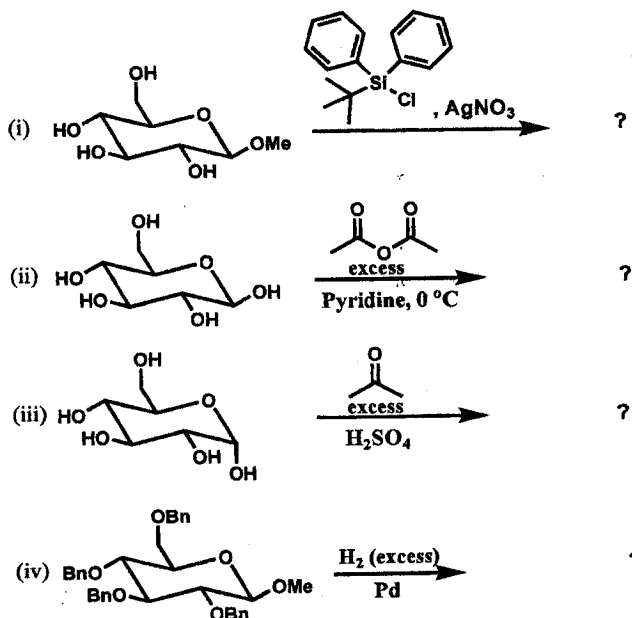


(b) Provide the systematic names for the following polyfunctional compounds. **(3 marks)**



(c) Predict the products of the following reactions:

(8 marks)



(d) How would you use the reaction in part a (iv) to derive evidence for the existence of the pyranose form of the glucose molecule? (3 marks)

END OF EXAMINATION QUESTIONS

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2018 ACADEMIC YEAR FINAL EXAMINATIONS
CHE 4102: BIOCHEMICAL RESEARCH TECHNIQUES

INSTRUCTIONS:

Time: Three (3) hours

All questions carry **equal marks** (25 marks each)

Answer any **four (4)** questions

Write your computer number on all answer booklets

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

Question 1

- a) With reference to lipid and protein hormones, **discuss** how the characteristics of hormones will influence the way in which they initiate signal transduction in a target cell.

[5 marks]

- b) **Write** short notes on the following:

- I. Viral oncogenes and their role in the development of cancer.
[4 marks]
- II. The role of G-proteins in signal transduction.
[4 marks]
- III. The role of liver enzymes in the inactivation of steroid hormones.
[4 marks]

- c) **What** is meant by the term 'receptor desensitization'? Using the example of the β -adrenergic receptor, **outline** the steps involved in the desensitization of a hormone receptor.

[8 marks]

Question 2

Glycogen break down and synthesis may be regulated hormonally.

- a) Name two main hormones that regulate these metabolic pathways.
[5 marks]
- b) Using the any hormone named in a), explain in detail the hormonal regulation of glycogen breakdown. (Include positive and negative regulation)
[20 marks]

epinephrine
Insulin
glucagon

Question 3

- a) Explain the following terms/expressions:
- i) epitope
 - ii) complement system
 - iii) phagocytosis
- [9 marks]
- b) Other than lupus, name any four (4) autoimmune diseases.
[6 marks]
- c) How do autoimmune diseases arise considering the fact that mechanisms that govern self/non-self discrimination are in place? In other words, what causes autoimmune diseases?
[10 marks]

Question 4

- a) A sample of radioisotope has an activity of 450 μCi after 2 days. If the rate constant for the isotope is 0.056 day^{-1} , what was the activity of the sample 2 days ago? [10 marks]
- a) A container having 10 μCi of L-phenylalanine – ^{14}C (uniformly labeled) in 1 mL of solution was found to have a specific activity of 15 $\mu\text{Ci}/\text{mmol}$. Calculate the concentration of L-phenylalanine in g/ml.
(H = 1.0, N = 14.0, O = 16.0) [15 marks]

no C-14

X
= 11
20

Question 5

- a) Four pure proteins were used as standards to construct a standard curve for a molecular weight analysis via SDS-gel electrophoresis. Protein 1, with molecular weight of 15,000, was the smallest. Protein 2 (MW = 35,000) moved only 39 % as far as protein 1. Protein 3 (MW = 25,000) moved only 63 % as far as protein 1. Protein 4 (MW = 20,000) moved only 81 % as far as protein 1.

Construct a standard curve (Rel. mobility Vs Log_{mw}) for this data, and then **determine** the molecular weight of the unknown protein that had a mobility value (under the same conditions) midway between that of proteins 2 and 3.
[15 marks]

- b) A different protein Z was divided into 2 aliquots. One aliquot was subjected to regular PAGE and the other to SDS-PAGE giving the results shown in figure 1 below. **What conclusion** can you make regarding the structure of the protein Z?
[10 marks]

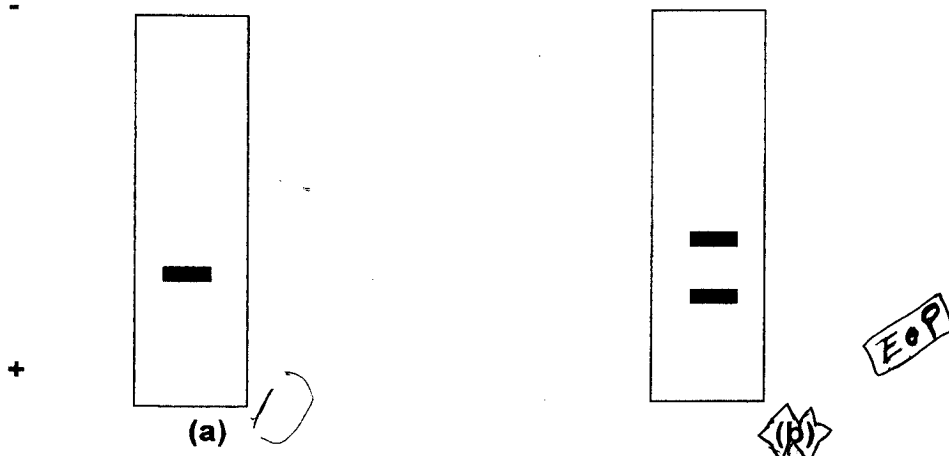


Figure 1 Regular (a) and SDS-PAGE (b) of protein Z

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
DEPARTMENT OF CHEMISTRY
2018/2019 ACADEMIC YEAR FINAL EXAMINATION

CHE4222 FOOD, DRUG, PESTICIDE AND DETERGENT ANALYSIS

DURATION: THREE HOURS

INSTRUCTIONS

1. Indicate your student ID number on each of the provided answer booklets.
 2. There are **five** questions in this examination paper; Answer any **four** questions.
 3. All questions carry equal marks.
 4. There are **three printed papers** for the questions; the periodic table is attached also.
 5. Show your reasoning and/ or calculations clearly.
-

Question 1

- (a) A 5.00 g sample of food grade oil was reacted with excess KI to determine peroxide value. The free iodine was titrated with a standardized solution of 0.01 N $\text{Na}_2\text{S}_2\text{O}_3$. The amount of titrant required was 0.60 ml blank corrected. Calculate the peroxide value of the oil.
- (b) Describe the procedure you would use to determine whether pasteurization or sterilization of your milk has been thoroughly carried out.
- (c) Define the following;
 - (i) acid value
 - (ii) peroxide value
 - (iii) iodine value
- (d) An unlabeled product smells like butter. How would you confirm whether it is butter or margarine and what compound(s) may give such an odour?

Question 2

- (a) Briefly explain what you understand by the following terms
 - (i) Drug of abuse
 - (ii) Narcotic drugs
 - (iii) Psychotropic substance
- (b) A drug derived directly from opium and used in its natural state without chemical modification is known as an opiate. Opiates include morphine, codeine, thebaine, narcotine and papaverine. Describe the extraction of morphine from opium and extraction of heroin from morphine.
- (c) Cannabis is an example of a psychotropic substance.
 - (i) Briefly describe the extraction and analysis of cannabis from plant material.
 - (ii) State what marijuana does to human beings when smoked.
 - (iii) Mr. Bando has been smoking marijuana for the past ten years. When recently learned about the effects of marijuana, he decided to suddenly stop. List the challenges that he is facing during the withdrawal period.

Question 3

- (a) Briefly describe the preparation of the 'fusion' filtrate. How is it used for the specific tests including nitrogen, sulphur, halides (chlorine, bromine and iodine)?
- (b) Describe a test that would be used to distinguish aldehydes from ketones.
- (c) Describe how you would distinguish Primary, Secondary and Tertiary Amines.
- (d) Briefly describe how you would determine nitrates and N-nitrosamines in cheese.

Question 4

PERIODIC TABLE OF ELEMENTS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
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		key																																																																																					
		element name atomic number symbol atomic mass																																																																																					
hydrogen 1 H 1.00784	beryllium 4 Be 9.012182	lithium 3 Li 6.941	boron 5 B 10.811	carbon 6 C 12.0107	nitrogen 7 N 14.00674	oxygen 8 O 15.9994	fluorine 9 F 18.9984	helium 2 He 4.002602	neon 10 Ne 20.1797	argon 18 Ar 39.964	potassium 19 K 39.0983	calcium 20 Ca 40.078	scandium 21 Sc 44.95591	titanium 22 Ti 47.867	vanadium 23 V 50.9415	chromium 24 Cr 51.9961	manganese 25 Mn 54.93805	iron 26 Fe 55.845	cobalt 27 Co 58.9332	nickel 28 Ni 58.6934	copper 29 Cu 63.546	zinc 30 Zn 65.409	gallium 31 Ga 69.723	germanium 32 Ge 72.64	arsenic 33 As 74.9216	selenium 34 Se 78.96	bromine 35 Br 79.904	krypton 36 Kr 83.798	rubidium 37 Rb 85.4678	strontium 38 Sr 87.62	yttrium 39 Y 88.90585	zirconium 40 Zr 91.225	niobium 41 Nb 92.90638	vanadium 42 V 92.90638	niobium 43 Nb 92.90638	technetium 43 Tc [98]	ruthenium 44 Ru 101.07	rhodium 45 Rh 102.9055	rhodium 46 Pd 106.42	silver 47 Ag 107.8682	cadmium 48 Cd 112.411	indium 49 In 114.818	tin 50 Sn 118.710	antimony 51 Sb 121.760	tellurium 52 Te 127.60	iodine 53 I 126.9045	xenon 54 Xe 131.293	cesium 55 Cs 132.90545	barium 56 Ba 137.327	lanthanum 57 La 138.9055	cerium 58 Ce 140.116	praseodymium 59 Pr 140.90765	neodymium 60 Nd 144.24	europium 63 Eu 151.964	gadolinium 64 Gd 157.25	terbium 65 Tb 158.9253	dysprosium 66 Dy 162.50	holmium 67 Ho 164.930	erbium 68 Er 167.259	thulium 69 Tm 168.934	ytterbium 70 Yb 173.04	francium 87 Fr [223]	radium 88 Ra [226]	actinium 89 Ac [227]	thorium 90 Th 232.038	protactinium 91 Pa 231.0359	uranium 92 U 238.0289	neptunium 93 Np [237]	plutonium 94 Pu [244]	americium 95 Am [243]	curium 96 Cm [247]	berkelium 97 Bk [247]	californium 98 Cf [251]	einsteinium 99 Es [252]	fermium 100 Fm [257]	mendeleevium 101 Md [258]	nobelium 102 No [259]	unquadium 114 Uuq [289]	ununquadium 114 Uuq [289]	ununseptium 115 Uus [285]	ununseptium 115 Uus [285]	ununhexium 116 Uuh [285]	ununhexium 116 Uuh [285]	ununpentium 117 Uup [285]	ununpentium 117 Uup [285]	ununquadium 118 Uuq [285]	ununquadium 118 Uuq [285]

lanthanum 57 La 138.9055	cerium 58 Ce 140.116	praseodymium 59 Pr 140.90765	neodymium 60 Nd 144.24	europium 63 Eu 151.964	gadolinium 64 Gd 157.25	terbium 65 Tb 158.9253	dysprosium 66 Dy 162.50	holmium 67 Ho 164.930	erbium 68 Er 167.259	thulium 69 Tm 168.934	ytterbium 70 Yb 173.04	actinium 89 Ac [227]	thorium 90 Th 232.038	protactinium 91 Pa 231.0359	uranium 92 U 238.0289	neptunium 93 Np [237]	plutonium 94 Pu [244]	americium 95 Am [243]	curium 96 Cm [247]	berkelium 97 Bk [247]	californium 98 Cf [251]	einsteinium 99 Es [252]	fermium 100 Fm [257]	mendeleevium 101 Md [258]	nobelium 102 No [259]
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**THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES**

**2018 ACADEMIC YEAR
FINAL EXAMINATIONS**

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

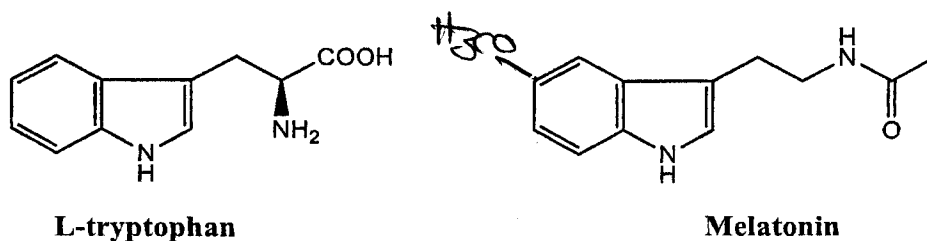
TIME ALLOWED: THREE (3) HOURS

INSTRUCTIONS:

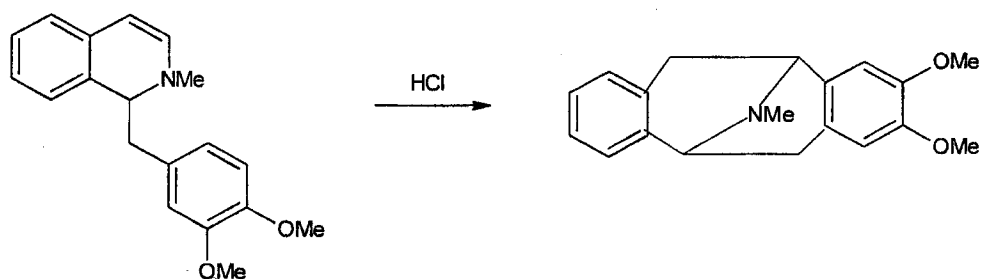
1. ANSWER ANY FOUR (4) QUESTIONS.
2. EACH QUESTION CARRIES 25 MARKS.
3. PRESENT YOUR ANSWERS IN A LOGICAL MANNER.
4. PLEASE ENSURE THAT YOU HAVE SEVEN (7) PRINTED PAGES AND FIVE (5) QUESTIONS.

QUESTION ONE

- (a) Melatonin, an indole alkaloid found in animals, plants and microbes, is a hormone which regulates circadian rhythm in humans. Outline a plausible biogenetic pathway for melatonin from its amino acid precursor *L*-tryptophan, showing all steps clearly. (10 marks)



- (b) Alkaloids undergo wide ranging acid and base catalyzed rearrangements. Propose a plausible mechanism for the transformation shown below: (7 marks)



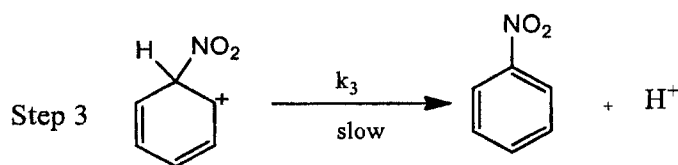
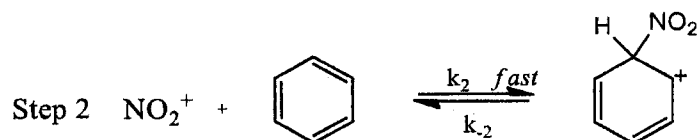
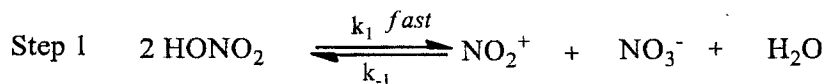
- (c) Match the ρ values with the appropriate reactions. Explain your reasoning.
Reaction constants (ρ): +2.45, +0.75, -2.39, -7.29

Reactions are:

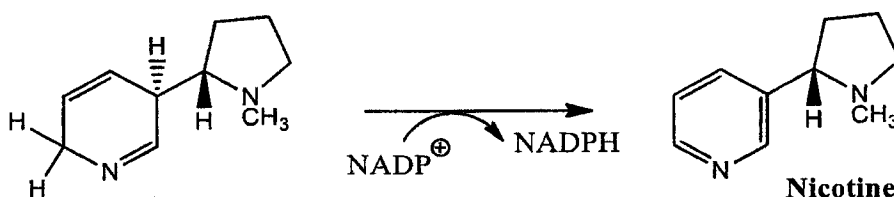
- | | |
|---|-----------|
| (i) Nitration of substituted benzenes | (2 marks) |
| (ii) Ionization of substituted benzenethiols | (2 marks) |
| (iii) Ionization of substituted benzenephosphonic acids | (2 marks) |
| (iv) Reaction of substituted <i>N,N</i> -dimethylaniline with methyl iodide | (2 marks) |

QUESTION TWO

- (a) For the following proposed reaction mechanism of the nitration of benzene, derive an overall kinetic rate equation by applying the steady state approximation method. (10 marks)



- (b) Suggest a plausible mechanism for the last step in the biosynthesis of the tobacco alkaloid Nicotine, shown below: (3 marks)



- (c) Show how the following experimental evidence can be used to deduce the structure of a disaccharide A, $\text{C}_{12}\text{H}_{22}\text{O}_{11}$. Use the ring (conformational) structures to answer this question.
- The disaccharide A gives positive Tollens test and undergoes mutarotation.
 - Treatment of A with a large excess of methyl iodide in presence of silver oxide followed by acidic hydrolysis gives *equimolar quantities* of 2,3,6-tri-O-methyl *D*-glucose and 2,3,4,6-tetra-O-methyl *D*-galactose.
 - Oxidation of A with bromine water gives a compound B, which upon hydrolysis with dilute hydrochloric acid gives *D*-galactose and *D*-gluconic acid.
 - Exhaustive methylation of B followed by acidic hydrolysis gives 2,3,6-tri-O-methyl-*D*-gluconolactone and 2,3,4,6-tetra-O-methyl *D*-galactose.
 - The coupling constant, $^3J_{\text{H}_1, \text{H}_2}$ for the hydrogen at anomeric carbon of glycosidic linkage in A was found to be 3.5 Hz.

(12 marks)

QUESTION THREE

(a) Substituted methyl benzoates hydrolyze rapidly in 95 % sulphuric acid. A study of the effect of substituents on phenyl ring on the rate of reaction gave the following results:

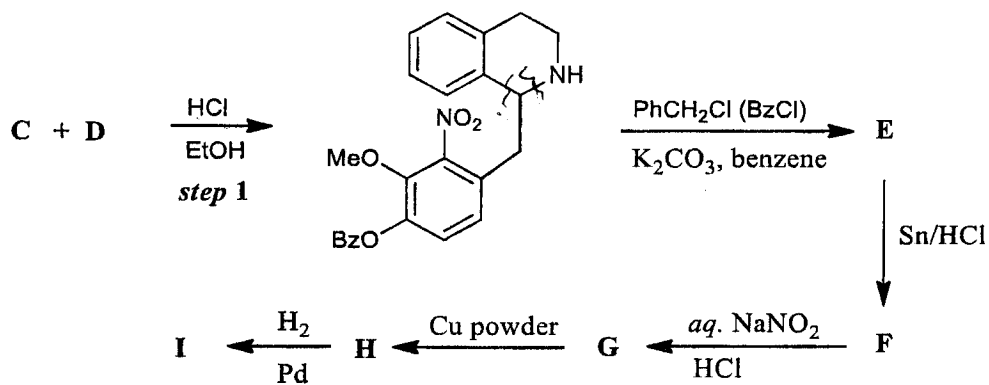
Substituent	<i>p</i> -Me	<i>m</i> -Me	H	<i>m</i> -Cl	<i>m</i> -Br
k (sec ⁻¹)	2.41×10^{-4}	1.51×10^{-4}	6.5×10^{-5}	3.5×10^{-6}	3.2×10^{-6}

(i) Determine the value of ρ (rho) for this reaction and predict the rate constant for the hydrolysis of methyl *p*-fluorobenzoate (5 marks)

(ii) For the hydrolysis of methyl *o*-methylbenzoate and methyl *p*-methoxybenzoate the rate constants are: 182×10^{-4} ; and 10.2×10^{-4} , respectively. Comment on these results. (2 marks)

(iii) Substituents have very little effect upon the rate of hydrolysis of methyl benzoates in dilute sulphuric acid. Compare this observation with the results given above and suggest an explanation. (4 marks)

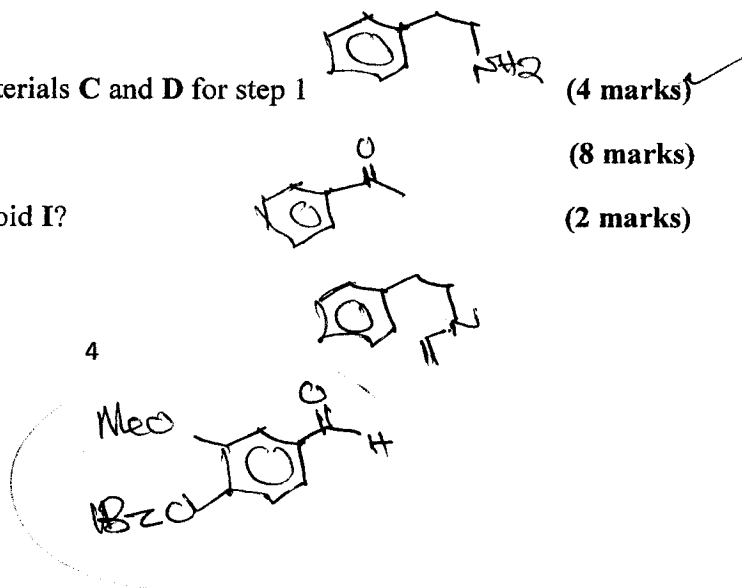
(b) A synthesis of a bronchodilator and anti-inflammatory alkaloid **I**, isolated from root bark of a plant is outlined below:



(i) Give the structures of starting materials **C** and **D** for step 1 (4 marks)

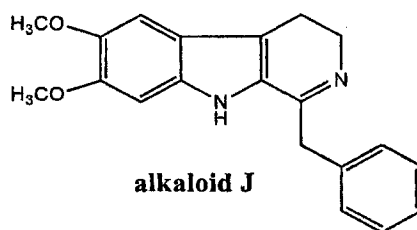
(ii) Identify the intermediates **E** - **H**. (8 marks)

(iii) What is the structure of the alkaloid **I**? (2 marks)

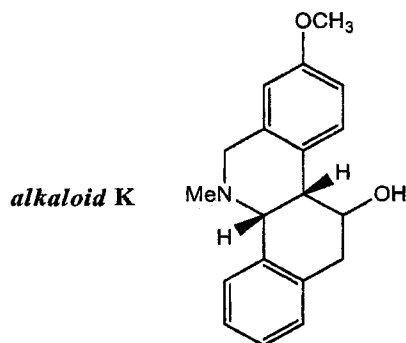


QUESTION FOUR

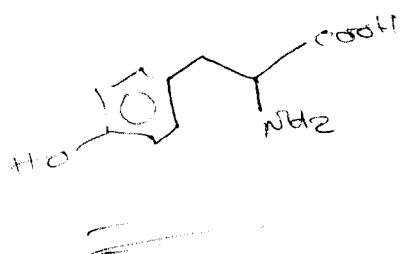
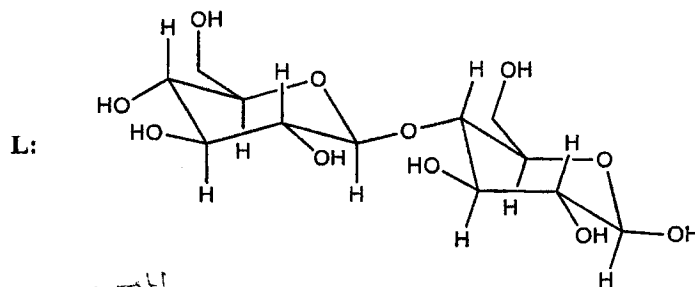
- (a) Using the disconnection approach, propose an efficient synthesis for the alkaloid **J** shown below. Show all steps clearly, including the reagents, conditions and the intermediates for each step. Please do not write any reaction mechanism. Assume that 5, 6-dihydroxyindole, and phenyl acetic acid ($C_6H_5CH_2COOH$) are available. (11 marks)



- (b) Consider the alkaloid **K**, shown below:



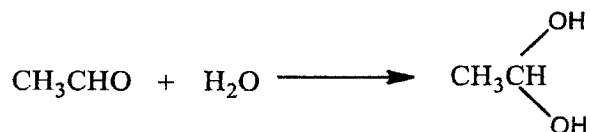
- (i) Classify the alkaloid **K** as *true-*, *pseudo-* or *proto-* alkaloid. (1 mark)
 (ii) Give the structure of amino acid from which the alkaloid **K** is derived. (1 mark)
 (iii) How many Hofmann degradation cycles are needed to expel nitrogen from the alkaloid **K**? (1 mark)
- (c) State two laboratory tests for detection of alkaloids in plant materials. (2 marks)
- (d) (i) Define the terms glycoside and disaccharide. (4 marks)
 (ii) Give the IUPAC name of the disaccharide, **L**, shown below: (2 marks)



- (e) The sulphonation of tritium-labelled bromobenzene is much slower than that of normal benzene, while nitration of nitrobenzene is unaffected by isotopic substitution on the aromatic ring. Explain these observations. (4 marks)

✓ QUESTION FIVE

- (a) In aqueous solution acetaldehyde is slowly hydrated.



In acetate buffer the reaction is subject to acid and base catalysis. The first order rate constants (k_{obs}) in two different acetate buffers, of known hydrogen ion concentration, were measured with the following results (r = buffer ratio) [$\text{CH}_3\text{CO}_2\text{H}/\text{CH}_3\text{CO}_2^-$].

(i) $[\text{H}^+] = 3.36 \times 10^{-3} \text{ M}$		$r = 0.118$				
$[\text{CH}_3\text{CO}_2\text{H}] \text{ (M)} \times 10^{-3}$	2.7	4.9	6.9	9.0	10.9	
$k_{\text{obs}} \text{ (min}^{-1}) \times 10^{-2}$	6.6	8.7	9.9	11.6	12.7	
(ii) $[\text{H}^+] = 8.78 \times 10^{-3} \text{ M}$		$r = 0.308$				
$[\text{CH}_3\text{CO}_2\text{H}] \text{ (M)} \times 10^{-3}$	3.0	4.7	7.4	8.7	11.3	15.2
$k_{\text{obs}} \text{ (min}^{-1}) \times 10^{-2}$	8.2	9.3	10.2	10.6	12.3	13.4

The overall rate equation for this general acid catalyzed reaction was found to be as follows:

$$k_{\text{obs}} = k_0 + k_1[\text{H}^+] + k_2[\text{CH}_3\text{CO}_2\text{H}] + k_3[\text{CH}_3\text{CO}_2^-]$$

- (i) Derive an equation relating k_{obs} to the concentration of acetic acid. (5 marks)
- (ii) From the derived equation plot a graph of k_{obs} versus $[\text{CH}_3\text{CO}_2\text{H}]$ for each set of values at $r = 0.118$ and 0.308 . (8 marks)
- (iii) Use the information obtained from the plotted graphs to calculate the values of the rate constants, k_0 , k_1 , k_2 , and k_3 . (12 marks)

45
7.5

**END OF EXAMINATION
GOOD LUCK!**

APPENDIX

USEFUL DATA

Substituent	HAMMETT CONSTANTS		
	σ	σ^+	σ^-
H	0.00	0.00	0.00
<i>p</i> -MeO	-0.27	-0.78	-0.27
<i>m</i> -MeO	0.12	0.05	
<i>p</i> -Me	-0.17	-0.31	-0.17
<i>m</i> -Me	-0.07	--0.07	-0.07
<i>p</i> -Bu ^t	-0.20	-0.26	
<i>m</i> -Bu ^t	-0.10	-0.06	
<i>p</i> -F	0.06	-0.07	
<i>m</i> -F	0.34	0.35	
<i>p</i> -Br	0.23	0.15	0.22
<i>m</i> -Br	0.39	0.41	
<i>p</i> -Cl	0.23	0.11	
<i>m</i> -Cl	0.37	0.40	0.38
<i>p</i> -CO ₂ Et	0.45	0.48	0.68
<i>p</i> -NO ₂	0.78	0.79	1.27
<i>m</i> -NO ₂	0.71	0.67	0.70

UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
CHEMISTRY DEPARTMENT

2018 Academic End of Year Exams

CHE 4822 Inorganic Industrial Chemistry II

Answer any FOUR Questions

Duration: 3Hours

Question 1

(a) In the Contact process, conversion of sulphur dioxide to sulphur trioxide is reversible, with the forward reaction forming sulphur trioxide being exothermic. There are a number of ways that the choice of conditions affects the process:

- they affect the position of equilibrium;
- they affect the rate of the reaction;
- they affect the economics of the process.

Where relevant, explain how each of these choices: (i) SO_2 : O_2 ratio, (ii) temperature, (iii) pressure and (iv) catalyst affect each of the following: (1) position of equilibrium (2) rate of the reaction and (3) economics of the process, i.e. what is the effect of each of SO_2 : O_2 ratio, temperature, pressure and catalyst on each of position of equilibrium, rate of reaction and economics of the process.

(b) State the challenges encountered during the solution synthesis operation in the manufacture of urea and how they are mitigated.

Question 2

(a) With the help of a process diagram, describe the production of weak nitric acid.

(b) (i) What emissions discharge from nitric acid production?

(ii) Where are they generated in the processing of nitric acid?

(iii) Suggest the factors that would lead to increased emissions discharge in this process.

(c) How would you bring these emissions under control?

Question 3

(a) (i) Draw a diagram to show how elemental sulphur is mined using Frasch Process.

(ii) Briefly describe the proceedings in the Frasch process of mining elemental sulphur.

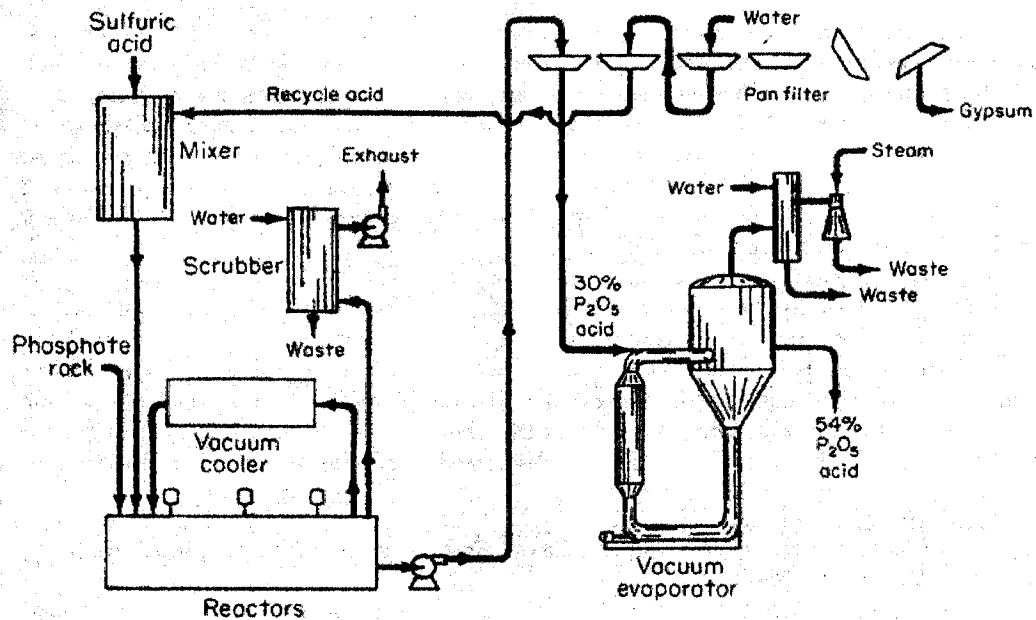
(iii) What two properties of sulphur does this process take advantage of?

(b) (i) Draw and label the process diagram for the manufacture of urea.

(ii) Describe solution synthesis operation in the manufacture of urea.

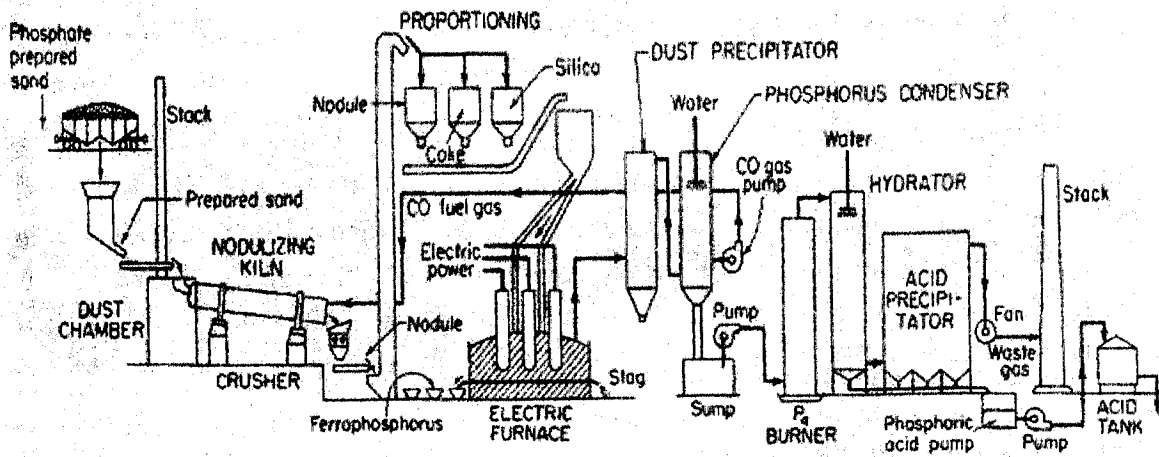
Question 4

- Discuss the characteristics, advantages and disadvantages of complex fertilizers such as NPK fertilizers. Critically compare NPK with Single Superphosphate fertilizer.
- List three types of Inorganic fertilizers and briefly discuss the functions and the major sources of macronutrients in crop production.
- With the aid of the process diagram provided, briefly discuss the manufacture of phosphoric acid using the Bird Prayon tilting pan filters.



Question 5

- Discuss briefly the Raw Materials and Principles of manufacturing for NPK fertilizers.
- Discuss briefly the manufacture of Triple Superphosphate with the help of a flow Diagram. Explain briefly the major Steps involved in the production of TSP and write the chemical reactions for this process.
- With the aid of the process diagram provided, briefly discuss the three major steps: combustion, hydration, and demisting involved in the Thermal process of phosphoric acid manufacture.



END OF EXAMINATION

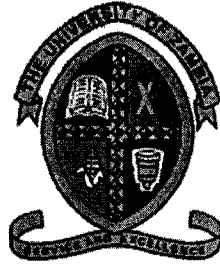
PERIODIC TABLE OF ELEMENTS

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

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18																
1 H hydrogen 1.00784	4 Be beryllium 9.012182																2 He helium 4.002602																
3 Li lithium 6.941	9 B boron 10.811	10 Ne neon 20.1797	11 Na sodium 22.98977	12 Mg magnesium 24.3050	13 Al aluminium 26.981538	14 Si silicon 28.0855	15 P phosphorus 30.97376	16 S sulphur 32.055	17 Cl chlorine 35.453	18 Ar argon 39.948	19 K potassium 39.0983	20 Ca calcium 40.078	21 Sc scandium 44.95591	22 Ti titanium 47.867	23 V vanadium 50.9415	24 Cr chromium 51.9961	25 Mn manganese 54.93805	26 Fe iron 55.845	27 Co cobalt 58.9332	28 Ni nickel 58.6934	29 Cu copper 63.546	30 Zn zinc 65.408	31 Ga gallium 69.723	32 Ge germanium 72.64	33 As arsenic 74.9216	34 Se selenium 78.96	35 Br bromine 79.904	36 Kr krypton 83.798					
37 Rb rubidium 85.4678	38 Sr strontium 87.62	39 Y yttrium 88.90585	40 Zr zirconium 91.224	41 Nb niobium 92.90638	42 Mo molybdenum 95.94	43 Tc technetium 98	44 Ru ruthenium 101.07	45 Rh rhodium 102.9055	46 Pd palladium 106.42	47 Ag silver 107.8682	48 Cd cadmium 112.411	49 In indium 114.818	50 Sn tin 118.710	51 Sb antimony 121.760	52 Te tellurium 127.60	53 I iodine 126.9045	54 Xe xenon 131.29	55 Cs caesium 132.90545	56 Ba barium 137.327	57 La lanthanum 138.9055	58 Ce cerium 140.116	59 Pr praseodymium 140.90765	60 Nd neodymium 144.24	61 Pm promethium 145	62 Sm samarium 150.36	63 Eu europium 151.964	64 Gd gadolinium 157.25	65 Tb terbium 158.9253	66 Dy dysprosium 162.50	67 Ho holmium 164.930	68 Er erbium 167.259	69 Tm thulium 168.934	70 Yb ytterbium 173.04
87 Fr francium 223	88 Ra radium 226	89 Lr lawrencium 262	90 Rf rutherfordium 261	91 Db dubnium 262	92 Sg seaborgium 263	93 Bh bohrium 264	94 Hs hassium 269	95 Mt meitnerium 269	96 Ds darmstadtium 271	97 Rg roentgenium 272	98 Uub ununbium 265	99 Tl thallium 204.3833	100 Pb lead 207.2	101 Bi bismuth 208.980	102 Po polonium 209	103 At astatine 210	104 Rn radon 222	105 Uuq ununquadium 269	106 Uuh ununhexium 271	107 Uuq ununquadium 269	108 Uuh ununhexium 271	109 Uuq ununquadium 269	110 Uuh ununhexium 271	111 Uuq ununquadium 269	112 Uub ununbium 265	113 Uuq ununquadium 269	114 Uuh ununhexium 271	115 Uuq ununquadium 269	116 Uuh ununhexium 271	117 Uuq ununquadium 269	118 Uuh ununhexium 271		

key

element name	atomic number
symbol	atomic mass



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

FINAL EXAMINATION

CSC 2000
Computer Programming

Date: 8th November 2019
Time: 09:00hrs – 12:00hrs
Duration: 3 Hours
Venue: P207

Instructions

1. There are **two (2) sections** in this exam paper.
2. Only the java programming language should be used in this exam
3. *Answer all* the questions in **Section A** and choose *any three (3)* questions from **Section B**

SECTION A. Short answers (40 marks)

You are required to answer all questions in this section.

1. Given the following code

```
public class Example2 {  
    public static void main(String argv[]) {  
        int a = 4;  
        int b = a-++a;  
        System.out.println(b);  
    }  
}
```

- What is the output? [2 marks]
 - Give a walk-through of how the interpreter interprets the given code taking into consideration operator precedence. [4 marks]
2. Illustrate and explain state transitioning of a java thread. [6 marks]
3. By making use of the printf method write code that outputs the following table. Do not make use of any mathematical calculations. Output the values as they literally are. [6 marks]

Degrees	Radians	Sine	Cosine	Tangent
30	0.5236	0.5000	0.8660	0.5774
60	1.0472	0.8660	0.5000	1.7321

4. A palindrome is a word that reads the same whether read from front to end or end to front. For example, the word *ANNA*. Write code for a method that gets a String as input and checks whether it is a palindrome or not. The method returns a boolean indicating whether the word is a palindrome or not. [6 marks]
5. Write Java code that implements the following UML. [10 marks]

Course	
-courseName: String	The name of the course.
-students: String[]	An array to store the students for the course.
-numberOfStudents: int	The number of students (default: 0).
+Course(courseName: String)	Creates a course with the specified name.
+getCourseName(): String	Returns the course name.
+addStudent(student: String): void	Adds a new student to the course.
+dropStudent(student: String): void	Drops a student from the course.
+getStudents(): String[]	Returns the students in the course.
+getNumberOfStudents(): int	Returns the number of students in the course.

6. What will be the output of the following Java program? [2 marks]

```
class main_class
{
    public static void main(String args[])
    {
        int x = 9;
        if (x == 9)
        {
            int x = 8;
            System.out.println(x);
        }
    }
}
```

7. Which relationship is demonstrated when the lifespan of a child is tightly coupled to its parent object? [2 marks]
8. What is method overloading? [2 marks]

SECTION B (60 marks)

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

1. A parallel array is a structure that contains multiple arrays. Parallel arrays use two or more arrays to represent a collection of data where each corresponding array index is a matching field for a given record. For example, if there are two arrays, one for names and one for ages, the array elements at names [2] and ages [2] would describe the name and age of the third person.

Name	Computer#	CHE 1000	PHY 1010	MAT 1100	BIO 1412
John Sibeso	201923211	45	54	45	54
Jack Phiri	201923212	56	65	78	89
Jane Banda	201923213	98	67	43	45
Kalumbi Bwalya	201923214	76	33	58	82

You have been tasked to write a program in Java which does the following

- a) Stores the results in the table above using a parallel array [**5 marks**]
 - b) Print a performance report for a student given the student's computer#. The report should indicate the overall position in class for the given student. Overall position is calculated by adding the scores for all the subjects and ranking the students based on the sum. The report should also indicate whether the students score is above average for each subject. [**15 marks**]
2. Calculating powers of numbers can be expensive if done naively. Below is one such naive approach

$$a^b = a_1 * \dots * a_b$$

That is multiply a repeatedly b times. A faster way of computing powers is by using a divide and conquer approach. In this approach we basically check if b meets a certain criterion and reduce the problem based on this criterion. An example criterion is checking if b is even or odd. If it is odd break down the problem into two parts. Calculate the value of one-part a^{b-1} and multiply by a . If b is even, multiply $a^{b/2}$ by itself to get the power based on the even value. Basically

$$a^b = \begin{cases} a * a^{b-1}, & \text{the case when } b \text{ is odd} \\ a^{\frac{b}{2}} * a^{\frac{b}{2}}, & \text{the case when } b \text{ is even} \end{cases}$$

- a) A rational number is one that can be written as the ratio of two integers in the form a/b . Write code for a rational number class, RationalNumber, that is a representation of a rational number that
- Has two public class variables, a numerator and a denominator [2 marks]
 - Has a constructor that accepts two integers, a numerator and a denominator. [2 marks]
- b) Write a Powers class that
- Has a method that gets an integer as input and checks whether the given integer is even or not. If even it returns true. If not, it returns false. [4 marks]
 - Has a method that calculates a^b using the proposed approach and criterion in 2(b.i) to make recursive calls. Working only with small numbers and the method return an integer. [6 marks]
 - Has a method that gets a RationalNumber object and integer n as input. It then calculates the RationalNumber to the power n. The method makes use of the method in 2(b.ii). It returns a RationalNumber. [6 marks]
3. One of the most powerful aspects of programming is that of inheritance. From inheritance we are capable of reducing duplication of code.
- What is polymorphism? [2 marks]
 - A programmer wants to develop a program that handles employees in a University. He realizes that a Faculty member is an employee and an employee is basically a person. He then plans to explore constructor chaining using this basic relationship.
 - Write code that implements the three solid classes. Each constructor should print out information about the type of object being created. [6 marks]
 - In what order would the constructors be called. [3 marks]
 - What is dynamic binding and why is it important? [3 marks]
 - What is the difference between method overloading and method overriding? [4 marks]
 - Why is it important for subclasses not to weaken visibility of variables and methods? [2 marks]

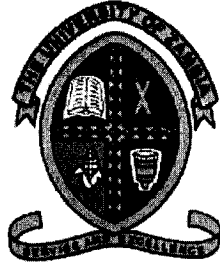
4. To execute more than one related task in parallel programmers often make use of threads.
- What is a thread? [2 marks]
 - When accessing shared resources inconsistency in results may arise due to race conditions.
 - What is synchronization? [2 marks]
 - How does java support synchronization implementation? [4 marks]
 - Write code for an account class that supports threads and is race condition safe. The class should have methods for depositing and withdrawing from the account. [12 marks]
5. You have been asked to implement an application that retrieves customer information from a database. The following information about the customers is stored; Name, CustomerID, Age and Residential address. The database administrator has already created the database and populated. You have been tasked to write a program that basically displays the information in the database using a GUI. The GUI should have a text field for entering the customerID and a button for submitting the customerID after which the customer's details are displayed. See figure below. You can use a database driver of your choice. Write code implementing this application. [20 marks]

CustomerID:

Name: Age:

Residential Address:

The end of the examination paper



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

DEFERRED FINAL EXAMINATION

CSC 2101
COMPUTER SYSTEMS

Date: 11TH DECEMBER 2019
Time: 14:00hrs – 17:00hrs
Duration: 3 Hours
Venue: SPORTS HALL

Instructions

1. There are five (5) questions and two (2) sections in this paper.
2. *Answer all the questions in Section A and choose any three (3) questions from Section B*

SECTION A

QUESTION ONE

- a. Name *three (3)* appliances that are candidates for being run by an embedded CPU. [6 marks]
- b. Babbage's difference engine had a fixed program that could not be changed. Is this essentially the same thing as a modern CD-ROM that cannot be changed? Explain your answer. [4 marks]
- c. A certain computer can be equipped with 268,435,456 bytes of memory. Why would a manufacturer choose such a peculiar number, instead of an easy-to-remember number like 250,000,000? [2 marks]
- d. You have been asked to remove a dual inline memory module and insert one with a larger capacity in its place. Describe the process for doing so [5 marks]
- e. List down the four basic components of the Central Processing Unit, stating the main function of each component [8 marks]

SECTION B (Choose any three)

QUESTION TWO

- a. Define the following; [3 marks]
 - i. Programming Language
 - ii. Syntax
 - iii. Semantics
- b. Discuss the following network topologies: [6 marks]
 - i. Bus
 - ii. Star
 - iii. Ring
- c. Write short paragraphs on the following;
 - i. Object oriented programming paradigm giving *two (2)* examples [4 marks]
 - ii. Functional programming paradigm giving *two (2)* examples [4 marks]
 - iii. Polymorphism [2 marks]

- iv. Pass by reference vs pass by value [2 marks]
- d. What is the meaning and what role do the following play in the CPU: [4 marks]
 - i. MAR
 - ii. MBR
 - iii. I/O AR
 - iv. PC

QUESTION THREE

- a. List and explain *four (4)* problems that are solved by the Transport layer [4 marks]
- b. Using an n-bit address, determine the value of n required to address 1023 cells. With this value of n, what will be the addresses of the last two cells in binary? [5 marks]
- c. List and explain *five (5)* services provided by the operating system [5 marks]
- d. Discuss the following ROM variations: [2 marks]
 - iv. PROM
 - v. EPROM
- e. Explain three techniques for I/O operation [9 marks]

QUESTION FOUR

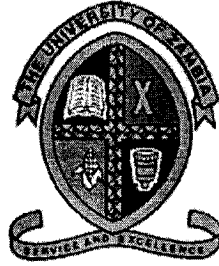
- a. Give brief definitions for each of the following; [3 marks]
 - i. Seek time
 - ii. Rotational latency
 - iii. Transfer time
- b. With the aid of a diagram, give the 4 layers of the TCP/IP protocol. Give a brief description of what each layer does. [8 marks]
- c. Compare and contrast the two physical network technologies, Circuit Switched (connection oriented) and Packet Switched (Store and Forward) [8 marks]
- d. What is the 8-bit binary representation of the integer 106? [1 mark]
- e. Compare compilation and interpretation [5 marks]

QUESTION FIVE

- a. What is a compiler? **[1 mark]**
- b. Compiling analysis consists of three phases. Explain each phase: **[6 marks]**
- i. Linear analysis
 - ii. Hierarchical analysis
 - iii. Semantic analysis
- c. Describe the advantages and disadvantages of magnetic storage, optical storage and solid-state storage using criteria such as versatility, durability, capacity, access time and transfer rate. **[10 marks]**
- d. What is an interconnection structure? **[2 marks]**
- e. Define *three (3)* functional groups into which bus lines can be classified and state the significance of each classification width. **[6 marks]**

END OF EXAM

Optimum!!!



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

OPERATING SYSTEMS
CSC2202

FINAL EXAMINATION

Date: Thursday, 14th November, 2019
Venue: P207
Time: 09 – 12hrs
Duration: 3hrs

Instructions

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

SECTION A (Answer all questions)

QUESTION 1 (20 marks)

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

QUESTION 2 (20 marks)

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

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

- A. **[4 marks]** A common problem in soccer collisions between players jumping for headers (this often leads to concussions). They've decided that clever CSC2202 students could easily solve this problem with a synchronization primitive that would arbitrate which player got to jump up for the header (such primitives would have to be very high performance). Which primitive would you suggest?
- B. **[4 marks]** Mrs Kumar was making pancakes for hungry teenagers. The pancakes come out in batches of three. She'd like a synchronization primitive that would allocate pancakes to teenagers without fighting. (There is no need to worry about leftovers between batches all pancakes are consumed pretty much instantly.) Suggestions?
- C. **[4 marks]** You are competing in a new Olympic event called a distributed relay. One team member 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.

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

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.
- 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]** Explain how a scheduling algorithm could produce good throughput, but poor response time. Then explain how a scheduling algorithm could produce good response time, but poor throughput.
- B. **[6 marks]** There are many system processes active on any Linux system. These are typically created at system startup, and operate in the background as daemon processes.

Give three examples of system (daemon) processes in a Linux system, and briefly state their role in the operation of the system.

- C. [4 marks] One of the design decisions in OS memory management is the choice between swapping and paging. Define each of these terms, and clarify their respective roles in OS memory management.
- D. [6 marks] Below are three different techniques for organizing the data blocks for each file in a file system. Briefly describe each approach, identifying the strengths and weaknesses of each.
1. Contiguous allocation
 2. Linked allocation
 3. Indexed allocation.

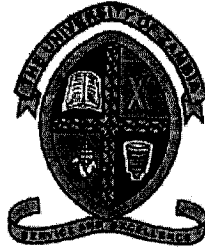
QUESTION 7

- A. [6 marks] The readers and writers problem can be formulated in several ways with regard to which category of processes can be started when. Carefully describe *three* different variations of the problem, each one favoring (or not favoring) some category of processes. For each variation, specify what happens when a reader or a writer becomes ready to access the database, and what happens when a process is finished.
- B. [4 marks] Two computer science students, Keziah and Haward, are having a discussion about inodes. Keziah maintains that memories have gotten so large and so cheap that when a file is opened, it is simpler and faster just to fetch a new copy of the i-node into the inode table, rather than search the entire table to see if it is already there. Haward disagrees. Who is right and why?
- C. [5 marks] A typical printed page of text contains 50 lines of 80 characters each. Imagine that a certain printer can print 6 pages per minute and that the time to write a character to the printer's output register is so short it can be ignored. Does it make sense to run this printer using interrupt-driven I/O if each character printed requires an interrupt that takes 50 μ sec all-in to service?

- D. [2 marks] Let's assume you have exactly three page frames and they contain the pages A, B, and C. Construct a page reference sequence of 10 page accesses, including A, B, C and any other pages you want demonstrating that MIN produces a better hit rate than does LRU. Include the hit rates for each algorithm. [2marks]
- 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

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

FINAL EXAMINATION

**CSC 2702 DATABASES AND
INFORMATION MANAGEMENT SYSTEMS**

Date: 19th NOVEMBER, 2019
Time: 14:00hrs – 17:00hrs
Duration: 3 Hours
Venue: P207

Instructions

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

SECTION A

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

Question 1 [20 Marks]

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

Question 2 [20 Marks]

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

SECTION B

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

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

Question 3

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

Question 4

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

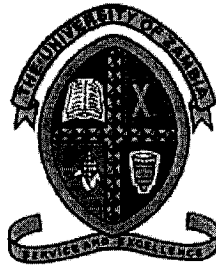
Question 5

- i. What is a partial dependency? With what normal form is it associated? [4 Marks]
- ii. Explain the difference between “Functional Dependency” and “Transitive Dependency”. [4 Marks]
- iii. When is a relationship in ER modelling said to be “recursive”? [2 Marks]
- iv. Define the following attributes and give example of each: [6 Marks]
 - a. Derived
 - b. Simple
 - c. Composite
 - d. Multi-valued
- v. Briefly, but precisely, explain the difference between single-valued attributes and simple attributes. Give an example of each. [4 Marks]

Question 6

- i. In database development process, what does the term “fact-finding” mean? [2 Marks]
- ii. State when “fact-finding” in Q6 (i) is particularly important during database development life cycle? [2 Marks]
- iii. Explain why “fact-finding” is crucial to the database development process? Especially to phase you have stated in Q6 (ii). [4 Marks]
- iv. State and briefly explain the five (5) most used fact-finding techniques you may adopt for your database design. [10 Marks]
- v. Why is a table whose primary key consists of a single attribute automatically in 2NF when it is in 1NF? [2 Marks]

---- End of Exam ----



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

FINAL EXAMINATION

CSC 2912
Numerical Analysis

Date: 4TH NOVEMBER 2019
Time: 14:00hrs – 17:00hrs
Duration: 3 Hours
Venue: NSLT

Instructions

1. There are **two (2) Sections** in this exam, **Section A** and **Section B**.
2. In **Section A**, **answer all the questions** and in **Section B** **choose any three (3) questions of the five (5) in any order.**

SECTION A: ANSWER ALL QUESTIONS IN THIS SECTION**[40 Marks]**

1. Define the following
 - a. Continuity of a function [3 Marks]
 - b. A fixed point of a function [3 Marks]
 - c. Differentiability of a function [3 Marks]
 - d. Relative error [3 Marks]

2. Concisely, state, without proof, the following theorems
 - a. Rolle's theorem [4 Marks]
 - b. Mean Value theorem [4 Marks]
 - c. Intermediate value theorem [4 Marks]
 - d. Taylor's theorem [4 Marks]
 - e. Fixed point theorem [4 Marks]

3. Prove that If a function is continuous in the interval $[a, b]$ and differentiable in the open interval (a, b) such that $f'(x) \neq 0$ for x in this interval, then f has at most one root, in the interval $[a, b]$ [8 Marks]

SECTION B: ANSWER THREE (3) OF THE FIVE (5) QUESTIONS.**[60 Marks]**

1.
 - a. Show that the graph of the equation $x^3 + 2x - 4 = 0$, crosses the x-axis exactly once in the interval $[1, 2]$ [8 Marks]
 - b. Approximate this root to 10^{-4} accuracy using the
 - i. Newton-Raphson method. [6 Marks]
 - ii. Secant method [6 Marks]

2.
 - a. Derive, P_4 , the fourth Taylor polynomial for the function $f(x) = e^x$ about the point $x_0 = 0$. [8 Marks]
 - b. Use P_4 to approximate \sqrt{e} . [4 Marks]
 - c. What is the relative error of this approximation? [4 Marks]
 - d. Using the remainder term, establish the upper bound of the error introduced by this approximation. [4 Marks]

3. Consider the function g defined below

$$g(x) = 1 + \frac{2}{1+x}$$

- a. Show that g has a unique fixed point in the interval $[1, 2]$ [8 Marks]

- b. Show that the fixed point of the g is the root of the function [6 Marks]

$$f(x) = x^2 - 3$$

- c. Hence, use the fixed point iteration method to approximate the number $\sqrt{3}$, to 10^{-3} accuracy. [6 Marks]

4. Consider the table of values of the function f at the given points of x

x	0.4	0.8	1.2
$f(x)$	2.225541	4.953032	11.02318

Approximate $f(0.5)$ using

- a. Neville's Iterated method [10 Marks]
 b. Newton's Forward Divided Differences [10 Marks]

5. Given the set of points for f below.

x	0.2	0.4	0.6	0.8	1.0
$f(x)$	1.105171	1.221403	1.349859	1.491825	1.648721

- a. Using $h = 0.4$, approximate
 i. $f'(0.6)$ [4 Marks]
 ii. $f'(0.2)$ [4 Marks]
 b. Evaluate

$$\int_{0.2}^{1.0} f(x) dx$$

Using Composite

- i. Trapezoidal rule $n = 2$ [6 Marks]
 ii. Simpson rule with $n = 2$ [6 Marks]

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

The University of Zambia Examination 2019
School of Natural Science
Department of Computer Science
Digital Electronics CSC 3120

Time: 3 Hours

Instructions: Answer any 5 questions

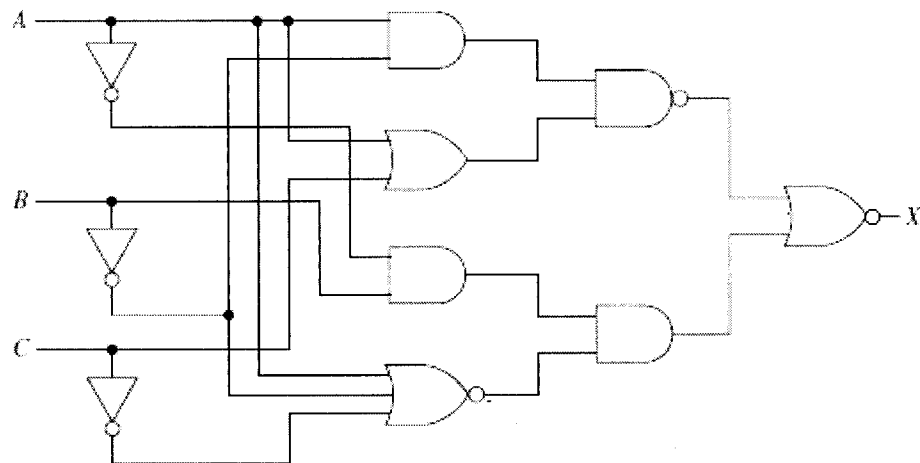
All questions carry 20 marks

1.

- a. Using Karnaugh map design a circuit which outputs a low when a number is a prime and a high when it is not a prime. The input is a 4 bit binary number. [11]
- b. Perform 2twos complement to perform the following
 - i. $52 - 84$ [5]
 - ii. $112 - 67$ [4]

2.

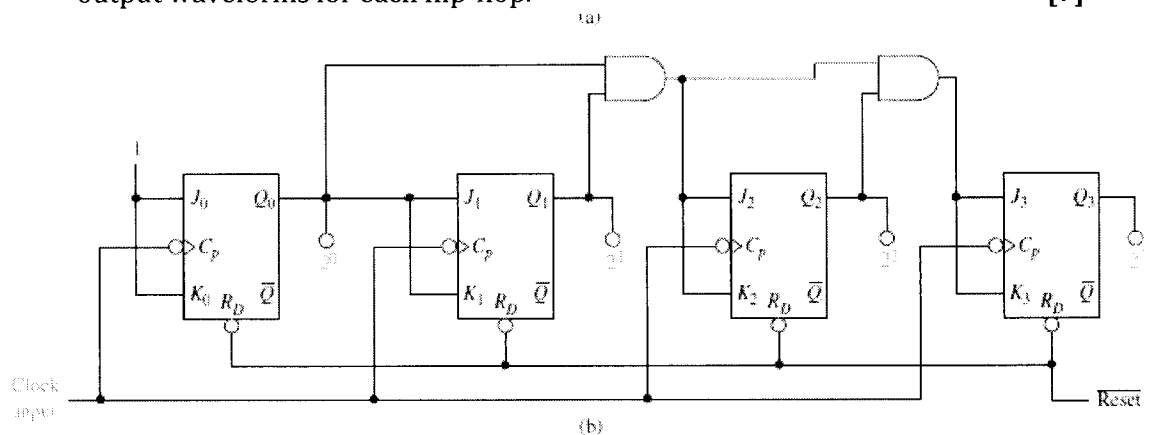
- a. Using Boolean algebra and DeMorgan's theorem to simplify the circuit below. [15]



- b. For the simplified circuit implement it using only NAND gates. [5]

3.

- a. Design a modulus ripple counter that counts from 0 up to 6. Draw the output waveforms. [10]
- b. What is the advantage of using synchronous counters over ripple counters? [3]
- c. Briefly explain how a synchronous counter shown below functions. Draw the output waveforms for each flip-flop. [7]

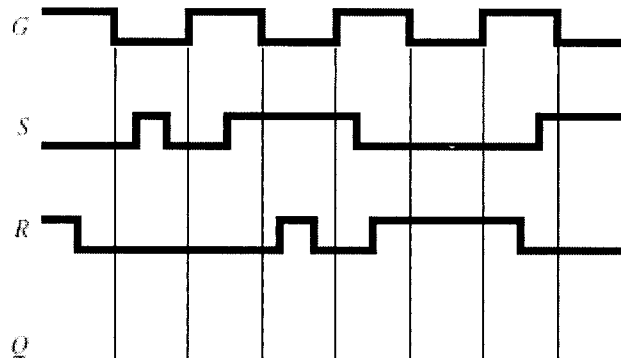


4.

- a. Draw a 4 bit Johnson shift register. Draw the output waveforms for each clock pulse. [12]
- b. Design a binary comparator circuit using exclusive-ORs and a NOR gate that will compare two 4-bit binary strings. [8]

5.

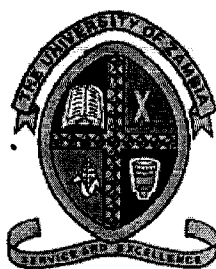
- a. Sketch the Q output waveform for a gated S - R flip-flop given the inputs at S , R , and G shown in below. [8]



6.

- b. Draw a four bit parallel in serial out shift register using J - K flip flops. [12]
- a. Draw an inverter using CMOS transistors. [8]
- b. Briefly explain the difference between static RAM and dynamic RAM. What are the advantages of each? [6]
- c. What is read only memory (ROM) used for? Name three types ROM. [6]

END OF EXAMINATION



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

IT PROJECT MANAGEMENT
CSC 3612

2018-2019 FINAL EXAM

Date: 12TH November 2019
Venue: P207
Time: 14:00hrs – 17:00hrs
Duration: 3 Hours

Instructions

- 1. This examination has two sections A and B*
- 2. Section A comprises six [6] questions. Answer any four [4] questions. Each question carries 20 marks.*
- 3. Section B comprises one [1] question. Answer the question. It carries 20 marks*

Section A

Answer any four [4] questions. Each question carries 20 Marks

Question 1 [20 marks]

- A. Define project Management? List at least 4 advantages of using Project Management? [6]
- B. List the 10 characteristics of Organizational culture? [5]
- C. Explain the three sphere model of System Management with examples? [6]
- D. Map the PM processes groups in Project Integration Management and Project Quality Management? [3]

Question 2 [20 marks]

- A. Explain the different processes involved in Project Integration Management? [6]
- B. Explain the different methods in selecting Projects? [10]
- C. Briefly explain SWOT analysis with examples? [4]

Question 3 [20 marks]

- A. Explain the different methods in collecting requirements? [6]
- B. What is the best practice guidance on Creating a WBS and WBS dictionary? [6]
- C. What are the different approaches in developing WBS? [5]
- D. Give some suggestions for improving user input?[3]

Question 4 [20 marks]

- A. Write short notes on Activity List, Activity attributes and Milestone? [6]
- B. Explain the Arrow Diagramming Method and Precedence Diagramming Method? [6]
- C. How you use Critical Path Analysis to make schedule trade-offs? [4]
- D. What are the techniques used to shorten the project schedule? [4]

Question 5 [20 marks]

- A. Distinguish between Cost and Project Cost Management? Explain the different processes in Project Cost Management? [6]

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

Planned Value (PV)	= \$40,000
Earned Value (EV)	= \$30,000
Actual Cost (AC)	= \$50,000
Budget at completion (BAC)	= \$200,000

- 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? [1]
 - iv) Use the SPI to estimate how long it will take to finish this project? [1]
 - v) Sketch the earned value chart based for this project? [2]
- C. What is Project Portfolio Management? What are the benefits Portfolio Management? [4]

Question 6 [20 marks]

- A. Explain the different types of cost categories related to quality? [6]
- B. Explain the seven basic tools of quality that help in performing in quality control? [14]

Section – B [Compulsory]

[1x20 = 20 Mark]

Answer the question. This question carries 20 marks

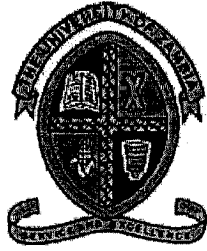
Question 7 [20 marks]

- A. Create a Work Breakdown Structure [5] and Cost estimate model [5] for building a new, state-of-the-art multimedia classroom for your organization within the next six months. The classroom should include 20 high-end personal computers with appropriate software for your organization, a network server, Internet access for all machines, an instructor station, and a projection system. Be sure to include personnel costs associated with the project management for this project. Document the assumptions you made in preparing the estimate and provide explanations for key numbers.

B. Consider the following table, Network Diagram Data for a Small Project. All duration estimates or estimated times are in days; and the network proceeds from Node 1 to Node 9.

Activity	Initial Node	Final Node	Estimated Duration
A	1	2	2
B	2	3	2
C	2	4	3
D	2	5	4
E	3	6	2
F	4	6	3
G	5	7	6
H	6	8	2
I	6	7	5
J	7	8	1
K	8	9	2

- i. Draw an AOA network diagram representing the project. Put the node in numbers in circles and draw arrows from node to node, labelling each arrow with the activity letter and estimated time. [4]
- ii. Identify all of the paths on the network diagram and note how long they are.[4]
- iii. What is the critical path for this project and how long is it?[1]
- iv. What is the shortest possible time it will take to complete this project? [1]



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

FINAL EXAMINATION

CSC 3712 ADVANCED DATABASES

Date: 15th NOVEMBER, 2019
Time: 14:00hrs – 17:00hrs
Duration: 3 Hours
Venue: P207

Instructions

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

SECTION A [40 Marks]

INSTRUCTION: Consider the **scenario** given below and answer the follow up questions. Answer **ALL** questions in this section. The marks culminates into 40% of 100 Marks.

SCENARIO: The ABC Car Service & Repair Centers are owned by the SILENT car dealer; ABC services and repairs only SILENT cars. Three ABC Car Service & Repair Centers provide service and repair for the entire state. Each of the three centers is independently managed and operated by a shop manager, a receptionist, and at least eight mechanics. Each center maintains a fully stocked parts inventory. Each center also maintains a manual file system in which each car's maintenance history is kept: repairs made, parts used, costs, service dates, owner, and so on. Files are also kept to track inventory, purchasing, billing, employees' hours, and payroll.

You have been contacted by the manager of one of the centers to design and implement a computerized database system.

Given the preceding information, do the following:

- a. Indicate the most appropriate sequence of activities by labeling each of the following steps in the correct order. (For example, if you think that "Load the database." is the appropriate first step, label it "1.") **[11 Marks]**

- _____ Normalize the conceptual model.
- _____ Obtain a general description of company operations.
- _____ Load the database.
- _____ Create a description of each system process.
- _____ Test the system.
- _____ Draw a data flow diagram and system flowcharts.
- _____ Create a conceptual model using ER diagrams.
- _____ Create the application programs.
- _____ Interview the mechanics.
- _____ Create the file (table) structures.
- _____ Interview the shop manager.

- b. Describe the various modules that you believe the system should include. **[5 Marks]**
- c. How will a data dictionary help you develop the system? Give two examples. **[5 Marks]**

- d. What general (system) recommendations might you make to the shop manager? (For example, if the system will be integrated, what modules will be integrated? What benefits would be derived from such an integrated system? Include at least two general recommendations) **[10 Marks]**
- e. What is the best approach to conceptual database design? Why? **[5 Marks]**
- f. Name and describe at least four reports the system should have. Explain their use, and who will use those reports? **[4 Marks]**

SECTION B [60 Marks]

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

Question 1. [20 Marks]

- 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. [20 Marks]

- 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]**

Question 3 [20 Marks]

Consider the following relations defined by the relational schema below and normalize all the relations. [20 Marks]

Student (stuID, fName, lName, emailID, telNo)

Student_Course (studID, courseName, courseFee)

Student_Housing (studID, hostelName, hostelFee)

Student

studID	fName	lName	emailID	telNo
S001	X	Y	xy@gmail.com	09761000000
S002	U	V	uv@gmail.com	09730000000, 09654444444

Student_Course

studID	courseName	courseFee
S001	Artificial Intelligence	2000.00
S002		2500.00

Student_Housing

studID	hostelName	hostelFee
S001	Soweto	600.00
S002	Kafue	800.00

Question 4. [20 Marks]

- 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 5. [20 Marks]

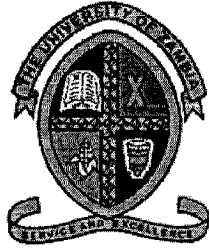
- i. Describe the three levels of backup that may be used in database recovery management?
[6 Marks]
- ii. The DBMS does not guarantee that the semantic meaning of the transaction truly represents the real-world event. What are the possible consequences of that limitation? Give an example. [2 Marks]
- 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]

---- End of exam ----

Question 5. [20 Marks]

- i. Describe the three levels of backup that may be used in database recovery management?
[6 Marks]
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- 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]

---- End of exam ----



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

FINAL EXAMINATION

CSC 3742
INFORMATION AND NETWORK SECURITY

Date: 5th NOVEMBER 2019
Time: 09:00hrs – 12:00hrs
Duration: 3 Hours
Venue: P207

Instructions

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

SECTION A [40 MARKS]

ANSWER ALL THE QUESTIONS IN THIS SECTION

Question 1 [20 marks]

- a) What are industry-standard frameworks and reference architectures that are required by external agencies known as? **[2 marks]**
- b) What is the difference between a network intrusion detection system (NIDS) and a network intrusion prevention system (NIPS)? **[2 marks]**
- c) Which tool is most commonly associated with nation state threat actors? **[2 marks]**
- d) Which type of mutation completely changes a virus from its original form by rewriting its own code whenever it is executed? **[2 marks]**
- e) Name the data that is to be encrypted by inputting it into a cryptographic algorithm? **[2 marks]**
- f) What entity calls in crypto modules to perform cryptographic tasks? **[2 marks]**
- g) Name the attack that intercepts communications between a web browser and the underlying computer? **[2 marks]**
- h) John was explaining about an attack that accepts user input without validating it and uses that input in a response. What type of attack was he describing? **[2 marks]**
- i) Which type of log can provide details regarding requests for specific files on a system? **[2 marks]**
- j) Which version of Simple Network Management Protocol (SNMP) is considered the most secure? **[2 marks]**

Question 2 [20 marks]

- a) What is the category of threat actors that sell their knowledge of vulnerabilities to other attackers or governments? **[2 marks]**
- b) Alexei was given a key to a substitution cipher. The key showed that the entire alphabet was rotated 13 steps. What type of cipher is this? **[3 marks]**
- c) Which act requires banks and financial institutions to alert their customers of their policies in disclosing customer information? **[2 marks]**
- d) What is the general term used for describing software that gathers information without the user's consent? **[3 marks]**

- e) What is the difference between a DoS and a DDoS attack? **[3 marks]**
- f) What kind of attack is performed by an attacker who takes advantage of the inadvertent and unauthorized access built through three succeeding systems that all trust one another? **[2 marks]**
- g) What is the difference between NFC and RFID? **[3 marks]**
- h) Which stage is a “quality assurance” test that verifies the code functions as intended? **[2 marks]**

SECTION B [60 MARKS]

ANSWER ANY THREE (3) QUESTIONS FROM FOUR (4) IN THIS SECTION

Question 3 [20 marks]

- a) Why do attacks continue to be successful, despite all the efforts to stop them? **[5 marks]**
- b) Employee onboarding refers to the tasks associated with hiring a new employee (onboarding). There are several steps that should be taken to not only make the new employee feel part of the team but also so that the employee can become productive as soon as possible. Discuss any five steps. **[5 marks]**
- c) Enforcing technical access control using the various access control models is only one means of providing security. In addition, establishing a set of “best practices” for limiting access also can help secure systems and their data. Discuss any five best practices. **[5 marks]**
- d) Although there are many different authentication credentials that can be presented to an IT system to verify the genuineness of the user, all credentials can be classified into one of these five categories. Discuss the categories. **[5 marks]**

Question 4 [20 marks]

- a) Two broad categories of information security personnel are responsible for providing protection for an enterprise like a business or nonprofit organization. Discuss the four generally recognized security positions. **[5 marks]**

- e) What is the difference between a DoS and a DDoS attack? **[3 marks]**
- f) What kind of attack is performed by an attacker who takes advantage of the inadvertent and unauthorized access built through three succeeding systems that all trust one another? **[2 marks]**
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Question 4 [20 marks]

- a) Two broad categories of information security personnel are responsible for providing protection for an enterprise like a business or nonprofit organization. Discuss the four generally recognized security positions. **[5 marks]**

- b) Once accounts have been created, it is important that they be periodically maintained and audited to ensure they follow all enterprise policies. Discuss the audits that should be done. **[5 marks]**
- c) In an offline attack, threat actors steal the file of password digests and load that file onto their own computers. Several offline password attack techniques attempt to match an attacker's known password digest with stolen digests. Discuss any five offline attacks. **[5 marks]**
- d) Due to the widespread use of mobile devices, it is not always feasible to require an employee to carry a company-owned smartphone along with his own personal cell phone. Many organizations have adopted an enterprise deployment model as it relates to mobile devices. Discuss the enterprise deployment models. **[5 marks]**

Question 5 [20 marks]

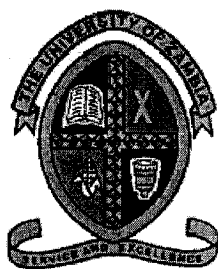
- a) Malware (malicious software) is software that enters a computer system without the user's knowledge or consent and then performs an unwanted and harmful action. Discuss any five types of malware. **[5 marks]**
- b) Access control models are variously referred to as access control models, methods, modes, techniques, or types and there are five access control models. Explain the models. **[5 marks]**
- c) There are several vulnerabilities inherent to mobile devices. Discuss any five vulnerabilities. **[5 marks]**
- d) There are several attacks that can be directed against wireless data systems. Discuss any five attacks. **[5 marks]**

Question 6 [20 marks]

- a) Discuss four technologies that spyware uses. **[5 marks]**
- b) Despite providing widespread protections cryptography faces constraints (limitations) that can impact its effectiveness. Discuss the constraints. **[5 marks]**
- c) The challenge of keeping computers secure has never been greater, not only because of continual attacks but also because of the difficulties faced in defending against these attacks. Discuss any five difficulties. **[5 marks]**

- d) Individuals are given different roles in relationship to access control objects or resources.
Explain the roles in access control. [5 marks]

THE END



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

MANAGEMENT INFORMATION SYSTEMS
CSC 3750

2018-2019 FINAL EXAM

Date: 8th November 2019
Venue: P207
Time: 14:00hrs – 17:00hrs
Duration: 3 Hours

Instructions

- 1. This examination has two sections A and B*
- 2. Section A comprises six [6] questions. Answer any four [4] questions. Each question carries 20 marks.*
- 3. Section B comprises one [1] question. Answer the question. It carries 20 marks*

Section A

[4x20 = 80 Marks]

Answer any four [4] questions. Each question carries 20 Marks

Question 1 [20 marks]

- A. Define the term Management Information System? [2] Briefly explain the three dimensions of Information Systems? [6]
- B. You are starting a small bike messenger company. Given your type of services (hand-delivering packages within a small geographical area), could your firm be a digital firm? If so, what would make this a digital firm? [2]
- C. What is a Business Process? [2] Identify four functional area and give 2 examples of business processes in each area? [4]
- D. Explain the different tools used for collaboration and team work?[4]

Question 2 [20 marks]

- A. Identify and describe the features of organizations that help explain differences in organizations use of information systems?[5]
- B. Explain the impact of information systems in the organization? [5]
- C. How does the use of electronic voting machines act as a "double-edged sword?" What moral dimensions are raised by this use of information technology? [5]
- D. Identify the five moral dimensions that are involved in political, social, and ethical issues and briefly describe each. Of these, which do you think is the most difficult for society to deal with? Support your opinion. [5]

Question 3 [20 marks]

- A. Explain how businesses can benefit from virtualization, green computing, and multicore processors?[6]
- B. Describe the evolving mobile platform and quantum computing? [4]
- C. Define big data and describe the technologies for managing and analyzing it? [6]
- D. Explain why data quality audits and data cleansing are essential? [4]

Question 4 [20 marks]

- A. Write short notes on Client/server computing, Packet switching and TCP/IP and connectivity?[6]
- B. How are RFID systems used in inventory control and supply chain management? [4]
- C. 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]
- D. Explain the tools and technologies used for safeguarding the information systems? [5]

Question 5 [20 marks]

- A. How do enterprise systems help businesses achieve operational excellence? [5]
- B. Identify two classifications for supply chain software. For each classification, identify five capabilities? [5]
- C. List all the unique factors that makes E-commerce different? [4]
- D. Name and describe the principal e-commerce revenue models? [6]

Question 6 [20 marks]

- A. Define and describe the various types of enterprise-wide knowledge management systems and explain how they provide value for businesses? [6]
- B. Describe the role of the following in facilitating knowledge management: portals, wikis, social bookmarking, and learning management systems? [4]
- C. List all the Mintzberg's managerial roles? [5]
- D. List and describe the analytic functionalities provided by BI systems? [5]

Section – B [Compulsory]

[1x20 = 20 Mark]

Answer the question. This question carries 20 marks

Question 7 [20 marks]

A. Management at your agricultural chemicals corporation has been dissatisfied with production planning. Production plans are created using best guesses of demand for each product, which are based on how much of each product has been ordered in the past. If a customer places an unexpected order or requests a change to an existing order after it has been placed, there is no way to adjust production plans. The company may have to tell customers it can't fill their orders, or it may run up extra costs maintaining additional inventory to prevent stock-outs.

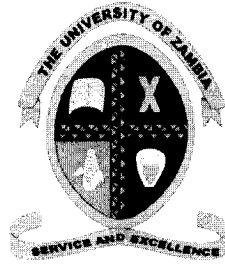
At the end of each month, orders are totaled and manually keyed into the company's production planning system. Data from the past month's production and inventory systems are manually entered into the firm's order management system. Analysts from the sales department and from the production department analyze the data from their respective systems to determine what the sales targets and production targets should be for the next month. These estimates are usually different. The analysts then get together at a high-level planning meeting to revise the production and sales targets to take into account senior management's goals for market share, revenues, and profits. The outcome of the meeting is a finalized production master schedule.

The entire production planning process takes 17 business days to complete. Nine of these days are required to enter and validate the data. The remaining days are spent developing and reconciling the production and sales targets and finalizing the production master schedule.

- a. Draw a diagram of the existing production planning process. [3]
- b. Analyze the problems this process creates for the company.[3]
- c. How could an enterprise system solve these problems? In what ways could it lower costs? Diagram what the production planning process might look like if the company implemented enterprise software. [4]

B. Your company manufactures and sells tennis rackets and would like to start selling outside the United States. You are in charge of developing a global Web strategy and the first countries you are thinking of targeting are Brazil, China, Germany, Italy, and Japan.

- a. Which of these countries would you target first? What criteria did you use? [3]
- b. What other considerations should you address in your Web strategy? [3]
- c. What features would you put on your Web site to attract buyers from the countries you target? [4]



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

FINAL EXAMINATION

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

Date: Thursday, 7th November 2019
Time: 14:00hrs – 17:00hrs
Duration: 3 Hours
Venue: Upper Dinning Hall

Instructions

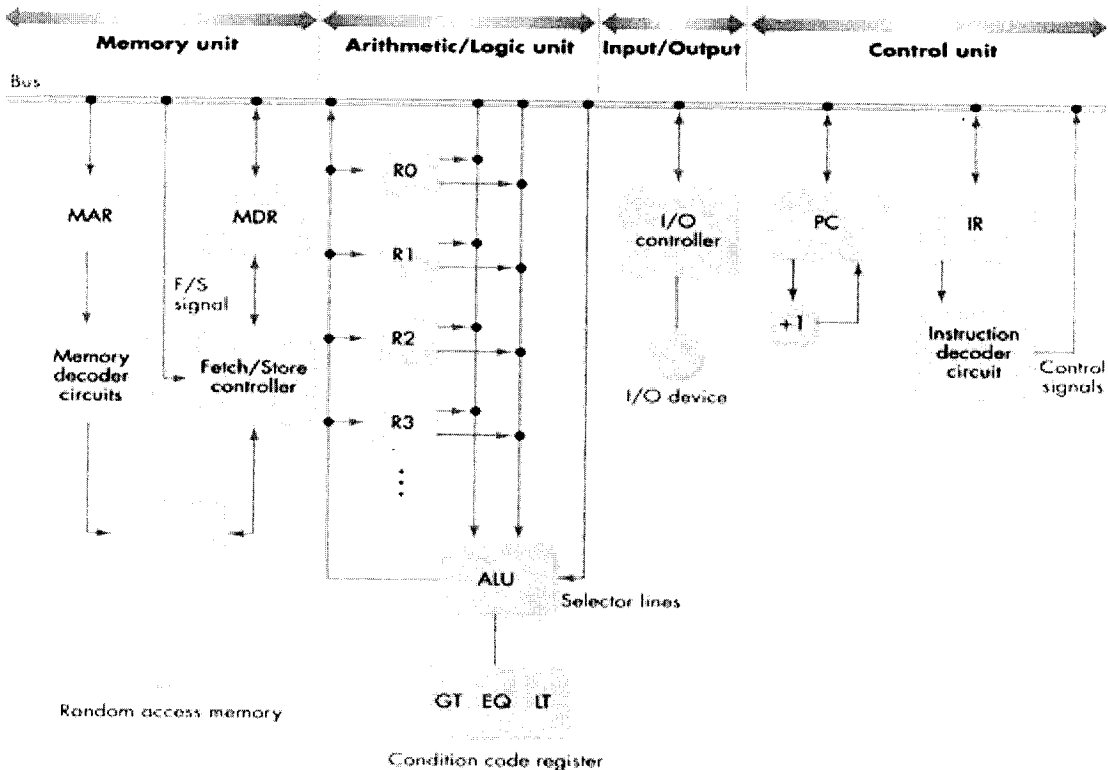
1. There are **six (6) questions** and **two (2) sections** in this paper.
2. Each question carries **20 marks**,
3. You are required to answer a total of Five (5) Questions
 - a. Answer **all the questions in Section A**
 - b. Choose **any two (2) questions from Section B**

SECTION A

This Section has Three Questions. Answer all the questions

Question I

- a) The diagram below shows the Von Neumann architecture which has four functional units namely Memory unit, Input/Output unit, Arithmetic/Logic unit and Control unit. Briefly discuss the Von Neumann computer architecture below [2 Marks]



- b) Flynn's taxonomy is a classification of computer architectures. The classification system has been used as a tool in design of modern processors and their functionalities. Since the rise of multiprocessing central processing units, a multiprogramming context has evolved as an extension of the classification system. Discuss each of the following **None Von Neumann Architectures** below [8 Marks]

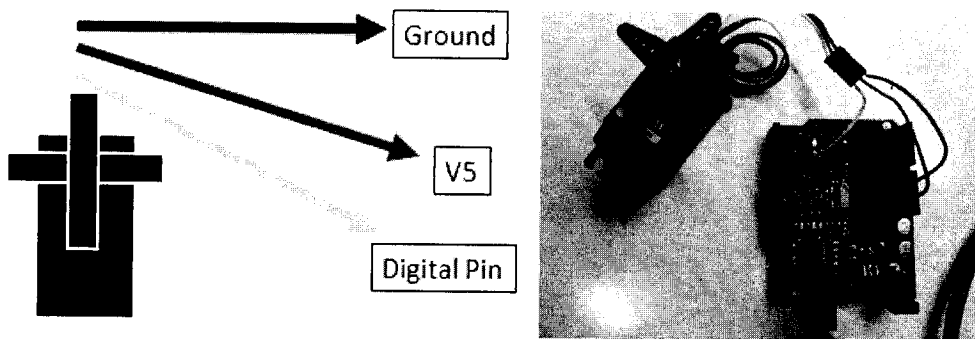
- Multiple instruction streams, multiple data streams (MIMD)
- Multiple instruction streams, single data stream (MISD)
- Single instruction stream, multiple data streams (SIMD)
- Single instruction stream, single data stream (SISD) SIMD architecture

c) The 8085 instruction set is classified into the following three groups according to word size [6 Marks]

- i. One-word or 1-byte instructions
- ii. Two-word or 2-byte instructions
- iii. Three-word or 3-byte instructions

Briefly discuss each of the above Intel 8085 instruction set above

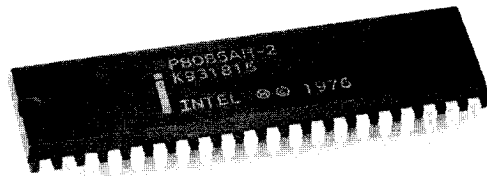
d) A servo motor is a motor that pulses at a certain rate moving its gear at a certain angle. It has three connections: the black is ground, the red is connected to 5V, and the white (yellow wire) is set to the digital pin.



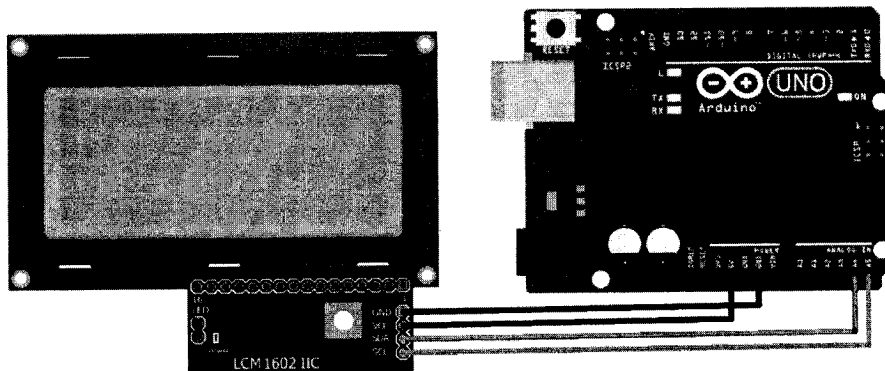
Using PIN 13 as the digital PIN, write the full well commented code for the **Arduino Standard Servo Rotation to Exact Angel** [4 Marks].

Question II

- a) Draw a well labelled diagram showing the following memory units. Discuss how each memory unit store a bit. [6 Marks]
- DRAM
 - SRAM
- b) The diagram below shows the intel 8085 Microprocessor chipset. The intel 8085 uses Machine language which is a set of instructions executed directly by the processing unit. Each instruction of the intel 8085 performs a very specific task, such as LOAD, JUMP, or an ALU operation on a unit of data in a CPU register or memory. **Write the machine code** for the Intel 8085 microprocessor used to [6 Marks]
- Add two numbers (11010011 and 10001010)
 - Subtract two numbers, 10001010 from 11010011

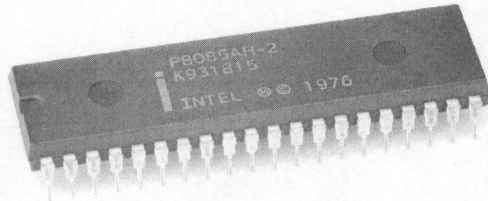


- c) The Department of Computer Science would like to improve on a number of services and features in the computer labs. As a fourth year student, you have been assigned to design and write the code for the prototype that would display the **Date, Time of the Day** and **Welcome Message** to anyone accessing the Computer Labs. The diagram below shows the setup for information display on the LCD screen with three rows. Write the full code to display the following [8 Marks]
- Row Number 1: **Time** (Hours: Minutes: Seconds)
 - Row Number 2: **Date** (Day, Month, Year)
 - Row Number 3: **Welcome Message as Scrolling Text** (WELCOME TO THE DEPARTMENT OF COMPUTER SCIENCE)

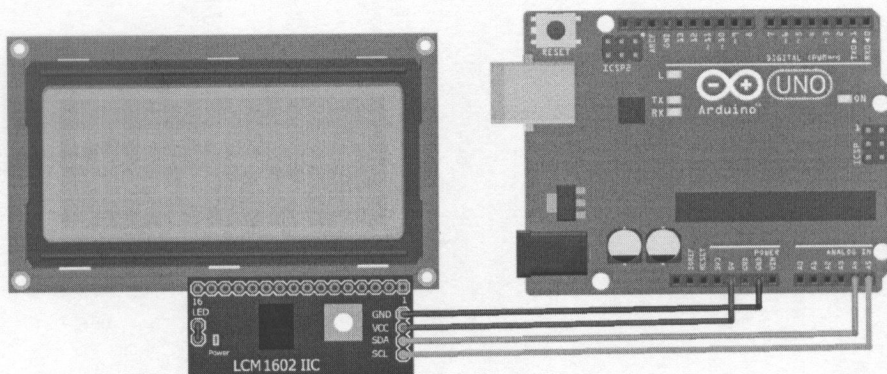


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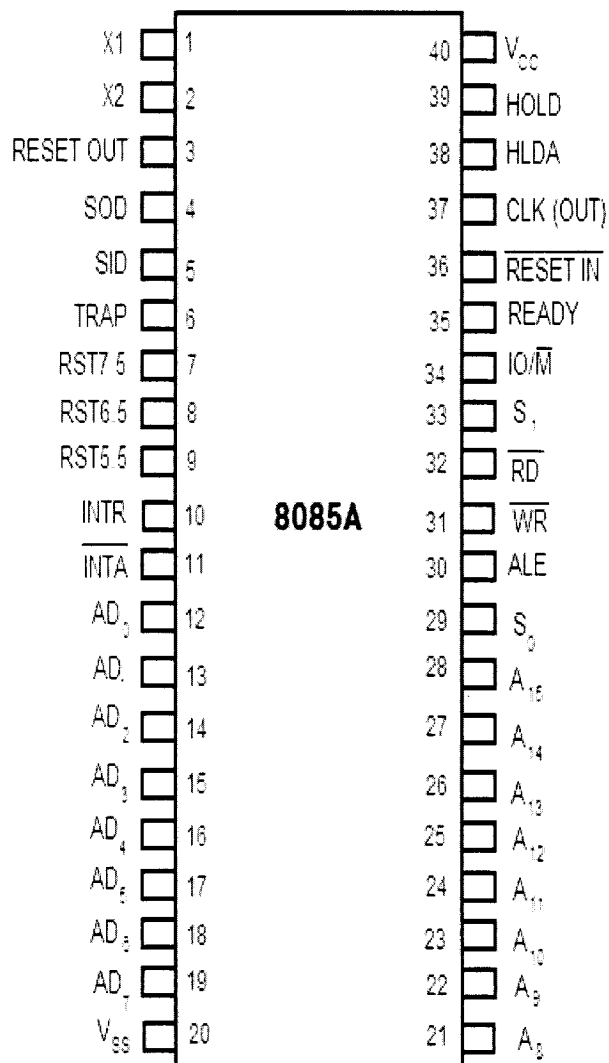


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Question III

- a) Computer memory can be defined as any physical device capable of storing information temporarily or permanently. Sequential circuits all depend upon the presence of memory. Briefly describe each of the following in relation to computer memory [4 Marks]
- Bit
 - Word
 - Memory Module
 - Memory Interfacing
- b) The figure below show the Intel 8085 Pin configuration. With reference to the diagram below, Give the function of each of the 40 PINS of the Intel 8085 processor chip [16 Marks]

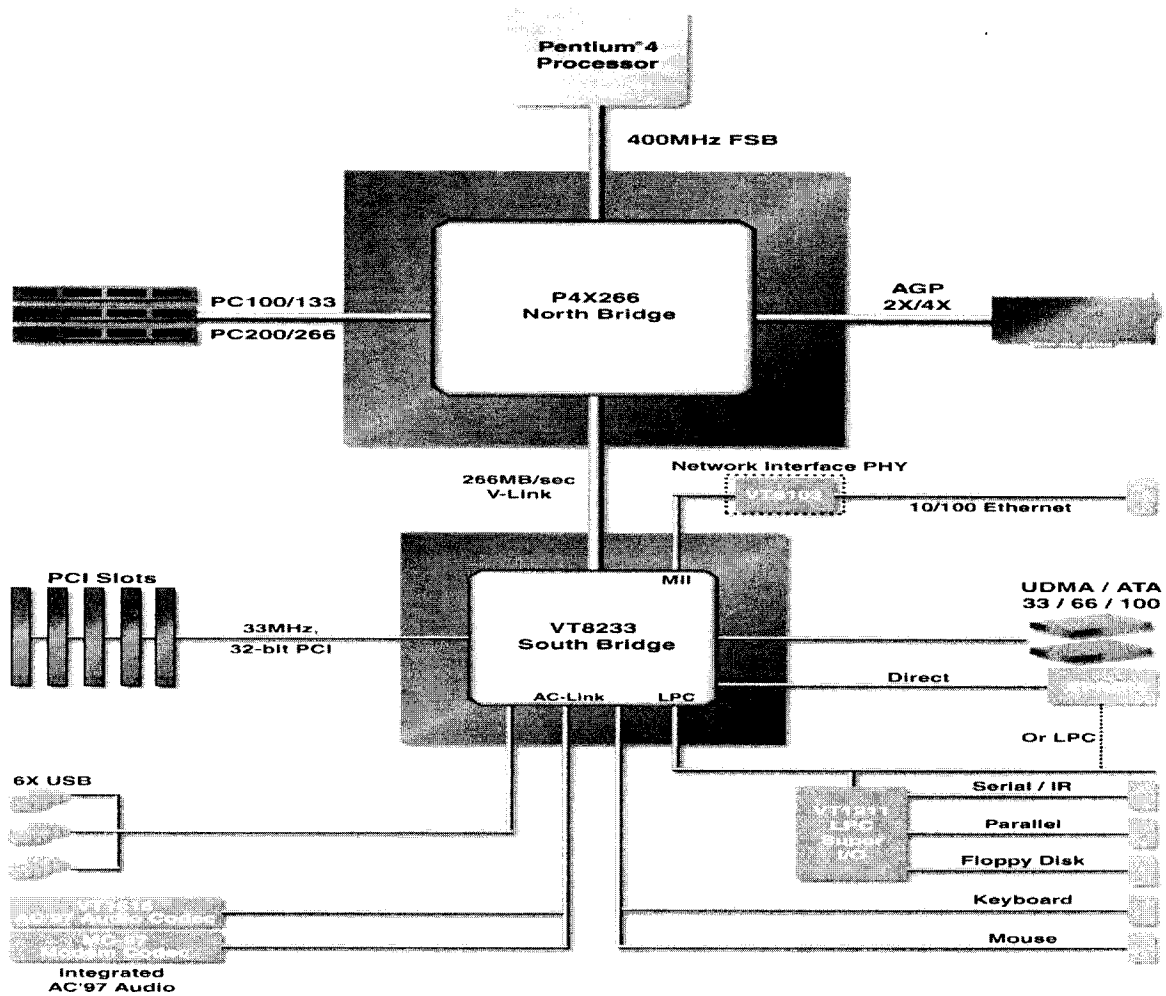


SECTION B

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

Question I

- a) A chipset is a group of integrated circuits, sold as one unit, designed to perform one or more related functions. The diagram below shows the Apollo Chipset designed for the Pentium (IV) processor. With reference to the diagram below, discuss in details the functions and roles of the chipsets (North Bridge and South Bridge) in relation to the Pentium 4 processor to manage the operation of the computer [10 Marks]

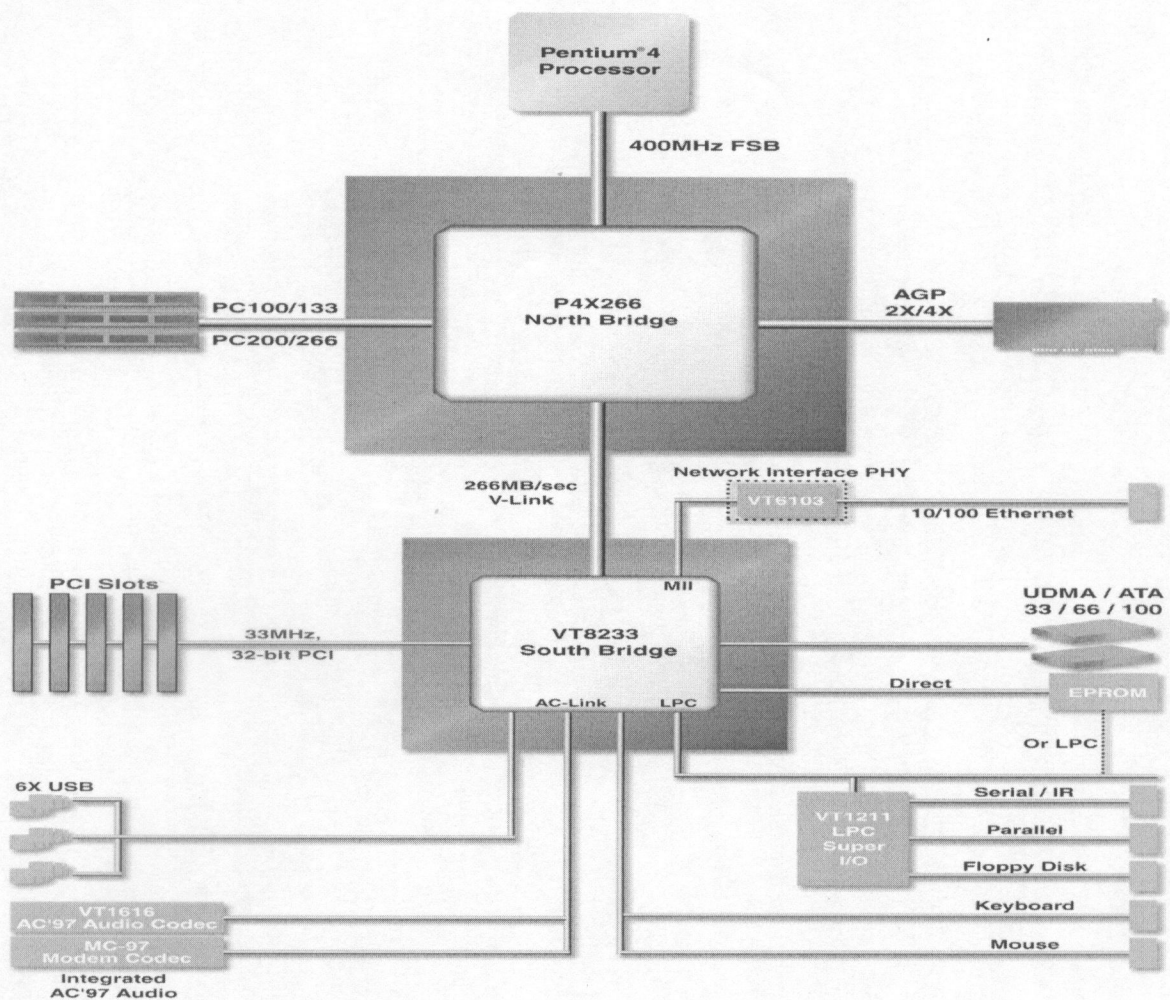


SECTION B

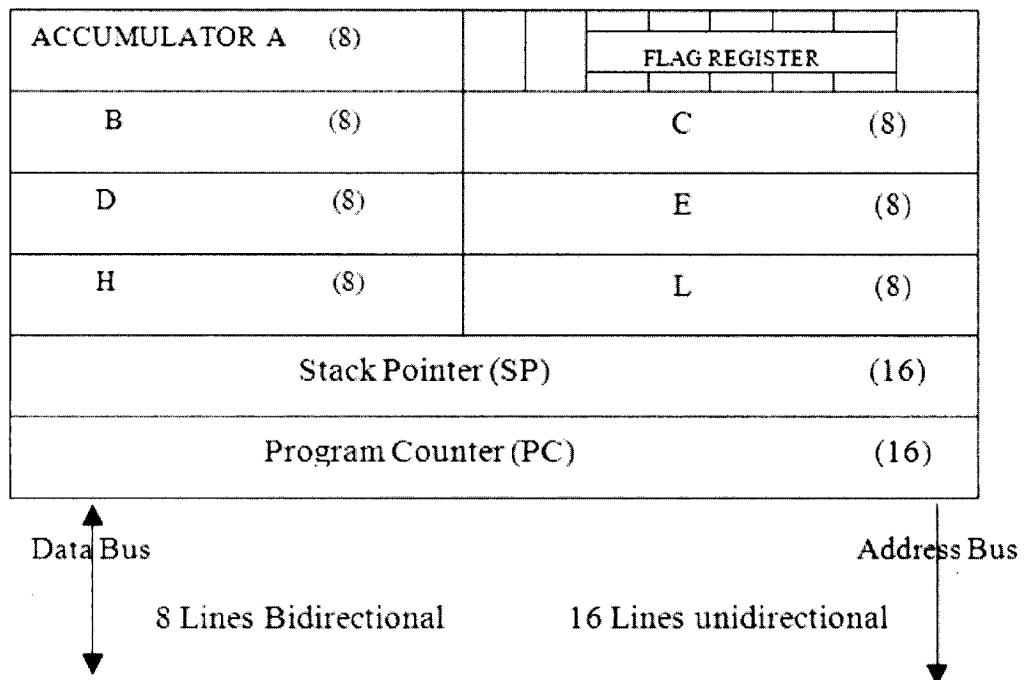
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- b) To implement process control, the computer must collect data from and transmit signals to the production process. Give a brief description for each of the following in relation to computer process interfaces [5 Marks]
- i. Sensors
 - ii. Actuators
 - iii. Analog-to-Digital Conversion
 - iv. Digital-to-Analog Conversion
 - v. Input / Output Devices
- c) The 8085 programming model includes six registers, one accumulator, and one flag register, as shown in the diagram below. In addition, it has two 16-bit registers, the stack pointer and the program counter. Briefly describe each of the following [5 Marks]
- i. Six registers,
 - ii. Accumulator,
 - iii. flag register
 - iv. Stack Pointer
 - v. Program Counter

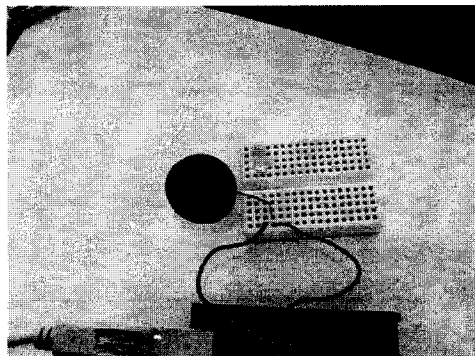


Question II

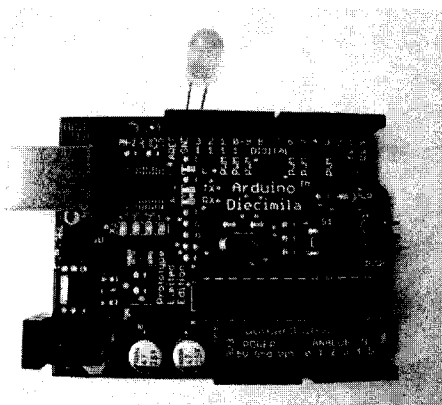
- a) An instruction is a binary pattern designed inside a microprocessor to perform a specific function. The entire group of instructions, called the instruction set, determines what functions the microprocessor can perform. The intel 8085 Instruction set can be classified into the following five functional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

- b) A Piezo is an electronic piece that converts electricity energy to sound. It is a digital output device. You can make white noise or even exact musical notes based on the duration that you iterate between HIGH and LOW signals. Give the full well commented code for the **Arduino Digital Output Sound Piezo** using the setup below by using PIN 13 for the Sound-Piezo in your design [5 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]

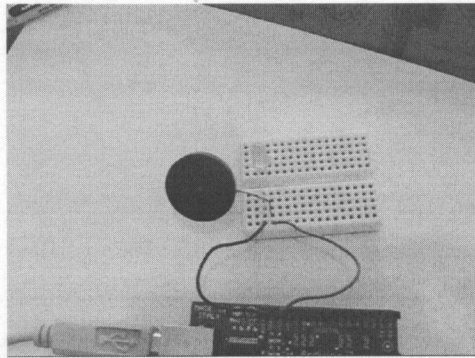


Question II

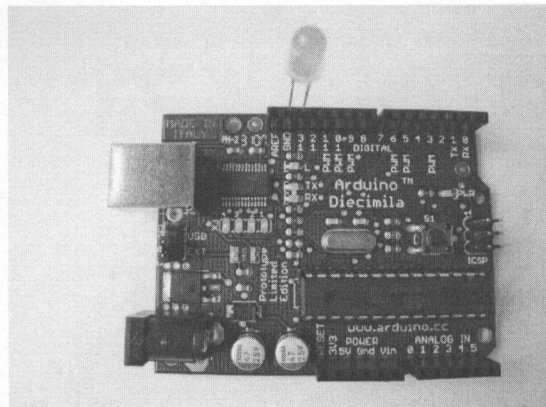
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 - machine-control operations

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

- b) A Piezo is an electronic piece that converts electricity energy to sound. It is a digital output device. You can make white noise or even exact musical notes based on the duration that you iterate between HIGH and LOW signals. Give the full well commented code for the **Arduino Digital Output Sound Piezo** using the setup below by using PIN 13 for the Sound-Piezo in your design [5 Marks]

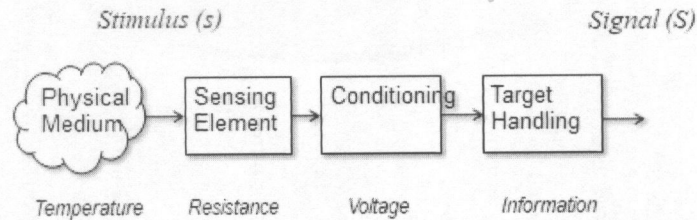


- c) The diagram below shows the setup of the **Arduino Digital Output-LED**. This can either be connected direct on the board or one can use the solderless breadboard. Give the full well commented code that can be used to programme this setup using PIN 13 on the Arduino board [5 Marks]



Question III

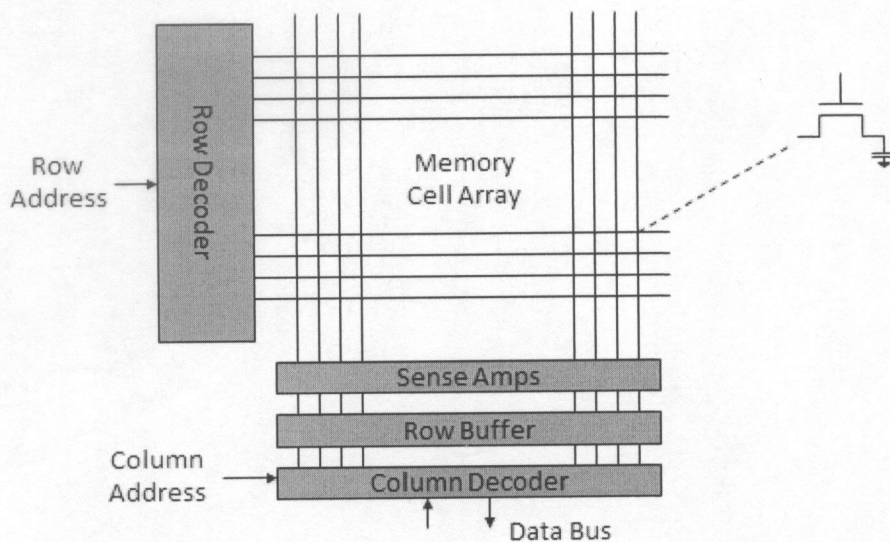
- a) The diagram below shows the basic principles used by sensors to collect and process information [5 Marks].
- Discuss the principle behind sensing technologies
 - List any three examples of sensors and what can be sensed from the physical environment apart from temperature sensors



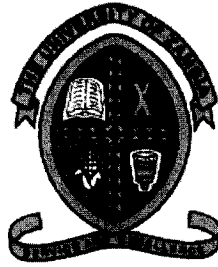
- b) Typical system uses a number of busses, collection of wires, which transmit binary numbers, one bit per wire. A typical microprocessor communicates with memory and other devices (input and output) using three busses namely [6 Marks]
- Address Bus
 - Data Bus
 - Control Bus

Using the Intel 8085 System Bus, give a brief description of each of three types of the bus systems above

- c) The diagram below shows the basic DRAM Chip Organization. Explain with reference to the diagram below how a computer stores and read data from memory using DRAM as your example. In your discussion make reference to [9 Marks]
- Row Decoder
 - Sensing Amps
 - Row Buffer
 - Column Decoder



End of the Examination



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

FINAL EXAMINATION

CSC 4630
ADVANCED SOFTWARE ENGINEERING

Date: 26th NOVEMBER 2019
Time: 09:00hrs – 12:00hrs
Duration: 3 Hours
Venue: P207

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]

1. A company is looking to develop a new proprietary software application that can compete amongst current social media platforms. As Chief Analyst, give an outline of the different stages of requirements engineering, and discuss the tools and techniques that you would adopt to derive a complete and consistent requirements specification from the company **[10 Marks]**
2. Discuss why many systems continue to fall below user expectations, despite the established practice of software requirements engineering. **[10 Marks]**

QUESTION 2 [20 marks]

1. You are asked to improve a data entry program used to enter a patient's personal information when he or she is first admitted to a hospital. Admission clerks have to enter each new patient's name, address, telephone number, and various other pieces of data. The customer tells you that the admissions clerks make an unacceptable number of mistakes that contaminate the database and cause administrative problems. You are told that the problem is lack of clarity in the user interface, which leads the clerks to put information in the wrong places. What, however, is the real problem and how might understanding this affect potential solutions? **[5 Marks]**

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CSC 4630: Advanced Software Engineering – Exam Questions

2. This is the inverse of the Question 1. This time, you are told by the customer that the problem is, 'the data-entry system is not "high-tech" enough'. Hence you are asked to write a system that scans drivers' licenses and other documents in order to enter a new patient's name and address accurately and quickly. What mistake could you be making if you accept this problem statement and proceed to do exactly what the customer asks? **[4 Marks]**

3. You are developing a system for managing the processes of a small town public library. List all the actors for this system. **[3 Marks]**

4. Justify the use of a composition to represent the association between a polygon and its line segments, as in figure below. **[6 Marks]**



5. Decomposing a system into subsystems reduces the complexity developers have to deal with by simplifying the parts and increasing their coherence. Decomposing a system into simpler parts usually results into increasing a different kind of complexity: Simpler parts also means a larger number of parts and interfaces. If coherence is the guiding principle driving developers to decompose a system into small parts, which competing principle drives them to keep the total number of parts small? **[2 Marks]**

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

QUESTION 3 [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).

1. 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]
2. 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.

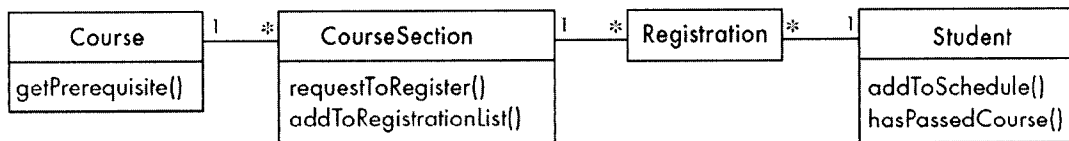
[3 marks]
3. Classify the following aspects of the LCC IBT bus reservation system into F for functional, Q for quality, PL for platform, PR for process, and X for 'should not be a requirement'. Also indicate the subcategory of requirement. For something that should not be a requirement, explain why not.
 1. What information appears on tickets and reports.
 2. How fares are calculated.
 3. The system must be available at all times. Only 2 minutes' downtime a week is to be permitted.
 4. The system must run on any Linux system.
 5. A merge-sort algorithm must be used to sort the flights by departure time.

[5 marks]
4. 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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QUESTION 4 [20 marks]

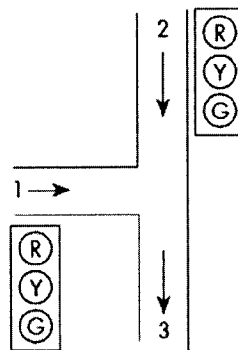
1. The diagram below shows the classes involved in a fictitious Student Registration System (SRS) for the University of Zambia (UNZA). It shows the classes involved when a student attempts to register for a course.



- 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:

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- i. The traffic light at point 1 has three colors Green, Yellow and Red. When the system starts up the robot is Red.
- ii. After startup, the system indefinitely rotates among Green, Yellow and Red. The Red light only stays on for 30 seconds, at which time the Green light comes on.
- iii. The Green light stays on for 25 seconds, at which time the system changes to Yellow.
- iv. After five more seconds the Yellow light gives way to the Red light again.
- v. Traffic moving from point 2 to 3 always has a Green light unless a vehicle arrives at point 1 and triggers a sensor.
- vi. When the sensor at point 1 is triggered, the robot their changes to Yellow, but only after the traffic coming from point 2 has had at least 25 seconds of Green light. Without this a steady series of vehicles arriving at point 1 would prevent the light at point 2 from staying green long enough for traffic to flow.



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

[4 marks]

QUESTION 5 [20 marks]

1. Design patterns are a tool for communication". Explain this statement, using an example. Your explanation should state who is doing the communication and what is being communicated. **[4 marks]**

2. In all organisations where the exam software is used, there is a requirement to store marked exam scripts for future reference. Suppose that this facility already exists, in that

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CSC 4630: Advanced Software Engineering – Exam Questions

scripts can be stored in the format required by the University of Zambia (UNZA). However, the Zambia Centre for Accountancy Studies (ZCAS) use a different format, and the University of Lusaka (UNILUS) use yet another, for example. Code exists to store the data in each of these formats, but the interface of that code is different in each case, and incompatible with the project's existing code base.

Draw a UML diagram to show how the Adapter pattern can be used to solve this problem. You should assume that the UoM storage code has a single public operation `storeScripts()` and that the storage code for each organisation can be represented as a single class which you should show on the diagram. **[5 marks]**

3. The **Façade** pattern has some similarities to Adapter. Explain what the similarities and differences are between the two patterns, and briefly discuss whether Façade would be a sensible alternative to **Adapter** for the problem of part 2). **[5 marks]**
4. Somewhere, there needs to be code that decides which adapter to create, depending on the organisation we're storing scripts for. Where would it be sensible to put this code, and how might it make that decision? **[2 marks]**
5. What are the consequences of using the Adapter pattern for this task in terms of cohesion and coupling? **[4 marks]**

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CSC 4630: Advanced Software Engineering – Exam Questions

QUESTION 6 [20 marks]

1. Design an architecture for the system that conforms to the pipe-and-filter architectural style. You do not need to fully elaborate the architectural design, but you must describe the components, the connectors, and how the system will basically work. State any assumptions you make. **[15 marks]**

2. What are two advantages of a 3-tier client-server architecture over a 2-tier client-server architecture **[5 marks]**

END OF PAPER



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

FINAL EXAMINATION

CSC 4722
Distributed Systems

Date: 19th November 2019
Time: 09:00hrs – 12:00hrs
Duration: 3 Hours
Venue: Upper Dinning 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.

1. What is the differences between partial and total ordering of events? **[2 marks]**
2. What is meant by Remote Procedure Calls(RPC)? **[2 marks]**
3. What is meant by exactly-once-semantics in the context of client/server communication?
[2 marks]
4. Give two advantages of a distributed system compared to a centralized system and also give two advantages of a centralized system compared to a distributed system. **[4 marks]**
5. Outline how a ring-based algorithm for mutual exclusion works by way of an example.
[4 marks]
6. Compare programming using sockets API with RMI. What are the advantages and disadvantages of each approach? **[6 marks]**
7. A client's clock reads 3:20:00. The server's clock reads 3:10:00 when they synchronize using the Berkeley algorithm. Assume message delays are negligible. What is the time at the client after synchronization? **[4 marks]**
8. When programming a server why is the creation of a new socket created in addition to the already existing server socket important? **[4 marks]**
9. What is an IDL (Interface Definition Language) used for in Corba? Why is there no need for an IDL when using Java RMI? **[4 marks]**
10. What is the purpose of middleware in distributed systems? **[4 marks]**
11. What is the difference between a blocking and non-blocking send primitive? What impact does the choice of send primitive have on the performance of a distributed system?
[4 marks]

SECTION B (60 marks)

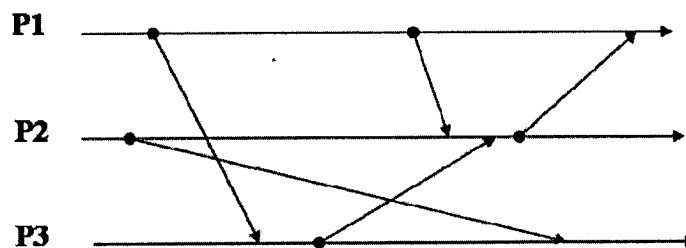
Answer any three (3) of the five (5) questions.

1.

- Explain the differences between a distributed system and a multi-processor system. **[4 marks]**
- When implementing a distributed system, middleware is often used. Explain, with examples, some of the services that middle-ware should provide to the programmer. **[6 marks]**
- Assume you have a Java client/server application that uses TCP. How should the server be implemented to avoid clients from blocking each other? **[4 marks]**
- RPCs in java attempt to give the programmer the illusion that remote procedures are running locally. Using an illustration explain how this is achieved. **[6 marks]**

2. Synchronization is a very important concept in distributed systems.

- Describe how clock synchronization can be done in a system with an external time reference. **[2 marks]**
- Describe how clock synchronization can be done in a system without an external time reference (master clock) and without sudden changes in time. **[2 marks]**
- What problem with Lamport clocks do vector clocks solve? **[4 marks]**
- Consider the following event diagram for processes P1, P2 and P3 executing in a distributed system. Compute the lamport and vector clock that is carried on each message. Show both approaches separately **[12 points]**

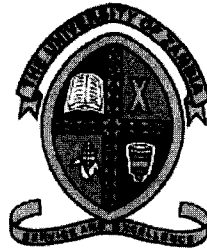


3.

- File systems like HDFS and GFS keep multiple replicas of each block, stored on different servers. Joe argues that one advantage of this approach is that the expensive scrubbing performed in most disk array systems is unnecessary. Do you agree? Explain your answer. **[4 marks]**

- b. Many scalable distributed file system designs use multiple data servers but just a single metadata server. Why is this a reasonable approach, despite the fundamental scalability limitation that the single metadata server represents? Explain your answer. **[4 marks]**
- c. With regards to Hadoop explain the following:
- Different types of nodes in a Hadoop cluster **[5 marks]**
 - How map-reduce works **[4 marks]**
 - How files are stored with replication. **[3 marks]**
4. Suppose that we have five processes, P1, P2, P3, P4 and P5. P5 is coordinator. Further, suppose that P1 and P5 crash and P2 detects the crash. Assuming the process IDs have alphanumeric value and that the priority of process P_i is i .
- What are the requirements of an election process? **[2 marks]**
 - Show how an election could proceed using the ring election algorithm and the bully algorithm. **[10 marks]**
 - What would happen if two processes, say P2 and P4 detect the crash at the same time? **[2 marks]**
 - What potential impact does communication latency have on the bully election algorithm and how is this resolved? **[2 marks]**
 - Using an illustration explain how the timestamp prioritized mutual exclusion algorithm work? **[4 marks]**
- 5.
- What are the three types of process scheduling techniques? **[3 marks]**
 - Briefly discuss any five desirable features of a resource scheduling algorithm. **[5 marks]**
 - What are the two main categories of load balancing algorithms and what are the important differences between the two categories? **[6 marks]**
 - What are the six main issues one needs to consider when designing load balancing algorithms? **[6 marks]**

The end of this examination question paper



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

FINAL EXAMINATION

**CSC 4792 DATA MINING AND
WAREHOUSING**

Date: 22nd NOVEMBER, 2019
Time: 09:00hrs – 12:00hrs
Duration: 3 Hours
Venue: UPPER D/HALL

Instructions

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

SECTION A [40 Marks]

INSTRUCTIONS: ANSWER ALL QUESTIONS IN THIS SECTION.

Question 1 [40 Marks]

- i. Imagine you build an image classification model that performs well on the training data but generalizes poorly to new instances. Explain this phenomenon, and the propose solutions to this problem. [4 Marks]
- ii. Consider the following activities and briefly describe whether or not is a data mining task: [2 Marks each]
 - a. Dividing the customers of a company according to their profitability
 - b. Computing the total sales of a company
 - c. Sorting a student database based on student identification numbers.
 - d. Predicting the outcomes of tossing a (fair) pair of dice.
 - e. Predicting the future stock price of a company using historical records
 - f. Monitoring the heart rate of a patient for abnormalities.
 - g. Monitoring seismic waves for earthquake activities.
 - h. Extracting the frequencies of a sound wave.
- iii. Briefly enumerate four (4) possible proximity function that can be used in the k-means algorithm to measure distances. [4 Marks]
- iv. For each proximity function you have listed in question (iii) above, state the appropriate measurement of the respective centroid [4 Marks]
- v. State two disadvantages of k-Means, and for each disadvantage explain how the algorithm can/has been improved on to overcome the challenges. [2 Marks]

SECTION B [60 Marks]

INSTRUCTIONS: There are four questions in this section. Answer ONLY three. Each question carries a weight of 20 Marks.

Question 2 [20 Marks]

- i. When you embark on any data mining task, the data pre-processing stage is a very important stage. It ensures data quality for data mining tasks. State and briefly describe seven (7) activities involved in the data pre-processing stage of the knowledge discovery in databases process. [7 Marks]
- ii. Discuss what is involved in the post-processing stage of the knowledge discovery in databases. State at least three activities involved. [3 marks]
- iii. Draw a well labelled diagram depicting the process of knowledge discovery in databases (KDD). [5 Marks]
- iv. State and briefly describe five (5) motivating challenges that has brought about development of data mining. [5 Marks]

Question 3 [20 Marks]

- i. How is it that traditional “databases” techniques are unsuitable for data mining tasks? Give five (5) possible reasons. [5 Marks]
- ii. State five (5) challenges that most data mining engineers get to face with data for their data mining tasks? [5 Marks]
- iii. State and briefly describe three (3) characteristics of data sets that have a significant impact on the data mining techniques used. [6 marks]
- iv. State and briefly describe four (4) characteristics that describe attributes of data objects in a given data set. [4 Marks]

Question 4 [20 Marks]

Consider the following algorithm for finding k-nearest neighbors:

for $i = 1$ to the *number of data objects* **do**:

-find the distances of the i^{th} object to all other objects

-sort these distances in decreasing order

(Keep track of which object is associated with each distance)

return the objects associated with the first K distances of the sorted list

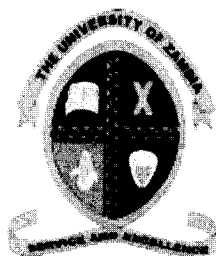
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- i. Describe four (4) potential problems with this algorithm if there are duplicate objects in the dataset. Assume the distance function will return a distance of 0 only for objects that are the same. [5 Marks]
- ii. What are your proposed solutions to the problems you have described in question (i) above. [5 Marks]
- iii. As you can observe, the kNN algorithm given above is for classification tasks. However, we also use kNN algorithm, with minimal modification of the algorithm in order to predict continuous variables. Your task is to modify the kNN above to make it suitable for regression tasks.[10 Marks]

Question 5 [20 Marks]

- i. Suppose after graduation you are employed as a data mining consultant for a financial institution like a bank. Describe how data mining can help the company by giving specific examples of how techniques, such as clustering, classification, regression, association rule mining, and anomaly detection can be applied. [20 Marks]

-- End of exam--



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

FINAL EXAMINATION

**CSC 4812: CLOUD AND HIGH PERFORMANCE
COMPUTING**

Date: Wednesday, 20th November 2019
Time: 14:00hrs – 17:00hrs
Duration: 3 Hours
Venue: P207

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

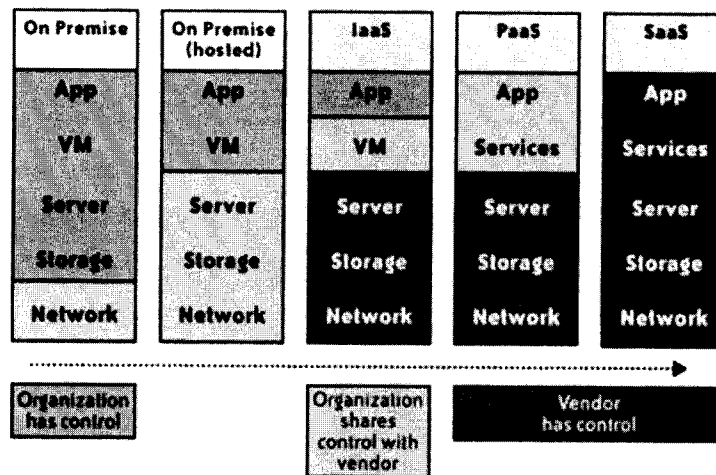
Question I

- a) Briefly discuss each of the following terminologies in relation to Cloud and High Performance Computing. Give at least one example in each case. [4 Marks]
- Grid Computing
 - Cluster Computing
 - Distributed Computing
 - Virtualisation
- b) Cloud computing is the delivery of computing as a service rather than a product, whereby shared resources, software, and information are provided to computers and other devices as a metered service over a network. Cloud computing provides computation, software, data access, and storage resources without requiring cloud users to know the location and other details of the computing infrastructure. The cloud service models can basically be classified as **Software as a Service**, **Platform as a Service** and **Infrastructure as a Service** [10 Marks].
- Draw a well labelled diagram showing the three Cloud Service Models as follows;
 - Software as a Service
 - Platform as a Service
 - Infrastructure as a Service
 - Show how each of the three services above are related to each other.
 - For each of the three service models above,
 - Give a brief description by citing the characteristics of the service model and the benefits that comes with the implementation
 - Give at least one major challenge that comes with each service model
 - Give one example implementation in real life
- c) The diagram below shows a virtual machine implementation [6 Marks].
- What is the Virtual Infrastructure Managers (VIMs)
 - Discuss the Key Features of the Virtual Infrastructure Managers

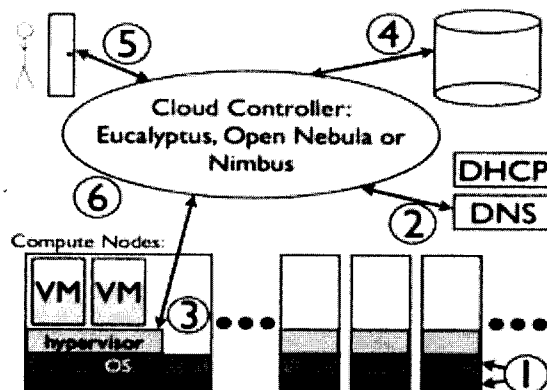


Question II

- a) With the aid of a diagram, describe each of the following Deployment Models of a Cloud [8 Marks]
- Private/Enterprise
 - Dedicated
 - Hybrid/Mixed
 - Cloud/Public
- b) The diagram below shows the impact of cloud computing on the governance structure of Information and Communications Technology (ICT) organizations. Discuss the Cloud Computing organization structures shown in the diagram below [6 Marks].

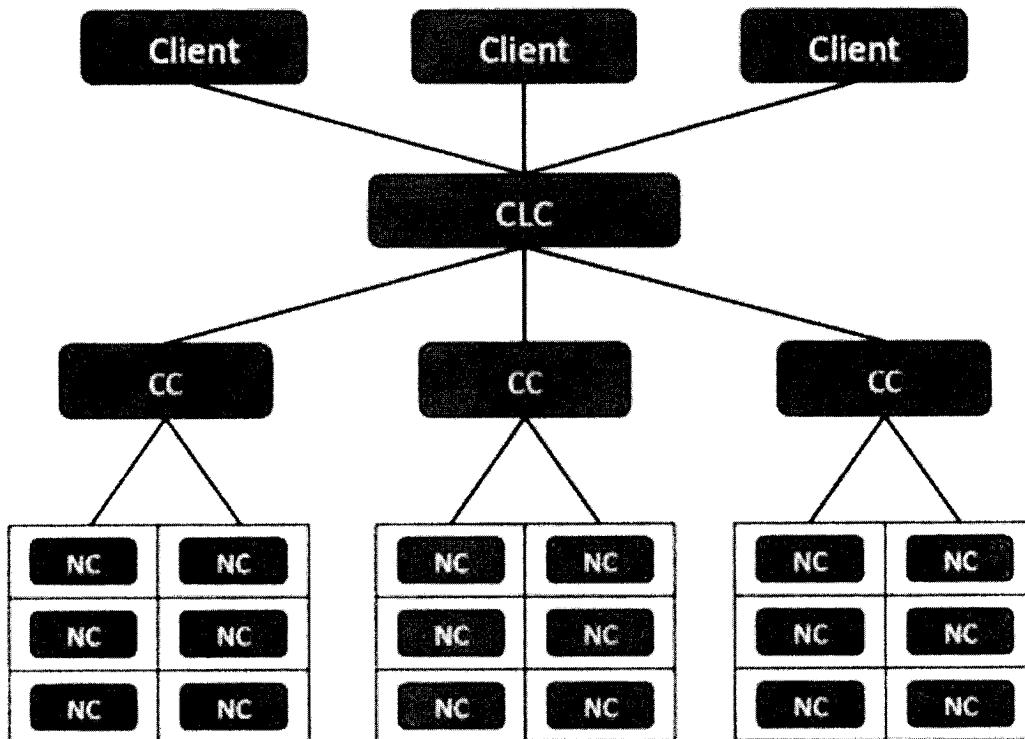


- c) With reference to the diagram below, discuss each of the key components of the cloud implementation. In your discussion make reference to the following [6 Marks]
- 1 - Instances
 - 2 - Networking
 - 3 - Compute nodes
 - 4 - Storage
 - 5 - User interface
 - 6 - Overall cloud platform



Question III

- a) With reference to Cloud Computing discuss each of the following **Cloud Management Services** [10 Marks]
- Deployment
 - Monitoring
 - Reporting
 - Service-Level Agreement
 - Metering Billing
- b) The diagram below gives the **Hierarchical Design of Cloud Computing Implementation**. With the help of a diagram, give a brief description and function of each of the following component in the implementation. [10 Marks]
- Client
 - CLC
 - CC
 - NC



SECTION B

This section has THREE Questions. Choose any two questions

Question I

- a) After completing your bachelor of computer science degree, one of the startup companies has decided to employ you. They would like you to advise management on the issues surrounding cloud computing. Management has requested that you give them a report on cloud services sourcing and concerns that come with cloud service sourcing [8 Marks].
- i. In your report to management, Give any four major reasons why **cloud sourcing** is becoming a Big Deal today why you would like the company to use this service
 - ii. In your report, highlight the major concerns that come with cloud computing sourcing
- b) Briefly discuss each of the following Prominent Components of Cluster Computers [5 Marks]
- i. State of the art Operating Systems
 - ii. High Performance Networks/Switches
 - iii. Fast Communication Protocols and Services
 - iv. Cluster Middleware
 - v. Applications and Subsystems
- c) A single system image is the illusion, created by software or hardware, that presents a collection of resources as one, more powerful resource. It makes the cluster appear like a single machine to the user, to applications, and to the network [7 Marks].
- i. Discuss the major and key benefits of a Single System Image
 - ii. What are the desired single system image services

Question II

a) There are several causes of problems associated with cloud computing. However, most security problems stem from [6 Marks]:

- i. Loss of control
- ii. Lack of trust (mechanisms)
- iii. Multi-tenancy

Discuss each of these challenges and how they are being addressed in cloud implementation

b) Cloud computing is a compilation of existing techniques and technologies, packaged within a new infrastructure paradigm that offers improved service delivery. Cloud computing definitely makes sense if your own security is weak, missing features, or below average [10 Marks].

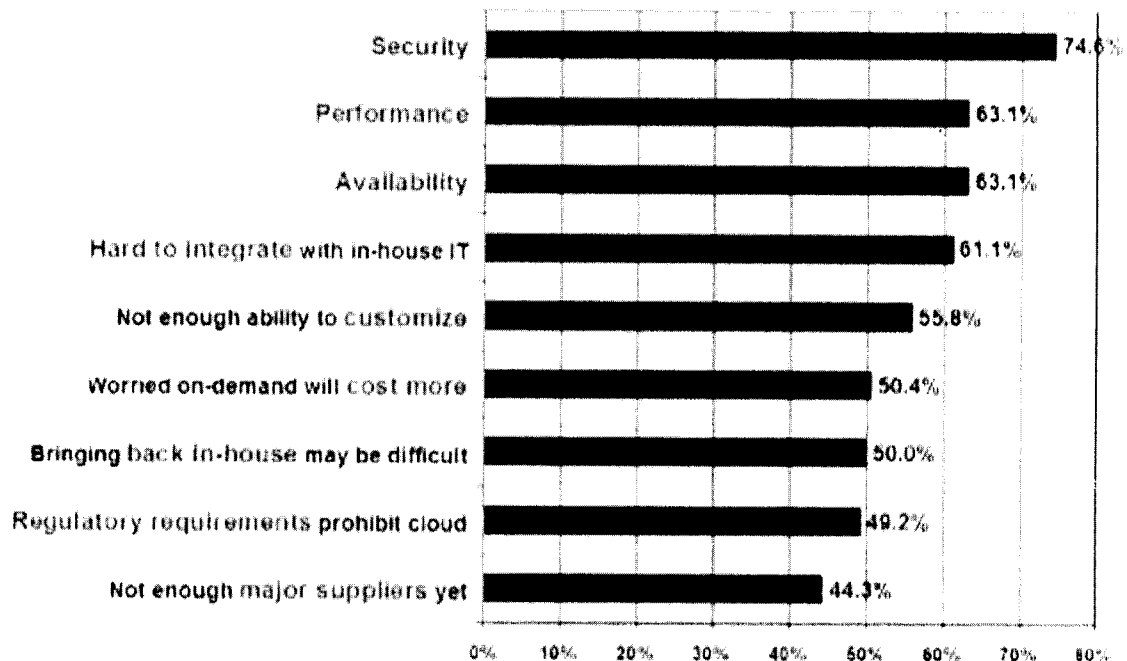
- i. List and describe the two key features of cloud computing
- ii. Describe the four major Attributes of Cloud Computing
- iii. List and describe any four Essential Characteristics of Cloud Computing

c) A cluster is a type of parallel or distributed processing system, which consists of a collection of interconnected stand-alone/complete computers cooperatively working together as a single, integrated computing resource [4 Marks]

- i. List and discuss the key characteristics of Cluster Computing
- ii. Discuss the main motivation in using Clusters Computing

Question III

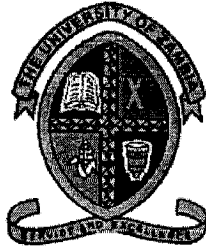
- a) Discuss each of the following in relation to the TAXONOMY OF FEAR [6 Marks]
- Confidentiality
 - Integrity
 - Availability
- b) The diagram below shows some of the major reasons why companies are afraid to use cloud services. Briefly discuss each of the following in relation to diagram below. Give at least one example in each case. [9 Marks]
- Cloud Threat Model
 - Cloud Confidentiality
 - Cloud Security



- c) In order to address the security challenges above and ensure that data is secure, that it cannot be accessed by unauthorized users or simply lost, and that data privacy is maintained, cloud providers attend to the following areas [5 Marks]
- Identity management
 - Availability
 - Privacy
 - Legal issues
 - Application security

Discuss each of the above in relation to cloud computing security

End of the Examination



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

FINAL EXAMINATION

CSC 4822
ROUTING AND SWITCHING
TECHNOLOGIES

Date: 6th NOVEMBER 2019
Time: 14:00hrs – 17:00hrs
Duration: 3 Hours
Venue: P207

Instructions

1. There are **two (2) Sections** in this exam, **Section A** and **Section B**.
2. In Section A, **answer all the questions** and in Section B **choose any three (3) questions**.

SECTION A [40 marks]

ANSWER ALL QUESTIONS IN THIS SECTION

Question 1 [20 marks]

- a) Name three layers of the hierarchical LAN design. [3 marks]
- b) Name two ways in which a host can be assigned an IP address? [2 marks]
- c) Router memory is classified as volatile or non-volatile. What is volatile memory? [1 mark]
- d) List two beneficial functions of the Routers. [2 marks]
- e) Name two console access requirements? [2 marks]
- f) There are five categories of switches for enterprise networks. List any three of them. [3 marks]
- g) Which command do you use when you want to name the device? [1 mark]
- h) What is the AD of RIP? [2 marks]
- i) Which command do you use when you want to activate an interface? [2 marks]
- j) Which command displays the contents of the IPv4 routing table stored in RAM? [2 marks]

Question 2 [20 marks]

- a) List any three considerations to take into account when selecting a switch. [3 marks]
- b) When do we use the default static routes? [2 marks]
- c) What is the metric of RIP? [1 mark]
- d) A router can learn about remote networks in one of two ways. Name the ways. [2 marks]
- e) When can multiple static routes can be summarized into a single static route? [1 mark]
- f) Why is a separate VLAN needed to support Voice over IP (VoIP)? [2 marks]
- g) Which command do you use to disable and eliminate RIP? [1 mark]
- h) Name two switch forwarding methods? [2 marks]
- i) Sending out unneeded updates on a LAN impacts the network in three ways in the case of passive interfaces. List the ways. [3 marks]
- j) List three categories of routers. [3 marks]

SECTION B [60 marks]

ANSWER ANY THREE (3) QUESTIONS IN THIS SECTION

Question 3 [20 marks]

- A router has the following networks attached to it: network 10.1.1.0/24, network 10.1.2.0/24, and network 192.168.10/30. Configure OSPFv2 on this router. Show all your work. [5 marks]
- OSPF defines five network types. Explain these types of networks. [5 marks]
- Differentiate static from dynamic routing. [5 marks]
- Discuss the purpose of dynamic routing protocols. [5 marks]

Question 4 [20 marks]

- A router has the following networks attached to it: network 10.1.1.0/24, network 10.1.2.0/24, and network 192.168.10/30. Configure EIGRP on this router. Show all your work. [5 marks]
- Discuss the primary uses of static routing. [5 marks]
- Discuss five important characteristics of switches that contribute to alleviating network congestion. [5 marks]
- Discuss the disadvantages of static routing. [5 marks]

Question 5 [20 marks]

- A router has the following networks attached to it: network 10.1.1.0/24, network 10.1.2.0/24, and network 192.168.10/30. Configure EIGRP for IPv6 on this router. Show all your work. [5 marks]
- User productivity and network adaptability are important for business growth and success. VLANs make it easier to design a network to support the goals of an organization. Discuss the primary benefits of using VLANs [5 marks]
- There are various types of switches used in business networks. It is important to deploy the appropriate types of switches based on network requirements. Discuss the types. [5 marks]
- EtherChannels can be formed through negotiation using one of two protocols, PAgP or LACP. Discuss the protocols PAgP and LACP. [5 marks]

Question 6 [20 marks]

- A router has the following networks attached to it: network 10.1.1.0/24, network 10.1.2.0/24, and network 192.168.10/30. Configure OSPFv3 on this router. Show all your work. [5 marks]
- There are guidelines and restrictions that you must use when configuring EtherChannel. Discuss the guidelines and restrictions. [5 marks]
- Explain briefly the difference between IGRP and EIGRP. [5 marks]
- In 1993, RIPv1 was updated to a classless routing protocol known as RIP version 2 (RIPv2). RIPv2 included a number of improvements. Discuss the improvements. [5 marks]

THE END

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
2018/2019 ACADEMIC YEAR FINAL EXAMINATIONS
GES 3241: CLIMATOLOGY

TIME: Three Hours

INSTRUCTIONS: Answer question 1 and any other **two** questions. All questions carry equal marks. Candidates are encouraged to make use of illustrations wherever appropriate.

-
1. Write short explanatory notes on **ALL** of the following:
 - (a) Latitudinal Variations (4 Marks)
 - (b) Stratospheric ozone (4 Marks)
 - (c) Colioris force (4 Marks)
 - (d) Forms of heat transfer in the earth-atmosphere system (4 Marks)
 - (e) Climate change mitigation (4 Marks)
 2. Using specific examples, explain the classification and naming of air masses (20 Marks)
 3. Explain the processes of exchange in the earth-atmosphere system during the day and during the night (20 Marks).
 4. 'Climate change is influenced by both natural and anthropogenic factors'. Elucidate. (20 Marks)
 5. With the aid of a diagram, describe the fundamental layers of the atmosphere and state their importance. (20 Marks)
-

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
2018/19 ACADEMIC YEAR FINAL EXAMINATIONS
GES 3262: BIOGEOGRAPHY

TIME: Three hours

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

1. Write short explanatory notes on **ALL** of the following:
 - (a) Merits and demerits of the species concept
 - (b) Convergent versus divergent evolution
 - (c) Industrial melanism
 - (d) Fossil succession
 - (e) Importance of the quaternary period in biogeography.
 2. Using an illustration, explain how an organism responds to changes in the environment.
 3. Why are island flora and fauna vulnerable to invasion by non native species? Explain in terms of interspecific competition and competitive exclusion.
 4. Outline the details of any five pieces of evidence that have been used as proof of past ice ages.
 5. Burney and Robinson (2003) proposed the synergistic scenario. Describe the synergistic scenario and any three pieces of evidence used by these authors in support of their theory for the extinction of some species in Madagascar.
-

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
2018/2019 ACADEMIC YEAR FINAL EXAMINATIONS
GES 3330: ENVIRONMENT AND DEVELOPMENT

TIME: Three Hours

INSTRUCTIONS: Answer one question from each section. All questions carry equal marks. Candidates are encouraged to use illustrations wherever appropriate.

Section A

1. On the 3rd of March 2017, Zambia launched a National Climate Change Policy aimed at lessening the impact of climate change in the country. Discuss how climate change is impacting Zambia's agricultural, water and health sectors addressed in this policy.
2. With reference to Zambia, discuss how sustainable development can be achieved.

Section B

3. 'Human development embodies a history of continuous redefinition to the human-environment relationship'. Elucidate.
4. 'The shift from modern to alternative agriculture is a mere return to traditional agricultural and indigenous knowledge practices'. Discuss.

Section C

5. 'Economic growth is good for ecosystems'. Discuss.
6. Write explanatory notes on all the following;
 - (a) Gini Coefficient
 - (b) Externalities and the environment
 - (c) Pathways for invasive alien species
 - (d) Resource curse hypothesis

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
2018/2019 ACADEMIC YEAR FINAL EXAMINATIONS

GES 3352: SPATIAL DIMENSIONS OF DISEASE AND HEALTH CARE SERVICE
PROVISION

TIME: Three Hours

INSTRUCTIONS: Answer questions 1 and any other two. Question 1 carries 40 marks and the rest of the questions carry 30 marks each. Candidates are encouraged to use illustrations wherever appropriate.

1. Write short explanatory notes on ALL of the following:
 - a) Diffusion of disease.
 - b) Disease surveillance
 - c) Water borne diseases
 - d) Market-oriented health care systems
 - e) Development and disease
 - f) Nutrition and health
 - g) Geographical epidemiology.
 - h) Disease prevention mechanism
 2. Explain factors that influence the use of traditional medicine.
 3. Explain reasons for inequalities in access to health care services in Zambia.
 4. Outline Nutrition Transition and explain its implications in low and medium income countries.
 5. Explain the process of disease mapping and its importance.
-

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2018/2019 ACADEMIC YEAR FINAL EXAMINATIONS

GES 4172: RURAL LAND USE AND LANDSCAPES

TIME: Three Hours

INSTRUCTIONS: Answer question 1 and any other **two** 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) Vulnerability versus Resilience
 - b) Gender and Natural Resources Management
 - c) Direct-use and non-use values of Community Based Natural Resources Management (CBNRM) in livelihoods
 - d) Dimensions of food security
 - e) Role of rural industrialization in poverty reduction.
2. 'Responses to the impacts of climate change in Africa cannot be left to be the responsibility of small-scale rural producers alone'. Explain.
3. Discuss the four factors of production in relation to rural livelihoods in Zambia.
4. Discuss the three basic foundations on which Participatory Rural Appraisal (PRA) is based.
5. 'Rural landscapes have temporal and spatial heterogeneity'. Elucidate.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
2018/19 ACADEMIC YEAR EXAMINATION
GES 4192 : GEOGRAPHICAL DIMENSION OF SETTLEMENTS

TIME: Three hours

INSTRUCTIONS: Answer question 1 and any other two. All questions carry equal marks.

Candidates are encouraged to make use of illustrations wherever possible.

1. Write short explanatory notes on ALL of the following:
 - a) Compact type rural settlement
 - b) The concept of urban
 - c) The peripheral urban structure model
 - d) Population distribution versus population density
 - e) Ebenezer Howard 'Garden City'.
 2. Explain the main stages in the evolution of a village community.
 3. Using examples of settlements, explain four (4) physical factors that cause areas to be sparsely populated.
 4. 'Rural development is the process of improving the quality of life of the people living in a village'. Discuss.
 5. 'No African was allowed to live outside the settlements designated by colonial authorities'. Elucidate.
-

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCE

2018/2019 ACADEMIC YEAR FINAL EXAMINATIONS

GES 4342: ENVIRONMENT AND NATURAL RESOURCES MANAGEMENT

TIME: Three Hours

INSTRUCTIONS: Answer Questions 1 and any other **two**. Candidates are encouraged to use illustrations wherever appropriate.

1. Write short explanatory notes on ALL of the following:
 - a) Survival value of wildlife (4 Marks)
 - b) Challenges of managing open access to fisheries (4 Marks)
 - c) Composting and sustainable waste management (4 Marks).
 - d) Threats to wetlands in Zambia (4 Marks)
 - e) Kabwe town as one of the top 10 most polluted city in the world (4 Marks)
2. 'The loss of key species can threaten the survival of all forms of life including human beings.'
Discuss.
3. Using specific examples related to pollution;
 - (a) explain the differences between a positive and a negative externality (10 Marks).
 - (b) Policy instruments the government may use to control pollution (10 Marks)
4. Explain the three Es policy principles of integrated water resources management.
5. Discuss the strategies for sustainable wetland conservation and management (20 Marks).

END OF EXAMINATION

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

2018/19 ACADEMIC YEAR FINAL EXAMINATIONS

GES 4372: TOURISM, ENVIRONMENT AND DEVELOPMENT

TIME: Three Hours

INSTRUCTIONS: Answer **questions 1** and any other two. Question 1 carries **40 marks** and the rest carry **30 marks** each. Use of an approved calculator is allowed. Candidates are encouraged to use illustrations wherever appropriate.

1. Walusungu Bird Sanctuary covers an area of 185 hectares. It is home for over 1,200 bird species. In 2018, it received 15,250 visitors and of these, 60% were foreigners while 40% were locals who usually go for day trips, picnics and educational excursions. The Sanctuary has several walking trails. The average time of 1 hour is needed for a visitor to complete the trail. An average width of the trail is 1 metre per visitor and visitors use 1 square metre per person. The distance between groups of 10 with 1 tour guide is 100 metres. The Sanctuary is open from 08:00 hours to 17:00 hours every day apart from Sundays. It is open for 360 days in a year. The actual management capacity is 7 members of staff while the ideal management capacity is 22 members of staff. You have been asked by the owner to give advice on the ideal number of visitors the garden should host.

Using the following correction factors;

Precipitation = 1.02%; Erosion = 25.1% and Slope = 25.1%

- a) Calculate the Physical, Real and Effective carrying capacities giving both daily and annual visitor capacities (show all calculations).
- b) Explain the major criticisms of the carrying capacity method.
2. Discuss the three key areas in which tourism can benefit the environment.
3. Using tourism in Zambia as an example, discuss the possible social effects of the interactions between tourists and host communities.
4. Explain the eight different aspects which should be included in national tourism planning.
5. What are visitor surveys and how can they be used to enhance the tourism sector in Zambia?

END OF EXAMINATION

The University of Zambia
Department of Mathematics & Statistics
2018/2019 Academic Year, Final Examinations
MAT1110: Foundation Mathematics & Statistics for Social Sciences
Tuesday, 5 November 2019

Time Allowed: 3 hours

Instructions:

1. There are **Seven** (7) questions in this examination paper. Attempt **any five** (5).
2. Indicate your **computer number** on all your answer booklets.
3. **Full credit** will only be given when **all necessary working** is shown.
4. **Calculators** are **Not** allowed.

This examination has (5) pages of questions.

1. (a) i. Let \mathbb{R} be the universal set, $A = (-3, 11]$ and $B = [0, 5)$. Find the set

$$A \cap B^c,$$

and display your answer on the number line.

- ii. Let A and B be sets such that $A \cap B = \emptyset$. Express the following in its simplest form:

$$A - (A^c \cap B^c).$$

- (b) Let $z = 6 + 4i$ and $\omega = 1 + i$ be complex numbers.

- i. Express

$$\frac{z}{\omega}$$

in the form $x + iy$, where x and y are integers.

- ii. Hence, or otherwise, solve the equation

$$\frac{z}{\omega} = x + iy + i^3y.$$

BZOB

(c) Let $f(x) = \frac{7x}{3x+1}$ and $g(x) = 4 - x$.

- i. On the same set of axes, sketch the graphs of $f(x)$ and $g(x)$.
- ii. Find the coordinates of the points of intersection of $f(x)$ and $g(x)$.
- iii. Hence, or otherwise, solve the inequality

$$\frac{7x}{3x+1} < 4 - x.$$

[8, 7, 10]

2. (a) Given that

$$f(x) = 6x^3 - 17x^2 - 4x + 3,$$

- i. Show that $(2x + 1)$ is a factor of $f(x)$.
- ii. Hence, or otherwise, factorize $f(x)$ completely.

(b) Solve each of the following equations;

i.

$$9^{2x+3} = \left(\frac{1}{27}\right)^{3x+1}$$

ii.

$$\log_5 6 + \log_5 2x^2 = \log_5 48.$$

(c) On the same set of axes, sketch the graphs of

$$f(x) = 1 - \left(\frac{1}{4}\right)^x$$

and

$$g(x) = \log_{\frac{1}{4}} \left(\frac{1}{x}\right) + 1.$$

(d) Evaluate

$$\lim_{x \rightarrow 5} \frac{\sqrt{x-1} - 2}{x-5}.$$

[6, 6, 8, 5]

3. (a) Solve each of the following equations for $0 \leq x \leq 2\pi$.

i.

$$\sqrt{3} \sin x - 2 \sin x \cos x = 0.$$

ii.

$$2 \sin x - 1 = \csc x.$$

(b) Prove each of the following identities:

i.

$$\cos^2 x \equiv \frac{\csc x \cos x}{\tan x + \cot x}.$$

ii.

$$\frac{\csc x}{\sin x} - \frac{\cot x}{\tan x} \equiv 1.$$

(c) Given that

$$f(x) = 3 \sin 2(x + 30^\circ) \text{ for } 0^\circ \leq x \leq 360^\circ,$$

i. Find the period, amplitude and phase shift.

ii. Hence, or otherwise, sketch **one revolution (cycle)** of the graph of $f(x) = 3 \sin 2(x + 30^\circ)$ for $x \geq -30^\circ$.

[11, 8, 6]

4. (a) i. Use the **first principle** to differentiate

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

ii. Show that if

$$y = \frac{\ln(e^{2x^2})}{(e^{x^2})^2},$$

then

$$\frac{dy}{dx} = \frac{ax - bx^3}{e^{cx^2}},$$

where a , b and c are integers to be found.

(b) i. Integrate

$$\int \frac{(x-2)(x+3)}{\sqrt{x}} dx.$$

ii. Show that

$$\int_0^{\frac{\pi}{2}} e^{(\cos x + 1)} \sin x dx = e^2 - e.$$

(c) Find the area of the region bounded by graphs of $f(x) = x^2$ and $g(x) = 4$.

[11, 9, 5]

$\frac{1}{1} - \frac{1}{3} = \frac{2}{3}$

5. (a) Let A and B be events with non-zero probability.
- When are events A and B said to be Independent?
 - State the **Bayes' theorem**.
- (b) Events A and B are such that $P(A) = 0.3$, $P(B) = 0.4$ and $P(A \cap B) = 0.1$
- Are events A and B independent? Give a reason for your answer.
- Find
- $P(A^c \cup B^c)$.
 - $P(A^c \cap B)$.
- (c) In a survey, to investigate the effects of SHISHA smoking on University students, 30% of males and 45% of females said that they did not smoke. The Proportion of females to males was 40 : 60. If a person is chosen at random and found to be a smoker, what is the probability that this person is a male?

(d) Given that

$$f(x) = \frac{4 - 2x}{(2x + 1)(x + 1)(x + 3)},$$

evaluate

$$\int_0^2 f(x) dx$$

leaving your answer in the form $\ln k$, where k is a constant.

[4, 7, 7, 7]

6. (a) Events A and B are such that $P(A|B) = \frac{2}{5}$, $P(B) = \frac{1}{4}$ and $P(A) = \frac{1}{5}$. Find
- $P(A \cap B)$
 - $P(B|A)$
 - $P(A \cup B)$

(b) A group of boys at a school is entered for Advanced Level Mathematics Examinations.

Each boy takes only As examination or A2 examination or both As and A2 examinations.

The probability that a boy is taking A2 given that he is taking As is $\frac{1}{5}$.

The probability that a boy is taking As given that he is taking A2 is $\frac{1}{3}$.

Find the probability that

- a boy selected at random is taking both As and A2 examinations.
- a boy selected at random is taking only As.

(c) Let

$$P(x) = x(100 - 2x),$$

where x is the number of items sold, be the profit function in dollars, for a small scale company. Find the value of x that maximizes the profit and determine the corresponding profit.

Handwritten calculations:

$$4 \frac{50}{25} = 20$$

$$\frac{100}{250} = \frac{2}{5}$$

$$\frac{1}{5} + \frac{1}{4} = \frac{4+5}{20} = \frac{9}{20}$$

$$\frac{1}{5} \times \frac{1}{10} = \frac{1}{50}$$

$$\frac{1}{10} \times \frac{1}{5} = \frac{1}{50}$$

$$\frac{1}{2} \times \frac{1}{10} = \frac{1}{20}$$

(d) The grouped frequency distribution below shows the masses, to the nearest gram, of 84 letters delivered by the postman.

Mass(g)	1 – 20	21 – 40	41 – 60	61 – 80	81 – 100
Number of letters	10	18	24	14	18

i. Complete the frequency distribution table below.

Mass(g)	Interval width	Frequency	Frequency density
$0.5 \leq x < 20.5$	20	10	0.5

2.5 x 10

ii. Which interval represents the modal class.

[7, 7, 5, 6]

7. (a) The following are test marks for a group of 120 MAT1110 students.

Mass(g)	0 – 9	10 – 19	20 – 29	30 – 49	50 – 79
Number of letters	8	21	53	28	10

i. Complete the frequency distribution table below.

Mass(g)	Interval width	Frequency	Frequency density
-0.5 – 9.5	10	8	0.8
9.5 – 19.5	10	21	2.1

ii. Draw a histogram to show the distribution of the test marks.

(b) Given that

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

i. find $f \circ f(x)$ leaving your answer in simplest form.

ii. find $f^{-1}(x)$.

iii. state the range of $f^{-1}(x)$.

(c) Integrate

$$\int x^2 e^{-2x} dx.$$

(d) Solve the equation

$$4x^3 + 8x^2 - x - 2 = 0.$$

$\frac{180}{20} = 9$
 $\frac{200}{20} = 10$
 $\frac{140}{20} = 7$

[8, 6, 6, 5]

The University of Zambia
School of Natural Sciences
Department of Mathematics & Statistics

2018/19 Academic Year Final Examinations

MAT1100 – Foundation Mathematics

4th November, 2019

-
- INSTRUCTIONS:**
- (1) Write down your **Computer number** and the **TG number** on each answer booklet used. (**Do not write your name**)
 - (2) There are seven (7) questions in this paper. **Answer any Five (5).**
 - (3) Show all essential working to score full marks.
 - (4) Write down the **number** of each question attempted on the cover of the main answer booklet.
 - (5) Calculators are **not allowed** in this Examination.

TIME ALLOWED: Three (3) hours.

Q1. (a) (i) By completing the square, find the centre and radius of the circle given by

$$x^2 + y^2 - 2x + 6y + 6 = 0.$$

(4 marks)

(ii) Hence, from part (i), find the equation of the tangent to the circle at

$$(2, \sqrt{3} - 3).$$

(3 marks)

(b) Let $A = \begin{pmatrix} 1 & 0 & 3 \end{pmatrix}$ and $B = \begin{pmatrix} 1 \\ 2 \\ 4 \end{pmatrix}$. Find the following products:

(i) AB

(2 marks)

(ii) BA .

(2 marks)

(c) Let $A = \begin{pmatrix} 1 & 0 & 2 \\ 1 & 1 & 2 \\ 0 & 1 & 1 \end{pmatrix}$.

(i) Find A^{-1} .

(5 marks)

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

$$x + 2z = 1$$

$$x + y + 2z = 2$$

$$y + z = 3.$$

(4 marks)

Q2 (a) (i) Simplify the set $((B - A) \cap C)'$, given that all the sets A, B and C intersect. **(2 marks)**

(ii) Given the sets $A = [-2, 6)$, $B = (-5, 3)$, $C = [-1, 8]$ and that $U = [-10, 10]$ is the universal set, find the set $A \cup (B' \cup C)'$. **(2 marks)**

(b) (i) Express $2.5\overline{34}$ in the form $\frac{p}{q}$ where p and q are integers and $q \neq 0$, in its lowest terms. **(3 marks)**

(ii) Express $\frac{3+\sqrt{3}}{(\sqrt{3}-1)^2}$ in the form $p + q\sqrt{3}$, where p and q are rational numbers. **(3 marks)**

(iii) Given that $\frac{1-2i}{z} = 2 + 5i$, find z in the form $a + ib$, where a and b are real numbers. **(3 marks)**

(c) (i) Let $*$ be a binary operation on the set of real numbers defined by

$$a * b = ab - (a + b).$$

Determine whether the binary operation $*$ is commutative. **(2 marks)**

(ii) Using the definition of $*$ in part (i) evaluate $2 * (3 * 4)$. **(2 marks)**

(iii) If $f(x) = 2x - 3$ and $g(x) = \frac{x+1}{2x}$, find $(f \circ g)^{-1}(x)$ and state its domain and range. **(3 marks)**

Q3. (a) (i) Complete the square of the quadratic function $f(x) = 3 + 2x - x^2$ and sketch its graph, indicating its turning point and the x - and y - intercepts. **(5 marks)**

(ii) Find the range of values of k for which the quadratic equation

$$x^2 + (2 - k)x + 1 - 2k = 0$$

has complex roots. **(3 marks)**

(b) Solve each of the following equations:

(i) $\sqrt{2x + 1} = \sqrt{x} + 1$ **(3 marks)**

(ii) $|2x - 3| = 3x - 5$. **(3 marks)**

(c) Solve each of the following inequalities:

(i) $\frac{5}{x-2} > \frac{2}{x+1}$ **(3 marks)**

(ii) $\left| \frac{x-2}{x+1} \right| \leq 3$. **(3 marks)**

Q4. (a) (i) Find the term independent of x in the expansion of $\left(x - \frac{1}{x}\right)^{12}$. (3 marks)

(ii) Use Binomial expansion to express $\frac{1}{1-2x}$ as a series up to and including the term in x^3 , and state the range of values of x for which the expansion is valid. (3 marks)

(iii) Using part (ii), find the approximate value of $\frac{1}{0.98}$, giving your answer correct to 5 decimal places. (2 marks)

(b) (i) The polynomial $p(x) = 3x^3 - 2x^2 + px - q$ is divisible by $(x - 1)$ and leaves a remainder of 10 when divided by $(x + 1)$. Find the values of p and q . (3 marks)

(ii) Solve the equation

$$x^3 - 3x^2 + 4 = 0. \quad (3 \text{ marks})$$

(c) Prove each of the following by the principle of mathematical induction, for all positive integers n :

(i) $1^3 + 2^3 + 3^3 + \dots + n^3 = \frac{1}{4}n^2(n+1)^2$. (3 marks)

(ii) $3^{2n} - 1$ is divisible by 8. (3 marks)

Q5. (a) (i) Express as a single logarithm $2 \log_4(2x + 3) - \log_4 x - \log_4(2x - 1)$. (2 marks)

(ii) Hence, solve the equation

$$2 \log_4(2x + 3) = 1 + \log_4 x + \log_4(2x - 1). \quad (3 \text{ marks})$$

(b) (i) Given the function $f(x) = 1 - 2 \sin\left(\frac{1}{2}x - \frac{\pi}{6}\right)$, find the amplitude, period, phase shift and vertical shift and sketch its graph in the interval $[0, 2\pi]$. (5 marks)

(ii) Prove that

$$\sec \theta - \cos \theta = \sin \theta \tan \theta. \quad (3 \text{ marks})$$

(c) Solve each of the following equations

(i) $2 \cos^2 x - \sqrt{3} \cos x = 0$, for $0 \leq x \leq 360^\circ$. (3 marks)

(ii) $4(3^{2x+1}) + 17(3^x) - 7 = 0$. (4 marks)

Q6. (a) Evaluate each of the following limits:

(i) $\lim_{x \rightarrow 2} \frac{x^2 - 4}{x^3 - 8}$ (3 marks)

(ii) $\lim_{x \rightarrow \infty} \frac{3x^3 + 5}{5 - x^2 - 3x^3}$. (3 marks)

(b) (i) Given that $y = \frac{(5x^2 - 4)^3}{e^{5x}}$, find $\frac{dy}{dx}$ at $x = 0$. (2 marks)

(ii) Find the equation of the normal to the curve $xy + x - 2y - 1 = 0$, at the point $(1, 0)$, expressing it in the form $ax + by + c = 0$, where a , b and c are constants. (3 marks)

(c) (i) Given the function $f(x) = \frac{1}{3}x^3 + \frac{1}{2}x^2 - 6x + 8$, find the intervals on which it is increasing and decreasing, and sketch its graph stating its local minima and maxima. (5 marks)

(ii) An open cylindrical tank with circular base is to be constructed of sheet metal so as to contain a volume πa^3 of water. Find the height and the radius of the base in terms of a so that the quantity of sheet metal required may be minimal. (Curved surface area of a cylinder is $2\pi rh$). (4 marks)

Q7. (a) Evaluate each of the following integrals:

(i) $\int \frac{x}{\sqrt{4-x^2}} dx$ (3 marks)

(ii) $\int x^2 \ln x dx$. (3 marks)

(b) Find the following definite integrals:

(i) $\int_2^3 \frac{4x+5}{(x+2)(x-1)} dx$. (3 marks)

(ii) $\int_0^{\frac{\pi}{2}} \sin^3 x dx$. (4 marks)

(c) (i) Sketch the region enclosed by the graph of $f(x) = \sin x$ and $g(x) = \frac{2}{\pi}x$ in the interval $[-\frac{\pi}{2}, \frac{\pi}{2}]$. (3 marks)

(ii) Hence, find the area of the region enclosed by the graphs of $f(x) = \sin x$ and $g(x) = \frac{2}{\pi}x$. (4 marks)

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
DEPARTMENT OF MATHEMATICS AND STATISTICS
2018/ 2019 ACADEMIC YEAR
FINAL EXAMINATION
ECONOMICS FOR ACTUARIAL SCIENCE (MAT 2012)
29TH NOVEMBER 2019

TIME ALLOWED: THREE (3) HOURS
TIME: 09:00 – 12:00 HOURS

INSTRUCTIONS TO THE CANDIDATE

1. *Enter your COMPUTER NUMBER on the answer booklet. Do NOT write your name.*
2. *You must not start writing your answers in the booklet until you are told to do so by the invigilator*
3. *Attempt all questions*
4. *Candidates should show calculations and well labelled graphs where appropriate to earn full marks*

- 1) If Goods X and Y are substitutes, a reduction in the price of Good X will have the following effect on the demand for Good Y:
 - a. a movement along the demand curve such that quantity demanded declines
 - b. a movement along the demand curve such that quantity demanded increases
 - c. a shift to the right of the demand curve
 - d. a shift to the left of the demand curve
- 2) When there is a surplus of a good or service:
 - a. consumers wish to purchase more of the product at the market price than is offered for sale
 - b. the quantity actually traded at the market price is determined by the supply curve
 - c. the market price is below the equilibrium price
 - d. the quantity actually traded at the market price is determined by the demand curve
- 3) The substitution effect of a price decrease causes an individual to purchase more units of a normal good because:
 - a. the change in price causes a decline in purchasing power
 - b. the good becomes more expensive relative to all other products
 - c. the change in price causes an increase in purchasing power
 - d. the good becomes less expensive relative to all other products
- 4) Revenues from the sale of a good will increase if:
 - a. income falls and the good is normal
 - b. income increases and the good is inferior
 - c. its price rises and demand is elastic
 - d. its price rises and demand is inelastic
- 5) When marginal product is decreasing, which of the following is true of marginal cost?
 - a. It increases initially, then eventually decreases.
 - b. It is decreasing.
 - c. It decreases initially, then eventually increases.
 - d. It is increasing.
- 6) Which of the following is NOT a feature of monopolistic competition?
 - a. Each firm faces a horizontal demand curve.
 - b. There is freedom of entry and exit to the industry.
 - c. There are many firms supplying the market.
 - d. Firms can change their actions without influencing the behaviour of other firms.

- 7) 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:
- increase output and reduce price
 - reduce price and output
 - increase price and output
 - reduce output and increase price
- 8) The prisoner's dilemma, applied to a situation involving two oligopolists, illustrates that:
- in avoiding the worst possible outcome the firms will fail to reach the best possible outcome
 - each firm will not take account of its rivals reactions when making its decision
 - the price set by one firm will not influence the price of the other firm
 - in avoiding the worst possible outcome the firms will succeed in reaching the best possible outcome
- 9) A perfectly competitive firm is not maximising profit if:
- total revenue is maximised
 - marginal cost equals price and price is above minimum average total cost
 - marginal cost equals average revenue
 - marginal cost equals marginal revenue
- 10) According to the kinked demand curve theory of oligopoly, at the quantity corresponding to the kink the firms:
- marginal revenue curve is discontinuous
 - average cost curve is discontinuous
 - marginal cost curve is discontinuous
 - average revenue curve is discontinuous
- 11) The multiplier is higher:
- the lower is the marginal propensity to consume and the lower is the marginal propensity to import
 - the higher is the marginal propensity to consume and the lower is the marginal propensity to import
 - the lower is the marginal propensity to consume and the higher is the marginal propensity to import

- d. the higher is the marginal propensity to consume and the higher is the marginal propensity to import
- 12) Which one of the following is NOT a function of money?
- a. A medium of exchange.
 - b. A measure of liquidity.
 - c. A store of value.
 - d. A unit of account.
- 13) Which one of the following accurately describes the opportunity cost of producing Good X?
- a. The cost of producing Good X in money terms.
 - b. The foregone output from the next best alternative use to which factors of production used to produce Good X could be put.
 - c. The stream of services provided by Good X over its entire lifetime.
 - d. The production of Good X foregone in the previous year to enable Good X to be produced this year.
- 14) The demand curve for Good X describes the amount of Good X that:
- a. buyers can but are not willing to purchase at different prices
 - b. buyers are both willing and able to purchase at different prices
 - c. buyers are both willing and able to purchase at one particular price
 - d. will be supplied at different prices
- 15) The law of diminishing marginal utility applied to consumption of Good X implies that the:
- a. more one consumes of Good X, the less utility one derives from the first unit of consumption of Good X
 - b. total utility derived from the consumption of Good X increases by smaller amounts for each extra unit of Good X consumed
 - c. marginal utility derived from the consumption of an extra unit of Good X falls if the price of Good X falls
 - d. marginal utility derived from the consumption of an extra unit of Good X falls if the price of Good X rises
- 16) The price of Good X will not change following an increase in the demand for Good X if the price elasticity of:
- a. supply is zero
 - b. demand is zero

- c. supply is infinite
 - d. demand is -1
- 17) Which one of the following will NOT shift the demand curve for a normal good to the left?
- a. A fall in consumers' incomes.
 - b. A rise in the price of a complementary good.
 - c. A rise in the price of the normal good.
 - d. A fall in the price of a substitute good.
- 18) Which ONE of the following statements is NOT applicable to a Giffen good?
- a. The demand curve has a positive slope.
 - b. The income effect on demand of a price change will affect demand in the opposite direction to the substitution effect.
 - c. The substitution effect of a fall in price of the good will lead to a fall in demand.
 - d. Demand falls if income increases, other things being equal.
- 19) A profit maximising monopolist that price discriminates is able to:
- a. achieve lower total production costs per unit of output
 - b. increase its profits and simultaneously lower its profit maximising output
 - c. achieve a greater average revenue than if it charged a single price
 - d. increase its profits by reducing its production costs more than its total revenue
- 20) Consumer A purchases Good X and Good Y. If consumer A's income and the prices of Good X and Good Y double Consumer A's Budget Line will:
- a. shift to the right but not change slope
 - b. shift to the right and become steeper
 - c. remain unchanged
 - d. shift to the right and become less steep
- 21) Which one of the following is NOT a feature of an industry characterised by monopolistic competition.
- a. There is freedom of entry and exit into the industry.
 - b. Firms in the industry produce differentiated products.
 - c. Firms in the industry charge prices above their marginal costs of production.
 - d. Some degree of monopoly power ensures that in the long run firms can make supernormal profits.
- 22) The "kinked" demand curve theory of oligopoly implies that the oligopolist:
- a. will seek to make only satisfactory rather than maximum profits

- b. has a discontinuity in its marginal cost curve
 - c. has a discontinuity in its average revenue curve
 - d. has a discontinuity in its marginal revenue curve
- 23) The short run supply curve for a firm in a perfectly competitive industry is its:
- a. average cost curve
 - b. average variable cost curve
 - c. marginal cost curve above the lowest point of the average total cost curve
 - d. marginal cost curve above the lowest point of the average variable cost curve
- 24) The marginal propensity to consume out of disposable income is 0.8 and the tax rate is 50 per cent of all income. The government decides to increase public spending by K100 million. According to the simple Keynesian model what is likely to be the total change in national income resulting from this increase in government expenditure?
- a. K200 million
 - b. K500 million
 - c. K1,000 million
 - d. K166 million
- 25) Which one of the following is most likely to lead to a rise in aggregate demand?
- a. A decrease in government expenditure.
 - b. An increase autonomous savings.
 - c. A increase in the rate of interest.
 - d. A decrease in the income tax rate.
- 26) Discuss with the aid of a diagram how a successful one-off advertising campaign is likely to affect sales of a product in the short, medium and long run.
- 27) Explain the two main characteristics of a public good, giving an example for each.
- 28) 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.
- 29) Explain, with the use of a diagram, the circular flow of income in an open economy with a government, financial/banking and a foreign sector, making clear which are the withdrawals and which are the injections in the system.

- 30) The government in a closed economy undertakes expenditure on goods and services of K200 million. Investment expenditure is K100 million and the rate of direct taxation is 25 per cent of all income. The consumption function is given by the equation:

$$C = 0.8 Yd$$

where C is planned consumption and Yd is disposable income (i.e. after deduction of income tax).

- (i) Calculate the level of national income at which the government has a balanced budget.
 - (ii) Calculate the government budget deficit/surplus if national income were K600 million.
 - (iii) Calculate the increase in the national income if government expenditure is increased from K200 million to K300 million.
 - (iv) Calculate the level of government expenditure required to achieve the full employment level of income of K900 million.
- 31) With the aid of aggregate supply and demand curves, explain the distinction between demand pull and cost push inflation.
- 32) Give two examples of the factors that can cause each type of inflation in **question 31 above**.
- 33) Outline the main items that are recorded in the current account of the balance of payments and the macroeconomic significance of a large current account deficit.
- 34) Outline some of the costs of unemployment to individuals, firms and the economy.
- 35) Explain the problem of adverse selection and how it might be dealt with by insurance companies.
- 36) Explain the problem of moral hazard and how it affects the price of insurance.
- 37) Explain how an expansionary monetary policy and the associated low short term interest rates can be useful in expanding economic activity in an open economy.
- 38) Explain the difference between actual and potential economic growth.
- 39) Draw a diagram to show a typical monopolistically competitive firm, such as a coffee shop, which is wishing to operate but is making a loss. Your diagram should show all the relevant cost and revenue curves and the area corresponding to the firm's losses.
- 40) Discuss, with the use of examples, two factors that influence the price elasticity of demand for a good.

END OF FINAL EXAMINATION

The University of Zambia
Department of Mathematics & Statistics
2018/2019 Academic Year Examinations
MAT2100 - Analytic Geometry and Calculus

Time allowed : Three (3) hrs

Full marks : 100

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- Instructions:**
- There are seven (7) questions in this paper. Attempt any five (5) questions. All questions carry equal marks.
 - **Full credit** will only be given when **all essential working** is shown.
 - Indicate your **computer number** on all answer booklets.
-

1. a) Prove that the length of the latus rectum of a hyperbola

$$\frac{x^2}{a^2} - \frac{y^2}{b^2} = 1$$

is $\frac{2b^2}{a}$. [8 marks]

- b) Identify and sketch the curve $73x^2 + 72xy + 52y^2 + 30x - 40y - 75 = 0$.
[12 marks]

2. a) A curve is given by the equation $y = x(x - 1)^2$. Calculate
- i) the radius of curvature about the point $(0, 0)$. [4 marks]
 - ii) the circle of curvature about the point $(0, 0)$. [5 marks]
- b) Use the method of upper sums to calculate the area bounded by the curve $f(x) = x^2$ and the x -axis between the limits $x = 1$ and $x = 4$. [6 marks]
- c) Calculate the volume of the solid formed by revolving the region bounded by the graphs of $y = \sqrt{x}$ and $y = x^2$ about the x -axis. [5 marks]

3. a) Find the following integrals

i) $\int \frac{dx}{\sqrt{6x-x^2}}$ [3 marks]

ii) $\int \frac{dx}{1+\cos x}$ [4 marks]

b) Find the fourth degree Taylor polynomial of $f(x) = \sin x$ at the point $x = \frac{\pi}{3}$.
[8 marks]

c) Calculate the area of the surface formed by revolving the graph of $f(x) = x^2$ on the interval $[0, \sqrt{2}]$ about the y -axis. [5 marks]

4. a) i) Find the parametric equations and the symmetric equations of the line L which passes through the points $P(-2, 1, 0)$ and $Q(1, 3, 5)$. [3 marks]

ii) Calculate the general equation of the plane which contains the points $P(2, 1, 1)$, $Q(0, 4, 1)$ and $R(-2, 1, 4)$. [4 marks]

b) Find the arc length of the curve $y = \frac{x^3}{6} + \frac{1}{2x}$ on the interval $[\frac{1}{2}, 2]$. [6 marks]

c) Let $I_n = \int \tan^n x dx$.

i) Find the reduction formula of the integral I_n . [3 marks]

ii) Hence or otherwise, calculate the integral $\int_0^{\pi/4} \tan^6 x dx$. [4 marks]

5. a) Use the limit definition of derivative to find $\frac{\partial f}{\partial x}$ for $f(x, y) = \sqrt{x+y}$. [5 marks]

b) i) State Euler's theorem for a homogeneous function of n variables. [2 marks]

ii) Verify Euler's theorem for the degree five homogeneous function

$$f(x, y) = x^3y^2 + 2x^2y^3 - xy^4 + 3y^5.$$

[3 marks]

c) Find and classify the stationary points of $f(x, y) = x^2 - 2xy + \frac{1}{3}y^3 - 3y$.

[10 marks]

6. a) i) Discuss the continuity at the origin of

$$f(x, y) = \begin{cases} \frac{y^2}{x^2+y^2}, & \text{if } (x, y) \neq (0, 0) \\ \frac{1}{2}, & \text{if } (x, y) = (0, 0) \end{cases}$$

[4 marks]

ii) Evaluate $\lim_{(x,y) \rightarrow (1,1)} \frac{x^2 - 2xy + y^2}{x-y}$. [2 marks]

b) Use total differential to estimate the value of

$$\frac{1 - (3.08)^2}{(5.98)^2}$$

correct to 2 decimal places. [7 marks]

c) Show that $(2x + y^3)dx + (3xy^2 - e^{-2y})dy = 0$ is exact and hence, find its general solution. [7 marks]

7. a) Find the general solution of

i) $(x^2 + 1)\frac{dy}{dx} = x(y + 1)$. [4 marks]

ii) $\frac{dy}{dx} - \frac{3}{x}y = x^2$. [4 marks]

b) Solve the initial value problem (IVP)

$$y'' + 2y' - 8y = e^{3x}; \quad y(0) = 1, y'(0) = \frac{3}{7}.$$

[12 marks]

End of Examination!

The University of Zambia
School of Natural Sciences
Department of Mathematics & Statistics
2018/2019 Academic Year
End of Year Final Examinations
MAT 2110 - Engineering Mathematics I

Time allowed : Three (3) hrs

Full marks : 100

Instructions:

- Indicate your **computer number** on all answer booklets.
- There are seven (7) questions in this examination. Attempt **any five (5)** questions. All questions carry equal marks.
- **Full credit** will only be given when **necessary work** is shown.

This paper consists of 4 pages of questions.

1. (a) A conic section is given by

$$12x^2 - 12x - 4y^2 + 8y - 37 = 0$$

- Identify the conic section.
 - Find the centre, focus or foci, vertex or vertices, asymptotes and directrices of the conic section.
 - Sketch the conic section.
- (b) Find the principle unit normal vector if

$$R(t) = \sqrt{3}ti + e^tj + 3k$$

at $t = 0$.

[14,6]

Turn Over/...

2. (a) Find the function $g(x)$ so that the function

$$f(x) = \begin{cases} \frac{\sqrt{x} - \sqrt{y}}{x^2 - y^2}, & x \neq y \\ g(x), & x = y \end{cases}$$

is continuous at the point where $x = y > 0$.

(b) Solve the Initial Value Problem (IVP)

$$y''' - y'' - 5y' - 3y = e^{-x}, \quad y''(0) = 0, \quad y'(0) = 1, \quad y(0) = 14.$$

[5,15]

3. (a) A line L_1 passing through the point $(-1, 1, 0)$ is parallel to the line L_2 given parametrically as

$$L_2 : x = \pi + 2t, \quad y = 1, \quad z = t.$$

(i) Find the equation of L_1 .

(ii) Find the cross product of the direction vectors of the lines L_1 and L_2 .

(b) Show that

$$I(x, y) = \frac{1}{x^2 + y^2}$$

is an integrating factor of the differential equation

$$[y + x(x^2 + y^2)^2] dx + [y(x^2 + y^2)^2 - x] dy = 0.$$

Hence, or otherwise, solve the differential equation.

(c) Determine the convergence or divergence of the following series:

(i) $\sum_{n=1}^{\infty} \left(\frac{(-1)^{n+1}}{2n-1} \right)$

(ii) $\sum_{n=1}^{\infty} \left(\frac{3}{2} \right)^n$

(iii) $\sum_{n=1}^{\infty} \left(\sqrt{\frac{1}{n^5}} \right)$

[3,10,7]

4. (a) Find the eigenvalues and corresponding eigenvectors of the matrix

$$\begin{pmatrix} 0.8 & 0.3 \\ 0.2 & 0.7 \end{pmatrix}$$

Turn Over/...

(b) (i) Find the point of intersection P , of the lines

$$L_1 : x + 1 = \frac{y + 4}{2} = \frac{z}{5}$$

and

$$L_2 : x = \frac{y - 2}{-2} = -(z - 11)$$

(ii) Find the equation of the plane passing through P , $Q(1, 1, 1)$ and $R(0, 1, 0)$. [8,7,5]

5. (a) Find the n^{th} derivative of the function

$$f(x) = x^k, \quad k \geq 1, n \leq k.$$

Hence, find the 4^{th} derivative when $k = 4$.

(b) The polar equation of a conic section with one focus at the origin is given by

$$r = \frac{2}{2 + \cos \theta}$$

Identify the conic section by finding its eccentricity. Hence, find its centre, focus or foci and directrix or directrices.

(c) Given that

$$\sin x = x - \frac{x^3}{3!} + \frac{x^5}{5!} - \dots (-1)^n \frac{x^{2n+1}}{(2n+1)!} + \dots, \quad |x| < \infty,$$

evaluate the definite integral

$$\int_0^1 \sin(x^8) dx,$$

giving your answer such that the error is positive and does not exceed 0.0005. [5,8,7]

6. (a) The function

$$f(x) = e^x(1 + \cos x)$$

satisfies the hypotheses of the Rolle's theorem in the interval $[-\pi, 3\pi]$.

(i) Find numbers c in $(-\pi, 3\pi)$ that satisfy the conclusion of the theorem.

Turn Over/...

- (ii) Choose one c in $(-\pi, 3\pi)$ such that the L'Hôpital's rule can be applied to evaluate

$$\lim_{x \rightarrow c} \frac{f(x)}{g(x)},$$

where $g(x) = \sin x$ and evaluate the limit.

- (b) The rate at which radioactive nuclei decay is represented by

$$\frac{dy}{dt} = -ky,$$

where y is the amount of radioactive nuclei present after t years and k is a constant of proportionality. The number of radioactive nuclei initially present is 1200 and half of that amount disintegrates after 20 years. Find the amount present after 50 years.

- (c) A region is bounded by the curve $y = x^2 - 2x$ and the line $y = 2x$. Find the volume of the solid generated by rotating this region about the line $y = 10$.

[9,5,6]

7. (a) Evaluate the following integrals:

(i) $\int_2^{\infty} \frac{1}{x^3} dx,$ (ii) $\int \frac{dx}{1 + \cos x + \sin x}$

- (b) Find the radius and interval of convergence of the series

$$\sum_{n=1}^{\infty} n! (x - 3)^n$$

- (c) A space probe in shape of the ellipsoid $4x^2 + y^2 + 4z^2 = 16$ enters the Earth's atmosphere and its surface begins to heat. After one hour, the temperature at the point (x, y, z) on the probe's surface is

$$T(x, y, z) = 8x^2 + 4yz - 16z + 600.$$

Find the hottest point on the probe's surface and the temperature at this point.

[6,4,10]

END OF EXAMINATION!

**THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
DEPARTMENT OF MATHEMATICS & STATISTICS**

2019 Academic Year Final Examinations
MAT 2200 Linear Algebra

18th November, 2019

Total time allowed: Three (3) hours

Instructions:

- There are seven questions in this paper; answer any five (5).
 - Show detailed working to earn full marks.
 - Leave your answers as simplified fractions or surds and NOT decimals.
-

1. (a) (i) Let u and w be vectors in an inner product space V . Then define the orthogonal projection of u onto w .
(ii) State the Rank Nullity Theorem.
 - (b) Let $u = (2 - 3i, 2 + 4i)$ and $w = (1 + i, 1 - i)$ be vectors in the inner product space \mathbb{C}^2 . Use the standard inner product on \mathbb{C}^2 to find the orthogonal projection of u onto w .
 - (c) Use the Gauss-Jordan Elimination method to solve the system of linear equations below:
$$\begin{aligned} 2x + 4y &= 2 \\ 3x + 2y + z &= 8 \\ 5x - 3y + 7z &= 15 \end{aligned}$$
 - (d) Prove that if A and B are similar matrices, then they have the same characteristic polynomial. [5, 4, 6, 5]
2. (a) Define a Hermitian matrix.
 - (b) State Cayley-Hamilton Theorem.
 - (c) The function defined by $\langle A, B \rangle = \text{tr}(AB^t)$ is an inner product on the vector space $M_{22}(\mathbb{R})$. Let $P = \begin{pmatrix} 1 & 1 \\ 0 & 0 \end{pmatrix}$ and $Q = \begin{pmatrix} 0 & -1 \\ 3 & 2 \end{pmatrix}$.
Then find the following:

- (i) the norm of Q (ii) $d(P, Q)$

(d) Given that $A = \begin{pmatrix} 4 & 0 & 1 \\ -1 & -6 & -2 \\ 5 & 0 & 0 \end{pmatrix}$. Find the following:

(i) the characteristic polynomial of A simplified to the form
 $C_A(x) = x^3 + ax^2 + bx + c$.

(ii) all the eigenvalues of A .

(iii) the eigenspace of each eigenvalue of A . [3, 3, 4, 10]

3. (a) (i) Define a diagonalizable matrix.

(ii) State the Fundamental Theorem of Symmetric Matrices.

(b) Use Cramer's Rule to solve the system of linear equations below:

$$x + 2y + z = 3$$

$$2x + 3y - z = -6$$

$$3x - 2y - 4z = -2$$

(c) Consider the linear transformation $T : \mathbb{R}^3 \rightarrow \mathbb{R}^3$, defined by
 $T(x, y, z) = (x - y, 0, x + y + z)$. Then find the following:

(i) the kernel of T ,

(ii) the image of T .

(d) Prove that the symmetric matrix $M = \begin{pmatrix} a & w \\ w & b \end{pmatrix}$ is diagonalizable.

[5, 6, 4, 5]

4. (a) Define the following terms:

(i) the basis for a vector space,

(ii) the minimal polynomial of a matrix.

(b) Find the standard matrix of the linear transformation $T : \mathbb{R}^3 \rightarrow \mathbb{R}^3$ defined by $T(x, y, z) = (8x + y - z, x - 4y, 7x + 5y - z)$ and hence use the standard matrix to determine whether or not the linear transformation T is invertible.

(c) Find the matrix P which diagonalises the matrix $B = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 1 \\ 0 & 0 & 0 \end{pmatrix}$.

(d) Let $S = \{v_1, v_2, \dots, v_n\}$, with $n \geq 2$, be a subset of a vector space V . Prove that S is a linearly dependent set if and only if at least one of the vectors v_j can be written as a linear combination of the other vectors in S . [5, 4, 6, 5]

5. (a) (i) Define an eigenvalue of a matrix.
(ii) State the Real Spectral Theorem.
- (b) Use elementary row operations to find the inverse of the matrix

$$M = \begin{pmatrix} 1 & 2 & 11 \\ 0 & -1 & -4 \\ 0 & 0 & -1 \end{pmatrix}.$$
- (c) Determine whether or not the matrix $A = \begin{pmatrix} 1 & 1 \\ 0 & 0 \end{pmatrix}$ is similar to the matrix $B = \begin{pmatrix} 0 & 0 \\ 2 & 2 \end{pmatrix}$.
- (d) Consider the vector space \mathbb{R}^3 . Find the change of basis matrix from the basis $D = \{(1, 2, 11), (0, -1, -4), (3, 0, -1)\}$ to the basis $E = \{(4, 0, 4), (0, 1, 1), (-3, 1, 6)\}$. [5, 3, 4, 8]
6. (a) Define the following terms:
(i) An upper triangular matrix,
(ii) the distance between two vectors in an inner product space.
- (b) Use the method of cofactors to find the inverse of the matrix

$$N = \begin{pmatrix} 0 & 0 & -1 \\ 1 & 0 & 0 \\ 0 & 1 & 1 \end{pmatrix}.$$
- (c) Let $f(x) = x^2$, $g(x) = e^x$ and $h(x) = \sin^2 x$ be elements in the vector space $C[0, \pi]$. Use the standard inner product in $C[0, \pi]$ to find the following:
(i) $\langle f, g \rangle$ (ii) $\|h\|^2$
- (d) Let A be an $m \times n$ matrix. Then prove that the function $T : \mathbb{R}^n \rightarrow \mathbb{R}^m$ defined by $T(w) = Aw$ is a linear transformation from \mathbb{R}^n into \mathbb{R}^m . [4, 6, 6, 4]
7. (a) (i) Define the geometric multiplicity of an eigenvalue.
(ii) State the Cauchy-Schwarz Inequality.
- (b) Given that $E = \begin{pmatrix} 4 & 0 & -1 \\ 0 & 3 & 0 \\ 1 & 0 & 2 \end{pmatrix}$. Find the minimal polynomial of the matrix E .
- (c) Use the Gram-Schmidt Orthogonalization Procedure to construct an orthogonal set from the set $S = \{(-2, 2, 3), (1, 1, 0), (2, 0, 0)\}$

- (d) Let $S = \{w_1, w_2, \dots, w_n\}$ be a basis for a vector space V . Then prove that every vector in V can be written in one and only one way as a linear combination of vectors in S . [4, 6, 6, 4]

END OF EXAM

Chicken	A	B	C	D	E	F	G	H	I	J
Amount of food supplement x (g)	7.0	9.8	11.6	17.5	7.6	8.2	12.4	15.5	9.5	19.5
Hardness of shells y	1.2	2.1	3.4	6.1	1.3	1.7	3.4	6.2	2.1	7.1

2. (a) Write four fallacies in the interpretation of the correlation coefficient, r .
- (b) In an experiment to find the strength for a brass wire eleven pairs of values x (suspended mass in kg) and y (length of wire in mm) given in the table below are obtained.

x	1	1.5	2	2.5	3	3.5	3	2.5	2	1.5	1
y	-1.1	-0.6	0	0.4	0.9	1.5	1.0	0.6	0.1	0.5	-0.9

The equation connecting x and y is assumed to take the form $y = a + bx$ where a and b are estimates of α and β respectively.

- (i) Obtain the least squares estimate values for α and β .
- (ii) Use this equation to find the value of y when $x = 1.35$.
(Hint: $\sum x^2 = 57.25$, $\sum y^2 = 7.22$, $\sum xy = 10.0$)
- (c) It is known that the true response Y in a certain chemical experiment is a linear function of the operating temperature X . However, the experimental determinations of Y are subject to random errors, so that when an experiment is performed at temperature x_i the observed response y_i is such that $y_i = \alpha + \beta x_i + e_i$, where $\alpha + \beta x_i$ is the true response and e_i is the error.

Temperature(X)	30	30	40	40	50	50
Observed response(Y)	14	12	10	11	7	6

The table above gives the observed responses in six experiments. Use the data to obtain the least squares estimate of the linear relationship between X and Y .

3. (a) Define the following statistical terms
- (i) Independence and uncorrelatedness and explain how they are related.
- (ii) Latin Square design
- (iii) The product moment correlation coefficient and with the use of a scatter diagram explain how you would interpret values of 0 and 1.

- (b) A stimulus-response experiment involving three treatments was laid out in a randomized block design using four subjects. The response was the

Subjects			
1	2	3	4
① 1.7	③ 2.1	① .1	② 2.2
③ 2.3	① 1.5	② 2.3	① 0.6
② 3.4	② 2.6	③ 0.8	③ 1.6

length of time to reaction measured in seconds. The data, arranged in blocks, are shown in the table above. The treatment number is circled and shown above each observation. Do the data present sufficient evidence at 5% level of significance to indicate a difference in the mean response for

- (i) stimuli (treatments)?
(ii) Subjects?

4. (a) State the following:
(i) two properties of the normal curve.
(ii) central limit theorem.
- (b) 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	4	7	6
Second time	4	2	1	1	7	6	8	10	3

- (i) Compute a 95% confidence interval for the difference in the mean number of pronunciation errors.
(ii) Are the number of pronunciation errors higher after a one-year period? Test at the 10% level of significance.
(iii) What assumption(s) are needed for (i) and (ii) to be valid?
- (c) A random sample of 52 customers who drive luxury cars showed that the average distance driven between oil changes was 5129 km with a standard deviation of 67.1 km. Another random sample of 48 customers who drive

compact lower-priced cars resulted in an average distance of 5172 km with a standard deviation of 80.5 km.

- (i) Construct a 90% confidence interval for the mean distance between oil changes for luxury cars.
- (ii) Is the mean distance between oil changes for luxury cars significantly different from 5000km? Explain.
- (iii) Is there sufficient evidence to indicate that the mean distance between oil changes is lower for luxury cars? Test using a 1% level of significance.

5. (a) Define the following:

- (i) dependent samples.
- (ii) type II error.

(b) A study was conducted to compare the effectiveness of two drugs in curing malaria in babies. Among 120 babies given drug A, 36 were cured within two days while 70 out of 280 babies on drug B were cured within two days.

- (i) Construct a 96% confidence interval for the proportion of babies cured of malaria within two days on drug B.
- (ii) Determine whether there is a significant difference in the effectiveness of the two drugs. Use $\alpha = 0.05$.
- (iii) How large a sample is required in order to be 99% confident that the estimate of the proportion cured on drug A within two days is less than 0.1 units of the true value?

(c) The following are data on 150 chickens, divided into two groups according to breed and into three groups according to yield of eggs:

		Yield		
		High	Medium	Low
Breed	A	45	28	29
	B	27	6	15

Test whether these data are consistent with the hypothesis that the type of breed does not affect the yield of eggs. Use a 5% level of significance.

6. (a) Define the following:

- (i) power of a test.
- (ii) sampling distribution.

(b) A committee was formed to study traffic conditions in an industrial complex. The committee wanted to determine whether the modes of transportation used to get to work changed over a period of 5 years. Five years before, 65% of the workers used public transportation, 22% used company transportation, 10% used personal vehicles and the rest used other

modes. The committee obtained the following information from a sample of 500 workers.

Transportation mode	Number of people
Public transport	320
Company transport	130
Personal vehicle	35
Other means	15

Is there sufficient evidence to indicate that the modes of transportation used to get to work have changed? Use $\alpha = 0.05$.

- (c) A sample of 13 cans of brand A diet soda gave a mean number of 23 calories with a standard deviation of 3 calories. Another independent sample of 11 cans of brand B diet soda had a mean of 25 calories with a standard deviation of 5 calories. Assume the amounts of calories of diet soda are normally distributed.
- (i) Is there a difference in the mean number of calories for the two brands? Carry out a test using a 5% level of significance assuming the variances of the two brands are equal.
 - (ii) Test whether the standard deviation of brand A diet soda is significantly different from 4 calories. Use a 10% level of significance.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
DEPARTMENT OF MATHEMATICS AND STATISTICS
2018/2019 ACADEMIC YEAR DEFERRED EXAMINATION
MAT3011 – PRINCIPLES OF FINANCE AND FINANCIAL REPORTING

Time Allowed: THREE (3) hours

INSTRUCTIONS

1. Answer ALL Questions
 2. Show all your workings to earn full credit
 3. Indicate your computer number on ALL answer booklets
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Question One

[20 Marks] – MULTIPLE CHOICE – [2 marks each]

1 Which of the following statements best explains the role of the external auditor from an agency perspective?

- A The auditor enables the shareholders to rely on the financial statements prepared by the directors.
- B The auditor ensures that the company is well managed.
- C The auditor provides the directors with independent advice on accounting and financing matters.
- D The shareholders can task the external auditor to examine particular areas of concern.

2 Which of the following statements best describes the driver of the market price of a quoted company?

- A Expectations of future revenues.
- B Expectations of future dividends.
- C Historical trends of reported profits.
- D Historical trends of dividend payments.

3 Martin has just been admitted to a long established business partnership. He has bought 20% of the partnership equity, although he has not paid for this yet. He will be entitled to 15% of the partnership profit. If the firm incurs any liability, what proportion of that liability will be Martin's legal responsibility?

- A 0%
- B 15%
- C 20%
- D 100%

4 When does a bondholder receive the nominal value of a bond?

- A At the time of purchase.
- B Annually.
- C Whenever coupon payments are made.
- D At maturity.

5 Which of the following statements describes the agency problem?

- A Agents may feel that they cannot trust their principals.
- B Agents may have insufficient authority to manage their principals' affairs.
- C Principals may feel that they cannot trust their agents.

D Principals may not have the necessary expertise to manage their own businesses.

6 Kumuzi is a 100% subsidiary of the Ndiyepano Group. Ndiyepano is a major quoted Corporation. Kumuzi has serious cash flow problems and is struggling to meet its immediate liabilities. Which of the following statements is correct?

A Ndiyepano has no reason to support Kumuzi.

B Ndiyepano is forbidden from supporting Kumuzi unless there is a contractual reason for doing so.

C Ndiyepano is required by law to support Kumuzi and settle the liabilities.

D Ndiyepano will make a commercial decision as to whether it will support Kumuzi.

7 A parent company's only asset is an K8 million investment in a 60% subsidiary. The subsidiary's assets are valued at K25 million. What value will be attributed to group assets in the consolidated financial statements?

A K8 million

B K15 million

C K25 million

D K33 million

8 A newly formed company was funded by an equity injection, in which the shareholders purchased a total of 10,000 K1 fully-paid shares for K2.50 each. Which of the following figures will appear in the company's statement of financial position?

<i>Share capital (K)</i>	<i>Share premium (K)</i>
--------------------------	--------------------------

A 10,000	15,000
----------	--------

B 10,000	25,000
----------	--------

C 25,000	0
----------	---

D 25,000	15,000
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9 Which of the following statements best describes the purpose of the depreciation charge?

A The depreciation charge creates a reserve for the replacement of assets when they reach the end of their useful lives.

B The depreciation charge ensures that asset values remain realistic.

C The depreciation charge ensures that businesses obtain tax relief on the consumption of assets' values.

D The depreciation charge reflects the consumption of an asset's value during the period that benefits from that consumption.

10 You have been asked to determine the internal rate of return (IRR) of a project that has an initial cash outflow, followed by seven years of net cash inflows. The project's net present value was + \$500,000 when determined at 11% and - \$500,000 when determined at 16%.

Which of the following statements concerning the project's IRR is correct?

A The IRR is approximately 13.5%.

B The IRR is exactly 13.5%.

C The IRR is greater than 16%.

D The IRR is less than 11%.

Question Two**[Total 20 Marks]**

You have been provided with the following trial balance as at 31 May 2018 for a limited liability company called Sowelani.

	<i>K'000</i>	<i>K'000</i>
Bank	50	
Inventory at 1 June 2017	1,200	
General expenses	600	
Heating and lighting	90	
Marketing and advertising expenses	248	
Wages	490	
Buildings at cost	5,000	
Motor vehicles at cost	160	
Plant and equipment at cost	700	
Retained earnings at 1 June 2017		280
Trade receivables	438	
Purchases	2,200	
Loan note interest paid	30	
5% Loan note		600
Revenue		5,876
Discounts received		150
Trade payables		500
K1 ordinary shares		1,500
Accumulated depreciation at 1 June 2017:		
Buildings		2,000
Motor vehicles		60
Plant and equipment		240
	<u>11,206</u>	<u>11,206</u>

The following notes are relevant.

- (a) Inventory at 31 May 2018 was valued at K800,000.
- (b) Marketing and advertising expenses include K6,000 paid in advance for a marketing campaign which will begin in June 2018. Marketing and advertising expenses should be allocated to administrative expenses.
- (c) There are wages outstanding of K10,000 for the year ended 31 May 2018.
- (d) A customer ceased trading owing the company K38,000; the debt is not expected to be recovered.
- (e) An allowance for receivables is to be established amounting to 5% of trade receivables.
- (f) Depreciation is to be provided for as follows.
 - (i) Buildings at 5% per annum on their original cost, allocated 50% to cost of sales, 20% to distribution costs and 30% to administrative expenses.
 - (ii) Motor vehicles at 25% per annum of their written down value, allocated to distribution costs.
 - (iii) Plant and equipment at 20% per annum of their written down value, allocated to cost of sales.
- (g) No dividends have been paid or declared.
- (h) Income tax of K250,000 is to be provided for the year.
- (i) The audit fee accrual is estimated to be K20,000.
- (j) The expenses listed below should be apportioned as follows.

	Cost of sales	Distribution costs	Administrative expenses
	%	%	%
General expenses	10	40	50
Heating and lighting	50	30	20
Wages and salaries	60	30	10

Required

Prepare the following financial statements for the year ended 31 May 2018 for Sowelani Limited, showing workings where appropriate.

- A. An income statement [10 marks]
 B. A statement of financial position [10 marks]

Question Three [Total 20 Marks]

(a) Discuss the need for formal and transparent procedures to determine the policy for directors' remuneration in a quoted company. [5 marks]

(b) The partners who own an actuarial consultancy are considering moving to a larger and more prestigious office, despite the fact that doing so has a negative net present value on the basis of a five-year cash flow projection.

Discuss the possibility that the move might be justified on the basis of strategic fit. [5 marks]

(c) National tax systems often have the objectives that the tax burden is fair and reasonable. Explain how these objectives are achieved. [5 marks]

(d) Define the term Eurobonds and give two advantages and two disadvantages of this form of government borrowing. [5 marks]

Question Four [Total 20 Marks]

Ukambachani is a major quoted company that manufactures timber products. The company has suffered a major setback during the past few months. The company's largest supplier was unable to meet Ukambachani's timber requirements because volcanic activity close to the supplier's forests caused forest fires which severely disrupted transport routes. Ukambachani was able to purchase timber from alternative sources, but paid much more than usual because Ukambachani receives a substantial discount from its usual supplier.

Most of Ukambachani's board members are concerned that the shareholders will blame them for allowing the company to become so heavily dependent on a single supplier.

The Production Director disagrees, though, on the basis that the Capital Asset Pricing Model (CAPM) suggests that shareholders diversify, which protects them from unsystematic risks. The volcanic disruption is an unsystematic risk and so the shareholders were protected. In any case, the Production Director had considered the risk of disruption due to the volcano and had concluded that the risk of an eruption in any given year was less than 5%.

Ukambachani has a high gearing ratio. The Production Director proposes that the board should determine the company's ungeared beta in order to determine whether the shareholders are earning a satisfactory return on their investment, despite the costs associated with the volcano.

(a) Discuss the Production Director's argument that holding diversified portfolios would have protected Ukambachani's shareholders from the volcanic disruption and so the shareholders will not blame the board. [8 marks]

(b) Discuss the Production Director's proposition that the risk had been evaluated and so the board should not be criticised. [7 marks]

(c) Discuss the respective relevance of Ukambachani's geared and ungeared betas to its shareholders. [5 marks]

Question Five [Total 20 Marks]

Serene Hotels is a family-owned company that is in the process of recovering from a major corporate scandal. Serene Hotels is a substantial business that is not quoted. None of its shareholders owns more than 5% of the equity shares. None of the shareholders is able to take an active role in the company's management.

Serene Hotels' directors were all forced to step down because of the discovery that the directors had been overstating reported profits, which had the effect of inflating their profit-related bonuses. The directors also provided themselves with lavish lifestyles at the company's expense. For example, the company provided chauffeur-driven limousines to transport the directors on both business and personal travel.

The entire board of Serene Hotels has resigned. The shareholders have met and have appointed a new chairman and a chief executive. Neither of these appointees have had anything to do with Serene Hotels in the past. They have both agreed that their first priority is to appoint a new board and to structure the management arrangements so that the shareholders' confidence is restored.

The chairman has suggested that the new board should be structured as follows:

- The chairman will work on a part-time basis and will be responsible for the management of the board, including chairing board meetings. The chairman will be paid a fixed annual salary that offers an appropriate rate for the time that he is expected to commit to the company.
- The chief executive will be employed on a full-time basis to manage the company itself and will receive both a substantial salary and a profit-related bonus.
- Four additional full-time directors will be appointed to take charge of particular areas such as marketing and finance. Each will receive a similar package to the chief executive.
- Two part-time directors will be appointed to participate in board meetings and to review corporate strategy. They will be paid a fixed salary.

- The chief executive and each of the full-time directors will receive a 5% shareholding after satisfactorily completing three years on Serene Hotels' board.
- The chairman and the two part-time directors will appoint a new larger and more reputable external audit firm to replace outgoing auditor and will pay a larger fee for the new auditor's services.

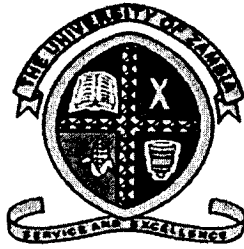
(a) Discuss the suitability of each of the proposals above from the perspective of maintaining shareholder confidence. [10 marks]

An advisor has recommended that the new team of executives seek a stock exchange quotation and commit in their prospectus to have a specific dividend pay-out ratio.

(b) Evaluate the decision to list the company at this particular moment. [4 marks]

(c) Outline the various factors to be considered in deciding on the dividend policy for Serene Hotels post listing. [6 marks]

..... **END OF EXAMINATION**.....



THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
DEPARTMENT OF MATHEMATICS & STATISTICS
2018/2019 ACADEMIC YEAR FINAL EXAMINATION
MAT3022 – INVESTMENT ANALYSIS AND PORTFOLIO MANAGEMENT

Time Allowed: THREE (3) hours

INSTRUCTIONS

1. Answer ALL FOUR (4) questions
 2. Show all your workings to earn full credit
 3. Indicate your computer number on ALL answer booklets
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Question One [Total 25 Marks]

- (a) Distinguish between operational and allocative efficiency [2 marks]
- (b) Outline the three forms of the Efficient Markets Hypothesis (EMH). [3 marks]
- (c) Explain what is meant by “excessive volatility” of share prices. [2 marks]
- (d) State two examples of empirical evidence of the “under-reaction” of share prices to events. [3 marks]
- (e) Briefly describe the implications of the price-volume relationship on market efficiency. [3 marks]
- (f) Define an index tracker fund and describe how you could create such a portfolio on the Lusaka Stock Exchange (LuSE). [5 marks]
- (g) Discuss the methodology of the following approaches to security analysis.
- (i) Fundamental analysis [4 marks]
- (ii) Technical analysis [3 marks]

Question Two [Total 25 Marks]

(a) Outline the key findings in behavioural finance. [8 marks]

(b) You are given the following results and data for Securities 1, 2 and 3 in Table 1 for the single index model.

$$E_i = \alpha_i + \beta_i E_M$$

$$V_i = \beta_i^2 V_M + V_{\epsilon_i}$$

and $C_{ij} = \beta_i \beta_j V_M$

Table 1: Single Index Model parameter values

Security	1	2	3
α_i	0.0	2.0	-2.2
β_i	1.3	0.8	2.0
V_{ϵ_i}	2.2	1.3	1.2

You are given that:

- the expected return and standard deviation of the market return are 6% and 10% respectively
- the returns of each security can be modelled using an appropriate single-index model.

(i) Calculate the expected return and standard deviation of return for each security. [3 marks]

(ii) Calculate the covariance of returns between each pair of securities. [2 marks]

(iii) Explain the difference between the single-index model and the Capital Asset Pricing Model. [2 marks]

(iv) A suggestion has been made to use a multi-index model instead of single-index model. Outline any two multi-index model choices available and how they can be fit to the data to predict future security price moves. [6 marks]

(c) State the assumptions in coming up with a budget line and describe its effect on consumer choice.

(d) Suppose that Elliot and Kaumba each have a log utility function and an initial wealth of 150 and 450 respectively. Both are offered a gamble such that they will receive a sum equal to 30% of their wealth should they win, whereas they will lose 10% of their wealth should they lose. The probability of winning is $\frac{1}{4}$.

(i) Calculate Elliot's certainty equivalent for the gamble alone and comment briefly on your answer. [2 marks]

(ii) Repeat part (i) in respect of Kaumba and compare your answer with that in part (i). [2 marks]

Question Three**[Total 25 Marks]**

(a) The probability density function $f(x)$ of the 2 parameter Burr distribution is:

$$f(x; c, k) = ckx^{c-1}(1 + x^c)^{-(k+1)}; \text{ where } x > 0, c > 0 \text{ and } k > 0$$

You are given that the cumulative distribution function of the above distribution is given by:

$$F(x; c, k) = 1 - (1 + x^c)^{-k}$$

You have very limited knowledge of an investor's utility function.

Three investment portfolios A, B and C provide returns that follow Burr distribution with the following parameters.

Table 2: Burr Distribution Parameters

Portfolio	c	k
A	1	1
B	1	2
C	2	1

- (i) Ascertain if an investor who prefers more to less would choose A over B? [4 marks]
- (ii) Show that the investor will not be able to choose between A and C based on first order stochastic dominance. [3 marks]
- (iii) What can be deduced about second order stochastic dominance between A and C [3 marks]
- (b) Describe the following active management styles.
- (i) Momentum
- (ii) Rotational [4 marks]
- (c) List any two domestic equities sector categories that are evident on our local LuSE and briefly describe the investment characteristic of each. [2 marks]
- (d) The following information relates to the performance of two investment trusts and their equivalent benchmark index over a three year period. The annual risk-free rate of return over this period was 4% per annum.

Table 3: Investment Trusts and Benchmark Index Performance

	Trust A	Trust A	Benchmark Index
Return	9.0% p.a.	8% p.a.	7% p.a.
Standard Deviation	13.5% p.a.	9.5% p.a.	6.5% p.a.
Correlation with benchmark	0.36	0.75	1.0

(i) Calculate three different risk adjusted performance measures for each trust. [6 marks]

(ii) Comment on the results from part (i), stating any limitations that apply to them. [3 marks]

You are given that:

$$\beta_p = \frac{\rho_{p,m} \sigma_p \sigma_m}{\sigma_m^2}$$

Treynor measure, Sharpe measure and Jensen measure

$$T_p = \frac{(\bar{r}_p - \bar{r}_f)}{\beta_p}, \quad S_p = \frac{(\bar{r}_p - \bar{r}_f)}{\sigma_p}, \quad \alpha_p = \bar{r}_p - [\bar{r}_f + \beta_p (\bar{r}_p - \bar{r}_f)]$$

Question Four [Total 25 Marks]

(a) Let X be a random variable denoting the rate of return on the fund ABC. The distribution of X is $N(\mu, \sigma^2)$.

(i) Define $VaR_\alpha(X)$ with $\alpha \in [0, 1]$. [1 mark]

(ii) Show that: $VaR_\alpha(X) = -(\mu + \sigma \Phi^{-1}(\alpha))$

where Φ denotes the cumulative Normal distribution function.

(Hint: Consider the probability that X is less than VaR_α). [4 marks]

(iii) An investor holds K350m invested in ABC, the expected return on the fund is 10% and the standard deviation of that return is 25%. Use the above results to calculate the $VaR_{0.05}$. [2 marks]

(b) A farmer has a small apple tree which produces one harvest of apples per year. The number of apples the tree produces follows a Binomial with parameters; $N = 10$ and $p = 0.6$.

Determine the expected shortfall below a harvest of 5 apples. [3 marks]

(c) Consider a market with N securities. Let x_i denote the weight of security i in a portfolio, V_i the variance of the return on security i and C_{ij} the covariance between the returns on security i and security j .

(d)

(i) State the main assumptions of modern portfolio theory [2 marks]

(ii) Describe how an efficient portfolio can be found under mean-variance portfolio theory. [You do not have to include details of the partial derivatives and their solutions.] [4 marks]

(e) A market comprises 2 risky assets A and B and a risk free Asset C; with the following returns in different states of the world.

Table 4 Asset Returns in different states of the world

State	Probability	Asset A	Asset B	Asset C
1	0.2	-1%	-2%	3%
2	0.4	3%	5%	3%
3	0.4	6%	8%	3%
Market Capitalisation		25,000	75,000	

(iii) State the equation of the capital market line under the CAPM and use the data in Table 4 above to calculate the market price of risk. [4 marks]

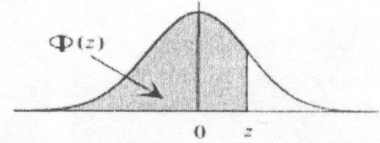
(f)

(i) Show that investors can diversify away specific risk by investing equal amounts in an increasing number of independent securities. [3 marks]

(ii) Without making any calculations, explain whether the result in part (iii) still holds true when the securities are correlated. [2 marks]

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

TABLE 1: AREAS UNDER THE NORMAL CURVE



z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
-3.4	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
-3.3	0.0005	0.0005	0.0005	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0003
-3.2	0.0007	0.0007	0.0006	0.0006	0.0006	0.0006	0.0006	0.0005	0.0005	0.0005
-3.1	0.0010	0.0009	0.0009	0.0009	0.0008	0.0008	0.0008	0.0008	0.0007	0.0007
-3.0	0.0013	0.0013	0.0013	0.0012	0.0012	0.0011	0.0011	0.0011	0.0010	0.0010
-2.9	0.0019	0.0018	0.0018	0.0017	0.0016	0.0016	0.0015	0.0015	0.0014	0.0014
-2.8	0.0026	0.0025	0.0024	0.0023	0.0023	0.0022	0.0021	0.0021	0.0020	0.0019
-2.7	0.0035	0.0034	0.0033	0.0032	0.0031	0.0030	0.0029	0.0028	0.0027	0.0026
-2.6	0.0047	0.0045	0.0044	0.0043	0.0041	0.0040	0.0039	0.0038	0.0037	0.0036
-2.5	0.0062	0.0060	0.0059	0.0057	0.0055	0.0054	0.0052	0.0051	0.0049	0.0048
-2.4	0.0082	0.0080	0.0078	0.0075	0.0073	0.0071	0.0069	0.0068	0.0066	0.0064
-2.3	0.0107	0.0104	0.0102	0.0099	0.0096	0.0094	0.0091	0.0089	0.0087	0.0084
-2.2	0.0139	0.0136	0.0132	0.0129	0.0125	0.0122	0.0119	0.0116	0.0113	0.0110
-2.1	0.0179	0.0174	0.0170	0.0166	0.0162	0.0158	0.0154	0.0150	0.0146	0.0143
-2.0	0.0228	0.0222	0.0217	0.0212	0.0207	0.0202	0.0197	0.0192	0.0188	0.0183
-1.9	0.0287	0.0281	0.0274	0.0268	0.0262	0.0256	0.0250	0.0244	0.0239	0.0233
-1.8	0.0359	0.0351	0.0344	0.0336	0.0329	0.0322	0.0314	0.0307	0.0301	0.0294
-1.7	0.0446	0.0436	0.0427	0.0418	0.0409	0.0401	0.0392	0.0384	0.0375	0.0367
-1.6	0.0548	0.0537	0.0526	0.0516	0.0505	0.0495	0.0485	0.0475	0.0465	0.0455
-1.5	0.0668	0.0655	0.0643	0.0630	0.0618	0.0606	0.0594	0.0582	0.0571	0.0559
-1.4	0.0808	0.0793	0.0778	0.0764	0.0749	0.0735	0.0721	0.0708	0.0694	0.0681
-1.3	0.0968	0.0951	0.0934	0.0918	0.0901	0.0885	0.0869	0.0853	0.0838	0.0823
-1.2	0.1151	0.1131	0.1112	0.1093	0.1075	0.1056	0.1038	0.1020	0.1003	0.0985
-1.1	0.1357	0.1335	0.1314	0.1292	0.1271	0.1251	0.1230	0.1210	0.1190	0.1170
-1.0	0.1587	0.1562	0.1539	0.1515	0.1492	0.1469	0.1446	0.1423	0.1401	0.1379
-0.9	0.1841	0.1814	0.1788	0.1762	0.1736	0.1711	0.1685	0.1660	0.1635	0.1611
-0.8	0.2119	0.2090	0.2061	0.2033	0.2005	0.1977	0.1949	0.1922	0.1894	0.1867
-0.7	0.2420	0.2389	0.2358	0.2327	0.2296	0.2266	0.2236	0.2206	0.2177	0.2148
-0.6	0.2743	0.2709	0.2676	0.2643	0.2611	0.2578	0.2546	0.2514	0.2483	0.2451
-0.5	0.3085	0.3050	0.3015	0.2981	0.2946	0.2912	0.2877	0.2843	0.2810	0.2776
-0.4	0.3446	0.3409	0.3372	0.3336	0.3300	0.3264	0.3228	0.3192	0.3156	0.3121
-0.3	0.3821	0.3783	0.3745	0.3707	0.3669	0.3632	0.3594	0.3557	0.3520	0.3483
-0.2	0.4207	0.4168	0.4129	0.4090	0.4052	0.4013	0.3974	0.3936	0.3897	0.3859
-0.1	0.4602	0.4562	0.4522	0.4483	0.4443	0.4404	0.4364	0.4325	0.4286	0.4247
0.0	0.5000	0.5040	0.5080	0.5120	0.5160	0.5199	0.5239	0.5279	0.5319	0.5359
0.1	0.5398	0.5438	0.5478	0.5517	0.5557	0.5596	0.5636	0.5675	0.5714	0.5753
0.2	0.5793	0.5832	0.5871	0.5910	0.5948	0.5987	0.6026	0.6064	0.6103	0.6141
0.3	0.6179	0.6217	0.6255	0.6293	0.6331	0.6368	0.6406	0.6443	0.6480	0.6517
0.4	0.6554	0.6591	0.6628	0.6664	0.6700	0.6736	0.6772	0.6808	0.6844	0.6879
0.5	0.6915	0.6950	0.6985	0.7019	0.7054	0.7088	0.7123	0.7157	0.7190	0.7224
0.6	0.7257	0.7291	0.7324	0.7357	0.7389	0.7422	0.7454	0.7486	0.7517	0.7549
0.7	0.7580	0.7611	0.7642	0.7673	0.7704	0.7734	0.7764	0.7794	0.7823	0.7852
0.8	0.7881	0.7910	0.7939	0.7967	0.7995	0.8023	0.8051	0.8078	0.8106	0.8133
0.9	0.8159	0.8186	0.8212	0.8238	0.8264	0.8289	0.8315	0.8340	0.8365	0.8389
1.0	0.8413	0.8438	0.8461	0.8485	0.8508	0.8531	0.8554	0.8577	0.8599	0.8621
1.1	0.8643	0.8665	0.8686	0.8708	0.8729	0.8749	0.8770	0.8790	0.8810	0.8830
1.2	0.8849	0.8869	0.8888	0.8907	0.8925	0.8944	0.8962	0.8980	0.8997	0.9015
1.3	0.9032	0.9049	0.9066	0.9082	0.9099	0.9115	0.9131	0.9147	0.9162	0.9177
1.4	0.9192	0.9207	0.9222	0.9236	0.9251	0.9265	0.9279	0.9292	0.9306	0.9319
1.5	0.9332	0.9345	0.9357	0.9370	0.9382	0.9394	0.9406	0.9418	0.9429	0.9441
1.6	0.9452	0.9463	0.9474	0.9484	0.9495	0.9505	0.9515	0.9525	0.9535	0.9545
1.7	0.9554	0.9564	0.9573	0.9582	0.9591	0.9599	0.9608	0.9616	0.9625	0.9633
1.8	0.9641	0.9649	0.9656	0.9664	0.9671	0.9678	0.9686	0.9693	0.9699	0.9706
1.9	0.9713	0.9719	0.9726	0.9732	0.9738	0.9744	0.9750	0.9756	0.9761	0.9767
2.0	0.9772	0.9778	0.9783	0.9788	0.9793	0.9798	0.9803	0.9808	0.9812	0.9817
2.1	0.9821	0.9826	0.9830	0.9834	0.9838	0.9842	0.9846	0.9850	0.9854	0.9857
2.2	0.9861	0.9864	0.9868	0.9871	0.9875	0.9878	0.9881	0.9884	0.9887	0.9890
2.3	0.9893	0.9896	0.9898	0.9901	0.9904	0.9906	0.9909	0.9911	0.9913	0.9916
2.4	0.9918	0.9920	0.9922	0.9925	0.9927	0.9929	0.9931	0.9932	0.9934	0.9936
2.5	0.9938	0.9940	0.9941	0.9943	0.9945	0.9946	0.9948	0.9949	0.9951	0.9952
2.6	0.9953	0.9955	0.9956	0.9957	0.9959	0.9960	0.9961	0.9962	0.9963	0.9964
2.7	0.9965	0.9966	0.9967	0.9968	0.9969	0.9970	0.9971	0.9972	0.9973	0.9974
2.8	0.9974	0.9975	0.9976	0.9977	0.9977	0.9978	0.9979	0.9979	0.9980	0.9981
2.9	0.9981	0.9982	0.9982	0.9983	0.9984	0.9984	0.9985	0.9985	0.9986	0.9986
3.0	0.9987	0.9987	0.9987	0.9988	0.9988	0.9989	0.9989	0.9989	0.9990	0.9990
3.1	0.9990	0.9991	0.9991	0.9991	0.9992	0.9992	0.9992	0.9992	0.9993	0.9993
3.2	0.9993	0.9993	0.9994	0.9994	0.9994	0.9994	0.9994	0.9995	0.9995	0.9995
3.3	0.9995	0.9995	0.9995	0.9996	0.9996	0.9996	0.9996	0.9996	0.9996	0.9997
3.4	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9998

$\alpha = 1 - \Phi(z_\alpha)$	
α	z_α
0.10	1.2816
0.05	1.6449
0.025	1.9600
0.010	2.3263
0.005	2.5758
0.001	3.0902
0.0005	3.2905
0.0001	3.7190
0.00005	3.8906
0.00001	4.2649

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
DEPARTMENT OF MATHEMATICS & STATISTICS

2018/2019 Academic Year Final Examinations
MAT 3100 ADVANCED CALCULUS

NOVEMBER, 2019

Total time allowed: Three (3) hours

Instructions:

- Answer any five (5) questions.
 - Show detailed working to earn full marks.
 - Each question carries 20 marks.
 - The total marks for this paper is 100.
-

1. (a) (i) State the Divergence theorem without proof.

[4 Marks]

- (ii) Hence or otherwise calculate the outward flux of \mathbf{F} ,

$$\iint_S \mathbf{F} \cdot d\mathbf{S},$$
 across the boundary of the region S :

$\mathbf{F}(x, y, z) = x^2\mathbf{i} + y^2\mathbf{j} + z^2\mathbf{k}$ and S is the region cut from the solid cylinder $x^2 + y^2 \leq a^2$ by the planes $z = 0$ and $z = 1$.

[6 Marks]

- (b) Use Lagrange Multipliers to find the maximum and minimum values of the function subject to the given constraints:

$$f(x, y, z) = x + 2y, \quad x + y + z = 1, \quad y^2 + z^2 = 4.$$

[6 Marks]

- (c) Let $\mathbf{F}(x, y, z) = e^x \sin y\mathbf{i} + e^x \cos y\mathbf{j} + z\mathbf{k}$. Find $\nabla^2 \mathbf{F}$.

[4 Marks]

2. (a) (i) Explain why the function $f(x, y) = ye^{xy}$ is differentiable at $(0, 1)$.

[4 Marks]

(ii) Find an approximation of $f(0.2, 1.2)$.

[2 Marks]

(b) Obtain the complex Fourier series for the function $f(t) = t$,
 $-\pi \leq t \leq \pi$, given that $f(t + 2\pi) = f(t)$.

[5 Marks]

(c) (i) State the Inverse Function theorem without proof.

[4 Marks]

(ii) Suppose that $\hat{f} : \mathbb{R}^2 \rightarrow \mathbb{R}^2$ is defined by

$$\hat{f} : \begin{pmatrix} x \\ y \end{pmatrix} \mapsto \begin{pmatrix} y^4 e^x + x - 4y \\ 2xy + 3y \end{pmatrix},$$

show that \hat{f} has a differentiable inverse near $(0, 1)$

[3 Marks]

(iii) Find the Jacobian matrix of the inverse mapping \hat{f}^{-1} .

[2 Marks]

3. (a) Find the general solution of the differential equation

$$t^2 y'' - 2y = 3t^2 - 1$$

using the method of variation of parameters.

[10 Marks]

(b) Evaluate

$$\int_{-2}^2 \int_{-\sqrt{4-x^2}}^{\sqrt{4-x^2}} \int_{\sqrt{x^2+y^2}}^2 (x^2 + y^2) dz dy dx.$$

[5 Marks]

(c) Given that

$$\mathbf{F}(x, y, z) = y\mathbf{i} + x\mathbf{j} + z\mathbf{k},$$

find

(i) $\text{curl}(\mathbf{F}) = \nabla \times \mathbf{F}$

[3 Marks]

(ii) $\text{div}(\mathbf{F}) = \nabla \cdot \mathbf{F}$

[2 Marks]

4. (a) (i) State Stokes' theorem without proof.

[4 Marks]

(ii) Hence or otherwise find $\int_C \mathbf{F} \cdot d\mathbf{r}$ given that $\mathbf{F}(x, y, z) = yz\mathbf{i} + 2xz\mathbf{j} + e^{xy}\mathbf{k}$ and C is the circle $x^2 + y^2 = 16, z = 5$.

[6 Marks]

- (b) Evaluate the integral

$$\iint_R 2e^{\frac{x+y}{x-y}} dA,$$

where R is the trapezoidal region with vertices $(1, 0)$, $(2, 0)$, $(0, -2)$ and $(0, -1)$.

[6 Marks]

- (c) Given that $z = f(x, y)$ has continuous second order partial derivatives and $x = r^2 + s^2, y = 2rs$, find $\frac{\partial^2 z}{\partial s^2}$.

[4 Marks]

5. (a) (i) Find the Fourier integral representation of the function

$$f(x) = \begin{cases} 1 & \text{if } |x| < 1, \\ 0 & \text{if } |x| > 1. \end{cases}$$

[5 Marks]

- (ii) Hence or otherwise prove that

$$\int_0^\infty \frac{\cos w \sin w}{w} dw = \frac{\pi}{4}.$$

[4 Marks]

- (b) Obtain the Fourier sine transform of the function $f(x) = e^{-ax}$, $a > 0$.

[7 Marks]

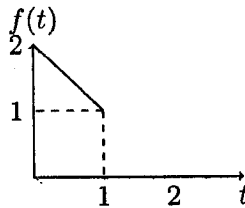
- (c) Find the directional derivative of $f(x, y) = 3x^3 - 4xy$ along the parabola $y = 2x^2 - x + 2$ at the point $((1, 3))$.

[4 Marks]

6. (a) Given that $\mathcal{L}(f) = \frac{2(e^{-s} - e^{-3s})}{s^2 - 4}$. Find the inverse Laplace transform.

[7 Marks]

- (b) (i) Obtain the even periodic extension of the function below



[5 Marks]

- (ii) Sketch the corresponding periodic extension of f for $0 \leq t \leq 5$

[2 Marks]

- (c) Given that $\mathbf{F}(x, y, z) = z\mathbf{i} + y\mathbf{j} + x\mathbf{k}$,

- (i) Show that $\mathbf{F}(x, y, z)$ is conservative.

[2 Mark]

- (ii) Find the work done by \mathbf{F} in moving a particle along the curve C given by

$$\mathbf{r}(t) = 3t\mathbf{i} - 5t\mathbf{j} + t^2\mathbf{k}, \quad -1 \leq t \leq 1.$$

[4 Marks]

7. (a) Solve the shifted data Initial Value Problem by the Laplace transform:

$$y'' + 3y' - 4y = 6e^{2t-3}, \quad y(1.5) = 4, \quad y'(1.5) = 5.$$

[5 Marks]

- (b) Find the general solution of the non-homogeneous system

$$\begin{cases} y_1' = y_1 - 2y_2 + \cos t \\ y_2' = -2y_1 + y_2 - \sin t. \end{cases}$$

[10 Marks]

(c) Evaluate the line integral

$$\int_C x^2 y^2 dx + 4xy^3 dy$$

where C consists of line segments from $(0, 0)$ to $(0, 3)$, $(0, 3)$ to $(1, 3)$ and $(1, 3)$ to $(0, 0)$.

[5 Marks]

-END OF EXAM-

The University of Zambia
School of Natural Sciences
Department of Mathematics and Statistics

2018/19 Academic Year Examinations

MAT 3110 Engineering Mathematics II

November 18, 2019.

Duration: THREE Hours

Instructions:

- Do not open this booklet until you are told to do so.
 - This paper consists of seven questions, each carry 20 marks. Attempt any FIVE questions. Total marks is 100.
 - Show all the essential working to earn full marks.
 - Non programmable calculators are allowed.
-

1. (a) Use power series method to find the general solution of the following ordinary differential equation. (9)

$$(x + 2)y'' + xy' - y = 0.$$

- (b) Find the general of the following Euler equation. (4)

$$x^2y'' - 7xy' + 16y = 0.$$

- (c) Find the solution to the following initial value problem (7)

$$\mathbf{x}' = \begin{pmatrix} 3 & -13 \\ 5 & 1 \end{pmatrix} \mathbf{x}, \quad \mathbf{x}'(0) = \begin{pmatrix} 3 \\ -10 \end{pmatrix}.$$

2. (a) Solve the initial value problem below using Laplace transforms. (12)

$$y'' + 4y' = \cos(t - 3) + 4t, \quad y(3) = 0, \quad y'(3) = 7.$$

- (b) i. Determine the Laplace transforms of the function (4)

$$f(t) = t^2 \cosh t$$

- ii. **Find and sketch** the inverse Laplace transform of (4)

$$F(s) = \frac{e^{-2s} - e^{-3s}}{s^2}$$

3. (a) Evaluate the following double integrals.

i.

$$\iint_D e^{-x-2y} dA$$

where D is the region in the 1st quadrant in which $y \leq x$.

ii.

$$\int_0^4 \int_{\sqrt{x}}^2 \frac{1}{1+y^3} dy dx$$

- (b) Find the area of the region in the 1st quadrant that is between $x^2 + y^2 = 1$ and $x^2 + y^2 = 4$. (5)

- (c) Using a double integral to find the volume of the solid that is bounded by $z = 3 - 2y$, $y = 1 - x^2$, $y = 0$ and the plane $z = 0$. (5)

4. (a) Evaluate the following triple integrals.

i.

$$\int_0^2 \int_0^4 \int_z^2 yze^{x^3} dx dy dz \quad (5)$$

ii.

$$\int_0^1 \int_0^{\sqrt{1-x^2}} \int_0^{\sqrt{1-x^2-y^2}} \frac{dz dy dx}{1+x^2+y^2+z^2} \quad (5)$$

(b) Find the volume of the solid that is bounded by $x^2+y^2+z^2 = 4$, $x^2+y^2+z^2 = 25$, and $z = -\sqrt{\frac{1}{3}x^2 + \frac{1}{3}y^2}$. (5)

(c) Convert the triple integral (5)

$$\int_{-1}^1 \int_0^{\sqrt{1-y^2}} \int_{x^2+y^2}^{\sqrt{x^2+y^2}} xyz dz dy dx$$

into a triple integral in cylindrical coordinates. (Do not evaluate the integral)

5. (a) Let $\mathbf{F}(x, y, z) = \frac{x}{\sqrt{x^2+z^2}} \mathbf{i} + (2yz - 6y) \mathbf{j} + \left(y^2 + \frac{z}{\sqrt{x^2+z^2}}\right) \mathbf{k}$.

i. Prove that \mathbf{F} is conservative. (4)

ii. Evaluate (6)

$$\int_C \mathbf{F} \cdot d\mathbf{r}$$

where C the line segment from $(1, 0, -1)$ to $(2, -4, 3)$.

(b) Evaluate (5)

$$\int_C z^3(x+7) - 2y ds$$

where C is a circle in space of radius 1 centered at $(-3, 0, 0)$ and lying on the plane $x = -3$.

(c) Evaluate the line integral (5)

$$\int_C \mathbf{F} \cdot d\mathbf{r}$$

where $\mathbf{F}(x, y) = y\mathbf{i} + (1-x)\mathbf{j}$ and C consists of the line segments $(-1, 0)$ to $(2, 0)$, $(2, 0)$ to $(3, 2)$, $(3, 2)$ to $(0, 2)$ and $(0, 2)$ to $(-1, 0)$.

6. (a) Evaluate

$$\int_S z dS$$

where S is the upper half of a sphere of radius 2 centered at the origin.

- (b) Use Stoke's theorem to evaluate the integral (6)

$$\int_C \mathbf{F} \cdot d\mathbf{r}$$

where $\mathbf{F}(x, y, z) = (zx^3 - 2z) \mathbf{i} + xz \mathbf{j} + xy \mathbf{k}$ and C is the triangle with vertices $(0, 0, 4)$, $(0, 2, 0)$ and $(2, 0, 0)$. Direction is $(2, 0, 0)$ to $(0, 0, 4)$, then $(0, 0, 4)$ to $(0, 2, 0)$ and then $(0, 2, 0)$ to $(2, 0, 0)$.

- (c) Evaluate the surface integral (6)

$$\int_S \mathbf{F} \cdot d\mathbf{S}$$

where $\mathbf{F}(x, y, z) = -xy \mathbf{i} + (z - 1) \mathbf{j} + z^3 \mathbf{k}$ and S the surface of the solid bounded by $y = 4x^2 + 4z^2 - 1$ and the plane $y = 7$. Note that both of the surfaces of this solid are included in S .

7. During an epidemic of a certain disease a doctor is consulted by 110 people suffering from symptoms commonly associated with the disease. Of the 110 people, 45 are female of whom 20 actually have the disease and 25 do not. Fifteen males have the disease and the rest do not.

- (a) A person is selected at random, The event that this person is female is denoted by A and the event that this person is suffering from the disease is denoted by B . Evaluate

- i. $P(A)$ (1)
- ii. $P(A \cup B)$, (2)
- iii. $P(B | A)$, (2)
- iv. $P(A | B)$. (2)

- (b) If three different people are selected at random without replacement, what is the probability of

- i. all three having the disease, (2)
- ii. exactly one of the three having the disease, (2)
- iii. one of the three being a female with the disease, one a male with the disease and one a female without the disease? (3)

- (c) Of the people with the disease 96% react positively to a test for diagnosing the disease as do 8% of people without the disease. What is the probability of a person selected at random

- i. reacting positively, (3)
- ii. having the disease given that he or she reacted positively. (3)

————— End of Examination —————

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
DEPARTMENT OF MATHEMATICS & STATISTICS
2018/19 Academic Year
End of Year Final Examinations

15 November 2019 (am)

MAT3300 – Real Analysis

Time allowed : **Three (3) hours**

Full marks : **100**

Instructions: • There are **six (6)** questions in this paper. Attempt **any five (5)** questions.

- Mark allocations are shown in brackets.
- **Full credit** will only be given when **necessary work** is shown.
- Indicate your **computer number** on all answer booklets used.

This paper consists of 4 pages of questions.

1. (a) Let A be a subset of \mathbb{R} . When is a point $x \in \mathbb{R}$ called

(i) an interior point of A , (1)

(ii) a limit point of A , (1)

(iii) a boundary point of A . (1)

(b) Let $A = \bigcap_{n=1}^{\infty} \left[a, b + \frac{1}{n} \right)$, where a and b are real numbers such that $a < b$.

(i) Discuss whether A is open or closed in \mathbb{R} . Justify each statement you make. (5)

(ii) Determine the interior, closure, and boundary of A . (1)

- (c) Let $K_1 = [0, \frac{1}{3}] \cup [\frac{2}{3}, 1]$ be obtained from $[0, 1]$ by removing the middle third $(\frac{1}{3}, \frac{2}{3})$. Repeat the process to obtain $K_2 = [0, \frac{1}{9}] \cup [\frac{2}{9}, \frac{1}{3}] \cup [\frac{2}{3}, \frac{7}{9}] \cup [\frac{8}{9}, 1]$. In general, K_{n+1} is obtained from K_n by removing the middle third of each interval in K_n .

Let $K = \bigcap_{n=1}^{\infty} K_n$, also known as the Cantor set. Prove that

- (i) K is compact, (2)
 - (ii) the interior of K is empty, (2)
 - (iii) K has infinitely many points, (2)
 - (iv) the total length of the intervals removed is equal to 1. (2)
- (d) (i) State what is meant by a set $E \subset \mathbb{R}$ is connected. (1)
- (ii) Let K be the Cantor set as defined in (c). Prove that K is totally disconnected. (2)
2. (a) (i) State the $\varepsilon - \delta$ definition that a function $f : \mathbb{R} \rightarrow \mathbb{R}$ is continuous at $c \in \mathbb{R}$. (2)
- (ii) Prove that if f is continuous at $c \in \mathbb{R}$ and $f(c) \neq 0$, then there exists a $\delta > 0$ such that for all $x \in \mathbb{R}$,

$$|x - c| < \delta \implies |f(x)| > \frac{|f(c)|}{2}. \tag{3}$$

- (b) Every rational x can be written in the form $x = m/n$, where $n > 0$, and m and n are integers without any common divisors. When $x = 0$, we take $n = 1$.

Consider the function f defined on \mathbb{R} by

$$f(x) = \begin{cases} 0 & \text{if } x \text{ is irrational,} \\ \frac{1}{n} & \text{if } x = \frac{m}{n}. \end{cases}$$

Prove that

- (i) f is continuous at every irrational point.
 - (ii) f has a simple discontinuity at every rational point. (7)
- (c) Use the Intermediate Value Theorem for continuous functions to prove that

$$\frac{2}{1+x^2} + 3\cos(\pi x) = 0$$

- has at least two solutions in $[-1, 1]$. (4)

(d) Use Rolle's Theorem to prove that

$$\frac{2}{1+x^2} + 3\cos(\pi x) = 0$$

has exactly one solution in $[-1, 1]$. (4)

3. (a) (i) Suppose $A \subseteq \mathbb{R}$ and $f : A \rightarrow \mathbb{R}$ is uniformly continuous. Prove that if $\{x_n\}$ is a Cauchy sequence in A , then $\{f(x_n)\}$ is Cauchy too. (3)

(ii) Find a continuous function $f : A \rightarrow \mathbb{R}$ and a Cauchy sequence $\{x_n\}$ such that $\{f(x_n)\}$ is not Cauchy. (2)

(b) Let A be a compact subset of \mathbb{R} and $f : A \rightarrow \mathbb{R}$ a continuous function on A . Prove that $f(A)$ is compact. (4)

(c) Suppose that $f : [a, b] \rightarrow \mathbb{R}$ is a Lipschitz function with a Lipschitz constant $c > 0$. Prove that f is absolutely continuous on $[a, b]$. (4)

(d) In the closed interval $[0, 1]$, a function f is defined as follows: $f(0) = 0$, $f(1) = 1$ and $f(m/n) = 1/n^3$, where m and n are positive integers such that $(m, n) = 1$. Furthermore, for irrational x , we define $f(x) = 0$.

Show that f is of bounded variation. (*Hint:* $\sum_{n=1}^{\infty} 1/n^2 = \pi^2/6$.) (7)

4. (a) (i) State the Interior Minimum Theorem. (1)

(ii) Suppose a real-valued function f is differentiable on $[a, b]$ and $f'(a) < \lambda < f'(b)$. Prove that there exists a point $c \in (a, b)$ such that $f'(c) = \lambda$. (4)

(b) (i) State the Cauchy Mean Value Theorem. (2)

(ii) Suppose that a real function f is continuous on $[a, b]$ and differentiable in (a, b) . Show that if $f > 0$ and $f' \neq 0$ on $[a, b]$, then there exists $c \in (a, b)$ such that

$$f(b) = f(a) + \ln\left(\frac{f(b)}{f(a)}\right)f(c).$$

Remark: No derivative appears on the right-hand side! (4)

(c) Suppose that the derivative f' is continuous on the closed interval $[a, b]$ and $\varepsilon > 0$. Prove that there exists $\delta > 0$ such that

$$\left| \frac{f(y) - f(x)}{y - x} - f'(x) \right| < \varepsilon$$

whenever $0 < |y - x| < \delta$, $a \leq x \leq b$ and $a \leq y \leq b$. (5)

(d) Suppose that $f : \mathbb{R} \rightarrow \mathbb{R}$ is a C^2 function that satisfies $f \geq 0$ and $f'' \leq 0$ everywhere. Use Taylor's theorem to show that f is a constant function. (4)

5. (a) Let $f : [a, b] \rightarrow \mathbb{R}$ be a bounded function. Define what is meant by
- (i) a partition P of $[a, b]$, (1)
 - (ii) the upper and lower sums, $U(P, f)$ and $L(P, f)$ respectively, (2)
 - (iii) the upper and lower integrals, $\overline{\int_a^b} f$ and $\underline{\int_a^b} f$ respectively, (2)
 - (iv) f is Riemann integrable over $[a, b]$. (1)
- (b) (i) State the Riemann–Stieltjes integrability criterion theorem. (1)
- (ii) 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 $P = \{0, 2/5, 3/5, 1\}$ of $[0, 1]$, (6)

$$U(P, f, \alpha) - L(P, f, \alpha) < \frac{1}{3}.$$

- (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 $\int_0^1 f \, dx > 0$. (5)
- (ii) Construct a nonnegative function f on $[0, 1]$ with $f(1/3) > 0$ but $\int_0^1 f \, dx = 0$. (2)
6. (a) (i) State the fundamental theorem of calculus. (2)
- (ii) Assume f is a real continuously differentiable function on $[a, b]$, $f(a) = f(b) = 0$, and $\int_a^b f^2(x) \, dx = 1$. Prove that (6)
- $$\int_a^b x f(x) f'(x) \, dx < 0 \quad \text{and that} \quad \int_a^b [f'(x)]^2 \, dx \cdot \int_a^b x^2 f^2(x) \, dx > 0.$$
- (b) Suppose f is a real continuously differentiable function on $[a, b]$ and $f(a) = f(b) = 0$.
 Prove that if f has integrable first and second derivatives then $\int_a^b f f'' \, dx \leq 0$.
Hint: Use the theorem for integration by parts. (4)
- (c) Consider the improper integral $\int_0^\infty e^{-x} \sin x \, dx$.
- (i) Prove that the integral converges. (5)
 - (ii) Does the integral converge absolutely? (*Hint:* $|e^{-x} \sin x| \leq e^{-x}$) (3)

END OF PAPER

The University of Zambia
School of Natural Sciences
Department of Mathematics and Statistics
2018/19 Academic Year Final Examinations
MAT3622 - Linear Regression

Time allowed : 3 Hours

Instructions:

- There are **five (5)** questions in this examination paper. Attempt **any four (4)** questions. **All** questions carry **equal** marks.
- Indicate your **Computer Number** on all your answer booklets.
- You are required to show all **necessary** steps in your solutions.

This paper consists of 4 pages of questions.

1. (a) Consider the multiple linear regression model $Y = X\beta + \epsilon$, $\epsilon \sim N(0, \sigma^2 I)$.
 - (i) Find the maximum likelihood estimates of β .
 - (ii) Show that the residuals from a linear regression model can be expressed as $e = (I - H)\epsilon$, where H is the "hat" matrix.
 - (iii) Show that H and $I - H$ are symmetric and idempotent.
 - (iv) Find $\text{Var}[e]$.
 - (v) Find $\text{COV}(\hat{\beta}, Y - X\hat{\beta})$.
 - (vi) Find $\text{Var}(\hat{\beta})$.
 - (vii) Find $E(e'e)$.
 - (b) Suppose we fit the model $y = X_1\beta_1 + \epsilon$ when the true model is actually given by $y = X_1\beta_1 + X_2\beta_2 + \epsilon$. For both models, assume $E(\epsilon) = 0$ and $\text{Var}(\epsilon) = \sigma^2 I$. Find the expected value of the ordinary least squares estimate, $\hat{\beta}_1$. Under what conditions is this estimate unbiased?
2. (a) Suppose that a one-way analysis of variance involves four treatments but that a different number of observations (e.g., n_i) has been taken under each treatment. Assuming that $n_1 = 3$, $n_2 = 2$, $n_3 = 4$ and $n_4 = 3$.
 - (i) Write down the y vector and X matrix for analysing these data as a multiple regression model.

- (ii) Obtain the least squares estimates of the model parameters.
- (b) The data below were used to relate annual regional advertising expenses to annual regional concentrate sales for a soft drink company. The table below presents the twenty years of these data. It is assumed that a straight-line relationship was appropriate.

Year (t)	Sales y_t	Expenditures $x_t(10^3 \text{ Kwachas})$	Residuals
1	3083	75	-32.3298
2	3149	78	-26.6027
3	3218	80	2.2154
4	3239	82	-16.9665
5	3295	84	-1.1484
6	3374	88	-2.5123
7	3475	93	-1.9671
8	3569	97	11.6691
9	3597	99	-0.5128
10	3725	104	27.0324
11	3794	109	-4.4224
12	3959	115	40.0318
13	4043	120	23.5770
14	4194	127	33.9403
15	4318	135	-2.7874
16	4493	144	-8.6060
17	4683	153	0.5753
18	4850	161	6.8476
19	5005	170	-18.9710
20	5236	182	-29.0625

- (i) Fit a simple linear regression model to these data.
- (ii) Plot residuals versus time and explain whether you find any evidence of positive autocorrelation.
- (iii) Conduct a formal test for positive autocorrelation using a significance level of 0.05. Clearly stating the alternatives, decision rule, and conclusion.
- (iv) Is the residual analysis in part (ii) in accord with the test result in (iii)?
3. (a) Suppose the experimenter postulates a model
 $y_i = \beta_0 + \beta_1 x_i + \varepsilon_i$ ($i = 1, 2, \dots, n$) and $\varepsilon_i \sim N(0, \sigma^2)$.
- (i) Find the least squares estimates of β_0 and β_1 .
- (ii) Find the variances of the estimators of β_1 and β_0 .
- (iii) Prove that the estimates in (i) are uncorrelated if and only if $\bar{x} = 0$.
- (iv) Show that $E\left[\sum_{i=1}^n (\varepsilon_i - \bar{\varepsilon})^2\right] = (n-1)\sigma^2$.
- (b) Suppose that we want to fit the no-intercept model
 $y_i = \beta x_i + \varepsilon_i$ using weighted least squares. Assume that the observations are uncorrelated but have unequal variances.

- (i) Find a general formula for the weighted least-squares estimator of β .
- (ii) Find the variance of the weighted least-squares estimator in (i)?
- (iii) Suppose that $Var(y_i) = cx_i$ that is, the variance of y_i is proportional to the corresponding x_i . Using the results of parts (i) and (ii), find the weighted least-squares estimator of β and the variance of this estimator.
- (iv) Suppose that $Var(y_i) = cx_i^2$ that is, the variance of y_i is proportional to the square of the corresponding x_i . Using the results of parts (i) and (ii), find the weighted least-squares estimator of β and the variance of this estimator.
4. (a) Consider a simple linear regression model with first-order autoregressive errors $y_t = \beta_0 + \beta_1 x_t + \varepsilon_t$ where $\varepsilon_t = \rho\varepsilon_{t-1} + a_t$.
- (i) Define autocorrelation.
- (ii) Show that $\varepsilon_t = \sum_{j=0}^{\infty} \rho^j a_{t-j}$.
- (iii) Find $E(\varepsilon_t^2)$.
- (iv) Find $Cov(\varepsilon_t, \varepsilon_{t-2})$.
- (b) In a small-scale regression study, the following data were obtained:

$Y_i:$	42	33	75	28	91	55
$X_{i1}:$	7	4	16	3	21	8
$X_{i2}:$	33	41	7	49	5	31

- (i) Define \mathbf{Y} , \mathbf{X} , β , and ε for a model involving both independent variables and an intercept.
- (ii) Compute $\mathbf{X}'\mathbf{X}$ and $\mathbf{X}'\mathbf{Y}$.
- (iii) $(\mathbf{X}'\mathbf{X})^{-1}$ for this problem is

$$(\mathbf{X}'\mathbf{X})^{-1} = \begin{bmatrix} 34.57855744 & -1.65089268 & -0.65704022 \\ -1.65089268 & 0.08030796 & 0.03112763 \\ -0.65704022 & 0.03112763 & 0.01268501 \end{bmatrix}$$

Verify that this is the inverse of $\mathbf{X}'\mathbf{X}$.

- (iv) Compute $\hat{\beta}$ and write the regression equation.
- (v) Test the significance of the regression at $\alpha = 0.05$.
- (vi) Construct a 95% confidence interval for each of the parameters in the model.



The University of Zambia
School of Natural Sciences
Department of Mathematics and Statistics
2018-19 Academic Year
End of Year University Examinations
MAT4022: Pension Design and Valuation

Time: Three hours.

[Maximum Marks : 100]

1. Attempt All questions. All questions carry equal marks.
2. Write clearly your computer number on each answer booklet.
3. Show all essential working

Some Useful Formulas:

Probabilities

Joint life

$$\begin{aligned} {}_t p_{x:y} &= {}_t p_x {}_t p_y \\ {}_t q_{x:y} &= {}_t q_x + {}_t q_y - {}_t q_{\overline{x:y}} \end{aligned}$$

last survivor

$$\begin{aligned} {}_t q_{\overline{x:y}} &= {}_t q_x {}_t q_y \\ {}_t p_{\overline{x:y}} &= {}_t p_x + {}_t p_y - {}_t p_{x:y} \end{aligned}$$

Joint Assurances and annuities

$$\begin{aligned} A_{\overline{x:y}} &= A_x + A_y - A_{x:y} \\ \ddot{a}_{\overline{x:y}} &= \ddot{a}_x + \ddot{a}_y - \ddot{a}_{x:y} \end{aligned}$$

Contingent Assurances

$$A_{x:y}^1 + A_{x:y}^{\overline{1}} = A_{x:y}$$

Reversionary annuities

$$\ddot{a}_{x|y} = \ddot{a}_y - \ddot{a}_{x:y} \cong a_y - a_{x:y} = a_{x|y}$$

Independent and Dependent joint life functions

$$\begin{aligned} (aq)_x^k &= \frac{(ad)_x^k}{(al)_x} \\ (al)_{x+1} &= (al)_x - (ad)_x^k - (ad)_x^{-k} \\ (aq)_x^k &= \frac{\mu_x^k}{\sum_j \mu_x^j} \left(1 - e^{-\sum_j \mu_x^j} \right) \\ q_x^k &= \frac{(aq)_x^k}{1 - \frac{1}{2}(aq)_x^{-k}} \quad \text{where } -k \text{ indicates the state not } k \\ (aq)_x^k &= q_x^k \left[1 - \frac{1}{2} \sum_{i \neq k} q_x^i + \frac{1}{3} \sum_{i \neq k} \sum_{j \neq i, k} q_x^i q_x^j + \dots \right] \end{aligned}$$

QUESTION ONE

- (a) List any two roles and two responsibilities of pension fund trustees. [2]
- (b) Outline any two possible challenges that arise in trying to achieve the above for trustees for pension funds in Zambia. [2]
- (c) The government of a developing SADC country is keen to ensure the adequacy of its future pension provision. The country has had only private pension provision through occupational schemes and private individual pension purchased through life assurance companies. Two proposals have been made.

Proposal A: To introduce a national social security scheme in line with existing global arrangements.

Proposal B: To introduce some form of compulsory private pensions provision

- (i) Outline the key issues associated with proposal A. [5]
- (ii) List the approaches that a state may take to maximise the security of benefits that are provided through proposal B. [5]
- (d) (i) Define the term net replacement ratio. [1]
- (ii) Discuss how the scheme design affects net replacement ratio for an individual member. [5]

[Total 20 marks]

QUESTION TWO

- (a) Distinguish between the *joint life* and *last survivor* statuses for two independent lives. Write down an expression for the future life time of each status in terms of the future life time of the two individual lives. Define all notation used. [5]
- (b) Assuming that the AM92 life table is appropriate for both lives and that the survival of each is independent. Calculate
- (i) ${}_3P_{62:65}$, [2]
- (ii) ${}_2P_{45:\overline{47}}$ [3]

- (c) A pension is payable at the rate of K24,000 p.a. (in arrears) to a married couple. On the first death, the pension continues to be paid at two thirds of its original level. Find the value of this pension if it is payable to a couple where the husband is 65 and the wife is aged 60. Use PFA92C20 and PMA92C20 at 4% interest [4]
- (d) Explain the following terms and give an example of each:
- (i) class selection
 - (ii) spurious selection
 - (iii) time selection

[6]

[Total 20 marks]

QUESTION THREE

- (a) (i) Describe three distinct methods of averaging salary that might be defined in the scheme rules of a pension fund [3]
- (ii) Define s_x and z_x , in the context of a pension fund. [2]
- (iii) In order to value the benefits in a final salary pension scheme as at 1 January 2008, a salary scale, s_x , has been defined so that s_{x+t}/s_x is the ratio of a member's total earnings between ages $x + t$ and $x + t + 1$ to the member's total earnings between ages x and $x + 1$.
Salary increases take place on 1 July every year. One member, whose date of birth is 1 April 1961, has an annual salary rate of K75 000 on the valuation date. Write down an expression for the member's expected earnings during 2008. [5]
- (b) An amount of K300 000 is to be divided between the survivors of the three males aged 30, 35 and 40 in 20 years time. Find the expected values of the amount received by (40). Use AM92 Ultimate and 4% interest. [10]

[Total 20 marks]

QUESTION FOUR

(a) A population is subject to three modes of decrement, a , b and c , all uniformly distributed over each year of age in a single decrement table.

(i) Starting from the definition

$$(aq)_x^a = \int_0^1 {}_t(ap)_x \cdot (a\mu)_{x+t}^a dt$$

and using the fact that ${}_t(ap)_x = {}_t p_x^a \cdot {}_t p_x^b \cdot {}_t p_x^c$ and $(a\mu)_{x+t}^a = \mu_{x+t}^a$ together with the assumption of uniform distribution of decrements, demonstrate that the probability of a life aged x exiting from an active life is

$$(aq)_x^a = q_x^a \left[1 - \frac{1}{2} (q_x^b + q_x^c) + \frac{1}{3} q_x^b q_x^c \right]$$

for integer ages x , where q_x^i and $(aq)_x^i$ are the independent and dependent rates of mortality for decrement i , respectively. [4]

(ii) In the particular case that

$$q_{40+t}^a = 0.010 + 0.002t, \quad q_{40+t}^b = 0.050 + 0.005t, \quad q^c = 0.002$$

for $t = 0, 1, \dots, 5$, calculate ${}_2(aq)_{40}^a$ defining the meaning of this quantity. [6]

(b) The table extract below shows the death statistics in a population due to cancer and other causes.

Age (x)	Population (al) $_x$	Cancer (ad) $_x^c$	Others (ad) $_x^o$
61	10,000	55	248
62	9,697	175	533
63	8,989		

Recent changes have resulted in an estimate that the annual independent cancer death rate is reduced by 20% than that previously used. Calculate a revised table assuming no changes to the other independent death rates.

- (i) Calculate dependent rates $[(aq)_x^k]$ from the information given. [1]
- (ii) Calculate approximate independent rates $[q_x^k]$ [3]
- (iii) Make the necessary adjustment given and calculate approximate dependent rates $[(aq)_x^k]$ from the adjusted independent rates. [4]
- (iv) Reconstruct the Revised Table. [2]

[Total 20 marks]

QUESTION FIVE

- (a) Explain in general terms, how a life office may become susceptible to adverse selection. [4]
- (b) A life insurance company issues a three-year unit-linked endowment assurance contract to a male life aged 45 exact under which level annual premiums of K6, 500 are payable at the start of each year. 90% of the premium is allocated to units. The units are subject to a bid-offer spread of 3% and an annual management charge of 1% of the bid value of the units is deducted at the end of each year before any benefits are paid.

If the policyholder dies during the term of the policy, the death benefit of K20, 000 or the bid value of the units after the deduction of the management charge, whichever is higher, is payable at the end of the year of death. On survival to the end of the term, the bid value of the units plus a bonus of 10% is awarded.

Basis:

- Mortality: AM92 Select
- Initial expenses: K250 incurred at outset
- Renewal expenses: K70 incurred at the start of each of years 2 and 3
- Non-unit fund interest rate: 4% per annum
- Unit fund growth rate: 7% per annum Calculate the profit vector, before allowing for non-unit reserves. [16]

[Total 20 marks]

=====END OF MAT4022 EXAMINATION =====

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
DEPARTMENT OF MATHEMATICS & STATISTICS
2018/19 Academic Year
End of Year Final Examinations

7 November 2019 (am)

MAT4032 – Financial Engineering

Time allowed : **Three (3) hours**

Full marks : **100**

- Instructions:**
- There are **six (6)** questions in this paper.
 - Attempt **any five (5)** questions. All questions carry **equal** marks.
 - Mark allocations are shown in brackets.
 - **Full credit** will only be given when **necessary work** is shown.
 - Indicate your **computer number** on all answer booklets used.

Formulae and Tables are provided.

1. (a) (i) Give four defining characteristics of a Brownian Motion W_t , such that $W_0 = 0$. (2)
(ii) Derive the value of a which makes

$$\exp(\sigma W_t - at)$$

a Martingale when W_t is a standard Brownian Motion. (3)

- (b) Consider a stochastic differential equation

$$dX_t = Y_t dW_t + A_t dt,$$

where A_t is a deterministic process and Y_t is a process adapted to the natural filtration of W_t .

- (i) Write down Ito's lemma for $f(t, X_t)$, where f is a suitable function. (2)

- (ii) Determine $df(t, X_t)$ where $f(t, X_t) = e^{4t^2 X_t}$. (3)

- (c) Let $(X_t; t \geq 0)$ be a stochastic process satisfying

$$X_t = X_0 + \int_0^t \mu_s ds + \int_0^t \sigma_s dW_t,$$

where W_t is a standard Brownian motion.

Let $f : \mathbb{R} \times \mathbb{R} \rightarrow \mathbb{R}$ be a function, twice partially differentiable with respect to x , once with respect to t .

- (i) State the stochastic differential equation for $f(t, X_t)$. (2)

- (ii) Let $dX_t = -\gamma(X_t - \mu) dt + \sigma dW_t$.

Prove that the solution of this stochastic differential equation is given by

$$X_t = X_0 e^{-\gamma t} + \mu(1 - e^{-\gamma t}) + \sigma \int_0^t e^{-\gamma(t-s)} dW_s. \quad (8)$$

2. (a) State how the price at time t of a zero-coupon bond paying K1 at T (denoted by $P(t, T)$) is related to

- (i) spot rate curve,
(ii) instantaneous forward rate curve,
(iii) instantaneous risk free rate.

Define all notation used. (6)

- (b) Let $B(t, T)$ be the price at time t of a zero-coupon bond paying K_1 at time T , r_t the short-rate of interest, P the real world probability measure and Q the risk neutral probability measure.
- (i) Write down two equations for the price of a zero-coupon bond, one of which uses the risk-neutral approach to pricing and the other of which uses the state-price-deflator approach to pricing. (2)
 - (ii) State the Stochastic Differential Equation (SDE) of the short rate r_t under Q for the Vasicek model and the general type of process this SDE represents. (3)
 - (iii) Solve the SDE for the short rate r_t from part (ii). (6)
 - (iv) Deduce the form of the distribution of the zero-coupon bond price under this model. (3)
3. (a) Explain what is meant by an option. (3)
- (b) Consider a three-period binomial model for a stock with the following parameters:
- $$u = 1.2, \quad d = 0.9 \quad \text{and} \quad S_0 = 60.$$
- Assume the discretely compounded risk-free rate of interest is $r = 11\%$ per period.
- (i) α) Verify that there is no arbitrage in the market. (2)
 - β) Construct the binomial tree. (2)
 - (ii) Calculate the price of a standard European call option with maturity date in three periods and strike price $K = 60$. (8)
- (c) Consider the problem in part (b). A new “knock-in” option is introduced which has the following characteristics: If the value of the stock crosses the level 80 during the whole life of the option, the contract holder has the right to obtain the difference between the value of the stock at maturity (in three periods) and 60. Calculate the price of this new option (5)
4. (a) Describe what is meant by an arbitrage opportunity. (3)
- (b) (i) List five factors that affect the price of a European put option on a non-dividend paying share. (3)
- (ii) State how the premium for a European put option would change if each of these factors increased. (3)
- (c) Discuss whether one-factor models are good models for the short-rate of interest (instantaneous risk free rate). Include discussion of extensions that may be considered to improve the model. Illustrate your discussion by defining and referring to particular models. (7)

- (d) Consider an asset with price S_t at time t , paying a dividend at a constant dividend yield D . Dividends are paid at the end of each year and are immediately reinvested in the asset. The continuously compounded risk-free rate of interest is r pa.

Derive the forward price of a contract issued at time 0 with maturity at time T , to trade one unit of the asset, where T is an integer number of years. State any assumptions you make. (4)

5. (a) Explain what is meant by a “risk-neutral probability measure” and state mathematically what it implies about the pricing of derivatives relative to the price of the underlying asset. (2)

- (b) A non-dividend paying stock has a current price of $S_0 = 140$ and trades in a market which is arbitrage free and has a constant effective risk-free rate of interest r . After one year the price of the stock could increase to 270, or decrease to 110. Over the following year the price could increase from 270 either to 410 or to 312. If the stock price had decreased to 110, then over the following year it could increase to 158 or decrease to 102.

- (i) Determine the range of values that the annual risk-free interest rate could take. (3)

- (ii) Assume that r takes the value 30% per annum. Calculate the price at time 0 of a non-standard derivative which pays off

$$(S_2 - 100)^2$$

at the end of two years. (7)

- (c) Consider a binomial tree model for the non-dividend paying stock with price S_t .

Assume this price either rises by 20% or falls by 10% each month for the next three months. Assume also that the risk-free rate is 3% per annum continuously compounded.

Let $S_0 = K100$.

- (i) Calculate the price of a vanilla European call option with maturity in three months' time and a strike price of K95. (4)

- (ii) Calculate the price of a vanilla European put option with the same maturity and strike price as the contract in part (i). (2)

- (iii) Assume the investor has a portfolio formed by a short position in the call option given in part (i) and a long position in the put option given in part (ii).

Determine how the value of the portfolio would differ if the possible change in the stock price was a fall of 20% instead of 10%. (2)

6. (a) List the six assumptions underlying the Black-Scholes model of option prices. (3)

(b) The current price of a non-dividend paying stock is K90 and its volatility is 30% per annum. The continuously compounded risk-free interest rate is 3% per annum.

Consider a European call option on this share with strike price K80 and expiry date in three months' time. Assume that the Black-Scholes model applies.

(i) Calculate the price of the call option. (4)

(ii) Define algebraically the delta of the call option. (1)

(iii) Calculate the value of the delta of the call option. (1)

(iv) Calculate the value of the delta of a European put option written on the same underlying, with the same strike and maturity as above. (1)

(c) A company's directors have decided to provide senior managers with a performance bonus scheme. The bonus scheme entitles the managers to a cash payment of K100,000 should the company share price have increased by more than 20% at the end of the next 6 months. In addition, the managers will be entitled to 5,000 free shares each, should the share price have increased by more than 10% at the end of the next 6 months. You are given the following data:

Current share price	K78.10
Continuously-compounded risk-free rate	5% pa
Share price volatility	25% pa
No dividends to be paid over the next 6 months.	

(i) By considering the terms of the Black-Scholes call option pricing formula, calculate the value of the bonus scheme to one manager. (6)

(ii) Explain two disadvantages of this bonus scheme as an incentive for managers to perform. (2)

(iii) Some shareholders are concerned that this scheme might cause an undesirable distortion to the managers' behaviour.

Suggest two modifications to the scheme that will ensure that the managers' aims coincide with the long-term objectives of the shareholders. (2)

End of Paper

STANDARD NORMAL DISTRIBUTION: Table Values Represent AREA to the LEFT of the Z score.

Z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
-3.9	.00005	.00005	.00004	.00004	.00004	.00004	.00004	.00004	.00003	.00003
-3.8	.00007	.00007	.00007	.00006	.00006	.00006	.00006	.00005	.00005	.00005
-3.7	.00011	.00010	.00010	.00010	.00009	.00009	.00008	.00008	.00008	.00008
-3.6	.00016	.00015	.00015	.00014	.00014	.00013	.00013	.00012	.00012	.00011
-3.5	.00023	.00022	.00022	.00021	.00020	.00019	.00019	.00018	.00017	.00017
-3.4	.00034	.00032	.00031	.00030	.00029	.00028	.00027	.00026	.00025	.00024
-3.3	.00048	.00047	.00045	.00043	.00042	.00040	.00039	.00038	.00036	.00035
-3.2	.00069	.00066	.00064	.00062	.00060	.00058	.00056	.00054	.00052	.00050
-3.1	.00097	.00094	.00090	.00087	.00084	.00082	.00079	.00076	.00074	.00071
-3.0	.00135	.00131	.00126	.00122	.00118	.00114	.00111	.00107	.00104	.00100
-2.9	.00187	.00181	.00175	.00169	.00164	.00159	.00154	.00149	.00144	.00139
-2.8	.00256	.00248	.00240	.00233	.00226	.00219	.00212	.00205	.00199	.00193
-2.7	.00347	.00336	.00326	.00317	.00307	.00298	.00289	.00280	.00272	.00264
-2.6	.00466	.00453	.00440	.00427	.00415	.00402	.00391	.00379	.00368	.00357
-2.5	.00621	.00604	.00587	.00570	.00554	.00539	.00523	.00508	.00494	.00480
-2.4	.00820	.00798	.00776	.00755	.00734	.00714	.00695	.00676	.00657	.00639
-2.3	.01072	.01044	.01017	.00990	.00964	.00939	.00914	.00889	.00866	.00842
-2.2	.01390	.01355	.01321	.01287	.01255	.01222	.01191	.01160	.01130	.01101
-2.1	.01786	.01743	.01700	.01659	.01618	.01578	.01539	.01500	.01463	.01426
-2.0	.02275	.02222	.02169	.02118	.02068	.02018	.01970	.01923	.01876	.01831
-1.9	.02872	.02807	.02743	.02680	.02619	.02559	.02500	.02442	.02385	.02330
-1.8	.03593	.03515	.03438	.03362	.03288	.03216	.03144	.03074	.03005	.02938
-1.7	.04457	.04363	.04272	.04182	.04093	.04006	.03920	.03836	.03754	.03673
-1.6	.05480	.05370	.05262	.05155	.05050	.04947	.04846	.04746	.04648	.04551
-1.5	.06681	.06552	.06426	.06301	.06178	.06057	.05938	.05821	.05705	.05592
-1.4	.08076	.07927	.07780	.07636	.07493	.07353	.07215	.07078	.06944	.06811
-1.3	.09680	.09510	.09342	.09176	.09012	.08851	.08691	.08534	.08379	.08226
-1.2	.11507	.11314	.11123	.10935	.10749	.10565	.10383	.10204	.10027	.09853
-1.1	.13567	.13350	.13136	.12924	.12714	.12507	.12302	.12100	.11900	.11702
-1.0	.15866	.15625	.15386	.15151	.14917	.14686	.14457	.14231	.14007	.13786
-0.9	.18406	.18141	.17879	.17619	.17361	.17106	.16853	.16602	.16354	.16109
-0.8	.21186	.20897	.20611	.20327	.20045	.19766	.19489	.19215	.18943	.18673
-0.7	.24196	.23885	.23576	.23270	.22965	.22663	.22363	.22065	.21770	.21476
-0.6	.27425	.27093	.26763	.26435	.26109	.25785	.25463	.25143	.24825	.24510
-0.5	.30854	.30503	.30153	.29806	.29460	.29116	.28774	.28434	.28096	.27760
-0.4	.34458	.34090	.33724	.33360	.32997	.32636	.32276	.31918	.31561	.31207
-0.3	.38209	.37828	.37448	.37070	.36693	.36317	.35942	.35569	.35197	.34827
-0.2	.42074	.41683	.41294	.40905	.40517	.40129	.39743	.39358	.38974	.38591
-0.1	.46017	.45620	.45224	.44828	.44433	.44038	.43644	.43251	.42858	.42465
-0.0	.50000	.49601	.49202	.48803	.48405	.48006	.47608	.47210	.46812	.46414

STANDARD NORMAL DISTRIBUTION: Table Values Represent AREA to the LEFT of the Z score.

Z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0.0	.50000	.50399	.50798	.51197	.51595	.51994	.52392	.52790	.53188	.53586
0.1	.53983	.54380	.54776	.55172	.55567	.55962	.56356	.56749	.57142	.57535
0.2	.57926	.58317	.58706	.59095	.59483	.59871	.60257	.60642	.61026	.61409
0.3	.61791	.62172	.62552	.62930	.63307	.63683	.64058	.64431	.64803	.65173
0.4	.65542	.65910	.66276	.66640	.67003	.67364	.67724	.68082	.68439	.68793
0.5	.69146	.69497	.69847	.70194	.70540	.70884	.71226	.71566	.71904	.72240
0.6	.72575	.72907	.73237	.73565	.73891	.74215	.74537	.74857	.75175	.75490
0.7	.75804	.76115	.76424	.76730	.77035	.77337	.77637	.77935	.78230	.78524
0.8	.78814	.79103	.79389	.79673	.79955	.80234	.80511	.80785	.81057	.81327
0.9	.81594	.81859	.82121	.82381	.82639	.82894	.83147	.83398	.83646	.83891
1.0	.84134	.84375	.84614	.84849	.85083	.85314	.85543	.85769	.85993	.86214
1.1	.86433	.86650	.86864	.87076	.87286	.87493	.87698	.87900	.88100	.88298
1.2	.88493	.88686	.88877	.89065	.89251	.89435	.89617	.89796	.89973	.90147
1.3	.90320	.90490	.90658	.90824	.90988	.91149	.91309	.91466	.91621	.91774
1.4	.91924	.92073	.92220	.92364	.92507	.92647	.92785	.92922	.93056	.93189
1.5	.93319	.93448	.93574	.93699	.93822	.93943	.94062	.94179	.94295	.94408
1.6	.94520	.94630	.94738	.94845	.94950	.95053	.95154	.95254	.95352	.95449
1.7	.95543	.95637	.95728	.95818	.95907	.95994	.96080	.96164	.96246	.96327
1.8	.96407	.96485	.96562	.96638	.96712	.96784	.96856	.96926	.96995	.97062
1.9	.97128	.97193	.97257	.97320	.97381	.97441	.97500	.97558	.97615	.97670
2.0	.97725	.97778	.97831	.97882	.97932	.97982	.98030	.98077	.98124	.98169
2.1	.98214	.98257	.98300	.98341	.98382	.98422	.98461	.98500	.98537	.98574
2.2	.98610	.98645	.98679	.98713	.98745	.98778	.98809	.98840	.98870	.98899
2.3	.98928	.98956	.98983	.99010	.99036	.99061	.99086	.99111	.99134	.99158
2.4	.99180	.99202	.99224	.99245	.99266	.99286	.99305	.99324	.99343	.99361
2.5	.99379	.99396	.99413	.99430	.99446	.99461	.99477	.99492	.99506	.99520
2.6	.99534	.99547	.99560	.99573	.99585	.99598	.99609	.99621	.99632	.99643
2.7	.99653	.99664	.99674	.99683	.99693	.99702	.99711	.99720	.99728	.99736
2.8	.99744	.99752	.99760	.99767	.99774	.99781	.99788	.99795	.99801	.99807
2.9	.99813	.99819	.99825	.99831	.99836	.99841	.99846	.99851	.99856	.99861
3.0	.99865	.99869	.99874	.99878	.99882	.99886	.99889	.99893	.99896	.99900
3.1	.99903	.99906	.99910	.99913	.99916	.99918	.99921	.99924	.99926	.99929
3.2	.99931	.99934	.99936	.99938	.99940	.99942	.99944	.99946	.99948	.99950
3.3	.99952	.99953	.99955	.99957	.99958	.99960	.99961	.99962	.99964	.99965
3.4	.99966	.99968	.99969	.99970	.99971	.99972	.99973	.99974	.99975	.99976
3.5	.99977	.99978	.99978	.99979	.99980	.99981	.99981	.99982	.99983	.99983
3.6	.99984	.99985	.99985	.99986	.99986	.99987	.99987	.99988	.99988	.99989
3.7	.99989	.99990	.99990	.99990	.99991	.99991	.99992	.99992	.99992	.99992
3.8	.99993	.99993	.99993	.99994	.99994	.99994	.99994	.99995	.99995	.99995
3.9	.99995	.99995	.99996	.99996	.99996	.99996	.99996	.99996	.99997	.99997

The University of Zambia
School of Natural Sciences
Department of Mathematics & Statistics

2018/19 Academic Year
End of Year Final Examinations
MAT4119 - ENGINEERING MATHEMATICS III

TOTAL TIME ALLOWED: THREE (3) HOURS

INSTRUCTIONS ANSWER ANY FIVE (5) QUESTIONS.

1. a. (i) Find the fifth Taylor polynomial, $P_5(x)$, of

$$f(x) = \sinh^{-1} x$$

about $x = 0$.

- (ii) Find the value of x that can be used in $P_5(x)$ to estimate the value of $\ln 2$.

Hence, use four-digit rounding arithmetic and $P_5(x)$ to estimate $\ln 2$.

- (iii) Find the upper bound of the error in part (ii). (10 Marks)

- b. Use the quadratic formula that will give the most accurate approximation of the roots of

$$1.002x^2 - 11.01x + 0.01265 = 0$$

using four-digit rounding arithmetic. (4 Marks)

- c. (i) Show that $p = 1.12$ is a root of multiplicity 2 of the equation

$$f(x) = x^4 - 2.24x^3 + 2.2544x^2 - 2.24x + 1.2544 = 0$$

- (ii) Use modified Newton-Raphson method to approximate this root to 5 significant figures starting with $p_0 = 1$. (6 Marks)

2. a. Show graphically that the system of non-linear equations

$$x^2 + y = 11$$

$$y^2 + x = 7$$

has four possible solutions. Starting with $X^{(0)} = (3, 2.5)'$, use Newton's method to approximate the solution to the system until

$$\frac{\|X^{(k)} - X^{(k-1)}\|_{\infty}}{\|X^{(k)}\|_{\infty}} < 5 \times 10^{-1}. \quad (8 \text{ Marks})$$

The University of Zambia
School of Natural Sciences
Department of Mathematics & Statistics

2018/19 Academic Year
End of Year Final Examinations
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Hence, use four-digit rounding arithmetic and $P_5(x)$ to estimate $\ln 2$.

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2. a. Show graphically that the system of non-linear equations

$$x^2 + y = 11$$

$$y^2 + x = 7$$

has four possible solutions. Starting with $X^{(0)} = (3, 2.5)^t$, use Newton's method to approximate the solution to the system until

$$\frac{\|X^{(k)} - X^{(k-1)}\|_{\infty}}{\|X^{(k)}\|_{\infty}} < 5 \times 10^{-1}.$$

(8 Marks)

- b. The following linear equations represent a system of pulleys where t_1 and t_2 (measured in pounds) are tensions in the ropes and a (measured in feet per second squared) is the acceleration:

$$t_1 - 2t_2 = 0$$

$$t_1 - 2a = 128$$

$$t_2 + a = 32$$

Find the solution to this system.

(5 Marks)

- c. The following system of linear equations represents the distribution of current flow in a circuit:

$$I_1 + I_2 - I_3 = 0$$

$$2I_1 - 4I_2 = 4$$

$$2I_1 + 5I_3 = 6,$$

where I_i , for each $i = 1, 2, 3$, is current in amperes. Starting with $I^{(0)} = (1, 0, 1)^T$, perform four iterations of the Gauss - Seidel method to approximate the solution to the system.

(7 Marks)

- 3 a. The following table gives the current density (D) in amperes per square millimeter (A/mm^2) of insulated copper conductors for selected cross sectional area (A) in square millimeters.

	x_0	x_1	x_2	x_3
A	2.0	3.0	5.0	5.5
D	0.015	0.009	0.006	0.0055
	y_0	y_1	y_2	y_3

Estimate D for cross sectional area of 3.8 mm^2 .

(6 Marks)

- b. Given the initial value problem $\frac{dy}{dx} = x + y^2$, $y(0) = 1$

Estimate $y(0.1)$ using the following Runge Kutta equations of order 4 and step size $h = 0.1$.

$$k_1 = hf(t_i, w_i), \quad k_2 = hf\left(t_i + \frac{h}{2}, w_i + \frac{k_1}{2}\right), \quad k_3 = hf\left(t_i + \frac{h}{2}, w_i + \frac{k_2}{2}\right),$$

$$k_4 = hf(t_{i+1}, w_i + k_3), \quad w_{i+1} = w_i + \frac{1}{6}(k_1 + 2k_2 + 2k_3 + k_4)$$

(8 Marks)

- c. Estimate the value of the integral $\int_0^1 \frac{x}{x^3+10} dx$ using the following Simpson's rule with eight subintervals :

$$\int_{x_0}^{x_n} y dx = \frac{h}{3} [y_0 + 4(y_1 + \dots + y_{n-1}) + 2(y_2 + \dots + y_{n-2}) + y_n]$$

(6 Marks)

$E \leq 10^{-6}$
 $E \geq 10^{-6}$

- 4 a. Consider the integral $\int_{0.1}^{0.2} \frac{x^2}{\cos x} dx$
 Find the largest value of h if the above integral is approximated by composite Trapezoidal rule within an error of 10^{-6} .
 The error in composite Trapezoidal rule : $E = -(b - a) \frac{h^2}{12} f''(\xi)$. (6 Marks)

- b. The specific enthalpy (h) is an important element in thermodynamic processes. It is a function of temperature T . The following data was recorded from an experiment:

$T(^{\circ}\text{F})$	800	1000	1200	1400	1600
$h(\text{Btu/lb})$	1305	1400	1585	1705	1825

- (i) Estimate h at $T = 1100^{\circ}\text{F}$ using Newton's forward difference polynomial.
 (ii) For a process in which the pressure is constant, the specific heat capacity (C_p) equals the slope of the specific enthalpy (h) i.e $C_p = \frac{dh}{dT}$.
 Estimate C_p at $T = 800^{\circ}\text{F}$ using the polynomial derived in part (i). (7 Marks)

- c. (i) Compute $f''(0.6)$ from the following table using the formula
 $f''(x_0) = \frac{f(x_0+h) - 2f(x_0) + f(x_0-h)}{h^2}$ with $h = 0.4$ and 0.2 .

x	0.2	0.4	0.5	0.6	0.7	0.8	1.0
$f(x)$	1.42	1.88	2.13	2.39	2.66	2.94	3.56

- (ii) Given that the error involved in approximating second derivative by the above formula is of $o(h^2)$, apply Richardson's extrapolation scheme to approximate $f''(0.6)$ with error $o(h^4)$.
 Richardson's extrapolation scheme : Suppose M is approximated by $N(h)$ with error $o(h^2)$, then improved estimate of M with error $o(h^4)$ can be found from

$$M_{\text{improved}} = \left(\frac{4N\left(\frac{h}{2}\right) - N(h)}{3} \right)$$

(7 Marks)

5. a. Let Z be a complex variable. Given the function $f(z) = e^{(1+i)z}$, apply Cauchy-Riemann equations to show that:

- (i) $f(z)$ is analytic
 (ii) $f'(z) = (1 + i)e^{(1+i)z}$

(6 Marks)

- b. (i) Find z such that $e^z = 1$.
 (ii) Find z such that $\sin z = 0$.

(8 Marks)

e^{2z}
 e^{2z}
 "

c. Evaluate the following integrals:

(i) $\int_C e^z dz$ where C is the line joining points (-1,1) and (1,1)

(ii) $\oint_C e^z dz$, where C is a circle of radius 5 units centered at the point $z_0 = 2 - i$.

(6 Marks)

6. a. Evaluate $\oint_C \frac{z}{z^2-1} dz$ where C is a circle described as

(i) $|z - 1| = 1$

(ii) $|z + 1| = 1$

(iii) $|z - i| = 1$

(9 Marks)

b. Express $\sin(2-i)$ in the form $a+ib$, a and b are reals.

(4 Marks)

c. Find the principal value of:

(i) $\ln(1 - i)$

(ii) $(1 + i)^{(-1+i)}$

(7 Marks)

-----END-----

$$\int t + i \int_{-1}^1 t$$
$$\frac{t^2}{2} + t$$
$$\frac{1}{2} - \frac{1}{2} + 1$$

The University of Zambia
School of Natural Sciences
Department of Mathematics & Statistics
2018/19 Academic Year Final Examinations
MAT4300 – Elements of Functional Analysis
8th November, 2019

INSTRUCTIONS: (1) Write down your **Computer number** on each answer booklet used.
(2) There are six questions in this paper. **Answer any Five (5)** only.
(3) Write down the **question number** for each question attempted in the first column on the right side on the cover of the main answer booklet.

TIME ALLOWED: Three (3) hours.

- Q1. (a) (i) Let X be a nonempty set. Define a metric on X . (2 marks)
(ii) Let (X, d) be a metric space. Define a closed sphere (ball) in X of radius r centered at a point $x_0 \in X$. (2 marks)
- (b) Prove that the function defined by $d(x, y) = \max_{t \in [a, b]} |x(t) - y(t)|$ on the space $C[a, b]$ of all continuous functions on $[a, b]$ is a metric. (8 marks)
- (c) Prove that in any metric space X , each closed sphere is a closed set. (8 marks)
- Q2. (a) Give the definition of each of the following:
(i) Baire space (2 marks)
(ii) Compact subset K of a metric space (X, ρ) . (2 marks)
- (b) (i) State (without proof) the Cantor Intersection theorem. (2 marks)
(ii) Use the theorem in (i) to prove that a complete metric space is a Baire space. (7 marks)
- (c) Let f be a continuous mapping from a compact metric space X to a metric space Y . Prove that the image $f[X] \subset Y$ is also compact. (7 marks)
- Q3. (a) (i) Define a contraction mapping on a metric space X . (2 marks)
(ii) When is a metric space said to be complete? (2 marks)
- (b) Show that if $T : X \rightarrow X$ is defined as $Tx = x^2$ where $X = [0, \frac{1}{3}]$, with the usual metric on \mathbb{R} , then T is a Contraction on $[0, \frac{1}{3}]$. (3 marks)
- (c) Let (X, ρ) be a complete metric space and the mapping $T : X \rightarrow X$ be a contraction. Prove that T has exactly one fixed point. (13 marks)

- Q4. (a) (i) Let $1 \leq p < \infty$. If $x = \{x_n\}_{n=1}^{\infty}$ and $x \in l^p$, define l^p . (2 marks)
- (ii) Give the definition of a bounded linear transformation. (2 marks)
- (b) (i) Show that $\left\{\frac{1}{\sqrt{n}}\right\}_1^{\infty} \notin l^2$. (2 marks)
- (ii) Prove that $\|x\|_p = \left(\sum_{n=1}^{\infty} |x_n|^p\right)^{\frac{1}{p}}$ is actually a norm in l^p space. (4 marks)
- (c) (i) Prove that a linear transformation $T : X \rightarrow Y$ is continuous at the origin if and only if and only if there exists a real number such that $\|Tx\| \leq k\|x\|$, for every $x \in X$. (4 marks)
- (ii) State and prove the Hahn-Banach theorem for normed linear spaces. (6 marks)
- Q5. (a) (i) When is a normed linear space said to be a Banach space? (2 marks)
- (ii) What is meant by a dual or conjugate space? (2 marks)
- (b) Let $X = C[0,1]$ and $F = \mathbb{R}$. Define $\Lambda_x(f) = f(x)$. Prove that $\Lambda_x \in X^*$. (6 marks)
- (c) Let X and Y be normed linear spaces. Prove that if Y is a Banach space, then the set $\mathfrak{B}(X, Y)$ of bounded linear transformations $T : X \rightarrow Y$ is itself a Banach space. (10 marks)
- Q6. (a) (i) Give the definition of a Hilbert space. (1 marks)
- (ii) When is an orthonormal set in an inner product space said to be complete? (2 marks)
- (b) (i) Prove that if M is a closed linear subspace of a Hilbert space \mathfrak{H} then $\mathfrak{H} = M \oplus M^{\perp}$. (4 marks)
- (ii) Let \mathfrak{H} be a Hilbert space and $\Lambda \in \mathfrak{H}^*$. Prove that there exists a unique $y \in \mathfrak{H}$ such that $\Lambda x = (x, y), \forall x \in \mathfrak{H}$. (5 marks)
- (c) (i) Let X be an inner product space and S an orthonormal set in X . Prove that there exists a complete orthonormal set S_0 in X such that $S \subset S_0$. (3 marks)
- (ii) State and prove the Parseval's relation for Hilbert spaces. (5 marks)

END OF EXAMINATION

The University of Zambia
School of Natural Sciences
Department of Mathematics and Statistics
2018/19 Academic Year Final Examinations
MAT4615 - Nonparametric Statistics

Time allowed : 3 Hours

Instructions:

- There are **five (6)** questions in this examination paper. Attempt **any four (5)** questions. **All** questions carry **equal** marks.
- Indicate your **Computer Number** on all your answer booklets.
- You are required to show all **necessary** steps in your solutions.

This paper consists of 4 pages of questions.

1. (a) (i) What is nonparametric statistics?
(ii) State two advantages and two disadvantages of using nonparametric tests.
(iii) State the four measurement scales and briefly explain about each of them.
- (b) Let $(X_i, Y_i), i = 1, 2, \dots, n$ be a random sample, representing n paired cases. Assume $X_i \neq Y_i$ for $i = 1, 2, \dots, n$. Let d_i denote the difference $X_i - Y_i$. Define a random variable $U_i, i = 1, 2, \dots, n$ as $U_i = 1$ if $d_i > 0$ and $U_i = 0$ if $d_i < 0$. Let $T = \sum_{i=1}^n R_i U_i$, where R_i is the rank associated with $|d_i|$.
 - (i) Find $E(T)$,
 - (ii) Find the variance of T .
2. (a) Samples of cream from each of 10 dairies (A to J) are each divided into two portions. One portion from each is sent to Laboratory I, the other to Laboratory II, for bacterium counts. The counts (thousands bacteria m/l) are:

Diary	A	B	C	D	E	F	G	H	I	J
Lab I	11.7	12.1	13.3	15.1	15.9	15.3	11.9	16.2	15.1	13.6
Lab II	10.9	11.9	13.4	15.4	14.8	14.8	12.3	15.0	14.2	13.1

Use the Wilcoxon signed-rank test to assess the evidence for any consistent difference between laboratories for subsamples from the same dairy. Use $\alpha = 0.05$ level of significance.

- (b) A physical education teacher conducted an action research project to examine a strength and conditioning program. Using 12 male participants, she measures the number of curl ups they could do in 1 min. She measured their performance before the programs. Then, she measured their performance at 1 month intervals. The table below presents the performance results.

Table 1: Number of curl ups in one minute

Participants	Baseline	Month 1	Month 2
1	66	67	69
2	49	50	56
3	51	52	49
4	65	65	69
5	42	43	46
6	38	39	40
7	33	31	39
8	41	41	44
9	46	47	48
10	45	46	46
11	36	33	34
12	51	55	67

- i. Use a Friedman test with $\alpha = 0.05$ to determine if one or more of the groups are significantly different.
 - ii. Which ones are different?
3. (a) Life expectancy showed a general tendency to increase during the nineteenth and twentieth centuries as standards of health care and hygiene improved. The table below gives the year of death and age at death for 13 males.

Year	1827	1884	1895	1908	1914	1918	1924	1928	1936
Age	13	83	34	1	11	16	68	13	77
Year	1941	1964	1965	1977					
Age	74	87	65	83					

- (i) Calculate Spearman's ρ .
 - (ii) Is there an indication that life expectancy is increasing for this clan in more recent years? Use Spearman's ρ at $\alpha = 0.05$.
 - (iii) Calculate Kendall's τ .
- (b) The data below shows assessment scores of two different classes who are being taught computer skills using two different methods.

Method 1	53	41	17	45	44	12	49	50
Method 2	91	18	14	21	23	99	16	10

Use Kolmogorov - Smirnov two-sample test to determine if there's a difference in methods of teaching computer skills. Use $\alpha = 0.05$.

4. (a) Lubischew (1962) gives measurements of maximum head width in units of 0.01 mm for three species of Chaetocnema. Part of his data is given below.

Species 1	53	50	52	50	49	47	54	51	52	57	
Species 2	49	49	47	54	43	51	49	51	50	46	49
Species 3	58	51	45	53	49	51	50	51			

Use a Kruskal - Wallis test to see if there is a species difference in head widths at 5% level of significance.

- (b) Maxson (1977) studied the activity patterns of female birds. Using surveillance techniques he recorded the movements of seven female birds over a fixed period of time in hours. The percentage of time that these birds were in active movement are recorded : 12.8 12.9 13.3 13.4 13.7 13.8 14.5.
Test if it is okay to assume that these data come from a normal distribution with mean 14 and standard deviation 2 at 5% level of significance.

5. (a) (i) State any two advantages of the sign test over other tests.
(ii) On the day of the second round of the Open Golf Championship in 1987 before play started a television commentator said that conditions were such that the average scores of players were likely to be higher than those for the first round. For a random sample of 10 of the 77 players participating in both rounds the scores were:

Player	A	B	C	D	E	F	G	H	I	J
Round 1	73	73	74	66	71	73	68	72	73	72
Round 2	72	79	79	77	83	78	70	78	78	77

Use the sign test at 0.01 significance level to verify the commentator's claim.

- (b) (i) A library has on its shelves 114 books on statistics. I take a random sample of 12 and want to test the hypothesis that the median number of pages, in all 114 books is 225. The numbers of pages in the sample of 12 books were: 126 142 156 228 245 246 370 419 433 454 478 503
At 0.05 significance level, test the hypothesis.
(ii) The measure of correlation as given by Spearman (1904) is usually designated by ρ (rho) and defined as

$$\rho = \frac{\sum_{i=1}^n R(X_i)R(Y_i) - n\left(\frac{n+1}{2}\right)^2}{\left(\sum_{i=1}^n R(X_i)^2 - n\left(\frac{n+1}{2}\right)^2\right)^{\frac{1}{2}} \left(\sum_{i=1}^n R(Y_i)^2 - n\left(\frac{n+1}{2}\right)^2\right)^{\frac{1}{2}}}$$

If there are no ties, show that

$$\rho = 1 - \frac{6 \sum_{i=1}^n [R(X_i) - R(Y_i)]^2}{n(n^2 - 1)}$$

6. (a) (i) State two advantages of using a binomial test.
- (ii) It is known that at least 0.25 of a certain species of insect exhibit a particular characteristic A. Eighteen insects of that species are obtained from an unusual environment, and five of these have characteristic A. Test at 5% level of significance if it is reasonable to assume that insects from that environment have same probability of 0.25 of having characteristic A.
- (iii) Lindsey, Herzberg and Watts (1987) give data for widths of first joint of the second tarsus for two species of the insect *Chaetocnema*. Do these indicate population differences between the width distributions for the two species?

Species A	131	134	137	127	128	118	134	129	131	115
Species B	107	122	144	131	108	118	122	127	125	124

Perform a Mann-Whitney hypothesis test at 5% level of significance.

- (b) Let X and Y be independent random variables with distribution functions $F(x)$ and $G(y)$ respectively. Let X_1, X_2, \dots, X_n and Y_1, Y_2, \dots, Y_m be random samples from these distributions. Define

$$Z_{ij} = \begin{cases} 1, & \text{if } X_i < Y_j \\ 0, & \text{if } X_i > Y_j. \end{cases}$$

Find $E[U]$, for the statistic

$$U = \sum_{i=1}^n \sum_{j=1}^m Z_{ij},$$

assuming $X_i \neq Y_i$.

END OF EXAM

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

2019 ACADEMIC YEAR FINAL EXAMINATIONS

MAT 4622: CATEGORICAL DATA ANALYSIS

INSTRUCTIONS:

1. Answer any FIVE (5) questions.
2. Calculators are allowed.
3. You may use statistical tables or formulae provided if necessary.
4. Show all your work to earn full marks.

TIME: THREE (3) Hours

Question 1

A random sample of students is asked their opinion on a proposed core curriculum change. The results are presented below.

Class	Opinion		Total
	Favouring	Opposing	
First year	120	80	200
Second year	70	130	200
Third year	60	70	130
Fourth year	40	60	100
Total	290	340	630

- (a) In bullet format, list possible statistics you could use to analyse the association between *opinion* and *class grouping*.
- (b) Test the hypothesis that the opinions are independent of the class grouping, at 5% level of significance using the G^2 statistic, i.e., the likelihood test.

Question 2

- (a)
 - (i) Briefly discuss the difference between nominal and ordinal variables.
 - (ii) Give reasons, in bullet form, why classifying variables correctly is important.
- (b) A news publisher, trying to pinpoint his market's characteristics, wondered whether newspaper readership in the community is related to readers' educational achievement. A survey questioned adults in the area on the level of education and their frequency of readership. The results are shown in the following table.

Frequency of readership	Level of educational achievement				
	Professional or postgraduate	College graduate	High school graduate	Did not complete high school	
Regularly	63	57	22	20	162
Sometimes	12	23	8	5	48
Never	10	17	11	21	59
	85	97	41	46	269

- (i) Calculate the Gamma statistic
- (ii) Interpret the result in (i).

Question 3

Assume that a response variable Y has four categories. Let n_1 be the frequency count for Y in level 1, n_2 be the frequency count for Y in level 2, n_3 be the frequency count for Y in level 3, and n_4 be the frequency count for Y in level 4. Further, assume that the level counts each independently follow a Poisson distribution, i.e., $n_i \sim Poi(m_i)$, for $i = 1, 2, 3,$ and 4.

- (a)
 - (i) Write down the Product Poisson probability function for $\underline{n} = (n_1, n_2, n_3, n_4)'$.
 - (ii) Determine the maximum likelihood estimate of m_i based on the probability function in (i).
 - (iii) If $m_1 = m_2 = m_3 = m_4 = m$ in (i) determine the maximum likelihood estimate of m .
- (b) Assume a study is carried out to determine where children go for assistance if they needed some quick pocket money. In a questionnaire the response to the question "What do you do if you need some quick pocket money?" with four responses 'Ask mom', 'Ask dad', 'Ask mom or dad' or 'Borrow from someone' yields the data below.

What do you do if you need some quick pocket money?				
Ask mom	Ask dad	Ask mom or dad	Borrow from someone	TOTAL
177	110	191	122	600

You wish to determine whether $m_1 = m_2 = m_3 = m_4$ through a test and using a Chi-square statistic given by: $\chi_{observed}^2 = \sum_{i=1}^4 \frac{(n_i - e_i)^2}{e_i}$.

- (i) What should be the estimate of e_i ?
- (ii) What are the appropriate degrees of freedom to use?
- (iii) Carry out the test at 5% level of significance.

Question 4

- (a) Assume X has two categories 1 and 2, and the response variable Y also has two categories 1 and 2. The conditional distribution of Y given X is displayed in Table 1 (a) and Table 1 (b) shows the cross classification of X and Y for a sample size of n, when data are available.

		Y		
		1	2	
X	1	$\pi_{1/1}$	$\pi_{2/1}$	1
	2	$\pi_{1/2}$	$\pi_{2/2}$	1

Table 1 (a)

		Y		
		1	2	
X	1	n_{11}	n_{12}	n_{1+}
	2	n_{21}	n_{22}	n_{2+}

Table 1 (b)

Note: in Table 1 (a) $\Pr(Y = 1/X = 1) = \pi_{1/1}$ and $\Pr(Y = 1/X = 2) = \pi_{1/2}$

- (i) If $n_{11} \sim \text{Bin}(n_{1+}, \pi_{1/1})$ and $n_{21} \sim \text{Bin}(n_{2+}, \pi_{1/2})$ and the two binomial distributions are independent, write down the joint distribution of (n_{11}, n_{21}) .
- (ii) If $\pi_{1/1} = \pi_{1/2} = \pi$, show that the joint distribution in (i) simplifies to $\binom{n_{1+}}{n_{11}} \binom{n_{2+}}{n_{21}} \pi^{n_{11}+n_{21}} (1 - \pi)^{n - n_{11} - n_{21}}$, where $n_{+1} = n_{11} + n_{21}$.
- (iii) Find the maximum likelihood estimator of π in (ii).
- (b) A food security program was carried out in Chipata in which 104 farmers were sponsored to practice conservation agriculture system while 405 were sponsored to carry out conventional agriculture system. At the end of the farming season the farmers were asked whether they felt food secure. The results of the study are shown below.

Farming type	Are you food secure?		Total
	YES	NO	
Conservation	60	44	104
Conventional	186	219	405
Total	246	263	509

We would like to test the null hypothesis that the proportion of farmers feeling food secure is the same, i.e., $\pi_{1/1} = \pi_{1/2}$, using the Chi-square test given by:

$$\chi_{observed}^2 = \sum_{i=1}^2 \sum_{j=1}^2 \frac{(n_{ij} - e_{ij})^2}{e_{ij}}$$

- (i) Briefly state why this test is not a test of independence.
- (ii) Carry out the test at 5% level of significance.

Question 5

- (a) Assume X has I categories and Y has J categories. A cross-classification of X and Y yields a table having IJ cells. If $P(X= i, Y= j) = \pi_{ij}$
- (i) Briefly discuss what is meant by a saturated model.
 - (ii) Briefly discuss what is meant by an independence model.
 - (iii) Determine the difference in the degrees of freedom for the two models?
- (b) Grades in a statistics course and an economics course taken during the same examination period for a group of students were as follows.

		Economics grade				
		A	B	C	Other	
Statistics grade	A	25	6	17	13	61
	B	17	16	15	6	54
	C	18	4	18	10	50
	Other	10	8	11	20	49
		70	34	61	49	214

Carry out a test at 5% level of significance to determine whether grades in statistics and economics are independent using the standard or alternative formula.

Question 6

- (a) The Gini's concentration measure of variation for a nominal response variable Y with J categories is defined by: $\text{Var}(Y) = 1 - \sum_{j=1}^J \pi_{+j}^2$
- (i) State a constraint imposed on π_{+j} s.
 - (ii) By taking into consideration the constraint in (i) show that $\text{Var}(Y)$ attains its maximum value of $\frac{J-1}{J}$ when $\pi_{+j} = \frac{1}{J}$
 - (iii) What value does $\text{Var}(Y)$ attain if $\pi_{+j} = 1$ for some j.
- (b) An educator has the opinion that the grades high school students make are dependent on the amount of time they spend listening to music. A questionnaire was administered to a survey of 400 students with the following two questions: "How many hours per week do you listen to music?" and "What is the average grade for all your classes?" The data from the survey and the proportions are given in the tables below.

Raw data

HOURS SPENT LISTENING TO MUSIC	AVERAGE GRADE					
	A	B	C	D	F	
Up to 10 hours	33	37	38	35	7	150
More than 10 hours	17	38	112	40	43	250
	50	75	150	75	50	400

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	50	75	150	75	50	400		

Data in proportional form

LISTENING TO MUSIC	AVERAGE GRADE					
	A	B	C	D	F	
Up to 10 hours	0.08	0.09	0.09	0.09	0.02	0.37
More than 10 hours	0.04	0.10	0.28	0.10	0.11	0.63
	0.12	0.19	0.37	0.19	0.13	1

- (i) Calculate the sample version of Gini's concentration given by:

$$\hat{\tau} = \frac{\sum_{i=1}^I \sum_{j=1}^J \frac{p_{ij}^2}{p_{i+}} - \sum_{j=1}^J p_{+j}^2}{1 - \sum_{j=1}^J p_{+j}^2}$$

- (ii) Give an interpretation of the result in (i).

END OF EXAMINATION

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The University of Zambia
Physics Department
University Examinations 2018-19
PHY 1010: Introductory Physics

All questions carry equal marks. The marks are shown in brackets. **Question 1 is compulsory.** Attempt **four (4) more** questions. Clearly indicate on the answer script left column on the cover page the questions you have answered. Some useful equations are given at the back of the question paper.

Time : Three hours.

Maximum marks = 100.

Do not forget to write your computer number clearly on the answer book as well as on the answer sheet for Question 1. Tie them together.

=====

Wherever necessary use:

$$g = 9.8 \text{ m/s}^2$$

$$P_A = 1.01 \times 10^5 \text{ N/m}^2$$

$$1 \text{ cal.} = 4.18 \text{ J}$$

$$C_{\text{water}} = 4184 \text{ J/kg} \cdot ^\circ\text{C}$$

$$R = 8314 \text{ J/kmol} \cdot \text{K}$$

$$K_B = 1.381 \times 10^{-23} \text{ J/K (Boltzmann's constant)}$$

$$\epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2/\text{Nm}^2$$

$$c = 3 \times 10^8 \text{ m/s}$$

$$h = 6.63 \times 10^{-34} \text{ J-s}$$

$$1 \text{ pascal} = 1 \text{ N/m}^2$$

$$1 \text{ eV} = 1.6 \times 10^{-19} \text{ J}$$

$$e = 1.6 \times 10^{-19} \text{ C}$$

$$m_e = 9.11 \times 10^{-31} \text{ kg}$$

$$k = 9 \times 10^9 \text{ Nm}^2/\text{C}^2$$

$$\mu_0 = 4\pi \times 10^{-7} \text{ N/A}^2$$

$$\rho_{\text{water}} = 1000 \text{ kg/m}^3$$

$$G = 6.67 \times 10^{-11} \text{ Nm}^2/\text{kg}^2$$

$$1 \text{ metric ton} = 1000 \text{ kg}$$

$$H_f = 80 \text{ cal/g-water}$$

$$H_v = 539 \text{ cal/g-steam}$$

$$1 \text{ litre} = 1 \times 10^{-3} \text{ m}^3$$

$$\text{Vol. sphere} = \frac{4}{3}\pi r^3$$

$$8.314 \text{ J/K} \cdot ^\circ\text{C}$$

N.B. Useful equations are on pages 7 and 8

$$1.0 \times 10^{-12}$$

$$8.85 \times 10^{-12}$$

Question 1: For each correct answer, 2 marks will be given. For each wrong answer, 0.67 will be deducted. For no answer, zero mark will be given. The minimum total mark for Question 1 is zero.

(A) In natural convection a heated portion of fluid moves because:

- a) of molecular vibrations about the equilibrium
- b) its density is less than that of the surrounding fluid.
- c) of molecular collisions within it.
- d) its molecular motions become aligned.

$$\frac{T_H - T_C}{T_H}$$

$$\frac{273 - 273}{273}$$

(B) A Carnot engine that operates between the absolute temperatures T_1 and T_2 :

- a) Has an efficiency of T_1/T_2 .
- b) Is 100% efficient.
- c) Has an efficiency of a non-reversible engine.
- d) Has the maximum efficiency possible for the given temperatures.

(C) Sound travels fastest in:

- a) water
- b) a vacuum
- c) solids
- d) air

T_1 or T_2

$$\text{stress} = \frac{F}{A}$$

(D) The stress on a wire supporting a load does not depend on:

- a) wire's length
- b) wire's diameter
- c) the mass of the load
- d) the acceleration of gravity

$$\text{strain} = \frac{\Delta L}{L}$$

(E) Objects may acquire an excess or deficiency of charge electrostatically by:

- a) grounding them
- b) rubbing them together
- c) shielding them
- d) putting them together

$$I \propto \frac{1}{2} MR^2$$

(F) The rotational corresponding term to force in linear motion is:

- a) angular momentum
- b) moment of inertia
- c) angular velocity
- d) torque

$$F = mg$$

$\tau = I\alpha$

$I = \frac{1}{2} MR^2$

$I \propto$

$I =$

(G) The amplitude of the motion of an object undergoing SHM is:

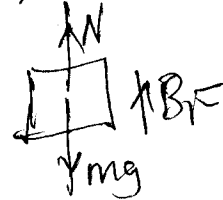
- a) its minimum displacement on either side of the equilibrium position
- b) its the maximum displacement on either side of the equilibrium position
- c) its total range of motion
- d) the number of cycles per second it undergoes \times

(H) In a perfectly elastic collision between two objects, their relative velocity after the collision is:

- a) zero
- b) less than their relative velocity before the collision
- c) more than their relative velocity before the collision
- d) equal to their relative speed before collision

(I) A tablet of soap placed in water filled bathtub sinks. The buoyant force on the soap is:

- a) more than its weight
- b) equal to its weight
- c) less than its weight
- d) negligible



(J) Which of the following formulas expresses the relationship between the pressure and absolute temperature of a gas whose volume is fixed?

a) $\frac{P_1}{T_2} = \frac{P_2}{T_1}$

b) $\frac{P_1}{T_1} = \frac{P_2}{T_2}$

c) $\frac{P_1}{P_2} = \frac{T_2}{T_1}$ \times

d) $\frac{P_1}{T_1} = \frac{T_2}{P_2}$ \times

$$\frac{P_1}{P_2} = \frac{T_1}{T_2} \quad \times$$

$$\frac{P_2}{P_1} \times \frac{T_2}{T_1}$$

$$\boxed{P_1 T_2} = P_2 T_1$$

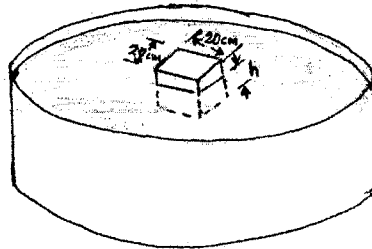
$$\frac{P_2}{P_1} \times \frac{T_2}{T_1}$$

Attempt any four questions from the following:

Q2 (a) What is the minimum amount of ice at $-15\text{ }^{\circ}\text{C}$ that must be added to 0.60 kg water at $20\text{ }^{\circ}\text{C}$ in order to bring the temperature of water down to $0\text{ }^{\circ}\text{C}$? Given $c_{\text{ice}} = 2.09\text{ kJ/kg }^{\circ}\text{C}$, $H_f = 335\text{ kJ/kg}$, and $c_{\text{water}} = 4.184\text{ kJ/kg }^{\circ}\text{C}$. [11]

(b) A cube of wood with edge dimension 20 cm and density 650 kg floats on water as shown in the figure below.

- What is the distance from the horizontal top surface of the cube to the water level? [6]
- What additional weight must be placed on the cube so that the top surface of the cube will be just level with the water surface? [3]



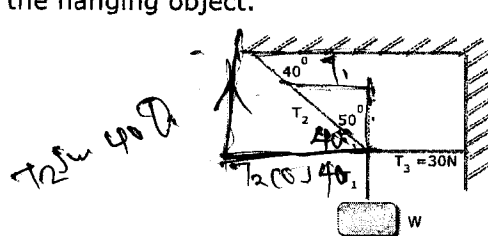
$$C_m \leftarrow L \leftarrow M$$

500

Q.3 (a) A sealed glass bulb is filled with pure nitrogen gas at a pressure of 2.0 atm . The volume of the container is 500 cm^3 and the temperature is $22\text{ }^{\circ}\text{C}$.

- Calculate the number of moles and mass of the nitrogen gas ($1\text{ mole N}_2 = 28\text{ g}$) within the bulb. [5]
- If the nitrogen gas is heated to $100\text{ }^{\circ}\text{C}$, what will be the pressure? [5]

(b) In the figure below, the tension in the horizontal cord is 30 N . Find the weight of W of the hanging object. [10]

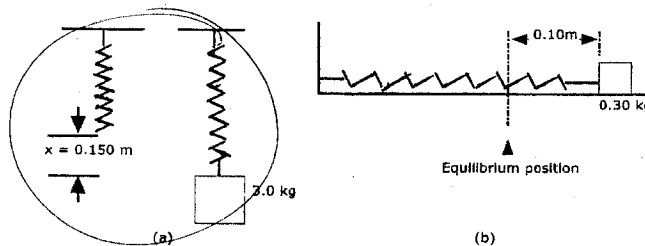


$$5 \frac{W}{K} CA$$

Q.4 (a) An ideal refrigerator, which is a Carnot engine operating in reverse, operates between inside temperature of $-4\text{ }^{\circ}\text{C}$ and a room temperature of $27\text{ }^{\circ}\text{C}$. In a certain period, it absorbs 115 J from the interior. How much heat is rejected to the room? [9]

Q.7 (a) A spring stretches 0.150 m when a 3 kg mass is gently hung on it as shown in figure (a) below. The spring is then setup horizontally with 0.30 kg mass resting on frictionless table as in figure (b) below. The mass is pulled so that the spring is stretched 0.100 m from equilibrium point, and released from rest. Determine the:

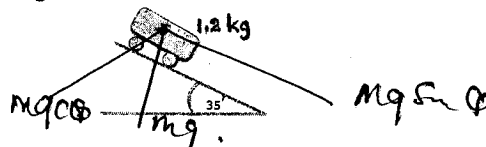
- spring constant of the spring; [1]
- amplitude of the horizontal oscillation of the 0.30 kg mass; [1]
- magnitude of the maximum velocity; [4]
- magnitude of the velocity when the mass is 0.05 m from equilibrium; and [2]
- the maximum acceleration of the mass. [2]



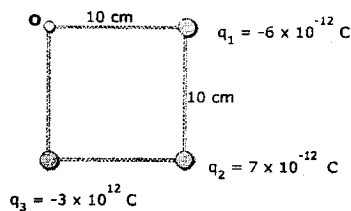
(b) A wagon with small wheels and well lubricated bearings (frictionless) is released from rest on an inclined plane which makes an angle of 35° with the horizontal. If the mass of the wagon is 1.2 kg. Determine the:

- magnitude of the force exerted by the surface on the wagon [3]
- acceleration of the cart [3]
- speed of the wagon after a time of 1.5 s [2]
- distance the wagon travels 1.5 s. [2]

$$F_f = Mg \sin \theta$$



Q.8 (a) Three charges $Q_1 = -6 \times 10^{-12} \text{ C}$, $Q_2 = 7 \times 10^{-12} \text{ C}$, and $Q_3 = -3 \times 10^{-12} \text{ C}$ are placed at three corners of a square 10 cm on a side, as shown. Find the magnitude and direction of the total electric field at point O. [11]



(b) A 100 kg box shown below is pulled by a 500 N force at an angle of 40° with respect to the horizontal. The coefficient of kinetic friction between the box and the surface is 0.5. Find the acceleration of the box. [9]



END OF EXAMINATION

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:

$$p = mv \quad F\Delta t = \Delta mv = m v_f - v_0$$

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:

$$\Delta Q = \Delta U + \Delta W : W = p.\Delta V \quad PV = nRT \quad n = \frac{m}{M} \quad P_1V_1^\gamma = P_2V_2^\gamma \quad T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$$

$$COP_{ref} = \frac{Q_c}{W} \quad COP_{heat\ pump} = \frac{Q_h}{W} \quad W_{isothermal} = nRT \ln \frac{V_2}{V_1}$$

$$W_{adiabatic} = \frac{1}{\gamma-1}(P_1V_1 - P_2V_2) : COP_{max-refr} = \frac{T_c}{W} \quad COP_{max-heat\ pump} = \frac{T_h}{W}$$

$$e = 1 - \frac{T_c}{T_h} = \frac{\text{work done}}{\text{input heat at high temp}}$$

Waves and Sound:

$$f = \frac{1}{\tau} \quad v = \pm \sqrt{\frac{k}{m}(x_0^2 - x^2)} \quad v = \sqrt{\frac{T}{m/L}} \quad \tau = \frac{1}{f} = 2\pi\sqrt{\frac{m}{k}} \quad a = -\left(\frac{k}{m}\right)x \quad v = \sqrt{\frac{Y}{\rho}}$$

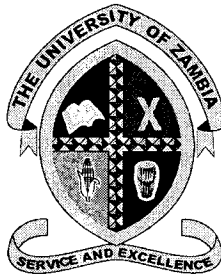
$$v = \sqrt{\frac{B}{\rho}} \quad f' = f \frac{v \pm v_L}{v \mp v_S} \quad (dB) = 10 \cdot \log \frac{I}{I_0}$$

$$\tau = \frac{2\pi x_0}{v_0} = 2\pi \left(\frac{x_0}{v_0}\right) = \frac{2\pi}{\omega} \quad f = \frac{1}{2L}\sqrt{\frac{T}{m}} \quad x = x_0 \cos(\omega t) \quad I_0 = 10^{-12} \text{ W/m}^2$$

Electric Field:

$$F \propto \frac{q_1 q_2}{r^2} \text{ or } F = k \cdot \frac{q_1 q_2}{r^2} ; k = 8.9874 \times 10^9 \text{ N.m}^2.\text{C}^{-2} \text{ or } k = (1/(4\pi\epsilon_0)) \text{ where } \epsilon_0$$

is the permittivity constant = $8.85 \times 10^{-12} \text{ C}^2.(\text{N.m}^2)^{-1}$.



THE UNIVERSITY OF ZAMBIA

School of Natural Sciences

DEPARTMENT OF PHYSICS

PHY 2112: Atomic Physics and Magnetism in Matter

2018/19 Academic year FINAL EXAMINATION Academic Year

Instructions: Answer any **five (5)** questions only. They are of equal marks.

Time duration: Three (3) hours.

Some formulae and constants you may find useful:

$$m_e = 9.11 \times 10^{-31} \text{ kg}$$

$$e = 1.6 \times 10^{-19} \text{ C}$$

$$h = 6.625 \times 10^{-34} \text{ J.s}$$

$$\frac{mv^2}{r} = qvB$$

$$2d \sin \theta = m\lambda$$

$$\lambda_{\max} T = 2.9 \times 10^{-3} \text{ mK}$$

$$\Delta\lambda = \lambda - \lambda_o = \frac{h}{m_o c} (1 - \cos \theta) \quad \text{Surface temperature of the Sun} = 6000\text{K}$$

$$E = e\sigma T^4$$

$$I = I_o e^{-\mu x}$$

$$B = \mu_o (H + M)$$

$$\mu_o = 4\pi \times 10^{-7} \text{ A/m}$$

$$A = \lambda N$$

$$N = N_o e^{-\lambda t}$$

$$N_A = 6.02 \times 10^{23} / \text{mol}$$

$$\mu_m = (1 + \chi)$$

$$R_{\text{sun}} = 7.0 \times 10^8 \text{ m}$$

Q1 (a) The question whether radiation was particulate or a wave was settled by a number of experiments. Briefly cite one experiment that supported the particulate nature of radiation and another that supported the wave nature of radiation. [6]

(b) Photons of wavelength 450 nm are incident on a metal surface. It is observed that the most energetic electrons ejected from the metal are bent into a circular arc of radius 20.0 cm when they enter a magnetic field of magnitude $2.00 \times 10^{-5} \text{T}$. What is the work function of the metal?

[9]

(c) Find the de Broglie wavelength of an electron that has a kinetic energy of 3.00 eV. [5]

Q2 (a) What is the difference between *hard* and *soft* X-rays? [4]

(b) (i) X-rays of wavelength 0.140 nm are reflected from a certain crystal, and the first order maximum occurs at an angle of 14.4° . What value does this give for the inter-planar spacing of the crystal?

[3]

(ii) Suppose an electron is accelerated through a potential difference V in an X-ray tube. Show that the minimum wavelength, λ_{min} of the X-rays produced is given by [5]

$$\lambda_{min} = \frac{1.242}{V} \mu\text{m}$$

(c) X-rays of wavelength $\lambda = 0.200 \text{ nm}$ are scattered from a block of material. The scattered x-rays are observed at an angle of 45° to the direction of the incident beam. Calculate [8]

(i) the wavelength of the x-rays scattered at this angle,

(ii) the fractional change in the energy of a photon in this collision.

- Q3 (a) (i) Figure 1 shows the spectrum of light emitted by a firefly. Determine the temperature of a black-body that would emit radiation peaked at the same frequency. [3]

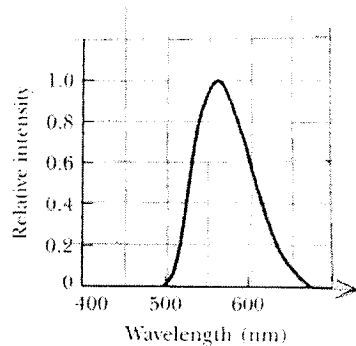


Figure 1

- (ii) Given that the hydrogen atom absorbs a photon and is made to transition from the state $n = 2$ to $n = 5$ state. Determine the wavelength of the absorbed photon. [5]
- (b) In our galaxy, there are a number of gas clouds which emit radiation with maximum intensity at a wavelength of $10\mu\text{m}$. Assuming that these clouds act as spherical black bodies with the same power as the Sun, estimate
- (i) their surface temperature, [2]
- (ii) their radius [7]
- (c) Calculate the binding energy of the electron in hydrogen in joules and in eV when it resides in a shell with $n = 3$ and $n = \infty$. Note: mind the signs. [3]

Q4 (a) (i) The expression for the transmission of X-rays is written as

$$I = I_0 e^{-\mu x} \quad [5]$$

Explain the meaning of all symbols appearing in this equation.

(ii) Using the expression cited in (i), obtain the thickness of a material of attenuation coefficient $= 0.4 \text{ cm}^{-1}$ that would absorb 75% of the intensity of X-rays falling on it. [5]

(b) (i) The expression below shows the decay of radioactive substances is written as

$$N = N_0 e^{-\lambda t}$$

Explain what the symbols N, N_0, λ and t stand for, [4]

(ii) In 2.00 days, the activity of a sample of unknown type radioactive material decreases to 84.2% of the initial activity. Determine the half-life of this material. [6]

Q5 (a) In the planetary model of the atom as proposed by Rutherford, the motion of an electron in the hydrogen atom describes an orbit of radius r . Given that the angular frequency of the motion is ω , show that the magnetic moment, μ of such a current is given by [4]

$$\mu = \frac{\pi r^2 \omega e}{2} \quad \mu = \frac{e \omega r^2}{2}$$

Where e is the electronic charge.

(b) (i) Distinguish between *soft* and *hard* magnetic materials and give one example of each. [4]

(ii) A toroid wound with 60.0 turns/m of wire carries a current of 5.0A.

The torus is made out of aluminium for which $\chi = 2.3 \times 10^{-5}$ under the given conditions. Compute the values of \mathbf{B} , \mathbf{H} and \mathbf{M} in this setup. [8]

(iii) From the calculations in part (ii), explain the reason why aluminium is not used as an electromagnet. [2]

(c) From the information given in part (a) would you rate aluminium to be a paramagnetic or diamagnetic material? [2]

Q6 (a) The compact form of a nuclear reaction is written as



State the significance of all the symbols appearing in this expression.

(b) Suppose ${}^{10}_5B$ is struck by an alpha particle, releasing a particle of mass number 1 and atomic number 1 and a product nucleus in the reaction. Write down this reaction in symbols and identify the product nucleus.

[4]

(c) A radioactive sample contains $3.54\mu\text{g}$ of pure ${}^{11}_6C$, which has a half-life of 20.4 min.

(i) How many moles of ${}^{11}_6C$ are present initially? [1]

(ii) Determine the number of nuclei present initially. [2]

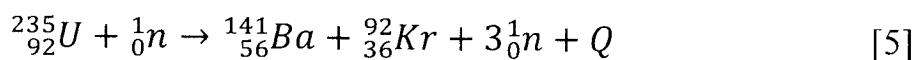
(iii) What is the initial activity of the sample at $t = 0$ and at $t = 2.00$ hours? [9]

Molar mass ${}^{11}_6C = 11.$

Q7 (a) When nuclear fission takes place in ${}^{235}_{92}U$, it collides with a slow neutron, and a lot of energy is produced.

(i) What is nuclear fission as understood in nuclear physics? [2]

(ii) Calculate the total energy, Q , released in the following reaction:



(iii) Explain what is meant by a slow neutron. [2]

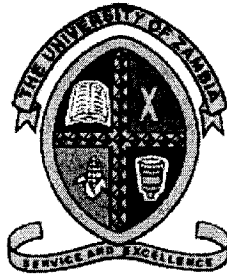
Data: ${}^{235}_{92}U = 235.043923\text{u}$; ${}^{141}_{56}Ba = 140.903496\text{u}$

$${}_{36}^{92}\text{Kr} = 91.907936; {}_0^1n = 1.008665\text{u}.$$
$$1\text{u} \equiv 931.494 \text{ MeV} .$$

- (b) (i) When an electron and a positron meet, the immediate result is *annihilation*. Explain what happens in this process. [2]
- (ii) The opposite of *annihilation* is *pair production*. Explain what is meant by *pair production* and state the conditions necessary for this process to take place. [3]
- (c) A mini nuclear electric power plant is observed to produce 45 MW. If the plant uses ${}_{92}^{235}\text{U}$ as fuel and has an efficiency of 90%, calculate the number of uranium atoms that have to fission per second to ensure constant power generation without load shedding. [6]

END OF PHY 2112 EXAMINATION

THE UNIVERSITY OF ZAMBIA



THE UNIVERSITY OF ZAMBIA
School of Natural Sciences
Department of Physics
2018/2019 Academic Year
End of Year Examinations

PHY2712 – 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.
 - Follow carefully instructions written on the answer booklets.
-

CONSTANTS THAT MAY BE USEFUL

$$\begin{aligned}
 e &= 1.602 \times 10^{-19} \text{ C} \\
 m_p &= 1.67 \times 10^{-27} \text{ kg} \\
 m_e &= 9.11 \times 10^{-31} \text{ kg} \\
 \epsilon_o &= 8.85 \times 10^{-12} \text{ C}^2\text{N}^{-1}\text{m}^{-2} \\
 h &= 6.63 \times 10^{-34} \text{ Js} \\
 \mu_o &= 4\pi \times 10^{-7} \text{ Ns}^2\text{C}^{-2} \\
 c &\cong 3.0 \times 10^8 \text{ m/s} \\
 n_{\text{water}} &= 1.33 \\
 n_{\text{glass}} &= 1.5 \\
 n_{\text{air}} &= 1
 \end{aligned}$$

FORMULAE THAT MAY BE USEFUL

$n_1 \sin \theta_1 = n_2 \sin \theta_2$	$\frac{1}{f} = \frac{1}{u} + \frac{1}{v} = -\frac{2}{R}$	$\frac{n_1}{u} + \frac{n_2}{v} = \frac{n_2 - n_1}{R_1}$
$\frac{1}{f} = \left(\frac{n_2}{n_1} - 1\right) \left(\frac{1}{R_1} - \frac{1}{R_2}\right)$	$m_T = -\frac{h_2}{h_1} = -\frac{v}{u}$	$P = \frac{1}{f}$
$P = U + V = -2K$	$I = I_{\max} \cos^2 \theta$	$\theta_{\min} = 1.22 \frac{\lambda}{D}$
$2nt = \left(m + \frac{1}{2}\right) \lambda,$ $m = 0, 1, 2, \dots$	$2nt = m\lambda,$ $m = 0, 1, 2, \dots$	$a \sin \theta_{\text{dark}} = m\lambda,$ $m = \pm 1, \pm 2, \pm 3, \dots$
$d \sin \theta_{\text{bright}} = m\lambda,$ $m = 0, \pm 1, \pm 2, \pm 3, \dots$	$d \sin \theta_{\text{dark}} = \left(m + \frac{1}{2}\right) \lambda,$ $m = 0, \pm 1, \pm 2, \pm 3, \dots$	$\tan \theta_p = \frac{n_2}{n_1}$

CONSTANTS THAT MAY BE USEFUL

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 e &= 1.602 \times 10^{-19} \text{ C} \\
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FORMULAE THAT MAY BE USEFUL

$n_1 \sin \theta_1 = n_2 \sin \theta_2$	$\frac{1}{f} = \frac{1}{u} + \frac{1}{v} = -\frac{2}{R}$	$\frac{n_1}{u} + \frac{n_2}{v} = \frac{n_2 - n_1}{R_1}$
$\frac{1}{f} = \left(\frac{n_2}{n_1} - 1\right) \left(\frac{1}{R_1} - \frac{1}{R_2}\right)$	$m_T = -\frac{h_2}{h_1} = -\frac{v}{u}$	$P = \frac{1}{f}$
$P = U + V = -2K$	$I = I_{\max} \cos^2 \theta$	$\theta_{\min} = 1.22 \frac{\lambda}{D}$
$2nt = \left(m + \frac{1}{2}\right) \lambda,$ $m = 0, 1, 2, \dots$	$2nt = m\lambda,$ $m = 0, 1, 2, \dots$	$a \sin \theta_{\text{dark}} = m\lambda,$ $m = \pm 1, \pm 2, \pm 3, \dots$
$d \sin \theta_{\text{bright}} = m\lambda,$ $m = 0, \pm 1, \pm 2, \pm 3, \dots$	$d \sin \theta_{\text{dark}} = \left(m + \frac{1}{2}\right) \lambda,$ $m = 0, \pm 1, \pm 2, \pm 3, \dots$	$\tan \theta_p = \frac{n_2}{n_1}$

1. (a) State Fermat's principle of least time. [2]
- (b) Use Fermat's principle of least time to derive Snell's law of refraction of light on a plane boundary. [7]
- (c) The radius of a spherical mirror is -18.0 cm. An object 4.0 cm high is located in front of the mirror at a distance of 45.0 cm. Find
- i. the focal length of the mirror, [1]
 - ii. the power of the mirror, [1]
 - iii. the image distance, and [2]
 - iv. the magnification and size of image. [2]
- (d) Two thin lenses having the following radii of curvature and refractive index are placed in contact. For the first lens, $R_1 = +12.0$ cm, $R_2 = -18.0$ cm and $n = 1.56$, and for the second lens $R_1 = -30.0$ cm, $R_2 = +20.0$ cm and $n = 1.65$. Find the combined powers and focal lengths of the optical system. [5]
-

2. (a) Derive the Gaussian form of the thin lens formula. [10]
- (b) Two thin lenses having focal lengths $f_1 = +9.0$ cm and $f_2 = -18.0$ cm are placed 3.0 cm apart. If an object 2.5 cm high is located 20.0 cm in front of the first lens, calculate the position and size of the final image. [10]
-

3. (a) Derive the Gaussian form of the mirror formula for a thin mirror. [10]
- (b) A thin lens made up of glass of index 1.740 has two faces with radii $R_1 = +10.0$ cm and $R_2 = -25.0$ cm. The thin lens is then submerged in water of index 1.333 and a 3.5 cm object is located 30.0 cm in front of the lens. Calculate
- i. the focal length of the submerged thin lens, [2]
 - ii. the power of the submerged thin lens, [2]
 - iii. the image distance in the water, [2]
 - iv. magnification of image formed in water, and [2]
 - v. size and nature of image formed in water. [2]
-

4. (a) Derive Bragg's Law of crystal diffraction and discuss briefly the method for crystal structure determination. [10]
- (b) Why are X-rays used for crystal structure analysis? [2]
- (c) In a typical experiment for X-ray production, X-rays are produced by acceleration of electrons through a potential difference V . If the potential difference is $V = 10$ kV, what is the wavelength of the produced X-rays? [2]
- (d) Monochromatic light from a helium-neon laser ($\lambda = 632.8$ nm) is incident normally on a diffraction grating containing 6000 grooves per centimeter. Find the angles at which the first and second-order maxima are observed. [4]

- (e) A telescope has an effective radius of 5.0 m. What is its limiting angle of resolution for 680 nm light? [2]
-

5. (a) What do you understand by the term interference of light? [1]
- (b) A viewing screen is separated from a double slit by 4.80 m. The distance between the two slits is 0.0300 mm. Monochromatic light is directed toward the double slit and forms an interference pattern on the screen. The first dark fringe is 4.50 cm from the center line on the screen.
- Determine the wavelength of light. [2]
 - Calculate the distance between adjacent bright fringes. [2]
- (c) A light source emits visible light of two wavelengths: $\lambda = 430$ nm and $\lambda' = 510$ nm. The source is used in a double-slit interference experiment in which the distance between the slits and the viewing screen is 1.53 m and the slit separation distance is 0.0250 mm.
- Find the separation distance between the third-order bright fringes for the two wavelengths. [5]
 - Find the location on the screen where the bright fringes from the two wavelengths overlap exactly. [5]
Use the small angle approximation
- (d) Solar cells - devices that generate electricity when exposed to sunlight - are often coated with a transparent, thin film of silicon monoxide (SiO , $n = 1.45$) to minimize reflective losses from the surface. Suppose a silicon solar cell ($n = 3.5$) is coated with a thin film of silicon monoxide for this purpose. Determine the minimum film thickness that produces

the least reflection at a wavelength of 550 nm, near the center of the visible spectrum. [5]

6. (a) What is meant by the phrase “direction of polarization of a light wave”? [2]

(b) A given light wave can be unpolarized, partially polarized or completely polarized. Name any three kinds of polarization that you know. [3]

(c) Suppose that two orthogonal optical disturbances are represented as

$$\vec{E}_x(z, t) = \hat{i}E_0 \cos(kz - \omega t),$$

and

$$\vec{E}_y(z, t) = \hat{j}E_0 \cos(kz - \omega t + \phi),$$

where $\phi = \pi/2 + 2m\pi$, $m = 0, \pm 1, \pm 2, \dots$. Find

i. the resultant wave, and [4]

ii. indicate the type of polarization of the resultant wave. [1]

(d) Show that a linearly polarized wave can be synthesized from a right-circularly polarized wave and a left-circularly polarized wave. [5]

(e) At a certain point in space, two orthogonal optical disturbances meet. One is given as

$$\vec{E}_x(z, t) = \hat{i}E_0 \cos(kz - \omega t)$$

and another one as

$$\vec{E}_y(z, t) = \hat{j}E_0 \cos(kz - \omega t + \phi),$$

where the phase difference between the two is $-\pi/2$.

- i. Write an expression representing the resultant optical disturbance. [2]
 - ii. What kind of polarization does the resultant optical disturbance depict? [1]
 - iii. If at $t = 0$, the resultant optical disturbance lies along a reference axis at an arbitrary point $z = z_0$, where will it lie at a later time, $t = \frac{kz_0}{\omega}$? [2]
-

7. (a) The most common technique for producing polarized light is to use two polarizing sheets (polarizer and analyzer) whose transmission axes make an angle θ with each other. Only a fraction of the polarized light incident on the analyzer is transmitted through it. Write
 - i. an expression that gives the intensity of the beam that is transmitted through the analyzer, and [2]
 - ii. the name of this expression. [2]
- (b) At what angle should the transmission axis of the analyzer be positioned relative to the transmission axis of the polarizer so that
 - i. the intensity of the transmitted beam is maximum, and [2]
 - ii. complete absorption by the analyzer takes place. [2]
- (c) In terms of the intensity of the unpolarized incoming light, what is the intensity of light as it passes through a single ideal polarizer? [2]
- (d) Unpolarized light passes through two polaroid sheets. The axis of the first is vertical, and that of the second is at 30.0°

to the vertical. What fraction of the incident light is transmitted? [2]

(e) Plane-polarized light is incident on a single polarizing disk with the direction of \vec{E}_0 parallel to the direction of the transmission axis. Through what angle should the disk be rotated so that the intensity in the transmitted beam is reduced by a factor of

i. 3.00 [2]

ii. 5.00 [2]

(f) The angle of incidence of a light beam onto a reflecting surface is continuously variable. The reflected ray is found to be completely polarized when the angle of incidence is 48.0° . What is the index of refraction of the reflecting material? [2]

(g) How far above the horizon is the Moon when its image reflected in calm water is completely polarized? ($n_{\text{water}} = 1.33$) [2]

End of Examination



The University of Zambia
2018/19 Academic Year
University Examinations
PHY3032: Computational Physics I

This paper contains 6 questions. 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. Show your working clearly. Omission of essential work will lead to loss of marks.

SOME USEFUL PHYSICAL CONSTANTS

Acceleration due to gravity, $g = 9.81 \text{ ms}^{-2}$	Universal gas constant, $R = 8.314 \text{ Jmol}^{-1}\text{K}^{-1}$
Density of mercury, $\rho_{\text{mercury}} = 13600 \text{ kg/m}^3$	Density of water, $\rho_{\text{water}} = 1000 \text{ kg/m}^3$
Newton's Gravitation Constant, $G = 6.674 \times 10^{-11} \text{ m}^3\text{kg}^{-1}\text{s}^{-2}$	Stefan Boltzmann constant, $\sigma = 5.672 \times 10^{-8} \text{ Wm}^{-2}\text{K}^{-4}$
Planck's constant $h = 6.6261 \times 10^{-34} \text{ J.s}$	Boltzmann's constant $k = 1.38066 \times 10^{-23} \text{ J/K}$
Radius of the earth, $R = 6.4 \times 10^6 \text{ m}$.	Mass of the Earth, $M_{\text{earth}} = 5.972 \times 10^{24} \text{ kg}$

Q1. (a) Express

(i) 38_{10} as a binary number, [3]

(ii) 11010110101101_2 its Hexadecimal equivalent, [4]

(b) Consider the following Fortran 90 code:

```
IMPLICIT NONE
REAL :: y
REAL (KIND = 8):: h, p
DOUBLE PRECISION :: x = 2.5d0 , 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 = NINT(x)            ;      z = cmplx(h,J)
p = n**10              ;      s = int(imag(z))
      PRINT*, w, y, f
      PRINT*, j, h, z
      PRINT*, p, s
END PROGRAM
```

What numerical values [including appropriate number of decimal points whenever necessary] for **w, y, f, j, h, z, p** and **s** [in this order] would be displayed on a computer screen after program execution? [8]

- (c) 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 < tmax)
```

```
            write(2,*) t, v(t)
```

```
            t= t + 1
```

```
        ENDDO
```

```
1000 FORMAT (2f10.7)
```

```
END PROGRAM driver
```

```
REAL (KIND =4) FUNCTION v(t)
```

```
    IMPLICIT NONE
```

```
    REAL (KIND = 4) ::      pi =4.0d0*atan(1.d0), Vo = 350.0d0
```

```
    REAL (KIND=4 ) ::      phase, t
```

```
        v(t)= Vo*sin(wf*t + phase)
```

```
    RETURN
```

```
END FUNCTION v
```

[10]

- Q2. (a) The following experimental data and were saved (together with headings) 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]
0.17	6.94
0.18	5.19
0.19	4.21
0.20	3.63
0.21	2.95
0.22	2.70
0.23	2.12

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*. [6]
 - (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) can identify an **empty input file**. [2]
- (b) What is meant by the following terms:
- a. Byte, [2]
 - b. Kibibyte[KiB], [2]
 - c. Kilobyte [KB], [2]
 - d. Computer. [3]
- (c) Calculate the maximum and minimum values that can be stored in a 2-byte integer variable. [6]

- Q3.** When air is assumed to be an ideal gas, the velocity of sound v_s in dry air can be approximated by

$$v_s = \sqrt{\frac{\gamma k_B T}{m}},$$

where $\gamma = 1.4$, $k_B = 1.38064852 \times 10^{-23} \text{ m}^2 \text{ kg s}^{-2} \text{ K}^{-1}$, $m = 28.9628 \text{ g/mol}$ while T is temperature. Write a code, using Fortran 90/95, which has a driver and a double precision function with the following specifications:

- a) The function should accept a value of temperature T and return the corresponding value of v_s . **[5]**
- b) The driver program should
 - (i) use loop to generate double precision values of T for $273.15\text{K} \leq T \leq 323.15\text{K}$ in steps of 0.10K , **[5]**
 - (ii) save values of temperature T and corresponding velocity v_s , correct to 6 decimal places, to a file called "velocity.txt", **[4]**
 - (iii) create a GNUPLOT script called "velocityplot.plt" which can be used to plot the graph of v_s against T with approximate axis labels, **[8]**
 - (iv) send an instruction to the computer system to ran the script "velocityplot.plt" using GNUPLOT software. **[3]**

- Q4. (a)** A definite integral of a function $f(x)$ from lower limit x_{\min} to upper limit x_{\max} is expressed as

$$\int_{x_{\min}}^{x_{\max}} f(x) dx.$$

- (i) If a definite integral is estimated as a single trapezoid whose coordinates are $(x_{\min}, 0)$, $(x_{\min}, f(x_{\min}))$, $(x_{\max}, 0)$ and $(x_{\max}, f(x_{\max}))$, show that the single segment trapezoidal approximation is

$$\int_{x_{\min}}^{x_{\max}} f(x) dx \approx \frac{dx}{2} [f(x_{\min}) + f(x_{\max})],$$

where $dx = x_{\max} - x_{\min}$ is the step size. [4]

- (ii) Hence, or otherwise, show that if the domain $[x_{\min}, x_{\max}]$ is partitioned into N subintervals, then the composite trapezoidal approximation is

$$\int_{x_{\min}}^{x_{\max}} f(x) dx \approx \frac{dx}{2} [V + 2W],$$

where $dx = \frac{x_{\max} - x_{\min}}{N}$, $V = f(x_{\min}) + f(x_{\max})$ and $W = \sum_{i=1}^{N-1} f(x_i)$,

for $x_i = x_{\min} + idx$ such that $i = 1, 2, 3, \dots, N-1$. [9]

- (b)** Use the composite Trapezoidal algorithm with 10 subintervals to show, correct to 6 decimal places, that

$$\int_0^1 \exp(-x^3) dx \approx 0.756590. \quad [12]$$

- Q5. (a)** Consider a set of N -data points $[x_i, y_i]$; for $i = 1, 2, 3, \dots, N$. Assuming a straight line model of the form

$$y = a_0 + a_1x,$$

is fitted to the data, use the Chi-square merit function

$$\chi^2 = \frac{1}{N} \sum_{i=1}^N [y_i - y]^2$$

to show that

$$a_0 = \frac{S_{xx}S_y - S_xS_{xy}}{NS_{xx} - S_x^2},$$

$$a_1 = \frac{NS_{xy} - S_xS_y}{NS_{xx} - S_x^2},$$

where $S_x = \sum_{i=1}^N x$, $S_y = \sum_{i=1}^N y_i$, $S_{xx} = \sum_{i=1}^N x_i^2$, $S_{xy} = \sum_{i=1}^N x_i y_i$ and $S_{yy} = \sum_{i=1}^N y_i^2$. [13]

- (b)** Write a code, using Fortran 90/95, that can read a set of N data $[x_i, y_i]$; for $i = 1, 2, 3, \dots, N$ from a file, called “*input.txt*” and implements linear least squares fitting to compute the intercept a_0 and gradient a_1 . [12]

- Q6. (a) Consider a continuous and differentiable function $f(z)$. Use the Taylor series expansion of $f(z)$ to show that if $f(z) = 0$, then for $|z - z_i| \ll 1$ and $f'(z_i) \neq 0$, the approximate value of the root z can be approximated using the Newton Raphson algorithm as

$$z_{i+1} \approx z_i - u_i,$$

where $u_i = f(z_i)/f'(z_i)$ and z_i is the initial guess. [5]

- (b) The spectral distribution of the radiant energy of a black body radiator, is given by the Planck equation, namely

$$u(\lambda, T) = \frac{8\pi ch}{\lambda^5} \left[\frac{1}{e^{(ch/\lambda kT)} - 1} \right],$$

where c is the speed of light in vacuum, h is plank's constant, k is Boltzmann's constant while $u(\lambda, T)$ is the energy per unit volume (i.e. energy density) at wavelength λ and temperature T . For $T = \text{constant}$, the energy density depends only on the wavelength and the value of λ at which $u(\lambda)$ has its maximum value is obtained by differentiating $u(\lambda)$ with respect to λ then setting the result to zero leading to the transcendental equation

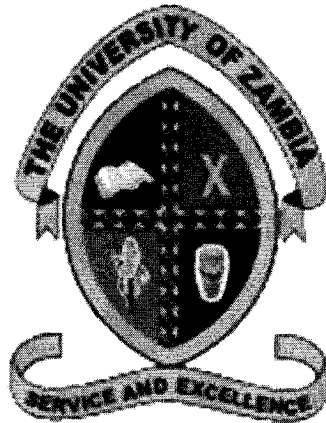
$$f(x) = 0,$$

where $f(x) = 5e^{-x} - 5 + x$ and $x = \frac{ch}{\lambda_m kT}$.

A trivial, and nonphysical solution is $x = 0$. Starting with an initial guess $x_0 = 7.00000$, use the Newton-Raphson Algorithm to show that the non-trivial solution of $f(x) = 0$ correct to 5 decimal points is obtained after 3 iterations as $x = 4.96511$. [10]

- (c) Write a Fortran 90/95 code that implements the Newton Raphson to estimate the value of x correct to 4 decimal places [10]

***** END OF PHY3032 EXAMINATION *****



THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
Department of Physics
2018/2019 ACADEMIC YEAR
End of Year University Examinations
PHY 4222 - Solid State Physics II

Duration : 3 Hours

Total marks: 100

INSTRUCTIONS

This question paper contains six questions.

Answer any four questions. Each question carries 25 total marks.

Write clearly your computer number on the answer booklet provided.

All working should be shown clearly.

Omission of essential work will lead to loss of marks.

Additional information can be found at the end of this question paper.

.....
QUESTION 1
.....

- (a) Beginning from $n = \int_{E_c}^{\infty} D_e(E) f_e(E) dE$ (where D_e is the density of states, f_e is the Fermi distribution function), show that

$$n = 2 \left(\frac{m_e k_B T}{2\pi \hbar^2} \right) \exp \left[\frac{\mu - E_c}{k_B T} \right].$$

[10]

- (b) With the aid of sketches, distinguish direct band gap semiconductors from indirect band gap semiconductors. [3]

- (c) The electron and hole mobilities in a Si sample are 0.15 and 0.17 $\text{m}^2\text{V}^{-1}\text{s}^{-1}$, respectively.

- (i) Determine the conductivity of intrinsic Si at 300 K if the intrinsic carrier concentration is 1.95×10^{20} atoms/ m^3 . [2]

- (ii) The sample is then doped with 6×10^{23} antimony atoms/ m^3 . Determine the equilibrium electron and hole concentrations, the conductivity and the Fermi level relative to the intrinsic level. [6]

- (iii) Hence find the resistance of a doped Si rod which is 1 cm long and 1 mm wide at 300K. [4]

.....
QUESTION 2
.....

- (a) Explain the origin of the energy gap using two standing waves $\psi(+)$ and $\psi(-)$. [7]
- (b) Derive the Clausius-Mossotti relation that expresses the relationship between the dielectric constant and atomic polarizability. [7]
- (c) Using the Kronig-Penney model, show that for $P \ll 1$, the energy of the lowest energy band is

$$E = \frac{\hbar^2 P}{ma^2}.$$

- [5]
- (d) A sample of silicon is purified until it contains 10^{18} donors m^{-3} . Below what temperature does it cease to show intrinsic behaviour? ($E_G = 1.1$ eV and the intrinsic carrier concentration at 300 K is $2 \times 10^{16} \text{ m}^{-3}$.) [6]

.....
QUESTION 3
.....

- (a) Compare and contrast the parent compounds of electron doped cuprates to hole doped cuprates. [4]
- (b) How is superconductivity without doping induced in the parent

compounds of electron doped cuprates? [3]

(c) The critical fields at 16 K and 23 K of NbGe alloy are 18 T and 7.5 T, respectively. Determine the transition temperature and the critical field at 0 K. [10]

(d) Estimate the energy gap for Niobium ($T_c=9.5$ K) at $T = 0$ and show that the minimum photon wavelength needed to break the Cooper pair is 4.3×10^{-4} m. [6]

(e) Which compound holds the highest superconducting transition temperature? State this highest transition temperature recorded. [2]

.....
QUESTION 4
.....

(a) Derive the classical Langevin law of diamagnetism. [6]

(b) The most important contribution to the paramagnetism of CuSO_4 comes from Cu^{2+} ions for which the magnetic moment is due to single unpaired spin ($L = 0, J = S = 1/2, g = 2$).

(i) Write down the probabilities at temperature T that the moment lies parallel and antiparallel to the field, [2]

(ii) hence show that the magnetization for N ions per unit volume in a magnetic field B is

$$M = N\mu_B \tanh(\mu_B B / K_B T). \quad [4]$$

-
- (iii) Write down the internal energy and hence calculate the magnetic heat capacity C_B of ions in a constant field B . [3]
- (iv) Deduce the limiting form of the specific heat at low temperatures. [2]
- (c) A ferromagnetic crystal with $J = \frac{5}{2}$ and $g = 2$ has a Curie temperature of 125 K. Calculate the intrinsic flux density near 0 K. Also calculate the ratio of magnetization at 300 K in the presence of an external field of 50 Oe (50 G) to the spontaneous magnetization at 0 K? [8]

.....
QUESTION 5
.....

- (a) With the aid of diagrams differentiate the three types of antiferromagnetism. [6]
- (b) Briefly define ferroelectricity and piezoelectricity; and state the difference between insulators and dielectrics. [4]
- (c) Find the frequency dependence of the electronic polarizability of an electron having the resonance frequency ω_0 , treating the system as a simple harmonic oscillator. [4]
- (d) The optical index of refraction and the dielectric constant of sodium chloride crystal are 1.7 and 8.2 respectively. Determine the percentage of electronic polarizability. [7]

-
- (e) Explain the meaning and origin of piezoelectricity. Justify the statement “All ferroelectric crystals are piezoelectric, but all piezoelectric crystals are not ferroelectric”. [4]

.....
QUESTION 6
.....

- (a) A magnetic material has a magnetization of 2520 A m^{-1} and produces a flux density of $0.00423 \text{ Wb m}^{-2}$. Calculate the magnetizing force and the relative permeability of the material. [6]
- (b) Use the London equation to show that the penetration of a parallel magnetic field into a superconducting film of thickness d in the xy plane is described by

$$B = B_e \frac{\cosh(z/\lambda)}{\cosh(d/\lambda)}$$

where B_e is the applied magnetic field and the centre of the film is at $z=0$. [9]

- (c) The London penetration depth for a superconductor at 3 K and 7.09 K are 39.61 nm and 173 nm respectively. Show that the superconducting temperature of this superconductor is 7.2 K. [9]
- (d) What are topological insulators? [1]

.....END OF EXAMINATION.....

ADDITIONAL INFORMATION

Planck's constant $h = 6.62 \times 10^{-34}$ Js, electron charge $e = 1.602 \times 10^{-19}$ C, electron mass $m_e = 9.11 \times 10^{-31}$ kg, proton mass $m_p = 1.67 \times 10^{-27}$ kg, neutron mass $m_n = 1.67 \times 10^{-27}$ kg, Avogadro's constant $A_v = 6.022 \times 10^{23}$ mol⁻¹, Boltzmann constant $k_B = 1.38 \times 10^{-23}$ JK⁻¹, Permittivity of free space $\epsilon_0 = 8.85 \times 10^{-12}$ s²m⁻², permeability of free space $\mu_0 = 4\pi \times 10^{-7}$, Bohr magneton $\mu_B = 9.274 \times 10^{-24}$ Am²

$$n_i = p_i = 2 \left[\frac{2\pi k_B T}{h^2} \right]^{\frac{3}{2}} (m_n^* m_p^*)^{\frac{3}{4}} \exp\left(\frac{E_V - E_C}{2k_B T}\right);$$

Or

$$n = n_i \exp\left(\frac{E_f - E_i}{k_B T}\right)$$

$$P \frac{\sin \alpha a}{\alpha a} + \cos \alpha a = \cos ka$$

$$M = Ng\mu_B J B_J(y)$$

where

$$y = \left(\frac{g\mu_B J B}{k_B T}\right); B_J(y) \approx \frac{y(J+1)}{3J}$$

$$\frac{\lambda(0)^2}{\lambda(T)^2} = 1 - \left(\frac{T}{T_c}\right)^2$$

$$\frac{\lambda(0)^2}{\lambda(T)^2} = 1 - \left(\frac{T}{T_c}\right)^4$$

$$H_c(T) = H_c(0) \left(1 - \left(\frac{T}{T_c}\right)^2\right)$$

$$\chi = \frac{\mu_0 N \mu_B^2}{3k_B T} g^2 J(J+1)$$

$$L = \sum m_l$$

$$\int_{-\infty}^{+\infty} \frac{x^3 e^x}{(e^x + 1)^2} dx = \frac{\pi^2}{3}$$

$$\int_0^{+\infty} \frac{x}{e^x - 1} dx = 1.51$$

$$\int_0^{+\infty} \frac{x^3}{e^x - 1} dx = \frac{\pi^4}{15}$$

$$g = 1 + \frac{J(J+1) + S(S+1) - L(L+1)}{2J(J+1)}$$

$$\int_0^{\infty} x^{\frac{1}{2}} e^{-x} dx = \frac{\pi^{\frac{1}{2}}}{2}$$

$$\int_0^{\infty} x^4 e^{-x} dx = 24$$

$$\lambda_k = \frac{\hbar^2 k^2}{2m}$$

$$\alpha = \frac{2mE}{\hbar^2}$$

$$\cos(2\Theta) = \cos^2 \Theta - \sin^2 \Theta$$

$$\sin(2\Theta) = 2 \sin \Theta \cos \Theta$$

$$\tan(2\Theta) = \frac{2 \tan \Theta}{1 - \tan^2 \Theta}$$

$$\sinh(x) = \frac{e^x - e^{-x}}{2}$$

$$\cosh(x) = \frac{e^x + e^{-x}}{2}$$

$$\tanh(x) = \frac{e^x - e^{-x}}{e^x + e^{-x}}$$



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

2019 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.**

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 the differences between a compiler and interpreter. [5]

(b) (i) Design a circuit to control the various appliances in a house. The control switches are in the kitchen and it is accessible to anyone in the house. The circuit should 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 02H. [6]

The appliances connected are as follows.

Air conditioner-ON

Television-OFF

Fan 1-OFF

Fan 2 -OFF

Light 1- ON

Light 2- ON

Light 3 - OFF

Light 4 -ON

(ii) Write a program to keep the lights 1 & 4 **ON** and fans 1 & 2 **ON** continuously without affecting the functions of the other appliances, even if someone turns off the switch. Illustrate your logic clearly. [7]

(c) (i) Explain the internal data operations of 8085 microprocessor. [5]

(ii) What are the general purpose registers of 8085 microprocessor and explain how they can be combined to perform 16-bit operations. [2]

Q2. (a) (i) Explain what is meant by *don't care conditions* in Karnaugh map technique. [5]

(ii) Reduce the following expression using a Karnaugh map.

$$X = \sum m(3,4,7,9,10,11) + d(0,1,2,13,14,15) \quad [10]$$

(b) Find the minimum product of sum expression for the following function.

$$F = \pi M(3, 5,7, 8, 10, 11, 12, 13) \quad [10]$$

Q3. (a) (i) Define the memory map of a computer. Explain the memory map of a (2K×8) memory chip with figure. [12]

(ii) Explain how the memory map can be changed by modifying the hardware of the chip select line. [7]

(b) Write short notes on [6]

(i) Cache controller

(ii) EPROM

Q4. (a) Using connection abbreviations, implement the following functions on a Field Programmable Logic Array (FPLA) circuit. [8]

$$G_3 = A$$

$$G_2 = A \bar{B} + \bar{A} B$$

$$G_1 = B \bar{C} + \bar{B} C$$

(b) Explain the functions of status flags in the 8085 microprocessor. [6]

(c) (i) Explain the functions of the following external signals. [6]

RESET, INTERRUPT, READY, HOLD

(ii) Write short notes on EPROM. [5]

Q5. A system is designed to monitor the temperature of a plant. A set of 10 temperature readings are recorded in 16 bits and stored in memory locations starting at 8060 H as shown below. 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 (05 H) of all temperature readings is constant.

<i>Temperature Readings</i>	<i>Memory addresses</i>
05 H	8060 H
81 H	8061 H
05 H	8062 H
95 H	8063 H
05 H	8064 H
A4H	8065 H
05 H	8066 H
C3 H	8067 H
05 H	8068 H
F2 H	8069 H

Draw the flow chart and write a program to transfer the low order temperature readings to consecutive memory locations starting at 8080 H and discard the higher order bytes.

<i>Low order Temperature readings</i>	<i>Memory addresses</i>
---	-----------------------------

81 H	8080 H
95 H	8081 H
A4 H	8082 H
C3 H	8083 H
F2 H	8084 H

Q6. A weather forecasting station stores a set of pressure readings in memory locations starting at 8000 H. The end of data string is indicated by the data byte 00 H.

Draw the flow chart and write a program to add the set of pressure readings. The answer may be larger than FF H. Store the sum in the memory locations 8090 H and 8091 H. [25]

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
PHYSICS DEPARTMENT
SECOND SEMESTER EXAMINATIONS 2019
PHY4535 QUANTUM MECHANICS II

TIME: THREE HOURS
ANSWER: ANY FOUR QUESTIONS
MAXIMUM MARKS: 100

The Hamiltonian of the harmonic oscillator is

$$H = -\frac{\hbar^2}{2m} \frac{d^2}{dx^2} + \frac{1}{2} kx^2$$

$$\int_{-\infty}^{\infty} e^{-\beta x^2} dx = \sqrt{\frac{\pi}{\beta}} \quad \text{and} \quad \int_{-\infty}^{\infty} x^2 e^{-\beta x^2} dx = \frac{1}{2\beta} \sqrt{\frac{\pi}{\beta}}$$

$$\int \cot \theta d\theta = \ln |\sin \theta| + C$$

$$\int_0^{\infty} x^n e^{-\mu x} dx = n! \mu^{-n-1}$$

1. (a) (i) Show that the expression for the first-order energy correction in non-degenerate time-independent perturbation theory is

$$E_n^{(1)} = \langle \psi_n^{(0)} | H' | \psi_n^{(0)} \rangle$$

where H' is the perturbation. [8]

(ii) A particle moving in a one-dimensional infinite potential well with walls at $x = -a$ and $x = a$ is acted upon by the perturbation $H' = \varepsilon |x|$, where ε is a very small parameter. This perturbation has the effect of modifying the bottom of the potential. Find the first-order correction to the energy of the ground state. [9]

The even-parity eigenfunctions are given by

$$\psi_n(x) = \sqrt{\frac{1}{a}} \cos \frac{n\pi x}{2a}, \quad n = 1, 3, 5, \dots$$

Note that $|x| = x$ for $x > 0$ while $|x| = -x$ for $x < 0$.

(b) If a system is initially in the state $\psi_a^{(0)}$ of the Hamiltonian H_0 and if the perturbation $\lambda H'(t)$ acts from t_0 to t on the system, transitions will occur to other states $\psi_b^{(0)}$ of H_0 with transition probability amplitudes given to first order by

$$c_{ba}^{(1)} = (i\hbar)^{-1} \int_0^t H'_{ba}(t') \exp(i\omega_{ba}t') dt'$$

where

$$H'_{ba}(t) = \langle \psi_b^{(0)} | H'(t) | \psi_a^{(0)} \rangle \quad \text{and} \quad \omega_{ba} = \frac{E_b^{(0)} - E_a^{(0)}}{\hbar}.$$

Show that if in fact the perturbation is constant and acts during the time interval $0 \leq t \leq t_0$ then the first-order change in the energy of any state is the same as is predicted by time-independent perturbation theory. [8]

2.(a) When a time-independent perturbation H' acts on a system, the first order change $E^{(1)}$ in the energy of an α -degenerate level is obtained from the secular equation

$$\begin{vmatrix} H'_{11} - E^{(1)} & H'_{12} & \dots & H'_{1\alpha} \\ H'_{21} & H'_{22} - E^{(1)} & \dots & H'_{2\alpha} \\ \dots & \dots & \dots & \dots \\ H'_{\alpha 1} & H'_{\alpha 2} & \dots & H'_{\alpha\alpha} - E^{(1)} \end{vmatrix} = 0$$

where

$$H'_{ij} = \langle \psi_i^{(0)} | H' | \psi_j^{(0)} \rangle$$

and $\{\psi_i^{(0)}\}$ are the degenerate eigenfunctions. Show that if the off-diagonal matrix elements vanish then the first-order energy corrections are the same as in non-degenerate perturbation theory. [5]

(b) A certain system has the Hamiltonian

$$H = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 0 & i \\ 0 & -i & 0 \end{pmatrix}$$

and is acted upon by the perturbation

$$H = \begin{pmatrix} 0 & \varepsilon & 0 \\ \varepsilon & 2\varepsilon & 0 \\ 0 & 0 & -\varepsilon \end{pmatrix}$$

where ε is very small.

(i) Show that the eigenvalues of the system are $E_1 = 1$, $E_2 = 1$ and $E_3 = -1$ with respective eigenvectors

$$\chi_1 = \begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix}, \chi_2 = \frac{1}{\sqrt{2}} \begin{pmatrix} 0 \\ 1 \\ -i \end{pmatrix} \text{ and } \chi_3 = \frac{1}{\sqrt{2}} \begin{pmatrix} 0 \\ -i \\ 1 \end{pmatrix}$$

[8]

(ii) Obtain the energies of the states of the perturbed system to first order. [12]

3. (a) The use of the variational method for estimating ground-state energies and eigenfunctions is based on the result

$$\langle E \rangle \geq E_0$$

where E_0 is the ground-state energy and $\langle E \rangle$ is the expectation value of the Hamiltonian for a selected trial function. Prove this result. [5]

(b) The trial function

$$\phi_\alpha(x) = e^{-ax^2}$$

is used to obtain an approximation to the ground-state energy of the one-dimensional harmonic oscillator, where the variational parameter is α .

(i) Give two properties of this trial function which it shares with the unknown ground-state eigenfunction. [2]

(ii) Show that this trial function gives the exact ground-state energy

$$E_0 = \hbar\omega/2$$

(iii) Explain why this result is not unexpected. [10]
[2]

(c) The effect of the ladder operators on the eigenvectors for spin-1/2 is

$$S_+\chi_- = [s(s+1) - m(m-1)]^{1/2} \hbar \chi_+$$

and

$$S_-\chi_+ = [s(s+1) - m(m+1)]^{1/2} \hbar \chi_-$$

Use this information to show that the operators for the x and y components for spin 1/2 are

$$S_x = \frac{\hbar}{2} \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} \text{ and } S_y = \frac{\hbar}{2} \begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix}$$

[6]

4. (a) One of the dynamical variables A of a certain system satisfies the eigenvalue equation

$$A\psi = a\psi$$

Prove that this can be transformed into the matrix eigenvalue equation

$$[A][\psi] = a[\psi]$$

[6]

(b) In a certain basis, a physical system has the Hamiltonian

$$[H] = \begin{pmatrix} a_1 & 0 & 0 \\ 0 & a_2 & 0 \\ 0 & 0 & a_3 \end{pmatrix}.$$

where the constants a_1 , a_2 and a_3 are all different from one another.

(i) What does the fact that the matrix $[H]$ is diagonal tell us about the basis set used to obtain it? [2]

(ii) Show that the eigenvectors of the Hamiltonian are [6]

$$\chi_1 = \begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix}, \quad \chi_2 = \begin{pmatrix} 0 \\ 1 \\ 0 \end{pmatrix} \text{ and } \chi_3 = \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix}$$

[4]

(c) (i) Show that the eigenvectors of a complete set satisfy

$$\sum_i |\phi_i\rangle \langle \phi_i| = \mathbf{1}$$

and explain the significance of this. [5]

(ii) Show the eigenvectors found in (b) satisfy this property. [2]

5.(a) The ladder operators for the harmonic oscillator are

$$a_{\pm} = \frac{1}{\sqrt{2}} \left[\frac{p}{(m\hbar\omega)^{1/2}} \pm i \left(\frac{m\omega}{\hbar} \right)^{1/2} x \right]$$

They satisfy the commutation relations

$$[H, a_{\pm}] = \pm \hbar\omega a_{\pm}$$

(i) Prove that the operators are indeed ladder operators. [6]

(ii) Prove that the ground state ψ_0 of the harmonic oscillator satisfies the equation

$$\frac{1}{\sqrt{2}} \left[-i \left(\frac{\hbar}{m\omega} \right)^{1/2} \frac{d}{dx} - i \left(\frac{m\omega}{\hbar} \right)^{1/2} x \right] \psi_0 = 0$$

[4]

(iii) Solve the equation and hence show that the ground state eigenfunction is

$$\psi_0 = \left(\frac{m\omega}{\pi\hbar} \right)^{1/4} \exp\left(-\frac{m\omega}{2\hbar} x^2\right)$$

[6]

(iv) Explain how to generate all the states of the harmonic oscillator. [4]

(v) Given that

$$H = \left(a_+ a_- + \frac{1}{2} \right) \hbar\omega$$

show that the energies of the states are given by

$$E_n = \left(n + \frac{1}{2} \right) \hbar\omega. \quad n = 0, 1, 2, \dots$$

[5]

6. (a) The ladder operators L_{\pm} for orbital angular momentum are given by

$$L_{\pm} = \hbar e^{i\phi} \left(\pm \frac{\partial}{\partial \theta} + i \cot \theta \frac{\partial}{\partial \phi} \right)$$

(i) Explain why L_+ satisfies

$$L_+ Y_{ll} = 0.$$

and L_0 satisfies

$$L_- Y_{l,-l} = 0$$

(ii) Solve the differential equation for L_+ to show that [4]

$$Y_{ll} = A (\sin \theta)^l e^{il\phi}$$

(iii) Hence find an un-normalised expression for $Y_{l,l-1}$. [12]
[3]

(b) A certain hydrogen atom has the wave function

$$\psi = Bre^{-r/2a_0} \cos \theta$$

, where B is a constant and

$$a_0 = \frac{4\pi\epsilon_0\hbar^2}{\mu e^2}$$

is the Bohr radius.

(i) Calculate the normalisation constant B . [4]

(ii) Obtain the quantum number of the z component of the angular momentum. [2]

Note that

$$L_z = -i\hbar \frac{\partial}{\partial \phi}$$

and

$$dV = r^2 \sin \theta dr d\theta d\phi$$

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



THE UNIVERSITY OF ZAMBIA
PHYSICS DEPARTMENT
UNIVERSITY EXAMINATIONS – 2019

PHY4815 - PHYSICS OF RENEWABLE ENERGY RESOURCES

TIME: 3 HOURS

MAX MARKS: 100

ATTEMPT ANY **FOUR** (4) QUESTIONS. ALL QUESTIONS CARRY EQUAL MARKS. THE MARKS ARE SHOWN IN BRACKETS.

You may use the following information:

Boltzmann constant k	$= 1.38 \times 10^{-23} \text{ JK}^{-1}$
Gas constant R	$= 8314 \text{ J/kmol.K}$
1 electron volt	$= 1.6 \times 10^{-19} \text{ J}$
Stefan's constant σ	$= 5.67 \times 10^{-8} \text{ W/m}^2\text{K}^4$
Sun's radius R_s	$= 6.96 \times 10^8 \text{ m}$
Mean Earth-Sun distance r_0	$= 1.496 \times 10^{11} \text{ m}$
Solar constant I_{sc}	$= 1367 \text{ Wm}^{-2}$
Earth's radius R_e	$= 6.37 \times 10^6 \text{ m}$
Planck's constant h	$= 6.6 \times 10^{-34} \text{ J.s}$
Speed of light c	$= 3.0 \times 10^8 \text{ m.s}^{-1}$

In the usual notation

$$E_0 = \left(\frac{r_0}{r} \right)^2 = 1 + 0.033 \cos \left(\frac{360 d_n}{365} \right)$$

$$\delta = 23.45^\circ \sin \left[\frac{360}{365} (d_n + 284) \right]$$

$$\cos \theta_z = \sin \delta \sin \phi + \cos \delta \cos \phi \cos \omega$$

$$\tan \psi = \frac{\cos \delta \sin \omega}{\cos \delta \sin \phi \cos \omega - \sin \delta \cos \phi}$$

$$\cos \psi = \frac{\sin \alpha \sin \phi - \sin \delta}{\cos \alpha \cos \phi}$$

$$\begin{aligned} \cos \theta &= (\sin \phi \cos \beta - \cos \phi \sin \beta \cos \gamma) \sin \delta \\ &+ (\cos \phi \cos \beta + \sin \phi \sin \beta \cos \gamma) \cos \delta \cos \omega \\ &+ \cos \delta \sin \beta \sin \gamma \sin \omega \end{aligned}$$

$$\omega = 15^\circ (12 - t); \quad \omega_s = \cos^{-1}(-\tan \phi \tan \delta)$$

$$\text{Solar time} = \text{clock time} + 4(L_l - L_s) \text{ min} + \text{EOT}$$

$$\text{Wien's Law:} \quad \lambda_{\max} T = 2898 \text{ } \mu\text{m.K}$$

The emissive power of a black body $B_\lambda(T)$ (in W/m^2 per unit wavelength range) is

$$B_\lambda(T) = \frac{2\pi hc^2}{\lambda^5 \left(e^{\frac{hc}{\lambda kT}} - 1 \right)}$$

Direct flux on an inclined surface

$$F^{dir} = I_{sc} \cos \theta \exp \left(-\frac{\tau}{\cos \theta_z} \right)$$

The convective heat flux from a plate to a glazing

$$J = h_d(T_2 - T_1)$$

In a single heat exchanger the exit temperature is

$$T_{f,e} = T_B - (T_B - T_{f,i}) \exp\left(-\frac{U_L L}{\dot{m} C_f}\right),$$

and the heat extraction rate is

$$\dot{Q} = \dot{m} C_f (T_B - T_{f,i}) \left[1 - \exp\left(-\frac{U_L L}{\dot{m} C_f}\right)\right].$$

Fresnel's equations

$$r_{\parallel} = \left[\frac{n_r^2 \cos \theta_i - n_i \sqrt{n_r^2 - n_i^2 \sin^2 \theta_i}}{n_r^2 \cos \theta_i + n_i \sqrt{n_r^2 - n_i^2 \sin^2 \theta_i}} \right]^2$$

$$r_{\perp} = \left[\frac{n_i \cos \theta_i - \sqrt{n_r^2 - n_i^2 \sin^2 \theta_i}}{n_i \cos \theta_i + \sqrt{n_r^2 - n_i^2 \sin^2 \theta_i}} \right]^2$$

Overall reflectance and transmittance of a single glazing are

$$R = r \left[1 + \frac{\alpha^2 (1-r)^2}{1 - \alpha^2 r^2} \right]$$

$$T = \frac{\alpha (1-r)^2}{1 - \alpha^2 r^2}$$

For an ideal selective surface

$$f(x)x^4 = x_0^4 \text{ where } x = \lambda_c T_P \text{ and } x_0 = \lambda_c T_0; T_0 = 394K$$

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$$r_{\perp} = \left[\frac{n_i \cos \theta_i - \sqrt{n_r^2 - n_i^2 \sin^2 \theta_i}}{n_i \cos \theta_i + \sqrt{n_r^2 - n_i^2 \sin^2 \theta_i}} \right]^2$$

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For an ideal selective surface

$$f(x)x^4 = x_0^4 \text{ where } x = \lambda_c T_p \text{ and } x_0 = \lambda_c T_0 ; T_0 = 394K$$

The carrier concentration in an intrinsic semiconductor is

$$n_i = p_i = AT^{3/2} \exp\left(-\frac{\epsilon_g}{2kT}\right)$$

The resistivity of an extrinsic material is

$$\rho = \frac{1}{e(n\mu_n + p\mu_p)}$$

The law of mass action

$$n_i p_i = np$$

The reverse saturation current density is

$$J_0 = DT^3 \exp\left(-\frac{\epsilon_g}{kT}\right)$$

The forward current density is

$$J = J_0 \left[\exp\left(\frac{eV}{kT}\right) - 1 \right]$$

The J-V characteristic equation for a single cell is

$$J = \bar{K} F - J_0 \left(e^{\frac{eV}{kT}} - 1 \right)$$

Yearly variation of the equation of time

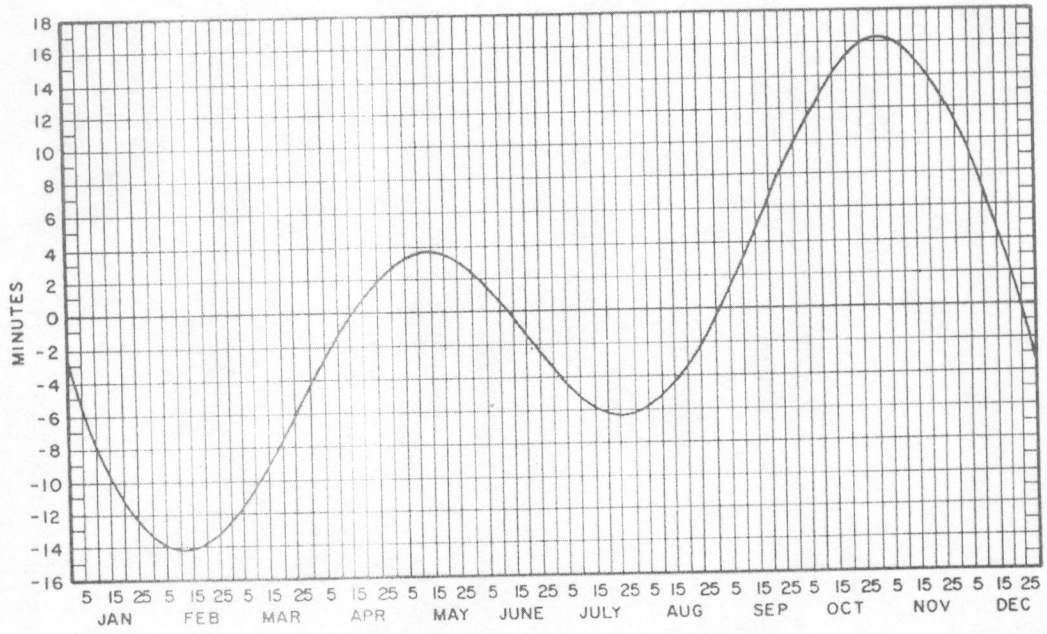


TABLE *The function $f(x)$*

$x(\mu\text{ m-K})$	$f(x)$	$x(\mu\text{ m-K})$	$f(x)$	$x(\mu\text{ m-K})$	$f(x)$
1100	0.001	4600	0.580	8100	0.860
1200	0.002	4700	0.594	8200	0.864
1300	0.004	4800	0.608	8300	0.868
1400	0.008	4900	0.621	8400	0.871
1500	0.013	5000	0.634	8500	0.875
1600	0.020	5100	0.646	8600	0.878
1700	0.029	5200	0.658	8700	0.881
1800	0.040	5300	0.669	8800	0.884
1900	0.052	5400	0.680	8900	0.887
2000	0.067	5500	0.691	9000	0.890
2100	0.083	5600	0.701	9100	0.893
2200	0.101	5700	0.711	9200	0.895
2300	0.120	5800	0.720	9300	0.898
2400	0.140	5900	0.730	9400	0.901
2500	0.161	6000	0.738	9500	0.903
2600	0.183	6100	0.746	9600	0.905
2700	0.205	6200	0.754	9700	0.908
2800	0.228	6300	0.762	9800	0.910
2900	0.251	6400	0.770	9900	0.912
3000	0.273	6500	0.776	10000	0.914
3100	0.295	6600	0.783	11000	0.932
3200	0.318	6700	0.790	12000	0.945
3300	0.340	6800	0.796	13000	0.955
3400	0.362	6900	0.802	14000	0.963
3500	0.383	7000	0.808	15000	0.969
3600	0.404	7100	0.814	16000	0.974
3700	0.424	7200	0.819	17000	0.978
3800	0.443	7300	0.824	18000	0.981
3900	0.462	7400	0.830	19000	0.983
4000	0.483	7500	0.834	20000	0.986
4100	0.499	7600	0.840	30000	0.995
4200	0.515	7700	0.844	40000	0.998
4300	0.533	7800	0.848	50000	0.999
4400	0.549	7900	0.852		
4500	0.564	8000	0.856		

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4500	0.564	8000	0.856		

Q.1 A horizontal solar panel is situated in Chipata (Zambia) with latitude 13.6°S and longitude 32.6°E . The standard longitude of Zambia is 30°E . On Zambia's Independence Day 24th October at 10.00 hour the optical thickness of the atmosphere is $\tau = 0.15$. Find

- (i) declination [3]
- (ii) sunset hour angle [3]
- (iii) day length [2]
- (iv) clock time for sunset [5]
- (v) angle of incidence of direct radiation on the panel [7]
- (vi) direct solar flux incident on the panel [5]

Q.2. (a) Listing the assumptions made show that for two parallel planes at temperatures T_1 and T_2 ($T_2 > T_1$) the net radiative flux transferred from the hotter surface is given by

$$J = \frac{\sigma (T_2^4 - T_1^4)}{1/\epsilon_1 + 1/\epsilon_2 - 1}$$

[12]

Find J if

- (i) one of the surface is a perfect reflector,
- (ii) both the surfaces are perfect reflectors,
- (iii) one of the surface is a perfect absorber. [2+2+2]

(b) A horizontal flat plate collector has an absorbing plate and a glazing separated by a distance of 10 cm. The emittance of the plate is $\epsilon_p = 0.9$ and that of the glazing is $\epsilon_g = 0.6$. The temperatures of the plate and the glazing are 80°C and 40°C , respectively. Estimate the

- (i) convective
- (ii) radiative

flux transfers from the absorber plate to the glazing. Given the value of the convection coefficient $h_d = 3.3 \text{ W/m}^2\text{-}^{\circ}\text{C}$. [3+4]

Q.3. Consider a pair of long concentric cylindrical surfaces of radii r_{in} and r_{out} whose temperatures are respectively T_{in} and T_{out} . The space between the cylinders is filled up with a material of thermal conductivity K . Assuming a steady state,

- (a) obtain an expression for the heat flowing per unit time per unit length of the cylinder, and hence for the U_L -value. [7]

- (b) Show that when two concentric layers of insulation are used around a pipe, the overall U_L is given by

$$\frac{1}{U_L} = \frac{1}{U_{I_1}} + \frac{1}{U_{I_2}}$$

where U_{I_1} and U_{I_2} refer to the individual insulation. [7]

- (c) A 2 m section of a plastic pipe ($K_p = 0.7 \text{ W/m } ^\circ\text{C}$) has inner and outer diameters of 1.5 cm and 2cm. It is holding water at 80°C . The pipe is wrapped in fiber glass insulation ($K_f = 0.05 \text{ W/m } ^\circ\text{C}$) up to an outside diameter of 5 cm. The outside temperature of the insulation is 40°C .
- (i) Find the overall U_L value for the pipe and the insulation.
 (ii) Calculate the heat flow rate.
 (iii) Calculate the temperature at the interface between the pipe and the insulation.

[6+2+3]

- Q.4 (a) Obtain the two conditions of anti-reflecting coatings for normal incidence. [8]
- (b) A glazing of index $n = 1.5$ is coated with a film to make it anti-reflective at normal incidence.
- (i) What should the film index be? [2]
- (ii) What should its minimum thickness be if it is to produce zero reflection at $\lambda_0 = 600 \text{ nm}$? [3]
- (c) (i) Plot a qualitative diagram of the emissivity/absorptivity vs wavelength for a non-selective (grey), real selective and an ideally selective surface. [3]
- (ii) A non-selective surface is exposed to an incident flux of solar constant. Neglecting back losses and convection losses, find the steady-state temperature of the surface. [4]
- (iii) If the surface in c(ii) above is an ideal selective surface with a cut-off at $6\mu\text{m}$, estimate the steady state temperature of the plate. [5]

Q.5 (a) Define optical efficiency, thermal efficiency and overall efficiency of a heating panel. Establish a relationship among the three. [5]

(b) (i) What do you understand by "stagnant conditions" as referred to a collector?

(ii) Write down the equation for energy balance under non-steady conditions of such a collector,

(iii) Solve the equation in (ii) above and show that

$$T_p - T_a = \frac{F_{abs}}{U_c} \left[1 - \exp\left(-\frac{\bar{U}_c t}{C_A}\right) \right].$$

(iv) Find the value of $T_p - T_a$ under steady-state stagnant conditions.

(v) What is the time constant of the collector and its physical significance?

[2+2+6+2+2]

(c) An absorber plate of a collector is made of copper ($C = 389 \text{ J/kg-}^\circ\text{C}$) and has an area of 5m^2 and a mass of 30 kg . The overall heat transfer coefficient to the surroundings is $U_c = 8 \text{ W/m}^2$.

(i) Find the time constant of the collector. [2]

ii) If the insolation suddenly changes from zero to some constant value, how much time will it take for $(T_p - T_a)$ to reach 80% of the stagnant limit? [4]

Q. 6 Consider silicon semiconductor with band gap $\epsilon_g = 1.12 \text{ eV}$.

(a) Show that the maximum theoretical efficiency of a silicon solar cell is about 24%. Take $V_{oc} = 0.6\text{V}$ and $K = 0.4\text{A/m}^2$. [5]

(b) Find the cut off wavelength λ_c for the silicon semiconductor. [3]

(c) Find the maximum fraction of solar spectrum (5800K) that can possibly be harnessed by the silicon semiconductor photovoltaic. [3]

(d) Considering radiation as photons and giving adequate physical explanations, obtain an expression for the photocurrent density in a semiconductor in terms of the average responsivity of the semiconductor and the incident flux. [7]

(e) If the spectral responsivity is equal to $K_\lambda = 0.2 \text{ A/W}$ for $0 < \lambda < 1 \mu\text{m}$ and $K_\lambda = 0.3 \text{ A/W}$ for $1 \mu\text{m} < \lambda < \lambda_c$, find the average responsivity for the solar spectrum (5800K) and calculate the photocurrent density at a flux of 1 Sun. [7]

----- END OF THE EXAMINATION -----