THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

NATURAL SCIENCES

1. Theory paper .... BS 111
2. Cell molecular Bilogy and Genetics Practical paper I. BS 211
3. Cell molecular BIology and Genetics.Theory paper .... BS 211
4. Form. Function and Diversity of plants. Pract. Paper. BS 221
5. Biostatistics. Theory paper .... BS 919
6. Ethology and Evolution. Practical paper II .... BS 321
7. Theory paper .... BS 331
8. Microbiology. Theory paper I .... BS 341
9. Entomology. Theory paper .... BS 351
10. Molecular Biology. Theory paper I .... BS 361
11. Molecular biology. Theory paper II .... BS 361
12. Inverterbrates. THeory paper .... BS 375
13. Insect Behaviour and Ecology: Theory paper II ...... BS 411
14. Microbiology: Theory paper I........................ BS 421
15. Advanced parasitology. Paper I .... BS 431
16. Advanced parasitology. Paper. Paper II (Practical)... BS 431
17. Advanced molecular Biology. Paper I .... BS 441
18. Population Ecology . Theory papaper I .... BS 475
19. Biology of seed plants: Theory paper .... BS 915
20. Plant pathology. Theory paper .... BS 935
21. Introductory Chemistry I .... C 101
22. Inorganic Chemistry ....C 205/C 225
23. Inorganic Chemistry ....C 205/C 245
24. Organic Chemistry ....C 251
25. Biochemistry I ....C 311
26. Spectroscopic Analysis ....C 321
27. Inorganic Chemistry ....C 341
28. Organic Chemistry ....C 435
29. Physical Chemistry ....C 361
30. Chemistry ....C 411
31. Advanced Inorganic Chemistry ....C 441
32. Advanced Analytical Chemistry ....C 421
33. Organic Chemistry ....C 451
34. Analytical/Physical/Organic Chemistry ....CAV 251
35. Introduction to Human Geography I ....GEO 111
36. Introduction to Human Georgraphy II (Distance)......GEO 112
37. The Geography of Africa.............................GEO 211
38. Quantative Techniques in Human Geography I ....GEO 271
39. Environment and development I ....GEO 381
40. Land Resources Survey ....GEO 451
41. Environment and development II ....GEO 481
42. Geography ....GEO 911
43. Urban Geography ....GEO 932
44. Climatology ....GEO 951
45. Geomorphology ....GEO 955
46. Soils Geography ....GEO 961
47. Aerial photography and Aerial interpretation........GEO 971
48. Mathematics: Distance Education .... M 111

49. Partial Entry .... M 111/112
50. Mathematics. Distance Education .... M 112
51. Mathematics .... M 161
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53. Mathematical Methods III .... M 211
54. Mathematical methods IV (Dist.Educ.) .... M 212
55. Mathematical Methods IV Feb 1998. .... M 212
56. Second Year Mathematics .... M 231
57. Introduction to Computer programming .... M 241
58. Mathematics .... M 261
59. Mathematics Group and Ring Theory .... M 325
60. Real Analysis III .... M 331
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63. Mathematics .... M 421
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65. Mathematics .... M 465
66. Mathematics .... M 491
67. Systems Analysis and Design .... M 492
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69. Numerical Analysis I .... M 991
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71. Partial Entry Examination in Physics .... P 191
72. Introductory Physics .... P 212
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74. Properties of Matter and Thermal Physics .... P 231
75. Classical Mechanics .... P 251
76. CLassical Mechanics II .... P 252
77. Statistical and Thermal Physics .... P 332
78. Introduction to Electronics .... P 341
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THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

BS 111

Theory paper

Time: Three hours

Instructions:

1. Answer all questions in any order
2. All questions carry equal marks
3. An incorrect answer carries -1 mark
4. "I don't know" carries 0 marks
5. Don't guess

SECTION A: CELL BIOLOGY

1. Think about the following statements and identify which **does not** make biological sense:

   1) Some organisms are composed of only one cell.
   2) Large organisms are composed of many small cells.
   3) Every organism, small or large, begins life as a single cell.
   4) All organisms begin life through the union of two cells.
   5) The cell is the basic unit of life.
   6) I don't know.

2. Which of the following statements about biological molecules **is not** chemically correct?

   1) Some molecules, like water, are held together by covalent bonds.
   2) The DNA molecule is held together by ionic bonding, only in places where its bases occur.
   3) Unlike hydrophilic polar compounds, non-polar substances are hydrophobic and form aggregates in water.
   4) Hydrogen bonds are weak associations formed between polar molecules attracted to the same hydrogen.
   5) Biological molecules need to be very stable, therefore their atoms are always linked together by covalent bonds.
   6) I don't know.

3. Only one of the following statements is **correct**. Identify it.

   1) Polysaccharides are polymers composed of sugars linked together by glycosidic bonds.
   2) Energy storage polysaccharides include starch, protein and fats.
   3) Fats and oils are complex biomolecules made up of three nucleotides attached to glycerol.
   4) None of the following molecules contain a combination of two or more biochemical types: lipoproteins, glycolipids and glycoproteins.
   5) Proteins are biomolecules without a monomer molecule.
   6) I don't know.

4. Which of the following cell structures matches with its function?

   1) microfilament (storage)
   2) ribosome (protein synthesis)
   3) cell wall (excretion)
   4) mitochondrion (enzyme synthesis)
   5) vacuole (prevents cell from bursting)
   6) I don't know.

5. Which of the following structures **does not** belong to a prokaryotic cell?

   1) cell wall
   2) plasma membrane
   3) nucleus
   4) ribosomes
   5) cytoplasm
   6) I don't know.

6. Which of the following structures **does not** belong to the protoplasm of a cell?

   1) plasma membrane
   2) nucleus
   3) cell wall
   4) cytoplasm
   5) middle lamella
   6) I don't know.

7. Which of the following items forms part of the plasma membrane?

   1) globular proteins
   2) nucleotides
   3) carbohydrates
   4) coacervates
   5) RNA
   6) I don't know.

8. Identify the chemical which crosses the plasma membrane by diffusion alone (**not** the ones assisted by membrane proteins).

1) water
2) amino-acids
3) glucose
4) proteins
5) urea
6) I don't know.

9. Why would an organism with respiratory equipment ever resort to fermentation?

1) Because the process of fermentation is part of an organism's respiratory process.
2) Because the organism's cells have an excess of oxygen.
3) Because the organism has a short supply of carbon dioxide.
4) Because the organism's cells have an excess of water.
5) Because the organism's cells are deficient in oxygen.
6) I don't know.

10. Which of the following **is not** an aspect of meiosis?

1) sperm production
2) formation of a scar
3) production of haploid cells
4) production of egg sex cells
5) chiasmata formation
6) I don't know.

11. What properties of oxygen would have made chemical evolution unlikely in an atmosphere containing oxygen?

1) for the reason that oxygen is one of the end products of photosynthesis
2) the significance of oxygen in promoting respiration
3) for the reason that oxygen is a strong reducing agent
4) for the reason that oxygen is a strong oxidizing agent
5) for the reason that oxygen is essential for fermentation
6) I don't know.

12. The single 4-centimetre cube, the eight 2-centimetre cubes and the sixty-four 1-centimetre cubes all have the same total volume. Assuming the cubes were cells, which cell would have the largest surface/volume ratio?

1) the 4-centimetre cube example
2) the eight 2-centimetre cubes example
3) cell efficiency is not dependent on surface/volume ratio
4) all examples would have the same surface/volume ratio
5) the sixty-four 1-centimetre cubes example
6) I don't know.

13. The following is a chemical reaction catalysed by an enzyme E. The reactants are represented by the letter R, while the products are represented by the letter P.

$$R \xrightarrow{E} P$$

Which of the following statements is true:

1) When the concentration of R is high and the concentration of P is low the enzyme activity is highest.
2) When the concentration of P is high and the concentration of R is low the enzyme activity is high.
3) When the concentration of P equals that of R the chemical reaction proceeds faster in the direction of P.
4) When the concentration of E somehow drops, the reaction stops.
5) When the concentration of E is somewhat increased the concentration of R similarly increases.
6) I don't know.

14. Name the important nucleotide that is the 'energy molecule' in cells:

1) NADH
2) RNA
3) ATP
4) Adenine
5) Cytosine
6) I don't know.

15. State where the Krebs cycle is believed to occur in the cell:

1) in the chloroplast
2) in the endoplasmatic reticulum
3) in the mitochondrion
4) in the ribosome
5) in the Golgi bodies
6) I don't know.

16. Which of the following statements is **false**?

1) Mammalian red blood cells do change in size in an environment of changing salt concentration.
2) If mammalian cells are transferred from plasma to a less concentrated solution, they swell.
3) If mammalian cells are transferred from plasma to a more concentrated solution, they normally shrink.
4) When mammalian cells which were previously in plasma are placed in a hypotonic solution for a prolonged period of time, they would completely shrink.
5) If mammalian cells were moved from a hypotonic solution to a hypertonic solution, they would shrink.
6) I don't know.

17. One of the following is **not** a macromolecule. Identify it.

1) Insulin
2) DNA
3) Glycine
4) Glycogen
5) Starch
6) I don't know.

18. Which of the following molecules would require the least energy to prepare it for the process of glycolysis?

1) cellulose
2) glycogen
3) sucrose
4) glucose
5) pyruvic acid
6) I don't know.

19. Proteins are large complex molecules made of simpler subunits called ......, that are joined by ...... bonds.

1) nucleotides; hydrogen
2) glycerol; disulphide
3) amino acids; peptide
4) nucleic acids; glycosidic
5) steroids; pyrophosphate
6) I don't know.

20. What is the main function of the Golgi complex?

1) modifies, packages and sorts proteins to vacuoles and other organelles.
2) transports and stores materials, wastes and water.
3) site of many diverse metabolic reactions
4) site of synthesis of polypeptides
5) lipid biosynthesis and drug detoxification
6) I don't know.

21. The citric acid cycle must turn ...... times to process the acetyl coAs formed from one molecule of glucose.

1) one
2) two
3) three
4) four
5) five
6) I don't know.

22. The two chains of DNA are held together through special bonds between adenine and ......, and between guanine and ....

1) thymine; cytosine ✓
2) cytosine; guanine
3) cytosine; uracil
4) uracil; thymine
5) guanine; cytosine
6) I don't know.

23. The pH of the human blood stream is kept more or less the same through the action of:

1) hydrogen cyanide
2) the ion hydrogen carbonate
3) hydroxide ions
4) carbon dioxide only
5) hydrogen ions
6) I don't know.

24. Which of the following statements is **not true** about the properties of water as a biological solvent?

1) A lot of energy in the form of heat is required to change it through one degree Celsius.
2) Because it is polar, water adheres to other substances.
3) The pH of pure water is neither acidic nor basic.
4) Water can easily be transformed into a gas by simply raising its temperature.
5) Water easily dissolves ionic substances.
6) I don't know.

25. Why did life have to start on earth and not any other planet in the solar system?
1) Only earth had pre-existing life.
2) Only earth had oxygen in its early atmosphere.
3) Earth's position in relation to the sun was one of the critical factors.
4) Earth's early atmosphere had pre-existing plasma.
5) Because earth is very close to the sun.
6) I don't know.

26. Louis Pasteur won the prize offered by the Paris Academy of Sciences, when he demonstrated in his remarkable experiment that spontaneous generation is not possible in the absence of already living organisms.

In which year did Louis scoop the prize?

1) 1860
2) 1864
3) 1936
4) 1810
5) 1920
6) I don't know.

27. The removal of $-NH_2$ from a molecule of an amino-acid is an example of:

1) hydrolysis
2) reduction
3) decarboxylation
4) deamination
5) phosphorylation
6) I don't know.

28. During the formation of fatty acids, the condensation process of the subunits leads to the formation of a special bond called ....

1) a covalent bond
2) an ionic bond
3) an ester bond
4) a hydrogen bond
5) a hydrolysis bond
6) I don't know.

29. A nucleotide is made up of three parts. Which of the following groups contains the correct three subunits which constitute the RNA molecule?

1) a pentose sugar; a base; a phosphate group
2) a ribose sugar; a base; a phosphate group
3) a deoxyribose; a base; a phosphate group
4) a ribose sugar; a phosphate group; deoxyribose
5) a hexose sugar; a phosphate group; a base
6) I don't know.

30. Which of the following statements is **false**?

1) animal and plant cells have vacuoles
2) in plants, vacuoles are largest in mature cells
3) modern research has shown that the model of the plasma membrane is a fluid mosaic one.
4) carbon dioxide and oxygen, which are both non-polar, are insoluble in lipids
5) the cell wall is porous, permitting both large and small molecules to pass with relative ease.
6) I don't know.

31. A growing cell has a cell cycle. Which stage is the longest?

1) synthesis phase
2) cytokinesis
3) G1 phase
4) mitosis
5) G2 phase
6) I don't know.

32. You are examining a dividing cell and observe the following conditions:

    The centromeres duplicate themselves. However the daughter centromere remains attached to one of the doublet chromosomes. The daughter chromosomes are apparently dragged away to opposite sides of the cell.

    At what stage of cell division is this cell?

    1) Leptotene phase
    2) Telophase
    3) Metaphase
    4) Anaphase
    5) Prophase
    6) I don't know.

33. During meiosis chiasma formation between chromosomes occurs during:

    1) early prophase
    2) metaphase
    3) anaphase
    4) telophase
    5) late prophase
    6) I don't know.

34. What do you understand the term synapsis to mean?

    1) The independent segregation of a homologous pair of chromosomes.
    2) A condition which occurs in meiosis I, when doublet chromosomes drift away from each other.
    3) A situation in meiosis I when two corresponding chromosomes come to lie beside each other.
    4) A condition in meiosis when chromosomes cross over.
    5) A condition in meiosis when chromosomes fragment into smaller pieces.
    6) I don't know.

35. Which molecule during glycolysis is the first molecule to receive inorganic

phosphorus? (NB. Names given are of the molecule before it receives a phosphate.)

1) glucose
2) glucose-6-phosphate
3) fructose-1,6-diphosphate
4) glyceraldehyde
5) glyceraldehyde phosphate
6) I don't know.

36. Which molecules during glycolysis breaks down into dihydroxy acetone phosphate and glyceraldehyde phosphate?

1) fructose-6-phosphate
2) fructose-1,6-diphosphate
3) 1,3-diphosphoglycerate
4) phosphoenolpyruvic acid
5) pyruvic acid
6) I don't know.

37. Given the following hypothetical reaction:

$$XH_2 + A \longrightarrow X + AH_2$$

Which molecule has been oxidized?

1) XH_2
2) A
3) AH_2
4) X
5) A and AH_2
6) I don't know.

38. The Kreb's cycle is known by many other names. But why is it referred to as the citric acid cycle by some authors?

1) Citric acid is the first chemical compound produced by the Kreb's cycle.
2) Citric acid yields the highest energy of the chemical compounds located in the Kreb's cycle.
3) Citric acid is the one molecule which drives the Kreb's cycle.
4) Citric acid is named after the founder of the Kreb's cycle.
5) Citric acid is the recipient of carbon dioxide molecules.
6) I don't know.

39. What are some of the end products of the Kreb's cycle?
    1) H_2O, CO_2, NAD and FADH
    2) ATP, H_2O, NAD and FADH
    3) H_2O, CO_2, ATP and FADH
    4) H_2O, CO_2, NAD and ATP
    5) ATP, CO_2, NAD and FADH
    6) I don't know.

40. The highest number of ATP molecules are produced by which biochemical process?
    1) glycolysis
    2) Kreb's cycle
    3) respiratory chain
    4) citric acid cycle
    5) fermentation
    6) I don't know.

41. During aerobic respiration, which molecule serves as the final acceptor of electrons during oxidative phosphorylation?
    1) oxygen
    2) water
    3) carbon dioxide
    4) hydrogen
    5) cytochrome a
    6) I don't know.

42. Which of the following statements is **false** about chromosome structure?
    1) The DNA molecule is neatly packaged with the help of histones.
    2) Eight histones are closely associated with the DNA molecule.
    3) Four kinds of histones are closely associated with the DNA molecule.
    4) Most of the DNA in a cell is inexpressible in genetic terms.
    5) About ten to fifteen nucleosomes make up a gene.
    6) I don't know.

43. The common thread of life which supplies evidence for the evolutionary kinship of organisms as descendants of the same early ancestor is:

    1) the deoxyribonucleic acid
    2) the ribonucleic acid
    3) nicotinamide adenine dinucleotide
    4) a coacervate
    5) a protein
    6) I don't know.

44. What kind of proteins participate in the movement of substances across the plasma membrane?

    1) keratin
    2) globular
    3) tubulin
    4) glycoproteins
    5) lysine
    6) I don't know.

45. Which of the following statements is **false**?

    1) Lipids are insoluble in polar solvents.
    2) Lipids are insoluble in water.
    3) Lipids are a high calorie substance.
    4) Lipids are useful energy sources because they release energy readily.
    5) Lipids contain the elements carbon, hydrogen and oxygen.
    6) I don't know.

46. The following is the chemical formula for aerobic respiration:

$$C_6H_{12}O_6 + 6\ O_2 + 6\ H_2O \longrightarrow 6\ CO_2 + 12\ H_2O + \text{Energy}$$

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

1) Glucose is oxidized to water
2) Oxygen is oxidized to carbon dioxide
3) Water is reduced to carbon dioxide
4) Glucose is neither oxidised nor reduced .
5) Oxygen is reduced to a molecule of water
6) I don't know.

47. The energy requirements for a cell are produced by one of the following organelles:

1) smooth endoplasmatic reticulum
2) lysosome
3) mitochondrion
4) plasma membrane
5) nucleus
6) I don't know.

48. Prokaryotic cells lack:
(a) a nuclear membrane
(b) membrane bound organelles like mitochondria
(c) DNA

1) answers a, b and c are correct
2) answers b and c are correct
3) only answer a is correct
4) only answer c is correct
5) answers a and b are correct
6) I don't know.

49. Phosphorylation of ......, which requires an input of energy, leads to the formation of adenosine triphosphate.

1) ADP
2) NAD
3) NADH
4) NAD^+
5) FADH
6) I don't know.

50. The plasma membrane is considered to have the following structure:

1) a uniform sheet of protein with pores at intervals
2) a uniform sheet of protein with cilia at intervals
3) two distinct layers of lipid molecules
4) phospholipid molecules embedded in a layer of protein
5) protein molecules embedded in a phospholipid bilayer
6) I don't know.

SECTION B: GENETICS

51. For a given trait, the two alleles of a gene are not alike. An individual possessing this gene combination is said to be:

    1) homozygous for that trait.
    2) heterozygous for that trait.
    3) recessive for that trait.
    4) pure for that trait.
    5) carrier for that trait.
    6) I don't know.

52. Three statements are made:

    A. A recessive sex-linked trait will not be expressed in females.
    B. If a boy expresses a recessive sex-linked trait, then its father will express it as well.
    C. When a mother expresses a recessive sex-linked trait, all her male children will express it as well.

    Choose the correct alternative:

    1) All statements are correct.
    2) All statements are false.
    3) Statements A and B are correct, statement C is false.
    4) Statements A and B are false, statement C is correct.
    5) Statement A is false, statements B and C are correct.
    6) I don't know.

53. A man of blood type AB marries a woman of blood type A. What are the possible types of their offspring if the woman's mother was blood type O?

    1) AB only
    2) A and B only
    3) A, B and AB
    4) A, B, AB and O
    5) pure for that trait
    6) I don't know

54. If a colour blind man marries a woman who is a carrier for colour blindness and they have two daughters and two sons, it is possible that:

1) all their sons will have normal colour vision
2) all their daughters will be colour blind
3) all their children will be colour blind
4) half their children will be colour-blind and half will have normal colour vision
5) choices 1, 2, 3 and 4 are each possible
6) I don't know

55. Male gametes can be produced through meiosis with non-disjunction of the sex chromosomes. When these male gametes fertilize female gametes produced through normal meiosis, the following genotypes can be formed:

1) XXX, XXY, X0 and Y0
2) XXY, XYY, XY and YY
3) XY and XX
4) XXY, X0
5) XXXY, XY, X0, 00
6) I don't know

56. Four-o'clocks possess one gene for flower colour. Their flowers can be red, pink and white. When two four-o'clock plants are crossed, 48 pink four-o'clocks and 52 white four-o'clocks are produced. The phenotypes of the parents are:

1) pink and white
2) pink and red
3) pink and pink
4) red and white
5) red and red
6) I don't know

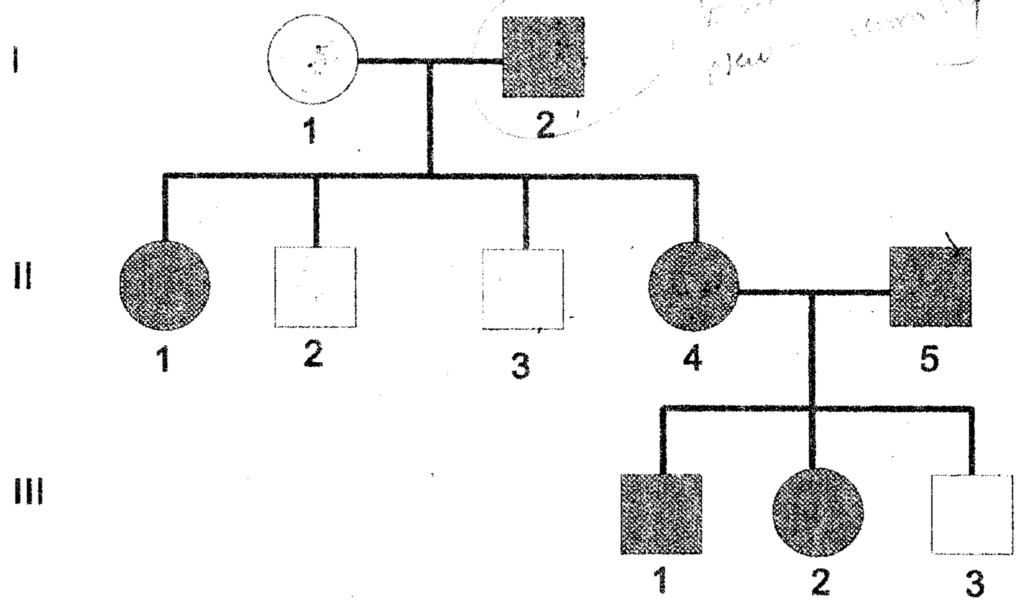
57. A boy has brown hair and blue eyes, and his sister has brown hair and brown eyes. The fact that they have different combinations of traits is best explained by the concept known as:

1) gene interaction
2) multiple alleles
3) incomplete dominance
4) sex linkage
5) independent assortment
6) I don't know

58. Phenylketonuria (PKU) is an inherited condition characterized by feeblemindedness. The symptoms of the disease result from the inability a particular **gene** to synthesize a certain type of:

1) enzyme
2) nutrient
3) blood cell
4) brain cell
5) amino-acid
6) I don't know

59. Consider the pedigree below:



The persons with darkened symbols in the pedigree express a certain inherited disease. The man I.2 comes from a family with a tradition of consanguineous marriages (inbreeding). All his brothers, sisters, uncles, aunts and grandparents have the disease.

Choose the correct alternative:

1) The allele determining the disease is sex-linked and recessive.
2) The allele determining the disease is sex-linked and dominant.
3) The allele determining the disease is autosomal and recessive.
4) The allele determining the disease is autosomal and dominant.
5) No definitive choice can be made from the four alternatives above, because the information is not sufficient.
6) I don't know.

60. The development of a bee's egg without fertilization is known as:

1) vegetative reproduction
2) meiosis
3) replication
4) metamorphosis
5) parthenogenesis
6) I don't know

61. During meiosis, portions of one chromosome may be exchanged for corresponding portions of its homologous chromosome. This process is known as:

1) recombination
2) nondisjunction
3) polyploidy
4) crossing-over
5) hybridization
6) I don't know

The following introduction belongs to questions 62-64. The fruit fly possesses a gene for body colour pattern and a gene for eye colour intensity.
S = the allele for normal body, s = the allele speck body
D= the allele for dark eyes, d = the allele for light eyes.
The following cross is executed: SsDd x ssDd. The table below specifies the phenotypes found in the offspring and their observed numbers.

Phenotype	Observed number
Normal body, dark eyes	93
Normal body, light eyes	18
Speck body, dark eyes	74
Speck body, light eyes	37

Determine whether these genes are linked or not, using the χ^2 test. The χ^2 table is appended to this exam paper.

62. The χ^2 value is:

1) 7.3
2) 8.7
3) 9.8
4) 63.0
5) 85.3
6) I don't know

63. The probability is:

1) between 1 and 5%
2) between 5 and 10%
3) between 10 and 20%
4) 20%
5) greater than 90%
6) I don't know

64. The genes are:

1) linked.
2) not linked.
3) I don't know.

65. In the mouse coat colour is determined by two genes. The following cross is executed: AaCc x AaCc. The offspring contained the following phenotypes and numbers:

agouti	106
albino	50
black	12

This modified Mendelian ratio is caused by:

1) a lethal allele
2) epistasis
3) linked genes
4) incomplete penetrance
5) variable expressivity
6) I don't know

66. Epistasis is:

1) the interaction between two genes
2) the cooperation between two genes
3) the inhibition of expression of one gene by another
4) the stimulation of expression of one gene by another
5) the equilibrium between two genes
6) I don't know

67. Three statements are made:

A. Lethal alleles are mostly recessive for their deadliness.
B. Genes with lethal alleles also influence traits other than longevity.
C. Lethal alleles are never dominant for their deadlines.

Huntington

Choose the correct alternative:

1) All statements are correct.
2) All statements are false.
3) Statements A and B are correct, statement C is false.
4) Statements A and B are false, statement C is correct.
5) Statement A is false, statements B and C are correct.
6) I don't know.

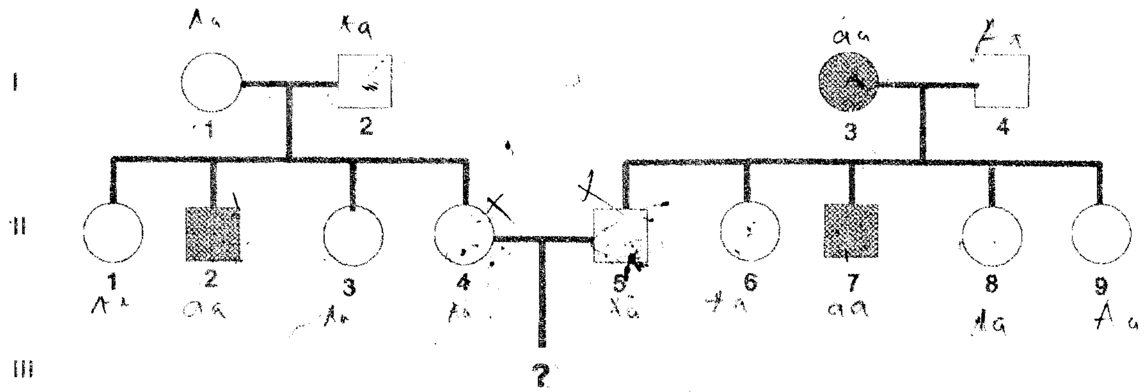
68. Polygenes show:

1) phenotypically discontinuous variation
2) phenotypically continuous variation
3) genotypically discontinuous variation
4) genotypically continuous variation
5) both genotypically and phenotypically continuous variation
6) I don't know

69. The frequency of the genotype aa among humans is 0.4, the frequency of the heterozygote genotype is 0.32. What is the probability that a marriage will constitute the genetic cross Aa x aa?

1) 0.13
2) 0.26
3) 0.36
4) 0.52
5) 0.72
6) I don't know

The following introduction refers to questions 70 and 71. The pedigree below shows the occurrence of retinoblastoma (a disease of the retina of the eye leading to blindness, darkened symbols) in two families.



70. Choose the correct alternative:

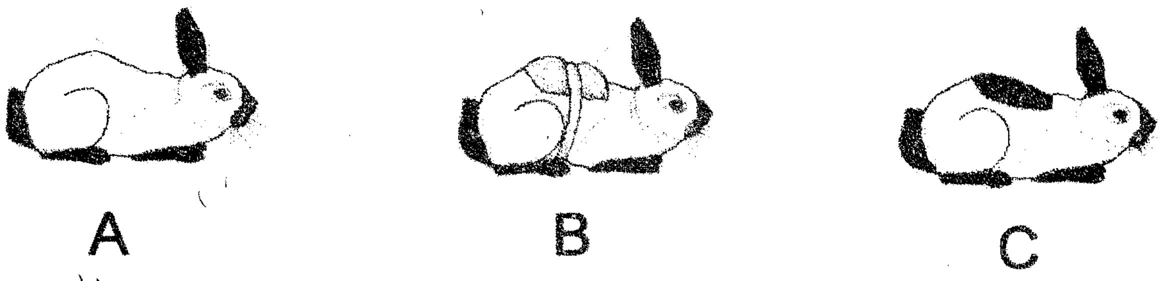
1) The allele determining the disease is sex-linked and recessive.
2) The allele determining the disease is sex-linked and dominant.
3) The allele determining the disease is autosomal and recessive.
4) The allele determining the disease is autosomal and dominant.
5) No definitive choice can be made from the four alternatives above, because the information is not sufficient.
6) I don't know.

71. What is the probability that couple II.4 and II.5 will have a normal child?

1) 0.25
2) 0.50
3) 0.75
4) 0.81
5) 0.88
6) I don't know

72. A plant is reproduced by cutting the stem in several pieces and planting them in another area than the mother plant, with different conditions of fertility, rain fall and sunshine. Compare the daughter plants with the mother plant.

1) The daughter plants will have the same genotype and the same phenotype.
2) The daughter plants will have the same genotype and a different phenotype.
3) The daughter plants will have a different genotype and a different phenotype.
4) The daughter plants will have a different genotype and the same phenotype.
5) The daughter plants will have half the genotype of the mother plant and a different phenotype.
6) I don't know.



This introduction belongs to questions 73 and 74. The picture above shows a rabbit with a colour pattern known as Himalayan (A, white body, black extremities). The genotype of this animal is bb. This recessive allele produces an enzyme that can synthetise a black pigment. When part of the white fur is shaven, and an ice-pack is applied to the bold patch (B), the hairs that grow back are black (C).

73. The white fur on animal A represents a phenomenon known as:

1) incomplete penetrance
2) variable expressivity
3) gene expression influenced by the environment
4) albinism
5) recessivity
6) I don't know

74. The black patch of regrown hair on animal C represents a phenomenon known as:

1) incomplete penetrance
2) variable expressivity
3) gene expression influenced by the environment
4) melanism
5) dominance
6) I don't know

75. The offspring of a large number of marriages between achondroplastic dwarfs has been analysed, with the following results: 304 dwarf children
149 children of normal height

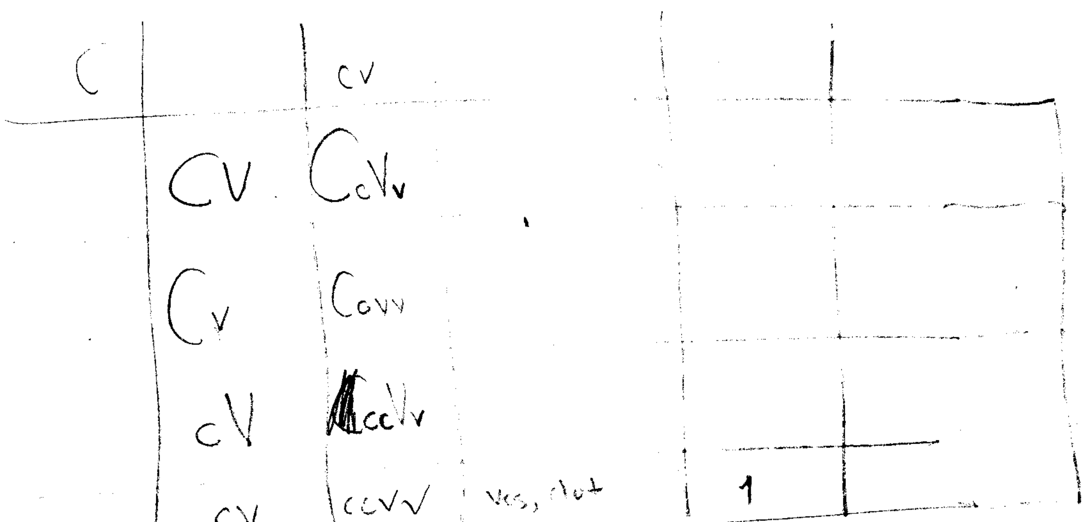
Analysis of marriages between dwarfs and people of normal height gives the following results: 54 dwarf children
51 children of normal height

Based on these results, the following conclusion can be drawn:
1) the dwarfism allele is incompletely penetrant
2) the dwarfism trait shows epistasis
3) the dwarfism allele is lethal
4) the dwarfism gene shows normal Mendelian ratio's
5) the dwarfism alléle is incompletely dominant
6) I don't know

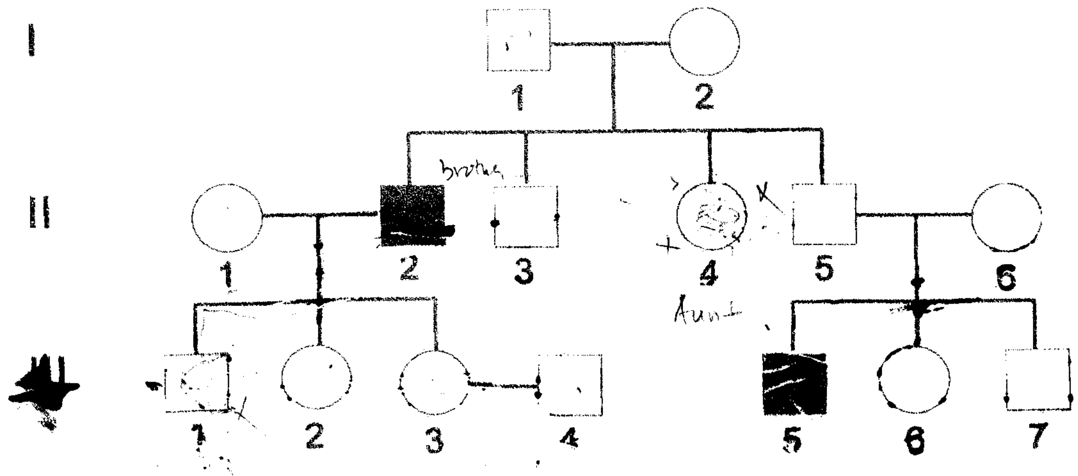
76. The fruit fly possesses a gene for of eye appearance and a gene for wing size.
C = the allele for normal eyes, c = the allele for clot eyes
V= the allele for normal wings, v = the allele for vestigial wings.
The following cross is executed: CcVv x ccvv. The table below specifies the phenotypes found in the offspring and their observed numbers.

Phenotype	Observed number
Clot eyes, normal wings	298
Clot eyes, vestigial wings	155
Normal eyes, normal wings	149
Normal eyes, vestigial wings	306

Based on these results the following conclusion can be drawn:
1) Alleles c and V are linked
2) Alleles C and V are linked
3) Alleles C and c are linked
4) Alleles V and v are linked
5) The genes are independent
6) I don't know.



77. Persons III.1 and II.4 in the pedigree below are:
    1) nephew and uncle
    2) nephew and aunt
    3) niece and uncle
    4) niece and aunt
    5) cousins
    6) I don't know



78. The dihybrid cross AAB^cB^p x aaB^cB^p will produce:

    1) 4 different genotypes and 4 different phenotypes
    2) 6 different genotypes and 4 different phenotypes
    3) 6 different genotypes and 6 different phenotypes
    4) 9 different genotypes and 4 different phenotypes
    5) 9 different genotypes and 6 different phenotypes
    6) I don't know

79. In spotted cattle, the coloured regions may be mahogany or red. A red female and a mahogany male, both from pure lines, are mated. Their offspring is mated to each other. The resulting F_2 consists of ⅜ mahogany males, ⅜ red females, ⅛ red males and ⅛ mahogany females.
    Choose the correct alternative:

    1) the trait is sex-linked
    2) the trait is sex-limited and sex-linked
    3) the trait is sex-influenced and sex-linked
    4) the trait is sex-limited and autosomal
    5) the trait is sex-influenced and autosomal
    6) I don't know

80. Choose the best alternative.

In humans:

1) some genes are linked to at least one other gene, and all genes are independent with respect to at least one other gene ✓
2) all genes are linked to at least one other gene, and some genes are independent with respect to at least one other gene
3) some genes are linked to at least one other gene, and some genes are independent with respect to at least one other gene
4) all genes are independent with respect to at least one other gene, and most genes are X-linked
5) all genes are independent with respect to at least one other gene, and all genes are linked to at least one other gene
6) I don't know

81. In humans, sex is normally determined at fertilization by:

1) one pair of sex chromosomes
2) two pairs of sex chromosomes
3) 11 pairs of autosomes
4) 22 pairs of autosomes
5) 23 pairs of chromosomes
6) I don't know

82. The inheritance of the ABO blood groups in humans is best explained by the fact that, of the alleles involved, each individual must inherit:

1) 1 allele
2) 2 alleles
3) 3 alleles
4) 4 alleles
5) 5 alleles
6) I don't know

83. In humans, most sex-linked traits are due to genes that are:

1) located on an X-chromosome ✓
2) inherited only by males
3) carried only by males
4) part of an autosome
5) none of the above
6) I don't know

84. A pair of chromosomes fail to separate during meiosis, producing a gamete with an extra chromosome. This process is known as:

1) crossing-over
2) polyploidy
3) nondisjunction
4) recombination
5) none of the above
6) I don't know

85. A student crossed wrinkled-seeded (rr) pea plants with round-seeded (RR) pea plants. Only round seeds were produced by the resulting plants. This illustrates the principle of:

1) independent assortment
2) segregation
3) dominance
4) incomplete dominance
5) codominance
6) I don't know

86. What is the total number of chromosomes in a typical body cell of a person with Down's syndrome?

1) 21
2) 22
3) 23
4) 46
5) 47
6) I don't know

87. Which principle of heredity was developed by Gregor Mendel?

1) incomplete dominance
2) multiple alleles
3) sex linkage
4) independent assortment
5) none of the above
6) I don't know

88. Animal breeders often cross members of the same litter in order to main- tain desirable traits. This procedure is known as:

1) hybridization
2) inbreeding
3) natural selection
4) vegetative propagation
5) none of the above
6) I don't know

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

1) 25%
2) 50%
3) 75%
4) 100%
5) none of the above
6) I don't know

0. An individual contains the sex chromosomes XYY. This combination of chromosomes was most likely the result of:

1) DNA replication
2) cleavage
3) nondisjunction
4) crossing-over
5) none of the above
6) I don't know

1. Down's syndrome is a condition which occurs as a result of:

1) crossing-over
2) polyploidy
3) gene mutation
4) nondisjunction
5) none of the above
6) I don't know

2. The cells in the petals of a particular flower each contain twenty-four chromosomes. A normal sperm nucleus produced in a pollen grain of this flower contains a maximum of:
1) 6 chromosomes
2) 12 chromosomes
3) 18 chromosomes
4) 24 chromosomes
5) 48 chromosomes

6) I don't know

93. Changes in the genetic composition of a chromosome may be the result of:

1) nondisjunction
2) crossing-over
3) independent assortment
4) replication
5) all of the above
6) I don't know

94. The principal function of genes is to:

1) pass on hereditary traits from one generation to the next
2) aid in the excretion of waste products from the organism
3) cause mutations to occur
4) aid in the maintenance of the water balance in the cell
5) all of the above
6) I don't know

95. Curly hair in humans, white fur in guinea pigs, and needle-like spines in cacti all partly describe each organism's:

1) alleles
2) autosomes
3) chromosomes
4) phenotype
5) none of the above
6) I don't know

96. Which can be used to examine the chromosomes of a fetus for possible genetic defects?:
1) pedigree analysis
2) analysis of fetal urine
3) amniocentesis and karyotyping
4) cleavage
5) all of the above
6) I don't know

97. Which is a genetic disorder in which abnormal hemoglobin leads to fragile red blood cells and obstructed blood vessels?:

1) phenylketonuria
2) sickle-cell anemia
3) leukemia
4) Down's syndrome
5) none of the above
6) I don't know

8. Traits controlled by genes on the X-Chromosome are said to be:

1) sex-linked
2) incompletely dominant
3) homozygous
4) mutagenic
5) sex-limited
6) I don't know

9. The genetic material in living organisms is composed of organic molecules known as:

1) starches
2) lipids
3) nucleic acids
4) fatty acids
5) proteins
6) I don't know

00. A human hereditary disorder that may result in mental retardation is:

1) phenylketonuria
2) hemophilia
3) sickle-cell anemia
4) albinism
5) none of the above
6) I don't know

END OF EXAM

The probabilities associated with values of χ^2

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

THE UNIVERSITY OF ZAMBIA
UNIVERSITY FIRST SEMESTER EXAMS - MARCH 1998
BS 211
CELL MOLECULAR BIOLOGY AND GENETICS
THEORY : PAPER I

TIME : THREE HOURS
ANSWER : THREE QUESTIONS

CELL MOLECULAR BIOLOGY

1. Write brief, concise notes on the following :
   a) The essence of template directed nucleic acid synthesis.
   b) Life and the steady state from bioenergetics point of view.
   c) The indispensable role of water as the universal solvent in biological systems.

2. Explain in detail what is meant by Michelis-Menten Kinetics and the Double-Reciprocal Plot.

3. a) Classify each of the following amino acids as likely to be found in the interior, on the exterior, or at either location of a globular protein in a cell, and explain.

valine	phenylalanine
glycine	alanine
aspartate	lysine

   b) For each of the following pairs of amino acids, choose the one that is more likely to be found in the interior of a protein molecule, and explain why.

alanine;glycine	glutamate;aspartate
tyrosine;phenylalanine	methionine;cystein

   c) Explain why cysteins with free sulfhydryl groups tend to be localized on the exterior of a protein molecule, whereas those involved in disulfide bonds are more likely to be buried in the interior of the molecule.

4. a) The hydrolysis of glucose-6-phosphate to glucose and phosphate is an important step in glycogen catabolism. The free glucose formed by this reaction is released into the blood for transport to cells in need of energy :

$$\text{glucose-6-phosphate} + H_2O \rightarrow \text{glucose} + \text{phosphate}$$

$\Delta G^{\circ\prime}$ for this reaction is -3.3 kcal/mol at 25°C and pH 7.0

If the concentration of glucose-6-phosphate is changed to 20 μM and the concentrations of glucose and phosphate are changed to 5 mM each, and assuming that the appropriate enzyme is present to catalyze this reaction at 25°C, which direction would you expect the reaction to proceed.

b/ The following reaction is another step in glycogen catabolism that precedes the hydrolysis of glucose-6-phosphate discussed in problem a) above :

glucose-1-phosphate ⇔ glucose-6-phosphate

K'_{eq} for this reaction is 19.0
Assuming that the appropriate enzyme is present to catalyze the reaction,

i/ In which direction is the reaction thermodynamically feasible under standard conditions.

ii/ If the cellular concentrations of glucose-1-phosphate and glucose-6-phosphate are equal, in which direction will the reaction proceed?

5. Write brief, concise notes on three the following :

a) Phospholipids are important in membrane structure.
b) Energy of C-C bond compared to energy of solar radiation.
c) Formation of the protein tertiary structure.
d) Polysaccharide structure depends on the kinds of glycosidic bonds involved.
e) The equilibrium constant of a reaction as a measure of directionality.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER DEF/SUPP EXAMINATIONS - APRIL 1998

BS 211

CELL MOLECULAR BIOLOGY AND GENETICS

THEORY PAPER

TIME: THREE HOURS

INSTRUCTIONS:

1. ANSWER FIVE QUESTIONS: TWO FROM SECTION A, TWO FROM SECTION B AND ONE FROM EITHER SECTION A OR SECTION B.

2. ANSWER SECTIONS A AND B IN SEPARATE ANSWER BOOKLETS.

SECTION A: CELL MOLECULAR BIOLOGY

1. Use the interconversion

glucose-6-phosphate <=> fructose-6-phosphate

of the glycolytic pathway, to illustrate the calculation and utility of $\Delta G°'$ and $\Delta G'$, given the following parameters:

K'eq. = 0.5
[glucose-6-phosphate] = 83 μM in human blood cells,
[fructose-6-phosphate] = 14 μM in human blood cells,
R = gas constant (1.987 cal./mol-K),
T = use standard temperature of 298K (25°C),
Use log. (to the base e).

2. Write brief concise notes on THREE of the following topics:

a) The effect of temperature on the active site of an enzyme.

b) The effect of pH on the active site of an enzyme.

c) The Lineweaver-Burk Doduble Reciprocal Plot.

d) The energy of the C-C bond and the ozone layer.

. In studying the kinetics of the hexokinase, an important enzyme which catalyzes the phosphorylation of glucose by using ATP as a source of both the phospate group and the energy needed for the reaction

glucose + ATP <==> glucose-6-phosphate + ADP

and by using the Double Reciprocal Plot (Lineweaver-Burk equation), Vmax and Km were found to be 100 µmol/min and 0.15 mM respectively.

a) Convert the Double-Reciprocal Plot to the classic Michaelis-Menten Plot.

b) Show the advantage and disadvantage of the Michaelis-Menten Plot.

. Describe in detail the importance of phospholipids as constituents of biological membranes.

. Describe

a) the sequential steps covered in the synthesis of biopolymers and

b) for each step give structural chemical examples to back up your explanations.

SECTION B: GENETICS

. Critics think that Mendel may have "massaged" data to support his observations. Agree or disagree.

. Trace and provide genetic evidence that showed that Mendel's particulate determinants of inheritance were located on chromosomes.

. Elucidate the Watson-Crick double helical structure of DNA.

. Using a named example, show how prokaryotes control expression of their genes.

. Discuss how environmental factors can influence the genetic material of an organism.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

BS 221

FORM, FUNCTION AND DIVERITY OF PLANTS

PRACTICAL PAPER

TIME: TWO HOURS

ANSWER: ALL Questions in Section A and B

Instructions: You are allowed 5 minutes to examine each specimen and answer the approciate question. At the end of each 5 minute period you will be directed to move to the next postion on your right, or as you may be instructed otherwise.

Name (surname first):	**Computer No**::
....	....

SECTION A

1. Comment on specimen **A1** and describe its:

(i) thallus feature

....

....

....

....

....

(ii) phase of life

....

(iii) identification

....

2. (a) Draw a portion of the specimen **A2** and label three (3) important cell types of its morphology:

(b) Assign the specimen to:

Division:

Class:

Order:

Family:

Genus:

---

3. Examine **A3** and describe its:

(i) thallus type

....

....

(ii) cell shape

....

(iii) taxonomy to include,

Order:

Family:

Genus:

4. Draw a small portion of specimen **A4** and show its structure and :

(i) label three parts

(ii) name the division to which it belongs

....

(iii) identify the specimen

....

5. Draw and label the structure shown by specimen **A5**:

(i) give its generic name

....

(ii) describe the following taxa

Order:

Family:

Genus:

6. Draw a vegetative cell of specimen **A6** and label:

(i) the cell shape

(ii) the chloroplast type

(iii) the protein bodies on it.

---

7. Examine specimen **A7** and describe its:

(i) cell shape

....

(ii) chloroplast type

....

(iii) identification

....

---

8. Examine specimen **A8** and describe:

(i) the structure seen

....

(ii) its branching

....

(iii) parasitism

....

(iv) generic name

....

9. Reconstruct the stages in the development of the sexual structure seen here in specimen **A9** and label its parts duringits development and the final product.

Identify the genus

....

---

10. Draw and label a portion of specimen **A10**:

Identify the specimen

....

END OF SECTION A

Name (surname first):	Computer No.
....	....

SECTION B

11. Make a microscopic study of specimen **B1** and set out to:

(a) draw the overall structure so revealed

(b) name the structure so depicted

Name of structure:...

12. Carefully examine specimen **B2** and then:

(a) make an accurate morphological description of the specimen:

....

....

....

....

(b) identify the specimen to its major taxonomic group:

Name of taxonomic group:..

13.. Examine specimen **B3** and thus:

(a) draw and label features of botanical interest

(b) determine the major taxonomic group to the level of the division:

Name of division:..

---

14. Draw and label specimen **B4** provided and then:

(a) identify the most perculiar feature(s)

....

....

(b) identify the organism up to the generic level:

Generic name:..

15. Critically examine specimen **B5** and proceed to:

(a) Comment on some features of ecological significance displayed:

....

....

....

....

....

(b) Name the specimen:..

---

16. Examine specimen **B6** under the microscope and set out to:

(a) draw a sketch of the principal tissue types;

(b) use the dichotonous key given in Sheet 1 to identify the nature of the vascular system:

Name of vascular system:...

---

17. (a) Describe the structure of the organ displayed by specimen **B7**:

....

....

....

....

(b) Comment on the pattern of sori arrangement exhibited in specimen B7.

....

....

....

....

....

---

18. Examine specimen **B8** and identify it with reasons to:

(a) the generic level:

....

....

....

(b) the division level:

....

....

....

---

19. Make a microscopic examination of specimen **B9** and then:

(a) name the organism displayed: ....

(b) describe the ploidy level attained by the organism:

....

....

....

....

....

20. Use the hand lens or dissecting microscope to examine specimen **B10** and then:

(a) describe the species ecological significance in Zambia:

....

....

....

....

....

....

....

(b) identify the specimen to the generic and division level:

Generic name:..

Name of division:...

END OF EXAMINATIONS

BS221

PRACTICAL PAPER

SHEET 1: KEY TO THE IDENTIFICATION OF STELE TYPES

1. Central core of vascular cylinder occupied by solid xylem tissue...(**Protostele**)..............2

1. Central core of vascular cylinder occupied by pith or entire organ with discrete vascular bundles embedded in matrix of ground tissue...4

    2. Outline of xylem cylinder more or less circular....................................**Haplostele**

    2. Outline of xylem cylinder star-shaped or arranged in longitudinal plates............3

3. Xylem mass star-shaped in outline...**Actinostele**

3. Xylem mass arranged in longitudinal plates..**Plectostele**

    4. Vascular tissue forming continuous cylinder..............(**Siphonostele**).................5.

    4. Vascular tissue consisting of discrete vascular bundles..6

5. Phloem located on external surface of xylem cylinder..............**Ectophloic Siphonostele**

5. Phloem located on both external and internal surfaces of xylem cylinder..........................
....**Amphiphloic Siphonostele**

    6. Vascular bundles scattered in ground tissue...**Atactostele**

    6. Vascular bundles forming one or more rings...7

7. Phloem located external to xylem tissue...**Eustele**

7. Phloem completely surrounding the xylem tissue...**Dictyostele**

****

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

BS 319

BIOSTATISTICS

(THEORY PAPER)

TIME: THREE (3) HOURS

INSTRUCTIONS: ANSWER TWO QUESTIONS FROM SECTION A AND THREE QUESTIONS FROM SECTION B.

SECTION A

1. What is the relationship between a histogram and a frequency polygon.

2. The mean is not always a good measure of data dispersion. Why?

3. Under what conditions is one likely to commit type 1 error in statistical work.

4. Describe the two main sampling designs in research work.

SECTION B

5. In a family of 12 children born to the same parents, the first six children born were boys and these were followed by six girls. Is there any significant difference between the observed frequencies of the sex of the children and the expected frequencies.

6. A researcher analysed the content of exchangeable phosphorus in burnt and unburnt soil and obtained the following results:

Soil type	Phosphorus Content (mg/kg)								
Burnt	20.9	21.6	13.8	35.0	22.1	32.2	16.6	26.6	-
Unburnt	7.9	13.3	35.3	5.8	32.2	14.0	4.9	4.6	14.8

/..

Using the Mann-Whitney test, determine if the concentration of phosphorus in the two soil samples are significantly different. Give reasons for your decision.

A researcher obtained one systematic and one random sample from the same seed population of a plant species and determined the seed weight of the two samples. The results were as follows:

Sample type	Seed weight (g)									
Systematic	2.93	1.86	2.35	2.11	2.46	3.33	3.21	2.87	3.17	3.58
Random	2.11	2.36	2.46	2.81	1.93	3.33	3.06	3.31	1.92	3.58

Was the mean weight between the two samples significantly different and why? What conclusion can you make about the differences between systematic and random sampling with regards to this question.

A researcher measured the area of leaves of <u>Acacia Polyacantha</u> seedlings, starting with the first leaf at the bottom (leaf 1 below) to the uppermost leaf on the stem and obtained the following results:

Leaf position	1	2	3	4	5	6	7	8	9
Leaf area (cm^2)	11.8	27.2	25.8	38.1	63.5	72.6	79.4	87.6	97.2

Do these results show any correlation between leaf position and area. If they do, develop a model for predicting leaf area from leaf position.

END OF EXAMINATION & GOOD LUCK!!

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

BS 321

ETHOLOGY AND EVOLUTION

(PAPER II - PRACTICAL)

TIME: THREE (3) HOURS

INSTRUCTIONS: ANSWER ALL QUESTIONS. ILLUSTRATE YOUR ANSWERS WHERE NECESSAR. ALL QUESTIONS CARRY EQUAL MARKS.

---

1. Briefly describe a procedure that could be used to study reproductive behaviour in antelopes such as the sable (*Hippotragus niger*).

2. Discuss the main features of the focal sampling method, and suggest ways of data analysis.

3. Briefly explain the evolutionary principles that each specimen illustrates, A, B.

4. Classify according to the kind of adaptation that each specimen illustrates, and describe the adaptive morphological features which characterize each specimen A, B.

5. Behavioural disorders may be a serious limitation in studying animal behaviour. Explain such disorders and discuss how these could affect the experiment on a natural species population.

END OF EXAMINATION & GOOD LUCK.

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

BS 331

THEORY PAPER

IME: THREE HOURS

NSTRUCTIONS: ANSWER FOUR QUESTIONS

. Discuss in detail how draught conditions would affect:

(a) water absorption from the soil by plants;

(b) control mechanisms for water loss from leaves in mesophytic plants.

. Outline the chemical reactions which lead to photorespiration in green leaves.

. Many factors contribute to the efficiency of photosynthesis in leaves. How do the structure and organization of the photosynthetic apparatus contribute to photosynthetic efficiency?

. Explain in detail how gaseous nitrogen is converted into the amide glutamine in the root nodules of leguminous plants.

. Explain in detail the role of Quinones in photosynthesis.

. Compare and contrast the physiological effets of Auxins and Gibberellins on stem growth.

. What are the roles of endogenous growth substances in regulating the activity and differentiation of cambium cells in stems?

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

BS 341

MICROBIOLOGY

(PAPER I - THEORY)

TIME: THREE (3) HOURS

INSTRUCTIONS: ANSWER FIVE QUESTIONS, TWO FROM EACH SECTION A AND B, AND ONE QUESTION FROM EITHER SECTION A OR B. ANSWERS MAY BE ENHANCED BY INCLUDING DIAGRAMS, RELEVANT TABLES AND GRAPHS. ALL QUESTIONS CARRY EQUAL MARKS. EACH QUESTION MUST BE ANSWERED IN A SEPARATE HANDBOOK.

SECTION A

Q1. Once a micro organism has been isolated in pure culture, it may be necessary to maintain the culture in a living condition for a considerable period of time. Discuss the procedures that may be used to preserve and maintain cultures of micro-organisms. Why should cultures be preserved? [20 marks]

Q2. (a) Write short notes on the role of the following minerals in microbial metabolism:

- magnessium [4 marks]
- Calcium [4 marks]
- Zinc [4 marks]
- Iron [4 marks]
- Potassium [4 marks]

(b) Discuss the fine structure of bacterial cells. [20 marks]

Q3. (a) What were the events between 1935 and 1960 that contributed to an understanding of viruses? [8 marks]

(b) Discuss the chemical composition of viruses. [12 marks]

Q4. (a) Describe the general growth cycle of a virus. [14 marks]

(b) Show diagramatically the replicative cycle of retrovirus. [6 marks]

SECTION B

Q5. Outline general morphological and biological characteristics of Rickettsiales as an order, comparatively to ordinary Bacteria, and name at least one (1) important species of:

(i) Rickettsia

(ii) Chlamydia

(iii) mycoplama

and disease caused.

Q6. What may be the relationship between glycolysis and microbial Beta - Oxidation in the process of fat digestion?

Q7. What are the two (2) major groups of molecular nitrogen (N_2) fixing Bacteria?
Give at least one (1) example in each case.

Q8. Discuss briefly aerobic and anaerobic respiration and explain the way ATP is regenerated and electrons transferred to molecular oxygen.
Enhance your answer by a clear concise diagram.

END OF EXAMINATIONS.

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

BS 351

ENTOMOLOGY

(PRACTICAL PAPER)

TIME: THREE (3) HOURS

INSTRUCTIONS: ANSWER ALL QUESTIONS.

---

1. Identify specimens A - J to Order and least four taxonomic features that distinguish each specimen from other insects.

2. Construct a dichotomous taxonomic key that can be used to identify specimens K - T to Order.

3. Using the equipment and chemicals provided, test for the presence of the enzyme amylase in the alimentary canal of a cockroach. Write a report on the results of your test indicating:
   (a) the kinds of equipment and chemicals used
   (b) the type of test conducted
   (c) your results
   (d) discussion and conclusions.

END OF EXAMINATION.

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

BS 361

MOLECULAR BIOLOGY

(PAPER I - THEORY)

ME: THREE (3) HOURS

STRUCTIONS: ANSWER ALL QUESTIONS. ONLY BRIEF ANSWERS ARE REQUIRED.

Watson and Crick showed that DNA is a double helix.

(a) Describe important features of the model.

(b) Explain three notions that converged in the construction of the model.

(c) How do base pairs contribute to the thermodynamic stability of the double helix?

(d) Why is the model in conformity with the role of DNA as the almost universal carrier of genetic information?

(a) Describe DNA supercoiling using current nomenclature.

(b) What is the Lk for a B-DNA molecule with 500 bp.

(a) Account for the hypochromic effect of DNA. How can one cause a decline in the said effect?

(b) The absorbance of a liver DNA sample measured at 260nm gives a concentration of 1.498 mg/g of tissue. However, when the same sample is assayed by the diphenylamine method, a concentration of 0.365 mg of DNA/g of tissue is obtained. How do you explain this discrepancy?

How can you demonstrate that the specificity of tRNA is determined by its anticodon and not the amino acid it carries?

Examine the following mRNA sequence:

5' -GAUUCCUAGGAGGUUUGACCUAUGCGAGCUUUUAGU-3'

(a) Is this prokaryotic or eukaryotic mRNA?

(b) what is the 5th amino acid in the peptide?

(c) Colicin E3 cleaves 50 nucleotides from a segment that is complimentary to the mRNA sequence shown. Predict the effect of Colicin E3.

. (a) In eukaryotes, chromosomes consist of nucleosomes. How does this pose a problem for transcription?

(b) Illustrate a method to demonstrate that an eukaryotic gene is transcribable.

. This year, several deaths in Zambia were caused by ingestion of poisonous mushrooms, particularly Amanita phalloides, also called the death cup or the destroying angel. How does this mushroom kill? In your answer, say why this mushroom is important to a molecular biologist.

. (a) RNA is readily hydrolyzed by alkali while DNA is not. why?

(b) How does cordycepin (3' -deoxydenosine) block the synthesis of RNA?

. During the isolation of nucleic acids, explain why the following reagents or materials are used: EDTA, SDS, Sarkosyl, Proteinase K, Chloroform, Isoamyl alcohol, and DEPPC.

0. Chinsembu and co-workers at the University Teaching Hospital, Lusaka, use the polymerase chain reaction (PCR) to detect the presence of DNA sequences of a new herpesvirus that is known to cause Kaposi's sarcoma, a cancer common in individuals with AIDS. Patient blood is collected and separated into serum and cells. DNA is isolated and its amount is determined using a spectrophometer linked to a computer. The following print-out was obtained for ten patient samples:

/..

UTH VIROLOGY

Date: 19/11/96
Time: 11:36

Nucleic Acid

Read Samples   Method   SaveClear   Print   Quit

Results file: A:/WORK_RES   Method: A:/DNA

Assay type: General Ratio and Concentration   Units ug/ml
Formula setup: VIEW   Background correction: [Yes]
Sampling device: None   Concentration [Yes]
Read average time: 0.50 sec   Peak Pick: [No]↑↓

Sample ID	"A"	"B"	Protein	Nucleic acid
1	0.7636	0.3608	1.3017	1.3017
2	1.0843	0.5216	1.8402	1.8402
3	0.6248	0.2885	1.2185	1.2185
4	1.3524	0.9120	2.5703	2.5703
5	1.1692	0.7343	2.2155	2.2155
6	2.6090	2.3702	4.6157	4.6157
7	0.8467	0.3874	1.5572	1.5572
8	0.3883	0.1303	0.8408	0.8408
9	0.7908	0.5645	0.8258	0.8258
10	0.1000	0.0115	0.2619	0.2619

(a) What do columns "A" and "B" represent?

(b) Analyse the data and comment on the results

(c) A mistake due to incorrect programming of the spectrophotometer was noted in the data shown. Identify the error.

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

BS 361

MOLECULAR BIOLOGY

(PAPER II - THEORY)

TIME: THREE (3) HOURS

INSTRUCTIONS: ANSWER ALL QUESTIONS.
DIAGRAMS MAKE BETTER ANSWERS THAN SENTENCES.

---

1. Using well-labelled diagrams, show how a "molecular switch" in phage λ gives way to lysogenic and lytic growth.

2. Describe and illustrate how bacteria control their transcriptional profiles in response to:
   (a) osmolarity
   (b) toxic materials and nutrients.

3. (a) Depict molecular schemes of T-DNA transfer from Agrobacterium tumefaciens to plant genomes. Why is A. tumefaciens important in modern agriculture+
   (b) Account for the use of antisense RNA in the treatment of diseases.

4. (a) Using a named example, show how operons are important in prokaryotes.
   (b) Compare intrinsic and ę-dependent termination.

5. Briefly explain the following terms:

   (a) Ribozyme
   (b) Junk DNA
   (c) Luxury genes
   (d) proto-oncogenes
   (e) Housekeeping genes

END OF EXAMINATION & GOOD LUCK!!

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

BS 375

INVERTERBRATES

(THEORY PAPER)

TIME: THREE (3) HOURS

INSTRUCTIONS: ANSWER QUESTION ONE (1) AND FOUR OTHER QUESTIONS. ALL QUESTIONS CARRY EQUAL MARKS.

---

1. (a) What are the distinguishing features of the following invertebrates orders. Give an example of the member of each order:
   - (i) Euglenoidina
   - (ii) Haemosporidia
   - (iii) Haplosderina
   - (iv) Errantia
   - (v) Spirurida
   - (vi) Stylommatophora
   - (vii) Hemiptera
   - (viii) Hymemoptera
   - (ix) Acarina
   - (x) Protomonadina

   (b) Describe the classification scheme for the three orders of the class Oligochaeta of the phyllum Annelida.

2. Compare and contrast respiratory mechanisms in aguatic and terrestial invertebrates.

3. (a) Define and briefly describe the processes of Osmoregulation and homeostasis.

   (b) What osmoregulatory mechanisms and adaptations occur in both fresh water and marine invertebrates?

4. (a) Give illustrated descriptions of the life histories of <u>Taenia sagnata</u> and <u>Faseiola hepatica</u>.

   (b) What are the major adaptations seem in parasitic invertebrates.

5. There is a great diversity in the form and function of the feeding and digestive systems of invertebrates. Discuss this statement.

6. Briefly describe the various modes of reproduction in the invertebrates, and give examples where each mode occurs in the various phylla.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

BS 411

INSECT BEHAVIOUR AND ECOLOGY

THEORY: PAPER I

TIME: THREE (3) HOURS

INSTRUCTIONS: ANSWER FIVE QUESTIONS

---

1. Describe five complex human-like behaviour that insects developed millions of years ago, long before man did. If insects do not think as it is claimed by Scientists, how are they able to accomplish these complex tasks?

2. Discuss the biological functions of insect behaviour in the following:
   (a) Defense
   (b) Dispersal

3. Discuss the roles of pheromones in insect behaviour giving examples of specific pheromones of named insect groups.

4. Write short notes on five of the following:
   (a) Bioluminescence
   (b) $CH_3(CH_2)_2(CH=CH)_2(CH_2)_8CH_2OH$
   (c) Host acceptance by phytaphagus insects
   (d) Mechanisms of dispersal in insects
   (e) Hair pencils
   (f) Learning in insects

5. Distinguish between termite and ant insect societies in terms of organisation and communication.

6. Discuss the role of biological clocks in maintaining insect activity?

7. What roles does sound produced by insects play in the survival and perpetuation of the organisms? In your answer also explain how sound is produced and perceived by insects.

8. Describe the biochemical pathways involved in cold light production by some insects. What is the significance of the light produced?

END OF EXAMINATION & GOOD LUCK!!

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER FINAL EXAMINATIONS - MARCH 1998

BS 421

MICROBIOLOGY

(PAPER I - THEORY)

TIME: THREE (3) HOURS

INSTRUCTIONS: ANSWER FIVE (5) QUESTIONS, BUT NOT MORE THAN THREE (3) FROM EACH SECTION. ANSWERS MAY BE ENHANCED BY GIVING RELEVANT GRAPHS, CYCLES OR DIAGRAMS. USE SEPARATE BOOK FOR EACH SECTION.

SECTION A (All questions carry 20 marks maximum)

---

1. What is meant by:
   (a) Primary metabolistes
   (b) Idiophase
   (c) Idiolites

   Give some examples of idiolites and choosing one of them, show by adequate scheme how it is manufactured within microbial cell. Name the microbial species involved.

2. Define "indicator microganism."
   Name the major indicator microorganisms in routine analysis of water for potability and discuss their significance.

3. What may be the metabolic pathways involved in:
   (i) Carbohydrates catabolism
   (ii) Degradation of lipids. Explain -

4. Discuss the common food-borne diseases known to you. Enhance your answer by naming the microbial species involved in each case.

SECTION B

1. Mr. D, a 33 year - old blood group O, fully immunized, rather a nervous accountant who is taking the blockers for ulcer disease, his 29 year - old healthy wife, and their 10 month old baby returned from a 2-week trip to Luapula Province, Zambia, towards the end of November in 1996.

/2

The next morning, Mr. D., passed a semi-solid stool, followed quickly by a large watery bowel movement. Within an hour, he passed another large watery stool, now of an opaque grey-white color. He vomitted several times and became slightly sweaty. When this movement was followed by another watery stool a short time later, Mr. D. called his physician who advised him to go to the University Teaching Hospital and report to the Emergency Room. There was a febrile but obeserved to have a rapid heart rate with somewhat feable pulse and mildy decreased blood pressure. Mr. D. complained of muscles cramps and dizzness. There were no abnormalities in the rest of the physical examination and laboratory results showed only findings consistent with dehydration.

Mr. D. was given two litres of fluid intravenously and then placed on oral rehydration solution (ORS). Culture grew Vibrio cholerae the same as a concurrent epidemic strain in Lusaka. Stool volumes progressively diminished over 48 hours and the patient was discharged in his usual state of good health -

a) What was the predisposing factor to infection in Mr. D's case? (2 marks)

b) What is the source and resevoir(s) of Virbriocholerae (2 marks)

c) Discuss two (2) virulence factors of Vibriocholerae showing explicitlyhow they could have caused "Secretory" (watery) diarrhoea and vomit ing. (14 marks)

d) Why was Mr. D. given two-litres of fluid intravenously. followed by oral rehydration solution (ORS)? (2 marks)

2. (a) What is the term used to mean "Living together"? (1 mark)

(b) This term has no overtones of benefit or harm, but includes a wide diversity of associations. Discuss. (9 marks)

(c) Attempts have, in the past, been made to categorize types of associations very specifically, but have failed because all associations form a continuum. Explain, giving examples, why this continuum exists. (5 marks)

3. (a) Prepare yourself to give a short talk to laymen about the history and importance of antibiotics in medicine. What would you emphasize? (4 marks)

   (b) Describe the mode of action of sulfonamides. What is meant by competitive and non-competitive inhibition? What is the basis of their selective toxicity? (4 marks)

   (c) Distinguish between bactericidal and bacteriostatic drugs. Under what conclusion is one type preferable to the other? (5 marks)

   (d) What are the general mechanisms for bacterial resistance to antibiotics? Give examples of each class. (7 marks)

4. Write an essay on general information on the collection, transport and storage of specimens from different body sites for microbiological testing.
   Why is there so much emphasis on this point? (20 marks)

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

BS 431

ADVANCED PARASITOLOGY I

(PAPER I)

TIME: THREE (3) HOURS

INSTRUCTIONS: ANSWER FIVE QUESTIONS. ALL QUESTIONS CARRY EQUAL MARKS.

---

1. Discuss reproduction in parasites explaining the advantages of hermaphroditism in the success of parasitic species and also in the expression of survival genes.

2. Differentiate between natural and acquired immunity. What factors are important in natural immunity and explain how.

3. The parasite is the benefitting partner in a parasitic relationship, explain in detail how parasites benefit while pointing out the hazards they are exposed to by their hosts.

4. In search for malaria vaccine, what are the four possible candidate vaccines based on their target stage. Giving reasons, which vaccine would you recommend. State the problems which have lead to the delayed development of a malaria vaccine.

5. Describe the developmental process of nematodes stating where the various stages occur. Explain how the feeding of named hookwork leads to anaemia in its host.

6. Describe the origin and composition of the cell-mediated and humoral types of immunity.

7. Discuss how parasites locate their hosts and relate the process to the behaviour of the next host. Give examples to illustrate your answer.

2/..

8. What protective mechanisms are employed by parasites against the unfavourable medium in the host? Give examples to illustrate your answer.

END OF EXAMINATION.

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

BS 431

ADVANCED PARASITOLOGY I

(PAPER I)

TIME: THREE (3) HOURS

INSTRUCTIONS: ANSWER FIVE QUESTIONS. ALL QUESTIONS CARRY EQUAL MARKS.

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2/..

8. What protective mechanisms are employed by parasites against the unfavourable medium in the host? Give examples to illustrate your answer.

END OF EXAMINATION.

THE UNIVERSITY OF ZAMBIA
DEPARTMENT OF BIOLOGICAL SCIENCES

BS 431 ADVANCED PARASITOLOGY I 1998 FINAL PRACTICAL EXAM.
TIME 3HRS.

Q.1. You are the parasitologist on a team which is conducting a survey of intestinal infections. Since a large community needs to be examined, you have selected to use the Kato/Katz technique. Proceed as follows:

a. List the materials required.
b. Prepare a Kato slide from the specimen provided.
c. Leave instructions as to when you want your microscopist to examine the slide.
d. Other than detecting the infection present, what other information can you obtain about the infection.
e. Giving reasons, what infections are you likely to miss by the choice of your method.

Q.2. There has been an outbreak of a urinary tract infection in the your district, being the district parasitologist, you have conducted a survey to identify the infective organism. Explain how you conducted the survey by providing the following information:

a. Specimen requested for.
b. Characteristics noted.
c. Other parameters investigated.
d. Method used and why.

On examination you detected presence of eggs similar to those of S. haematobium, but strangely smaller that all the geographical strains reported. (NB: In literature, the ranges reported are 232 - 179 in length and 71-49 in breadth). Give a report providing the following information:

e. illustration of the egg morphology.
f. magnification of your drawing.
g. range of measurements based on 5 eggs.

Q.3. Draw and identify speciment A.

Q. 4. A total of 20 urine specimens were given to you to examine as in exercise 1 above. Dipstix were also provided to examine microhaematuria. Your results were as below:

Case No:	No. of eggs/10ml urine	Microhaematuria
1	226	1
2	0	0
3	40	1
4	2	1
5	0	0
6	145	1
7	78	1
8	0	1
9	45	0
10	23	0
11	0	0
12	34	1
13	678	1
14	908	1
15	0	0
16	0	0
17	0	0
18	29	0
19	0	1
20	37	1
21	5	0
22	0	0
23	0	0
24	234	1
25	56	0

Make a report for the school and Ministry of health survellaince section based on this sample giving the following information.

1. Prevalence of disease i.e.

   i. Parasitological prevalence:

   ii. Prevalence by dipstix:

2. Intensity among positives only:

3. Diagnostic value of Dipstix giving:
   (Construct a contigency table)

   i. <u>Sensitivity</u> ii. <u>Specificity</u>

NB: Sensitivity = a/a + c and Specificity = d/b +d

4. Comment on the sensitivity and specificity of microhaematuria as a screening test.

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

BS 431

ADVANCED PARASITOLOGY I

(PAPER I)

TIME: THREE (3) HOURS

INSTRUCTIONS: ANSWER FIVE QUESTIONS. ALL QUESTIONS CARRY EQUAL MARKS.

---

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6. Describe the origin and composition of the cell-mediated and humoral types of immunity.

7. Discuss how parasites locate their hosts and relate the process to the behaviour of the next host. Give examples to illustrate your answer.

8. What protective mechanisms are employed by parasites against the unfavourable medium in the host? Give examples to illustrate your answer.

END OF EXAMINATION.

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

BS 441

ADVANCED MOLECULAR BIOLOGY I

PAPER I

IME: 3 HOURS

NSTRUCTIONS: ANSWER ALL QUESTIONS

. Write short notes on each of the following:

(a) Mutation
(b) Transduction
(c) Chromatography
(d) Use of isotopes to follow biological activity
(e) Protein secondary structure

. Explain briefly the principle on which the isoelectric focusing technique is based.

. Briefly discuss the applications of analaytical centrifuges.

. Analytical centrifugation of a protein solution exhibits a single symmetrical peak during sedimentation. However, SDS polyacrylamide gel electrophoresis of the same protein solution reveals two (2) zones after the gel is stained. What can be concluded about the protein solution?

. Name four types of bonds that bring about the tertiary structure of proteins.

. Mathematically define sedimentation coefficient and make 5 deductions from the equation.

. Briefly explain how tropical plants avert the oxygenase catalysis of Rubisco.

. Describe th structure of the pyrimidine dimer formed by U.V. light. Briefly outline the mechanism of repair of such DNA damage.

. Briefly describe the steps involved in general recombination and state the major enzymes involved.

0. How does an F^{+} cell become an F' cell?

11. Briefly discuss the fine structure of the mitochondria.

12. A closed circular viral DNA is treated with a restriction endonuclease. This DNA has a single restriction site with the structure shown below:

5'-A-T-G-C-T-A-G-C-A-T-3'
3'-T-A-C-G-A-T-C-G-T-A-5'

Write the two fragments that will result from this enzyme action.

13. Briefly explain the malate and glycerol phosphate shuttles.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

BS 475

POPULATION ECOLOGY

(THEORY PAPER II)

TIME: THREE (3) HOURS

INSTRUCTIONS: ANSWER QUESTION ONE AND FOUR OTHER QUESTIONS.

---

1. (a) Define and distinguish between "carrying capacity" and "population density."

   (b) A farmer under a new resettlement scheme estimated that his new 2000-hectare farm would only carry one animal per 10 hectares. He discovered that one half of his farm had a large population of duickers which he wanted to keep but only after culling off excess duickers. But before that he wanted to know the duicker population using the mark and recapture method (Lincoln Index). In the preliminary trapping 126 duickers were caught, marked and released. In the second trapping 96 duickers were captured, of which 56 were marked individuals.

   (i) What is the duicker population?

   (ii) How many duickers should be culled as excess?

   (iii) What would be the total number of animals on the farm should he decide to use the other half of the farm as a cattle ranch?

   (iv) If the death rate among duickers is 7% and birth rate is 10%, how many duickers will be culled off in two years time?

2. Construct a life table for the lesser corn borer in a groundnuts field given the sampling data below. Be certain to compute generation totals as well as calculations for each life stage. Identify key factors of mortality and critical age intervals affected as indicated in this table.

2/..

Life stage	No. of Insects Collected (No. Entering Life Stage)	Mortality Factors
Egg	600	Parasite
Small larva	540	Rainfall
Large larva	400	Predators
Pre-pupa	360	Parasites
Pupa	240	Rainfall
Adult	40	(sex ratio 1.5♂: 1♀)
Adult females	24	

3. Write brief notes on five of the following topics:

(i) Pyramid of numbers
(ii) r and k selection
(iii) Niche, Habitat, Home range and territoriality.
(iv) Kin selection
(v) Population parameters
(vi) Types of mating systems in natural populations.

(a) Discuss the various hypotheses that seek to explain population fluctuations.
(b) What factors create and maintain genetic variability in natural populations.

Discuss the various physical and biological elements of the environment which affect population dynamics of a species.

(a) Why is old age referred to as a genetic dustbin?
(b) Discuss the density dependent and density independent factors affecting animal population

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END OF EXAMINATION & GOOD LUCK!!

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER DEF/SUPP EXAMINATIONS - APRIL 1998

BS 915

BIOLOGY OF SEED PLANTS

PRACTICAL PAPER

TIME: TWO HOURS

INSTRUCTIONS: ANSWER ALL QUESTIONS

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1. Examine specimens A to J and and then:

    (a) Explain whether they are

    bark
    condiment
    fruit
    herb
    root
    spice

    (b) Identify the botanical name of each specimen (i.e. A-J).

2. Use the dichotomous key provided to identify specimens K, L, M, N, O and P to species level.

3. Examine specimens Q and R and identify each to generic and division levels.

4. Study a slide preparation labelled S and then identify:

    (a) the aspect along which the section was cut;
    (b) the taxonomic group to division level.

5. Study specimens T and U and then postulate their ecological significance.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

BS 935

PLANT PATHOLOGY

THEORY PAPER

IME: THREE HOURS

NSWER: ANY FIVE QUESTIONS. ALL QUESTIONS CARRY EQUAL MARKS

. Examine the following and explain what important conclusions can you draw from your observation.

rain yield (Kg/ha) in three wheat cultivars challenged by certain athogens locally.

YEAR	LORIE II	UMNIATI	ZAMBEZI
1974	4000	3820	3980
1975	4550	4200	5009
1976	4690	1500	5380

. Define micotoxins and explain their role in plant disease.

a. Distinguish between rusts and smuts in relation to their:

- pathogens
- taxonomic status
- disease symptoms

b. Describe how rusts and smuts are influenced by weather?

. Describe features which characterize pathogens. How would you confirm that an organism is a pathogen? List various biotic (animate) pathogens.

. A recent survey of several farms and farmer's fields in Central, Lusaka and Southern provinces showed that many pathogens have become common and rather prevalent in comparison to the past. As a plant pathologist what explanations would you offer that would provide a clear picture of the agricultural scene in the above provinces.

. With the use of relevant examples distinguish between parasites and pathogens and explain the degree of parasitism of the two.

. Describe the different types of plant resistance known and indicate which of these would be your choice, and why.

. Write short notes on any **TWO** of the following:

i. Stable resistance
ii. Infection structures produced by *Uromyces*
iii. Primary inoculum and its types
iv. Polycyclic plant disease

END OF EXAMINATION

UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS FIRST SEMESTER - FEBRUARY/MARCH 1998

C 101 INTRODUCTORY CHEMISTRY I

Time: 3 hours

INSTRUCTIONS

This examination has two (2) sections: section A and section B.

Section A: This section contains **24 multiple choice questions.**
You must answer **all questions** in this section.
Use the **answer grid** provided for your answers.
Indicate your **computer number**, and **tutorial group number** on the answer grid.
Tear the answer grid out of this paper and insert in your answer booklet.
Section A carries **48 marks** in total.

Section B: This section contains **open-end questions**.
You must answer **any four (4)** of the five (5) questions given.
Use the **answer booklet** provided for your answers.
Indicate your **computer number**, and **tutorial group number** on the answer book.
Indicate on the answer book **which questions** you have answered.
Make sure your work is **clearly and neatly** presented.
Show your **working, calculations** and **reasoning**.
Each question carries **13 marks**, giving a total of 52 marks for this section.

DATA ARE PROVIDED ON PAGE 2 OF THIS QUESTION PAPER.

A COPY OF THE PERIODIC TABLE IS PROVIDED ON PAGE 3.

USEFUL DATA

1. Standard Reduction Potentials at 25 °C

Half - reaction	E^{o}_{red} (in V)
$Cl_2(g) + 2e \longrightarrow 2Cl^-(aq)$	+ 1.36
$O_2(g) + 4H^+(aq) + 4e \longrightarrow 2H_2O(l)$	+ 1.23
$I_2(s) + 2e \longrightarrow 2I^-(aq)$	+ 0.54
$Cu^{2+}(aq) + 2e \longrightarrow Cu(s)$	+ 0.34
$2H^+(aq) + 2e \longrightarrow H_2(g)$	0.00
$Pb^{2+}(aq) + 2e \longrightarrow Pb(s)$	- 0.13
$Fe^{2+}(aq) + 2e \longrightarrow Fe(s)$	- 0.44
$Cr^{3+}(aq) + 3e \longrightarrow Cr(s)$	- 0.74
$Zn^{2+}(aq) + 2e \longrightarrow Zn(s)$	- 0.76
$2H_2O(l) + 2e \longrightarrow H_2(g) + 2OH^-(aq)$	- 0.83
$Al^{3+}(aq) + 3e \longrightarrow Al(s)$	- 1.66
$Mg^{2+}(aq) + 2e \longrightarrow Mg(s)$	- 2.36
$Na^+(aq) + e \longrightarrow Na(s)$	- 2.71
$Ca^{2+}(aq) + 2e \longrightarrow Ca(s)$	- 2.87

2. Some useful constants

Avogadro's Number, $N_A = 6.02 \times 10^{23}$ mol^{-1}

Universal Gas Constant, R = 0.08206 dm^3 atm mol^{-1} K^{-1} <u>or</u> 8.314 J mol^{-1} K^{-1}

Faraday's constant, F = 9.65×10^4 C mol^{-1}

1.00 atm = 101.3 kPa = 760 mmHg = 760 Torr

3. Electronegativity values

H	2.1	N	3.0	Al	1.5	K	0.8
Li	1.0	O	3.5	Si	1.8	Ca	1.0
Be	1.5	F	4.0	P	2.1	Se	2.4
B	2.0	Na	0.9	S	2.5	Br	2.8
C	2.5	Mg	1.2	Cl	3.0	I	2.5

4. Standard Enthalpies of Formation (in kJ mol^{-1} at 25 °C)

Al_2O_3 (s) = - 1676

Fe_2O_3 (s) = - 824

he Periodic Table of the Elements

																2 He 4.002602
e 182											5 B 10.811	6 C 12.011	7 N 14.00674	8 O 15.9994	9 F 18.998403	10 Ne 20.1797
g 50											13 Al 26.981539	14 Si 28.0855	15 P 30.973762	16 S 32.066	17 Cl 35.4527	18 Ar 39.948
a 78	21 Sc 44.95591	22 Ti 47.88	23 V 50.9415	24 Cr 51.9961	25 Mn 54.93805	26 Fe 55.847	27 Co 58.93320	28 Ni 58.69	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.92159	34 Se 78.96	35 Br 79.904	36 Kr 83.80
r 2	39 Y 88.90585	40 Zr 91.224	41 Nb 92.90638	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.90550	46 Pd 106.42	47 Ag 107.8682	48 Cd 112.411	49 In 114.82	50 Sn 118.710	51 Sb 121.75	52 Te 127.60	53 I 126.90447	54 Xe 131.29
a ★ 27	71 Lu 174.967	72 Hf 178.49	73 Ta 180.9479	74 W 183.85	75 Re 186.207	76 Os 190.2	77 Ir 192.22	78 Pt 195.08	79 Au 196.96654	80 Hg 200.59	81 Tl 204.3833	82 Pb 207.2	83 Bi 208.98037	84 Po (209)	85 At (210)	86 Rn (222)
a ▼ 54	103 Lr (260)	104 § (261)	105 § (262)	106 § (263)	107 §	108 §	109 §									

★ Lanthanides

★57 La 138.9055	58 Ce 140.115	59 Pr 140.90765	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.965	64 Gd 157.25	65 Tb 158.92534	66 Dy 162.50	67 Ho 164.93032	68 Er 167.26	69 Tm 168.93421	70 Yb 173.04

▼ Actinides

▼89 Ac 227.0278	90 Th 232.0381	91 Pa 231.03588	92 U 238.0289	93 Np 237.0482	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)

te: For use in the calculations, atomic masses could be rounded off to two decimal places.

ECTION A - MULTIPLE CHOICE QUESTIONS

The enthalpy of formation for $Fe(OH)_3(s)$ corresponds to the reaction

a. $Fe^{3+}(aq) + 3OH^-(aq) \longrightarrow Fe(OH)_3(s)$

b. $Fe(s) + 1\frac{1}{2}O_2(g) + 1\frac{1}{2}H_2(g) \longrightarrow Fe(OH)_3(s)$

c. $Fe(OH)_2(s) + \frac{1}{4}O_2(g) + \frac{1}{2}H_2O(l) \longrightarrow Fe(OH)_3(s)$

d. $Fe(s) + \frac{3}{4}O_2(g) + 1\frac{1}{2}H_2O(l) \longrightarrow Fe(OH)_3(s)$

e. $Fe^{3+}(g) + 3OH^-(g) \longrightarrow Fe(OH)_3(s)$

The following reactions are investigated in a bomb calorimeter:

(i) $H_2(g) + Cl_2(g) \longrightarrow 2HCl(g)$

(ii) $CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(l)$

(iii) $Ag^+(aq) + Cl^-(aq) \longrightarrow AgCl(s)$

For which reaction(s) will the heat change (q_V) be equal to the reaction enthalpy (ΔH) ?

a. For none of the three reactions.

b. For reaction (iii) only.

c. For reactions (i) and (ii).

d. For reactions (i) and (iii).

e. For all three reactions.

Which one of the following statements concerning a mixture of gases is WRONG ?

a. The partial pressure of a gas in a mixture is the pressure the gas would have if it alone would occupy the volume of the gas mixture.

b. The total volume of the gas mixture equals the sum of the volumes of the components if these would be at the same pressure as the mixture.

c. The partial volume of a gas in a mixture is the volume the gas would have if it alone would occupy the volume of the gas mixture.

d. Dalton's Law of partial pressures assumes that gases in a mixture do not interact with each other.

e. When gases are mixed, diffusion ensures that after a while each gas is found throughout the volume occupied by the mixture.

If the temperature is 100 °C, at what pressure will the density of CO_2 gas be 0.750 g/dm^3?

a. 0.140 kPa

b. 0.522 kPa

c. 5.28 kPa

d. 14.2 kPa

e. 52.8 kPa

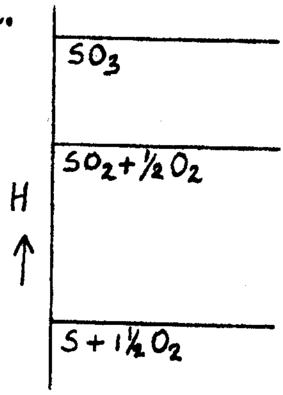
5. Sulphur trioxide (SO_3) can be prepared in two steps:

$$S(s) + O_2(g) \longrightarrow SO_2(g) \qquad \Delta H^\circ = -297\ kJ$$

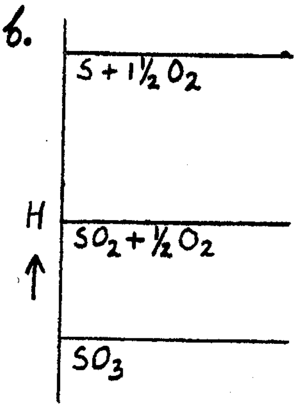
$$SO_2(g) + \tfrac{1}{2}O_2(g) \longrightarrow SO_3(g) \qquad \Delta H^\circ = -99\ kJ$$

The enthalpy diagram for this two-step reaction would be

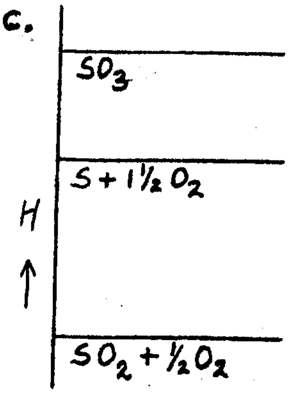
a.



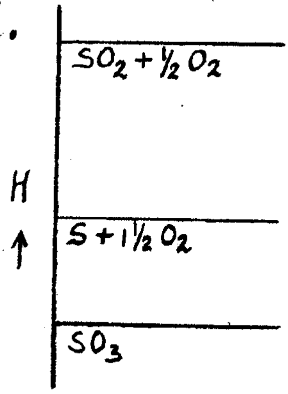
b.



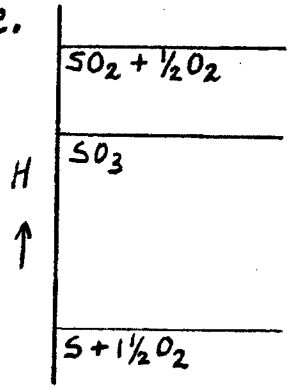
c.



d.

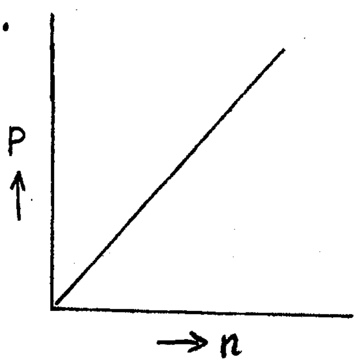


e.

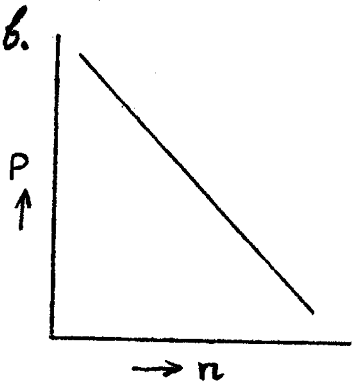


6. For an ideal gas, kept at constant volume and temperature, the relation between the number of moles (n) and its pressure (P) is shown by graph

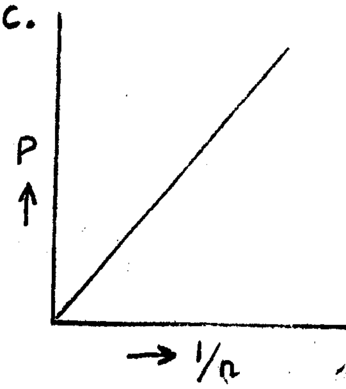
a.



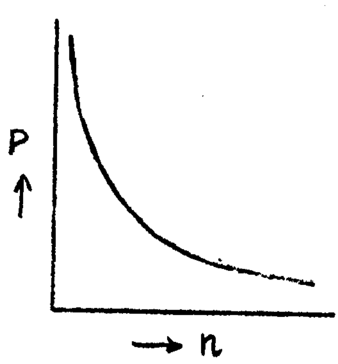
b.



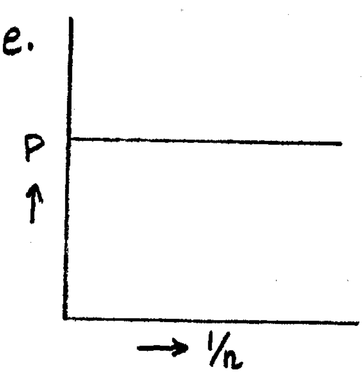
c.



d.



e.



The standard cell potential for the cell $Zn(s)/Zn^{2+}(aq)//Cu^{2+}(aq)/Cu(s)$ is

a. - 1.10 V

b. - 0.42 V

c. + 0.42 V

d. + 0.55 V

e. + 1.10 V

A student tried to determine the value for Faraday's constant, F, using an electrolysis experiment. He took a solution which he thought contained the copper(II) ion, and passed a current of 1.50 A for exactly 30 minutes. The mass of metal deposited was 3.56 g. According to his experiment, the value for Faraday's constant is

a. 8.04×10^2 C/mol

b. 1.61×10^3 C/mol

c. 4.82×10^4 C/mol

d. 9.64×10^4 C/mol

e. 1.93×10^5 C/mol

What is the overall reaction taking place in a galvanic cell with cell diagram:

$Cd(s)/Cd^{2+}(aq)//Fe^{3+}(aq),Fe^{2+}(aq)/Pt$

a. $Cd(s) + Fe^{3+}(aq) \longrightarrow Cd^{2+}(aq) + Fe^{2+}(aq)$

b. $Cd(s) + Fe^{3+}(aq) + Pt^{+}(aq) \longrightarrow Cd^{2+}(aq) + Fe^{2+}(aq) + Pt(s)$

c. $Cd(s) + Fe^{3+}(aq) + Fe^{2+}(aq) + Pt(s) \longrightarrow Cd^{2+}(aq) + 2Fe(s) + Pt^{3+}(aq)$

d. $Cd(s) + Fe^{3+}(aq) + Pt^{+}(aq) \longrightarrow Cd^{2+}(aq) + Fe^{2+}(aq) + Pt(s)$

e. $Cd(s) + 2Fe^{3+}(aq) \longrightarrow Cd^{2+}(aq) + 2Fe^{2+}(aq)$

Which one of the following statements about an electrolytic cell is NOT correct ?

a. The cathode is the negative electrode, while the anode is the positive electrode.

b. Oxidation occurs at the anode, while reduction occurs at the cathode.

c. The standard potential for the overall reaction is negative.

d. The standard reduction potentials for both half-reactions are negative.

e. Both half-reactions can occur in the same compartment.

Compare light with a wavelength of 450 nm and light with a wavelength of 750 nm. The light with the lower wavelength has

a. a lower frequency.

b. a higher frequency.

c. the same frequency.

d. a lower speed.

e. a higher speed.

Information for questions 12 and 13: Consider the molecules: N_2 , BF_3 , CH_4 , H_2S , CO_2 .

12. Which one of the molecules does NOT obey the octet rule ?

a. N_2

b. BF_3

c. CH_4

d. H_2S

e. CO_2

13. Which one of the molecules is polar ?

a. N_2

b. BF_3

c. CH_4

d. H_2S

e. CO_2

14. Consider the following three sets of quantum numbers:

(i)	$n = 3$	$l = 2$	$m_l = -2$	$m_s = ½$
(ii)	$n = 1$	$l = 1$	$m_l = 0$	$m_s = -½$
(iii)	$n = 4$	$l = 3$	$m_l = 2$	$m_s = ½$

Which of these sets could NOT occur ?

a. Only set (i) could not occur.

b. Only set (ii) could not occur.

c. Only set (iii) could not occur.

d. Sets (i) and (ii) could not occur.

e. Sets (ii) and (iii) could not occur.

15. Consider the following statements about phosphoric acid:

(i) Phosphoric acid is a weak acid.

(ii) Concentrated aqueous phosphoric acid solution is a strong acid.

(iii) Phosphoric acid is an ionic compound containing the H^+ and PO_4^{3-} ion.

a. Only statement (i) is correct.

b. Statements (i) and (ii) are both correct.

c. Statements (i) and (iii) are both correct.

d. Statements (ii) and (iii) are both correct.

e. All three statements are correct.

6. Which of the following species would be diamagnetic: Al , Mg , Cl^- , S ?

a. Mg only.

b. Cl^- only.

c. Mg and Cl^-.

d. Al only.

e. Al and S.

7. Arrange the following species in terms of INCREASING first ionisation energy:
F , Cs , Br , Cl , K.

a. Cs , K , Br , Cl , F.

b. Br , Cl , F , Cs , K.

c. Br , Cl , F , K , Cs.

d. Cs , K , F , Cl , Br.

e. F , Cl , Br , K , Cs.

. Salts are called electrolytes since they

a. dissolve in water.

b. are formed from acids and bases.

c. produce electricity when heated.

d. dissociate into ions in aqueous solution.

e. conduct electricity when pure.

. Which one of the following equations would NOT represent a chemical reaction correctly ?

a. $3Fe_2O_3(s) + CO(g) \longrightarrow 2Fe_3O_4(s) + CO_2(g)$

b. $K^+(aq) + Br^-(aq) \longrightarrow KBr(aq)$

c. $Zn^{2+}(aq) + 2OH^-(aq) \longrightarrow Zn(OH)_2(s)$

d. $N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g)$

e. $3Ca^{2+}(aq) + 2PO_4^{3-}(aq) \longrightarrow Ca_3(PO_4)_2(s)$

. X is the symbol for a particular element. Which one of the following formulae is most likely NOT correct ?

a. X_2O_3

b. $X_2(SO_4)_3$

c. X_2S_3

d. XCl_3

e. $X_2(NO_3)_3$

21. Consider the following statements on experimental errors:

(i) Experimental data can not be both very accurate and very precise.

(ii) Both systematic and random errors can be avoided by a skilled experimenter.

(iii) Systematic errors affect the accuracy of an experiment, while random errors affect the precision.

a. Only statement (iii) is correct.

b. Statements (i) and (ii) are correct.

c. Statements (i) and (iii) are correct.

d. Statements (ii) and (iii) are correct.

e. All statements are correct.

22. 5.90×10^3 μg mm^{-3} expressed in kg m^{-3} would be

a. 5.90×10 kg m^{-3}

b. 5.90×10^2 kg m^{-3}

c. 5.90×10^3 kg m^{-3}

d. 5.90×10^4 kg m^{-3}

e. 5.90×10^5 kg m^{-3}

23. Which one of the following reactions is an oxidation ?

a. Changing hydrogen atoms to hydride ions.

b. Changing copper(II) ions to copper(I) ions.

c. Changing iron(II) ions to iron atoms.

d. Changing sulphide ions to sulphur atoms.

e. Changing iodine atoms to iodide ions.

24. Steam reacts with hot manganese. Hydrogen reduces lead oxide. Steam does not react with hot lead. Based on this evidence, between which of the following is there likely to be a reaction ?

a. lead and manganese oxide.

b. manganese and lead oxide.

c. lead oxide and steam.

d. manganese oxide and steam.

e. manganese oxide and lead oxide.

END OF SECTION A - PROCEED WITH SECTION B

UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS FIRST SEMESTER - FEBRUARY/MARCH 1998

C 101 INTRODUCTORY CHEMISTRY I

nputer Number: acting V.C. U.N.ZA **Tutorial Group Number:** MMD

Name : Mutale Chande

ANSWER GRID FOR SECTION A. (indicate your answer with a cross)

uestion	a	b	c	d	e	Question	a	b	c	d	e
						13					
						14					
						15					
						16					
						17					
						18					
						19					
						20					
						21					
						22					
						23					
						24					

Tear out of this question paper and insert in your answer booklet.

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

C 205/C 225

SECTION A: C205/C225 STUDENTS

TIME: TWO HOURS

ANSWER: ALL QUESTIONS FROM THIS SECTION

Q1. (a) Define or explain the following terms:

(i) Accuracy and precision
(ii) Determinate and indeterminate errors
(iii) Normality, equivalent weight, ppm and mg%
(iv) Sampling, confidence interval, confidence level and confidence limit

(b) How many milliliters of a concentrated commercial H_2SO_4 solution that has a density of 1.84 g/mL and contains 96% H_2SO_4 by weight should be diluted with water to obtain 1.0 liter of solution containing 50% H_2SO_4 by weight.

What is the normality of the initial and final solutions? (MM of H_2SO_4 = 98.08).

Q2. (a) Calculate the pH of a solution obtained by mixing equal volumes of HCl solutions having pH 2.00 and 3.00, respectively.

(b) A buffer solution is 0.20 M in acetic acid and sodium acetate. Calculate the change in pH upon adding 1.0 mL of 0.01M HCl to 10 mL of this solution.

$Ka = 1.75 \times 10^{-5}$

$Ksp = 1.9 \times 10^{-12}$

Q3. (a) Define the following terms:

(i) Arrhenius theory, theory of solvent systems, Brnsted - Lowry theory and Lewis theory.

(ii) The pH scale, Buffer solution and the Henderson-Hasselbalch equation.

(b) Calculate the pH of a 1.0 x 10^{-7} M HCl solution.

(c) The total carbon dioxide content (HCO_3^- + CO_2) in a blood sample is determined by acidifying the sample and measuring the volume of CO_2 evolved with a Van Slyke manometric apparatus. The total concentration was determined to be 28.5 mmole/L. The blood pH at 37.0°C was determined to be 7.48. What are the concentrations of HCO_3^- and CO_2 in the blood?

$CO_2 + H_2O$ ====== $HCO_3^- + H$: $K_a = 7.94 \times 10^{-7}$

Hint: CO_2 is taken as the acid in the above reaction.

Q4. A new gravimetric method is developed for Fe(III) in which the iron is precipitated in crystalline form with an organoboron "cage" compound. The accuracy of the method is checked by analyzing the iron in an ore sample and comparing with the results using the standard precipitation with ammonia and weighing of Fe_2O_3. The results, reported as % Fe for each analysis, were as follows:

Test Method	Reference Method
20.10%	18.89%
20.50	19.20
18.65	19.00
19.25	19.70
19.40	19.40
19.99	
$\bar{X}_1$ = 19.65%	$\bar{X}_2$ = 19.24%

95% C.L

Is there a significant difference between the two methods?

SECTION B: C225 STUDENTS ONLY

TIME: ONE HOUR

ANSWER: ALL QUESTIONS

Q5. Calculate the molar solubility of Ag_2CrO_4 in the following solutions:

(a) In water
(b) In a 0.05 M Na_2CrO_4 solution
(c) In a 0.05 M $AgNO_3$ solution

(Disregard the hydrolysis of chromate ions)

Q6. (a) The concentration of Ag^+ ion in a saturated aqueous solution of Ag_2CrO_4 was found to be equal to 1.56×10^{-4} M. Calculate the solubility of Ag_2CrO_4 in g/L, and its solubility product. (m.m. of Ag_2CrO_4 = 331.7)

(b) How many grams of NH_4Cl should be added to 50 mL of 0.20 M NH_3 solution so that after mixing of the resulting solution with 50 mL of 0.02 M $MnCl_2$ solution, no precipitate of $Mn(OH)_2$ will be formed.

K_b for $NH_3 = 1.8 \times 10^{-5}$

m.m. for NH_4Cl = 53.5

K_{sp} for $Mn(OH)_2 = 2.0 \times 10^{-13}$

END OF EXAMINATION

205/0225

Values of t for v Degrees of Freedom for Various Confidence Levels

v	Confidence Level, 90%	95%	99%	99.5%
1	6.314	12.706	63.657	127.32
2	2.920	4.303	9.925	14.089
3	2.353	3.182	5.841	7.453
4	2.132	2.776	4.604	5.598
5	2.015	2.571	4.032	4.773
6	1.943	2.447	3.707	4.317
7	1.895	2.365	3.500	4.029
8	1.860	2.306	3.355	3.832
9	1.833	2.262	3.250	3.690
10	1.812	2.228	3.169	3.581
15	1.753	2.131	2.947	3.252
20	1.725	2.086	2.845	3.153
25	1.708	2.060	2.787	3.078
[redacted]	1.645	1.960	2.576	2.807

v = N - 1 = degrees of freedom.

Rejection Quotient, Q at [redacted] Different Confidence Limits

Number of Observation	CONFIDENCE LEVEL Q_{90}	Q_{95}	Q_{99}
3	0.94	0.970	0.994
4	0.76	0.829	0.926
5	0.64	0.710	0.821
6	0.56	0.625	0.740
7	0.51	0.568	0.680
8	0.47	0.526	0.634
9	0.44	0.493	0.598
10	0.41	0.466	0.568
[redacted]	[redacted]		
15	0.338	0.384	0.475
20	0.300	0.342	0.425
25	0.277	0.317	0.393
30	0.260	0.298	0.372

Values of F at the 95% Confidence Level

	v_1= 2	3	4	5	6	7	8	9	10	15	20	30
v_2= 2	19.0	19.2	19.2	19.3	19.3	19.4	19.4	19.4	19.4	19.4	19.4	19.5
3	9.55	9.28	9.12	9.01	8.94	8.89	8.85	8.81	8.79	8.70	8.66	8.62
4	6.94	6.59	6.39	6.26	6.16	6.09	6.04	6.00	5.96	5.86	5.80	5.75
5	5.79	5.41	5.19	5.05	4.95	4.88	4.82	4.77	4.74	4.62	4.56	4.50
6	5.14	4.76	4.53	4.39	4.28	4.21	4.15	4.10	4.06	3.94	3.87	3.81
7	4.74	4.35	4.12	3.97	3.87	3.79	3.73	3.68	3.64	3.51	3.44	3.38
8	4.46	4.07	3.84	3.69	3.58	3.50	3.44	3.39	3.35	3.22	3.15	3.08
9	4.26	3.86	3.63	3.48	3.37	3.29	3.23	3.18	3.14	3.01	2.94	2.86
10	4.10	3.71	3.48	3.33	3.22	3.14	3.07	3.02	2.98	2.85	2.77	2.70
15	3.68	3.29	3.06	2.90	2.79	2.71	2.64	2.59	2.54	2.40	2.33	2.25
20	3.49	3.10	2.87	2.71	2.60	2.51	2.45	2.39	2.35	2.20	2.12	2.04
30	3.32	2.92	2.69	2.53	2.42	2.33	2.27	2.21	2.16	2.01	1.93	1.84

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER SUPPLEMENTARY/DEFERRED EXAMINATIONS – APRIL 1998

C205/C245

INORGANIC CHEMISTRY

TIME: THREE HOURS

ANSWER: ALL QUESTIONS

C205: ANSWER ALL QUESTIONS FROM SECTION A ONLY.
TIME: TWO HOURS

SECTION A

1. (a) Sketch a graph showing the variation of kinetic energy of the ejected electron and the frequency of the photon. Indicate the intercept of the graph as well as its slope.

   (b) Calculate the workfunction of a strontium metal in $Jmol^{-1}$ if an electron travels with a speed of 3.36×10^7 cm/s when the light of wavelength 405 nm falls on it.

   (c) Using Slater's rules, calculate the effective nuclear charge, Z*, for the following electrons.
   (i) the valence (most easily ionizable) electron in Ca.
   (ii) the valence electron in Mn.
   (iii) a 3d electron in Mn.
   (iv) the valence electron in Br
   Ca(Z = 20), Mn(Z = 25), Br(Z = 35)

   (d) The Lyman series of spectral lines in the spectrum of atomic hydrogen arises from electronic transitions from the levels $n_2 = 2,3,4$ etc to $n_1 = 1$. Calculate the wavelength of the series limit ($n_2 = \infty$) in Angstrom. Hence calculate the energy in Kilojoules (KJ) per mole needed to remove the electron completely.

2. (a) (i) Draw a molecular orbital energy level diagram of a nitrosyl molecule (NO).
   (ii) Use the diagram to deduce the bond orders of NO, NO^- and NO^+.
   (iii) Arrange the species in the order of decreasing bond strength
   N(Z = 7), O(Z = 8)

(b) In each of the following pairs which is the larger ion?

(i) O^{2-}, F^{-}

(ii) Mn^{2+}, Fe^{3+}

(iii) S^{2-}, Se^{2-}.

O(Z = 8), F(Z = 9), Mn(Z = 25), Fe(Z = 26)
S(Z = 16), Se(Z = 34)

Explain the reasoning behind each choice.

3. (a) The aqueous ions Zn^{2+} and Ag^{+} form complexes with ammonia that have similar stabilities, yet zinc and silver are in different columns (groups) in the Periodic table. Suggest a reason for this similar chemistry.
Zn(Z = 30), Ag(Z = 47)

(b) Explain in detail, using both hybridization and the resonance theory why the CO bonds in CO_3^{2-} have a bond order of 1 and 1/3.
C(Z = 6), O(Z = 8)

4. (a) Write the formula of the common oxide for each of the following:

(i) Na (ii) Al (iii) S

Na(Z = 11), Al(Z = 13), S(Z = 16)

(iv) Classify each of the oxides as being basic, acidic or amphoteric.

(v) For basic and acidic oxides, write balanced equations of their reaction (if any) with water.

(b) Account for the observation that B forms BF_4^{-} whereas Al forms AlF_6^{3-}.

SECTION B

1. (a) When the four-coordinate square planar complex $[IrCl(PPh_3)_3]$ (where PPh_3 = triphenylphosphine) reacts with Cl_2, the six-coordinate product $[IrCl_3(PPh_3)_3]$ is formed by a reaction known as 'oxidative addition'. What isomers of the product are possible?

(b) Give the oxidation state of Iron in each of the following:

(i) $K_4[Fe(CN)_6]$

(ii) $Na_2[Fe(CN)_5NO]$

(iii) $[(CO)_3Fe(CO)_3Fe(CO)_3]$

(c) Name the following coordination compounds:

(i) $[Co(en)_2Cl_2]^{+}$

(ii) $[Pt(NH_3)_2Cl_2]$

(d) Determine the number of unpaired electrons and the ligand field stabilization energy (LFSE) for each of the following:

(i) $[Fe(CN)_6]^{4-}$

(ii) $[Cr(NH_3)_6]^{3+}$

Fe(Z = 26), Cr(Z = 24)

2. (a) Write balanced chemical reactions, when

(i) Lithium sulphate reacts with barium hydroxide solution.

(ii) Carbon dioxide gas is passed into the aqueous solution of sodium carbonate.

(iii) Colemanite is heated in aqueous solution of sodium carbonate.

(iv) Boron reacts with dilute sulphuric acid.

(v) A mixture of boron trioxide, calcium fluoride and conc. sulphuric acid is heated.

(b) Write the structures of the following species:

(i) B_2H_6 (ii) $B_3O_3(OH)_4^-$

(c) Complete and balance the following reactions:

(i) $KMnO_4 + 8H_2SO_4 + FeSO_4 \rightarrow$

(ii) $Na_2S_2O_3 + I_2 \rightarrow$

(iii) $PCl_5 + B_2O_3 \rightarrow$

(iv) $Al(OH)_3 + NaOH \rightarrow$

(v) $Na_2B_4O_7 + H_2O \rightarrow$

CONSTANTS

h = 6.626×10^{-34} Js

c = 2.998×10^{8} ms^{-1}

m = 9.109×10^{-31} Kg

N_A = 6.023×10^{23} mol^{-1}

R_H = 1.097×10^{7} m^{-1}

ε_o = 8.854×10^{-12} $J^{-1}c^2m^{-1}$

e = 1.602×10^{-19} c

1 eV = 1.602×10^{-19} J

END OF SUPPLEMENTARY/DEFERRED EXAMINATION

THE UNIVERSITY OF ZAMBIA
UNIVERSITY EXAMINATIONS

MARCH 1998
C251-ORGANIC CHEMISTRY

TIME: 3HOURS
INSTRUCTIONS: ANSWER ANY 4 0UT 5 QUESTIONS
EACH QUESTION CARRIES 15 MARKS.
DO NOT SPEND MORE THAN FORTY FIVE MINUTES
ON EACH QUESTION

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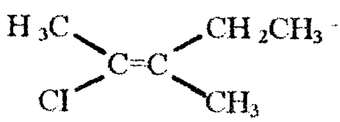
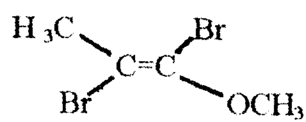
1. (a) (i) What kinds of compounds exhibit OPTICAL isomerism?

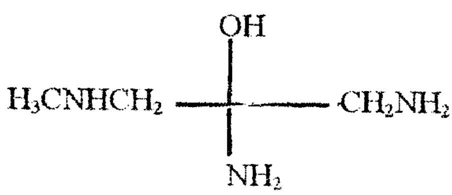
(ii) Name each of the following geometrical isomers by the *E-Z* method.

(a) 

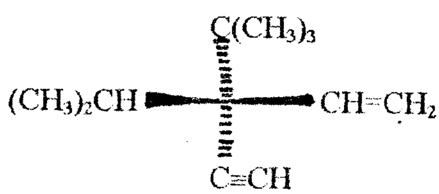
(b) 

(b) (i) Assign *R*, *S* configuration to the following molecules.

(a)



(b)



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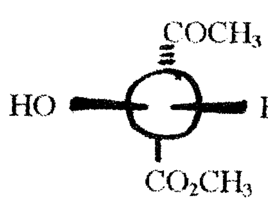


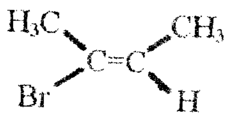
(ii) Draw the stereostructures for each of the following compounds.

(a) (2*R*, 3*R*)-3- bromo-2-butanol

(b) Optically active isomers of 1-Bromo-4-Chloro cyclohexane.

(c) What is the relationship between the following pairs of compounds?

(i)



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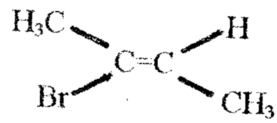

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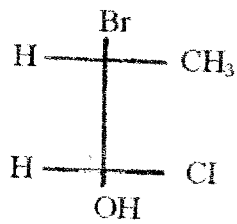

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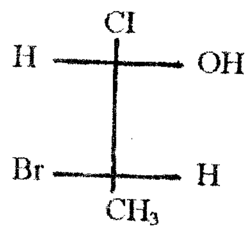
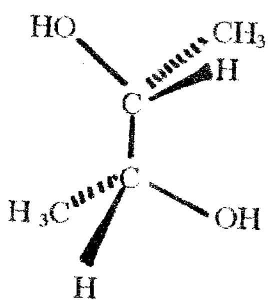


(iii)



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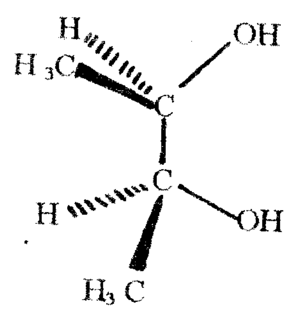
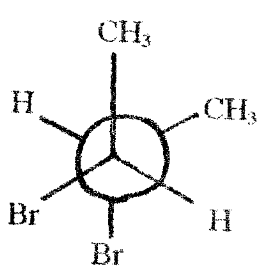


(iv)



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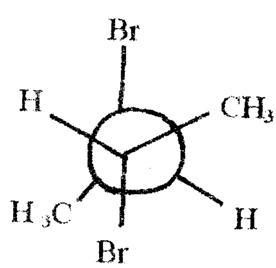


2. (a) Alkyl halides undergo an elimination reaction to yield alkenes on treatment with strong base. If axial chlorohexanes are generally more reactive than their equatorial isomers, which do you think react faster cis-2-chloro-tertbutyl cyclohexane or trans-2-chloro-tertbutyl cyclohexane? Give reason(s) for your answer.

(b) (i) Give the product(s) that would be obtained from the cis and trans conformers in (a) and

(ii) State the major product giving reason for your answer.

(c) Assuming that anti-elimination of hydrogen bromide is favoured, predict the structures of the stereoisomers that would give

(i) (*E*)-2-Bromo-2-butene

(ii) (*Z*)-2-Bromo-2-butene.

3. (a) (i) Give the mechanism for the reaction between 2-methyl-2-propanol with HBr.

(ii) State the rate-determining step.

(iii) What kinetic order does the reaction follow?

(b) For each of the following pairs of reactions ,predict which one is faster and give reason(s) for your choice.

(i) (a) $(CH_3)_3CBr + CH_3CH_2OH \longrightarrow (CH_3)_3COCH_2CH_3 + HBr$

(b) $(CH_3)_3CBr + CH_3OH \longrightarrow (CH_3)_3COCH_3 + HBr$

(ii) (a) $CH_2{=}CHCH_2Br + CN^- \xrightarrow{DMSO} CH_2{=}CHCH_2CN + Br^-$

(b) $CH_3CH{=}CHBr + CN^- \xrightarrow{DMSO} CH_3CH{=}CHCN + Br^-$

(iii) (a) $(CH_3)_2CHCH_2Cl + I^- \xrightarrow{acetone} (CH_3)_2CHCH_2I + Cl^-$

(b) $CH_3CH_2CH_2CH_2Cl + I^- \xrightarrow{acetone} CH_3CH_2CH_2CH_2I + Cl^-$

(iv) (a) $(CH_3)_3CBr + OH^- \longrightarrow (CH_3)_3COH + Br^-$

(b) $(CF_3)_3CBr + OH^- \longrightarrow (CF_3)_3COH + Br^-$

(v) (a) CH_3I + CN^- $\xrightarrow{(CH_3)_2C=O}$ CH_3CN + I^-

(b) CH_3I + CN^- $\xrightarrow{H_3CNHCH=O}$ CH_3CN + I^-

(c) Consider the table below showing the transition states of the nucleophilic substitution reactions and the types of solvents used.

Mechanism	Transition state	Type of solvent
S_N1	$R^{\delta+}$------$L^{\delta+}$	Polar protic
S_N1	$R^{\delta+}$------$L^{\delta-}$	Polar aprotic
S_N2	$Nu^{\delta-}$----R----$L^{\delta+}$	Polar aprotic
S_N2	$Nu^{\delta+}$----R----$L^{\delta-}$	Polar aprotic

Give the nature of reactants and comment on the effects of the type of solvent on the rate of reaction.

4. (a) Give simple chemical tests to distinguish between

(i) 2-pentanol and 3- pentanol.

(ii) n-butanol and 2-buten-1-ol.

(b) Show how you would make the following conversions using the compounds indicated and any necessary inorganic reagents.

(i) 2,3-dimethyl-2-butanol from 2-propanol as the only available organic compound.

(ii) 1-cyclohexylmethanol from 3- methylcyclopentanol.

(iii) 1,2-cis diol derivative of 1,2-dimethylcyclohexane from 1,2-dimethylcyclohexene and give the product(s) that would be obtained when the diol is treated with a concentrated acid.

(c) Give products and their IUPAC names resulting from the reaction of 1-methylcyclopentene with

(i) Diborane and then hydrogen peroxide

(ii) m-chloroperacetic acid

(iii) Ozone followed by zinc and water

(iv) Mercuric acetate and basic sodium borohydride

5. (a) What does the following observation tells you about the mechanism of the addition of chlorine to an alkene? In the presence of a bromide salt, vic-dichloride and some bromochloroalkane are isolated but no dibromide is obtained.

(b) Account for the following facts;

(i) Acetylenic hydrogens are more acidic than ethylenic hydrogens.

(ii) Acetylides can not be used with secondary or tertiary alkylides in the preparation of alkynes.

(c) (i) Show how you would convert *trans*-3- pentene to *cis*-3-pentene.

(ii) Compound A (C_4H_6) reacts with H_2 and Pt catalyst to yield butane. compound A decolourises Br_2 in CCl_4 and aqueous $KMnO_4$, but it does not react with $Ag(NH_3)_2^+$. On treatment with Na in NH_3 , A is converted to B (C_4H_8). When B is treated with OsO_4 followed by treatment with $NaHSO_4$, B is converted to C ($C_4H_{10}O_2$). Compound C can be resolved. Provide structures for A to C.

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS-FEBRUARY/MARCH 1998

C311-BIOCHEMISTRY I

TIME: <u>THREE</u> HOURS

INSTRUCTIONS:

SECTION A

ANSWER ALL QESTIONS IN SECTION A

SECTION B

1. ALL QUESTIONS IN THIS SECTION CARRY EQUAL MARKS.

2. CHOOSE ANY 4 QUESTIONS.

....

SECTION A

1. (i) **Calculate** the change in redox potential ($\Delta E'_0$) and in the free energy of oxidation ($\Delta G'_0$) associated with of oxidation of NADH by O_2. The partial reactions are:

(a) $1/2\ O_2 + 2H^+ + 2e^- \rightarrow H_2O$

$E'_0 = +0.820V$

(b) $NAD^+ + 2H^+ + 2e^- \rightarrow NADH$

$E'_0 = -0.320V$

If the amount of energy required to synthesize 1 molecule of ATP is equivalent to $\Delta E'_0$ of +0.167V for a 2e⁻ oxidation-reaction reaction, **calculate** from the $\Delta G'_0$ from the $\Delta G'_0$ for ATP the maximum number of ATP molecules synthesized during the oxidation of NADH by O_2.**(Farady contant = 23.1kcal/v/mol).**
[3 marks]

(ii) The $\Delta G'_0$ for hydrolysis of ATP to ADP and Pi -7.3kcal/mol.

(a) **Calculate** the equilibrium constant for this reaction at 298K.

(b) Is this reaction at **equilibrium** in the cells? **Explain.**
(Gas constant = 1.987cal/mol)
[4 marks]

2. (a) Radioactive glucose, labeled at position 4 with ^{14}C, was incubated with cell-free liver homogenate under anaerobic conditions. **What** position in lactate produced would be labeled with ^{14}C?
[6 marks]
(b) Oxygen transport can be affected in genetic disorders of glycolysis in red blood cells.
(i) **How** are glycolysis and oxygen transport linked?
[2 marks]
(ii) **How** is oxygen affinity affected by a deficiency of hexokinase?
[2 marks]
(iii) **How** is oxygen affinity affected by a deficiency of pyruvate kinase.
[2 marks]

3. **TRUE or FALSE.** If false **explain** why.

(a) Isocitrate dehydrogenase is an allostric enzyme.
[1 mark]
(b) The TCA cycle is limited to the aerobic oxidation of pyruvate derived from glucose.
[1 mark]
(c) Fumarate is a cis isomer.
[1 mark]
(d) Intermediates of the TCA cycle can be used for amino acid synthesis but not for gluconeogenesis.
[1 mark]
(e) The activity of pyruvate dehydrogenase can be regulated by covalent modification.
[1 mark]

(ii) The TCA cycle has many points of control. **Briefly discuss** why it is necessary for this pathway to have so many points that control it.
[2 marks]

4. Name the **THREE** types of enzyme specificity and the **THREE MECHANISMS** used to explain them.
[6 marks]

5. Using diagrams only, **DESCRIBE** the effects of the following on enzyme activity.

(a) Hydrogen concentration.
(b) Temperature.
(c) Substrate concentration.
(d) Enzyme concentration.
[4 marks]

6. **Identify** the following:

(a) The Merrifield procedure.
(b) Pauly Reaction.
(c) Isoelectric point.
(d) Linus Pauling.
[4 marks]

SECTION B

7. **Describe** five methods for the determination of the primary structure of proteins.
[15 marks]

8. **Differentiate** biochemically and in detail between haemoglobin and myoglobin.
[15 marks]

9. (i) Nitrite is very effective in treating cyanide poisoning when administered immediately. **What** is the molecular basis for the action of this antidote? (Hint: Nitrite oxidizes ferrohaemoglobin to ferrohaemoglobin.)
[5 marks]

(ii) In the 1960's Peter Mitchell proposed that the oxidation of NADH by Oxygen is coupled to the phosphorylation of ADP by means of a proton motive force. **Discuss** the experiemental evidence that supports his noble prize winning hypothesis.
[10 marks]

10. (i) **Where** in the cell does that pentose phosphate pathway take place?
[2 marks]

(ii) **Briefly discuss** its purpose.
[3 marks]

(iii) If ribose 5-phosphate, uniformly labeled with radioactve carbon was incubated in suitably buffered solution containing xylulose 5-phosphate (NO ^{14}C), thiamine pyrophosphate, Mg^{++}, transketolase, **what** two new carbohydrates would be produced and **what** would be the labeling pattern of carbons in each one?
[10 marks]

12. (i) A sample of glucogen from a patient with liver disease is incubated with orthophosphate, phosphorylase, the transferase and debranching enzyme. The ratio of glucose 1-phosphate to glucose formed in this mixture is 100. **What** is the likely enzymatic deficiency in this patient? **Briefly discuss** your reasoning.
[5 marks]

(ii) In thermodynamic terms, **what** is the significance of the reactions between 1,3-bisphosphoglycerate and fructose 6-phosphate during gluconeogenesis?
[10 marks]

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

C 321

SPECTROSCOPIC ANALYSIS

ME: THREE HOURS

SWER: ANY FOUR QUESTIONS

---

a) Explain photometric titrations.

(i) What type of titration curve can you expect when $\varepsilon_r > 0$ and $\varepsilon_p = \varepsilon_t = 0$ in another example when

(ii) $\varepsilon_p > 0$ and $\varepsilon_s = \varepsilon_t = 0$

where ε_r is molar absorptivities of substance titrated, ε_p is product, and ε_t is titrant respectively.

b) Explain continuous variations method for determining numbers of ligand.

c) How can you determine pK weak acid spectrophotometricaly.

d) Molar absorptivity data for the cobalt and nickel complexes with 2-3-quinoxalinedithiol are ε_{Co} = 36,400 and ε_{Ni} = 5,520 at 510 nm and ε_{Co} = 1,240 and ε_{Ni} = 17,500 at 656 nm. A 0.850 g sample was dissolved and diluted to 50.0 ml. A 25.0 ml aliquot was treated to eliminate interferences, after addition of 2,3-quinoxalinedithiol, the volume was adjusted to 50.0 ml. This solution had an absorbance of 0.446 at 510 nm and 0.326 at 656 nm in a 1.00 cm cell.

Calculate the parts per million of cobalt and nickel in the sample. [Co = 58.9332, Ni = 58.6934].

f) A standard solution was put through appropriate dilutions to give the concentrations of iron shown below. The iron (II)/1,10-phenantroline complex was then developed in 25.0 ml aliquots of these solutions, following which each was diluted to 50.0 ml. The following absorbances were recorded at 510 nmm:

Concentration of Fe (II) in ppm	Absorbance A (in 1.00 cm cell
2.00	0.164
5.00	0.425
8.00	0.628
12.00	0.951
16.00	1.260
20.00	1.582
Unknown	1.125

(i) Produce a calibration curve from these data.

(ii) By method of least squares, derive an equation relating absorbance and concentration of iron (II).

(iii) Calculate the standard deviation of the residuals.

(iv) Calculate the standard deviation of the slope. [Fe = 54.857]

a) Explain briefly thhe differences between IR and Raman spectroscopy.

b) What type of molecular vibrations do you know? Sketch them.

c) Explain quantum treatment of vibrations.

d) Explain sample handling techniques in IR-spectroscopy.

e) Calculate the wave number and wavelength of the fundamental absorption peak due to stretching vibration of carbonyl group C = O.
[k = 1.0 x 10^3 N/m, C = 12.0 and O = 16.0]
(Calculate results in cm^{-1} and μm).

a) Explain the principle of ^1H NMR spectroscopy.

b) Compare ^1H NMR and ^{13}C NMR spectroscopy.

c) Explain chemical shifts in ^1H NMR spectroscopy.

d) Explain spin-spin sliting in ^1H NMR spectroscopy.

e) Explain protons on alcohols in ^1H NMR spectroscopy.

f) In H NMR spectrum of organic compound we found three signals, which has the frequencies in Hz from TMS: 162,535 and 942.

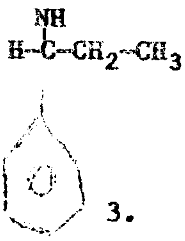
Calculate their chemical shifts, if the spectrum were measured in apparatus with υ_o = 60 MHz.

At which frequencies from TMS can we find these signals if we use apparatus with υ_o = 300 MHz.

g) Write a ^1H NMR spectrum of below compounds, their integrated derivative spectrum and their ratio respectively.

1. $Br-CH_2-CH=CH-CH_3$

2. $NH_2-CH=CH-CH_2-OH$



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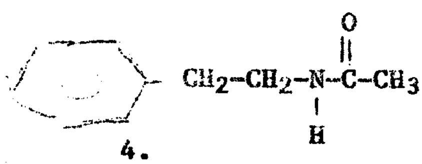


4.

a) Explain the principle of AAS method.

b) Explain Inductively Coupled Plasma (ICP) source.

c) Explain standard addition method for AAS.

d) A serum sample is analyzed for lithium by atomic emission spectroscopy using the method of standard additions. Three 0.50 ml aliquots of sample are added to 5.0 ml portions of water. To these are added 0, 10.0 and 20.0 ul of standard 0.050 M LiCl solution. The emission signals (in arbitrary units) are 23.0, 45.3 and 68.0 for the three solutions respectively.

What is the concentration of lithium in the serum sample in ppm (weight per volume)? [Li = 6.941, Cl = 35.4527]

e) A water sample containing trace amounts of zinc in analyzed using an ICP with a photomultipliar tube detector. A calibration sample containing 1.4 ppm of zinc gives a signal of 124.5 units. If the background signal is 8.2 units and the concentration equivalent of the background is 0.02 ppm.

Calculate the concentration of zinc in a sample that gives a signal response of 94.5 units. [Zn = 65.39].

f) Duplicate 0.5 g samples of finely powdered gold-bearing ore are treated in the following manner. Digest in 5 ml of hydrochloric acid, add 3 ml of nitric acid and 40 ml of hot water and allow to cool. To one sample 1 ml of a 5.0 µg/ml gold standard is added. Each sample is then treated into 5 ml of methylisobutyl ketone. If the atomic absorption calibration graph is linear what is the original gold concentration in the sample in µg/g if the two absorbance reading are 0.22 and 0.37 respectively?
[Au = 196.96654]

a) Describe the type of sources for emission spectroscopy.

b) Explain principle of emission spectroscopy.

c) Explain resolving power for optical grating and prism respectively.

d) Explain characteristic curve of photographic emulsion.

e) In the spectrographic determination of lead in an alloy, using a magnesium lines as an internal standard, the results shown in the table were obtained.

(i) Prepare a calibration on a log-log scale.

(ii) Evaluate the concentration for solutions A,B and C respectively.

	Densitometer reading		Concentration of Pb (mg/ml)
Solution	Mg	Pb	
1.	7.3	17.5	0.151
2.	8.7	18.5	0.201
3.	7.3	11.0	0.301
4.	10.0	12.0	0.402
5.	11.6	10.4	0.502
A.	8.8	15.5	
B.	9.2	12.5	
C.	10.7	12.2	

f) The sodium series of cement samples was determined by flame emission spectroscopy. The flame photometer was calibrated with a series of standards containing 0, 20.0, 60.0 and 80.0 µg Na_2O per milliliter. The instrument readings for these solutions were 3.1, 21.5, 40.9, 57.1 and 77.3.

(i) Plot the data
(ii) Derive a least-squares line for the data
(iii) The following data were obtained for replicant 1.00 g samples of cement dissolved in HCl and diluted to 100.0 ml after neutralization.

	Emission Reading sample:			
	Blank	A	B	C
Replicate 1	5.1	28.6	40.7	73.1
Replicate 2	4.8	28.2	41.2	72.1
Replicate 3	4.9	28.9	40.2	spilled

Calculate the % Na_2O in each sample.
[Na = 22.989768, O = 15.9994]

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

C 341

INORGANIC CHEMISTRY

TIME: THREE HOURS

INSTRUCTIONS:

1. THIS EXAMINATION HAS SIX (6) QUESTIONS.
2. ANSWER ANY FOFUR (4) QUESTIONS.
3. A TIDY AND ORDERLY PRESENTATION IS A MUST.

Q1. (a) Define the Racah Parameter.

(b) An aqueous solution of divalent nickel state are light green in colour which are traced to the presence of weak bands in the red and the blue portions of the visible spectrum. These bands are

Cm	ε
8700	1.6
14500	2.0
25300	4.6

(i) Determine Δ_o and B for the complex.

(ii) Given that B_o for Ni^{2+} is 1030 cm^{-1} .Comment on the implications of the calculated B for the complex.

Q2. (a) Discuss, by using suitable examples, two methods that are commonly employed for the preparation of transition metal complexes.

(b) Account for the following:

(i) Cu^{2+} complexes are coloured where as Zn^{2+} complexes are colourless.

(ii) $[Fe(CN)_6]^{3-}$ is an inner orbital complex where as $[FeF_6]^{3-}$ is an outer orbital complex. [Atomic No: Fe = 26; Cu = 29; Zn = 30]

(c) Name the following coordination compounds.

(i) $[Co\ SO_4(NH_3)_4]\ NO_3$

(ii) $Na_2[ZnCl_4]$

(iii) $[Cr\ (en)_2\ (NH_3)\ Cl]\ SO_4$

(iv) $[(NH_3)_5\ Co.NH_2.CO(NH_3)_5]^{3+}$

(d) Draw a labelled molecular energy level diagram for the octahedral complex $[Co(NH_3)_6]^{3+}$. Determine bond order also.
[Atomic No: Co = 27]

Q3. (a) Coordination complexes exhibit many types of isomerism. Explain briefly three different types of isomerism that are shown by transition metal complexes.

(b) Determine the crystal field stabilization energy for a d^6 complex having Δ_o = 25000 cm^{-1} and pairing energy, P = 15000 cm^{-1}.

(c) Sketch all possible isomers for the following complexes.

(i) $[Rh\ Cl_3\ (py)_3]$ py = Pyridine

(ii) $[Co\ (NH_3)_4\ (NO_2)_2]\ X$ X = Halide ion

(d) A complex of a certain metal ion has a magnetic moment of 4.90 BM; another complex of the same metal ion in the same oxidation state has a zero magnetic moment. Identify the central metal ion from the following.

Cr^{2+}, Co^{2+}, Co^{3+}, Ni^{2+}

[Atomic No: Cr = 24; Co = 27; Ni = 28]

4. (a) Describe the laboratory method for the preparation of hydrogen peroxide. How does it react with

(i) Chromic hydroxide in presence of caustic soda.

(ii) Sodium hypochlorite

(iii) Lead dioxide

(iv) Formaldehyde

(b) Write the structures of the following species.

$(P_3O_{10})^{5-}$; $H_2S_2O_7$; N_2O_5; IF_7

(c) Write balanced chemical reactions between silica and

(i) XeF_6

(ii) XeO_2F_2

(iii) Na_2CO_3

5. (a) Write balanced chemical reactions, when

(i) Potassium ferrocyanide is heated with conc. sulphuric acid in aqueous medium.

(ii) A mixture of sodium nitrite and sodium iodide is heated with conc. sulphuric acid.

(iii) Calcium phosphate is reduced with silica and charcoal.

(iv) Hydroiodic acid reacts with sulphur dioxide gas in aqueous medium.

(v) Xenon tetrafluoride reacts with boron trichloride.

(b) Give a brief account on 'INTERHALOGEN COMPOUNDS'.

(c) How would you obtain,

(i) Antimony pentasulphide from antimony pentachloride.

(ii) Colloidal sulphur from hydrogen sulphide.

(iii) Carborundum from silica.

(iv) Sodium arsenat from arsenic pentasulphide.

. (a) Give three methods for the preparation of phosphine gas. Write balanced chemical reactions, when it reacts with

(i) Aqueous silver chloride
(ii) Oxygen
(iii) Chlorine

(b) Write four commercial uses of each of the following

(i) Phosphates
(ii) Sulphuric acid

(c) Complete and balance the following reactions.

(i) $COCl_2 + NH_3 \text{ -----> }$

(ii) $PCl_3 + CH_3OH \text{ -----> }$

(iii) $Cl_2O_7 + I_2 \text{ -------> }$

(iv) $Ba(ClO)_2 + H_2SO_4 \text{ ------> }$

(v) $Cl_2 + F_2 \text{ (excess) } \xrightarrow{280^oC}$

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
University Examinations

C361 Physical Chemistry
Semester 1 Final Examination March 2, 1998

Useful Information: $R = 8.314\ J\ mol^{-1}\ K^{-1}$
$N_A = 6.02 \times 10^{23}$
Atomic masses: Cs 133
Ar 40

Instructions: Answer any four questions
Time 3 hours

---

1. (a) Briefly define the following terms and explain how each of them may be determined experimentally.

(i) Boyle temperature.
(ii) Ideal gas temperature.
(iii) Critical volume.
(iv) Compressibility factor, Z, of Van der Waals gas.
(v) Mean free path, λ.

(b) In an experiment of metal vapour pressure determination, 385 mg of Cesium, Cs, was lost in a period of 100 s through a hole of diameter 0.5 mm in a wall of container. The determination was carried out at a temperature of 500 °C. Calculate the vapour pressure of cesium.

2. (a) Given that methane gas obeys the following equation of state for 1 mole

$$PV = RT + BP + CP^2$$

(i) Derive an equation for the reversible work of an isothermal expansion of the gas in terms of pressure, P. B and C are constants.

(ii) For the gas initially at a pressure of 10 atmospheres and temperature of 200 K expanded to a final pressure of 5 atmospheres, calculate the work done by the gas. At 200 K, $C = 6.86 \times 10^{-6}$.

(b) Use the Maxwell distribution equation to derive the most probable velocity C^*, and use it to calculate the most probable velocity of argon gas at 200 °C.

3. (a) The Carnot cycle is a sequence of events which was used a great deal in classical thermodynamics and still plays a central role in the discussion of efficiency of heat engines and refrigerators. Show the sequence of isotherms and adiabats in a Carnot cycle using a clearly labelled P-V indicator diagram.

(b) Using the information from (a) above show that the efficiency of the heat engine is given by

$$\varepsilon = \frac{q_2 + q_1}{q_2}$$

4. (a) Derive an expression for the variation of the equilibrium constant with temperature. What is the behaviour of the equilibrium constant with temperature if the reaction is (i) endothermic and (ii) exothermic.

(b) Sulphur exist as S_2 vapour at temperatures between 700 °C and 1500 °C. At 1200 °C it combines with hydrogen according to the equation

$$H_2(g) + \frac{1}{2}S(g) \rightarrow H_2S(g)$$

At 750 °C the equilibrium constant is 1.07×10^2 and at 1200 °C it is 4.39. Determine the heat of reaction in the temperature range 750 °C to 1200 °C, and the change in the free energy at each of these temperatures.

5. (a) Draw a labelled phase diagram for a pure substance Q which has the following properties: (i) normal boiling point at 220 °C, normal freezing point at 80 °C, and a triple point at 60 °C and 2 atm?

(b) (i) What are colligative properties? Show how the freezing point depression can be used to determine the molecular weight of a compound.

(ii) A vehicle has a 100 litres cooling system. Suppose it was filled with a 50-50 solution by volume of ethylene glycol ($(CH_2OH)_2$) and water. At what temperature would freezing become a problem? Assume the density of ethylene glycol and water to be 1.115 g cm^{-3} and 1.000 g cm^{-3} respectively. The freezing point depression constant for water is 1.86 ° C mol^{-1}.

6. (a) Define briefly the hydration number of an ion.

(b) The following data is given for the radius of Na^+ in crystals and in aqueous solution.

Ionic species	Ionic radius / nm	Radius in aqueous solution / nm
Na^+	0.095	0.24
K^+	0.133	0.17

Explain why the radius of Na^+ is larger than that of K^+ in aqueous solution.

(c) (i) Define briefly the transport number and mobility of an ion.

(ii) Explain why H^+ and OH^- have unusually high transport numbers.

—— End of Examination ——

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

C 411

TIME: 3 HOURS

SECTION A: SHORT ANSWER QUESTIONS

INSTRUCTIONS: ANSWER ALL QUESTIONS

TIME ALLOWED: FORTY MINUTES

1. Classify hormones (a) on the basis of the distance over which they act and (b) on the bases of their chemical origins. (6 pts)

2. Identify the following

   (a) Transcription Attenuation
   (b) Partition Coeficient
   (c) Osmotic Pressure
   (d) Donnan equilibrium
   (e) Heterotropic allosteric enzymes (5 pts)

3. Using diagrams only, identify the four types of rings found in prostaglandins. (4 pts)

4. Calculate

   (a) the number of radioactive atoms and

   (b) the weight in grams of phosphorus in 1 ci of pure phosphorus

   (c) calculate the specific activity of pure ^{32}P. The half life of ^{32}P is 14.3 days.

   (5 pts)

C 411

SECTION B: ESSAY QUESTIONS

INSTRUCTIONS: ANSWER ANY FOUR QUESTIONS

TIME ALLOWED: TWO HOURS TWENTY MINUTES (2 HRS 20 MIN).

All Questions Carry Equal Marks

With the aid of a diagram, describe the biosynthesis of steroid hormones. Name all the sex hormones and their functions. Explain why the female human is physiologically superior to the male human.

Using a table, show the protein-lipid ratios in the different membranes you have studied. How many kinds of protein are associated with membranes? Name them. Describe in detail the various types of membrane architecture you have studied.

How are (1) the metabolism of carbohydrates and (2) the activities of Gluthamine synthetase, controlled?

Discuss in detail the contraction of muscles at the molecular level.

(a) Describe the principles that underlie the separation of polypeptide by electrophoresis on SDS-polyamylamide gel.

(b) An enzyme was purified to homogeneity, reduced, and denatured and then subjected to gel electrophoresis on 20% SDS-polyacrylamide gel. The run was terminated when the marker dye had moved 10 cm into the gel. On staining for protein, three bands were observed. The three had approximately equal intensities, and had moved 4.3 cm, 4.6 cm and 7.3 cm into the gel. Four protein calibration markers of M_r 68 000, 45 000, 25 000 and 12 000 moved 2.0 cm, 3.7 cm, 6.3 cm and 9.5 cm into the gel respectively. What may be deduced about the subunit structure of the enzyme from this experiment?

END OF EXAMINATION

UNIVERSITY EXAMINATIONS - MARCH 1998
C 421

ADVANCED ANALYTICAL CHEMISTRY

TIME: 4 HOURS

ANSWER ANY 4 QUESTIONS OUT OF 6 QUESTIONS IN THIS PAPER

Question 1

(a) 0.2g of copper ore is anlysed iodometrically. Cu(11) was reduced to Cu(1) by iodide. $2Cu^{2+} + 4I^{-}$ -------------> $2CuI + I_2$
What is the %Cu in the ore if 20ml of 0.2M $Na_2S_2O_3$ is used for titrating liberated iodine. $I_2 + 2S_2O_3^{2-}$ ---------------> $2I^{-} + S_4O_6^{2-}$ (4)

(b) Describe how to determine "Base saturation" and "Exchangeable acidity" in soils.(4)

(c) Describe in detail the analysis of 2 nitrogenous compounds in soils. (3)

(d) How would you determine organic C as well as "alkalinilty of ash" in soils.(4)

Question 2.

(a) What weight of pyrite (impure FeS_2) must be used in analysis so that $BaSO_4$ precipitate formed will be equal to half that of the %S in the sample.(3)

(b) Describe 2 procedures used to prepare rock samples for analysis using the determination of Cd as an example. (4)

(c) Explain the main steps in atomization of an analyte using electrothermal furnace including the physical and chemical processes that occur in each step. (4)

(d) Desribe any 3 schemes used in the analysis of silicate rocks. (4)

Question 3

(a) A soda ash sample is analysed by titration with standard HCl. The analysis is done in triplicate with the following results: 93.50, 93.58 and 93.43% Na_2CO_3. Within what range are you 95% confident that the true value lies? ($t = 4.303$). (3)

(b) Describe in detail the analysis of Zn and Fe in Brass. (4)

(c) How would you determine B and silica in Glass. (4)

(b) A monitoring exercise is planned for Pb deposited on soil close to a busy roadway. How do you select sampling positions and how do you determine Pb in such samples? (3)

(c) Which techniques would you use for the following analyses:
(I) NO_2 in the external atmosphere at several locations
(ii) An organic solvent in a lab atmosphere
(iii) CO to protect a worker in an area where there may be rapid increases in concentration. (4)

(d) Compare the routes by which high molecular mass organic compounds and toxic metals may disperse and reconcentrate in the environment and in organisms. (4)

(USE: Ba = 137.3 , Cu = 63.5, I = 126.9,S = 32.1, Fe = 55.8, Al = 27.0,O = 16, Cl = 35.5)

THE UNIVERSITY OF ZAMBIA
UNIVERSITY FIRST SEMESTER EXAMINATIONS
FEBRUARY/MARCH 1998

C441

ADVANCED INORGANIC CHEMISTRY

TIME: THREE HOURS

INSTRUCTIONS:

(i) ATTEMPT ANY FOUR (4) QUESTIONS.

(ii) CLEARLY INDICATE WHICH QUESTIONS YOU HAVE ATTEMPTED ON THE FRONT ANSWER BOOKLET.

---

1. (a) The ν(C-N) stretching frequency is a distinctly strong and characteristic infrared band found in the region 2100 - 2030 cm^{-1} and can be used to distinguish complexes of the type $Mn(OPPh_3)_4(SCN)_2$. The complex $Mn(OPPh_3)_4(SCN)_2$ is known to be bonded to its thiocyanate group, SCN^-, in a *cis*-fashion.

    (i) What is the point group to which the complex belongs?

    (ii) What symmetry operations are found in the complex?

    (iii) By using the method of internal coordinates and by taking the C-N stretching frequency as the basis set, determine $\Gamma_{C\text{-}N\ stretch}$, and discuss the nature and type of the ν(C-N) observed.

    (b) Discuss the π (⊥) bonding scheme expected in ICl_4^- and predict which atomic orbitals on I are available for π (⊥) bonding.

2. Consider the organometallic compound $(C_4H_6)Fe(CO)_3$. By ignoring the actual coefficients on the wavefunctions of the 1,3-butadiene and by regarding them simply as unit:-

    (i) Determine the molecular orbital wavefunctions ψ_1, ψ_2, ψ_3 and ψ_4 where $\psi_1 < \psi_2 < \psi_3 < \psi_4$ in energy

    (ii) Draw the shapes of the frontier orbitals on 1,3-butadiene and calculate their approximate energies in terms of α and β units.

    (iii) Discuss which appropriate orbitals on Fe will bond to each of the ψ_1, ψ_2, ψ_3 and ψ_4 molecular orbitals and the type of bonding (σ, π, δ, etc.) resulting from the interaction. What effects does each bonding type have on each of the four carbons in 1,3-butadiene?

3. NO_3^- ion has the following bands:

Infrared: 1350, 830 and 680 cm^{-1}

Raman: 1355, 1049 and 690 cm^{-1}

Given that the bands can be assigned as ν_1, ν_2, ν_3 and ν_4

(i) How many fundamental modes of vibration are expected in the molecule?

(ii) Account why the actual number of bands can only be assigned as ν_1 to ν_4.

(iii) Explain which N-O vibration frequency ν_1 or ν_2 or ν_3 or ν_4 is missing in the infrared spectrum. Why?

(iv) Which Raman frequency is also missing?

(v) Correlate the above bands to the ν_n system.

4. (a) For the C_6H_6 group, draw an energy level diagram in β units and show the shapes of the SALCs on benzene.

(b) Compare the energy obtained in (a) to that expected from a Kekule' benzene structure. What conclusions can be drawn?

5. (a) Which of the following molecules can have infrared spectrum?

NH_3, HCl, H_2, CO_2, O_2

Explain your answer.

(b) What must occur for a molecular vibration to be Raman active?

(c) State the rule of mutual exclusion and give an example of a <u>molecule</u> in which this rule is applicable.

6. (a) How can one separate the following mixture of compounds?

(i) $SiMe_4$ and $Me_3SiOSiMe_3$.

($SiMe_3$, b. p. = 68.2 °C; $Me_3SiOSiMe_3$, b. p. = 101 °C)

(ii) $NbOCl_3$ and $NbCl_5$.

(Both compounds are solids)

(b) The reaction of PCl_3 with $[IrCl(CO)(PEt_3)_2]$ gives a compound of the composition $[Ir(PCl_3)Cl(CO)(PEt_3)_2]$. Discuss which spectroscopic techniques are required to elucidate the structure of the compound

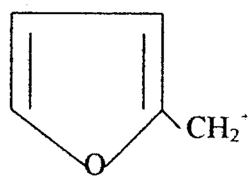
(c) Consider a hypothetical inorganic compound A-B-C-D.

(i) Give the sequence of processes that may occur when ABCD is bombarded with an electron.

(ii) What array of ions will be separated and recorded on the mass spectrum?

(d) (i) Sulphur-carbon π bonding is not as effective as nitrogen-carbon π bonding. In the mass spectrum of $HSCH_2CH_2NH_2$, would the m/z = 30 or m/z = 47 peak be more intense? Explain.

(ii) The intensity of the peak for the fragment,



is much greater than would normally be expected. Explain the above observation.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

C 451

ORGANIC CHEMISTRY

SECTION A

IME: 1.5 HOURS

NSTRUCTIONS: ANSWER ANY TWO (2) QUESTIONS IN SEPARATE ANSWER BOOKS.

. (a) Draw the structure of the bridged intermediate expected if each of the following were to act as a neighbouring group

(i) - $C_6H_4OCH_3$-P

(ii) - CH=CHR

(iii) - $\bar{O}$

(iv) -OH

(v) - $N(CH_3)_2$

(b) Identify the lettered products of the following chemical transformations.

(See accompanying sheets for diagrams)

(c) Upon reaction with bromine water, allyl bromide gives directly the primary alcohol $CH_2BR-CHBr-CH_2OH$. When allylbromide ^{82}Br undergoes this reaction, the following products were obtained

$$\underset{\underset{^{82}Br}{|}}{CH_2}-CH{=}{=}CH_2 \xrightarrow{Br_2,\,H_2O} \underset{\underset{^{82}Br}{|}}{CH}-\underset{\underset{Br}{|}}{CH}-\underset{\underset{Br}{|}}{CH_2} \quad +$$

(55%)

(24%) (21%)

(i) How do you account for the formation of the 24% product with ^{82}Br attached to C-2?

(ii) When similarly labelled allyl chloride is used there is obtained only 4% of the product with the label attached to C-2. How do you account for this difference the chloride and bromide?

2. (a) Give a plausible mechanism involved in the following reactions.

(See accompanying sheets for diagrams)

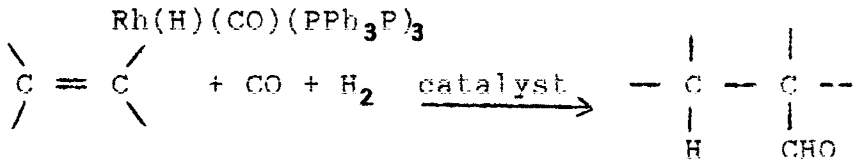
(b) Comment on the results below for the reaction of an alkene with methylene and provide a most plausible explanation of the observed trend.

(See accompanying sheets for diagrams)

(c) Discuss (not more than 2 pages) the enantioselectivity trends in olefin hydrogenation reactions. Which factors are critical for enhancing this character in organic reactions. Illustrate your answer with relevant equations.

3. (a) From the reaction of erythro-2-bromo-3-butanol with hydrogen bromide is obtained the product meso-2,3-dibromobutane. Suggest in considerable mechanistic detail as to how the product may be realised. Is there an intermediate involved in your proposal mechanism? If the answer is yes, is it ionic dissymmetric or noionic dissymetric or ionic non-dissymmetric or nonionic non-dissymmetric? Explain.

(b) Describe in as much mechanistic details possible the "Oxo" reaction involving an alkene, carbon monoxide and hydrogen to yield aldehydes using the catalyst.



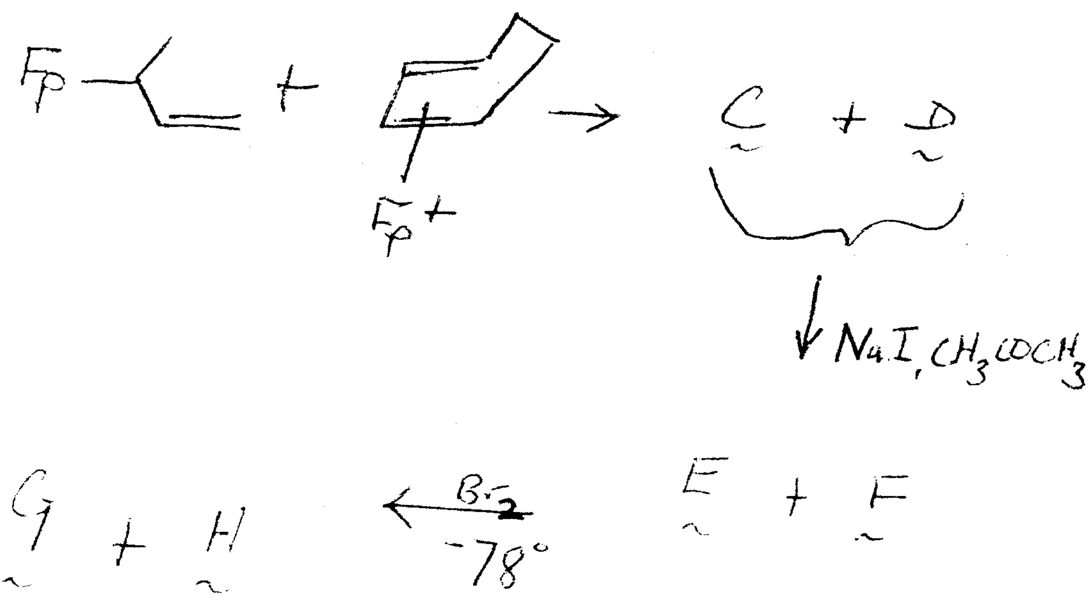
Is there any evidence of symphoric effects in the suggested mechanism? Explain.

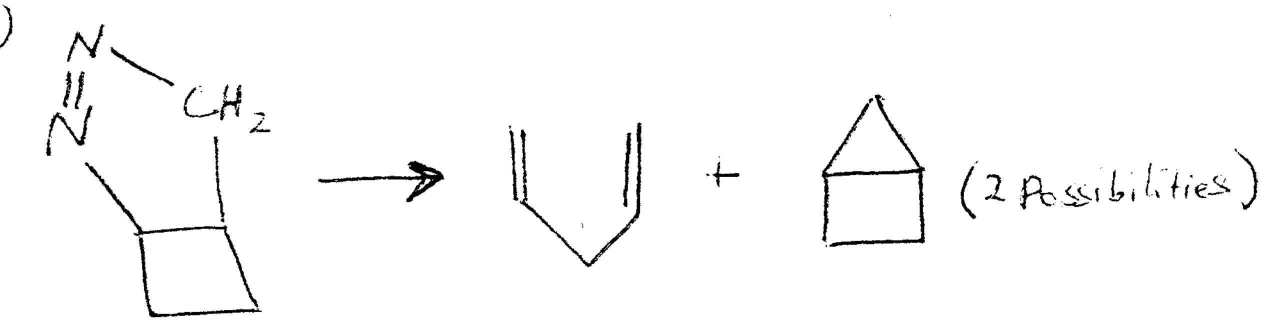
(c) Identify all steps involving

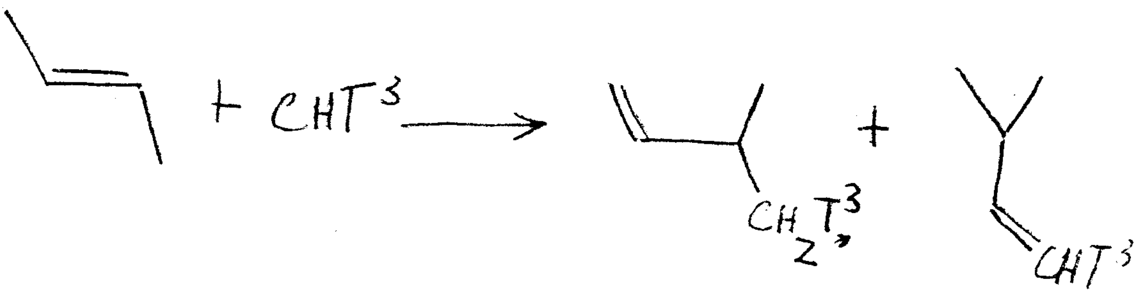
- (i) oxidative addition
- (ii) reductive elimination
- (iii) ligand association
- (iv) insertion
- (v) changes in oxidation state of the metal
- (vi) coordinatively saturated and unsaturated species

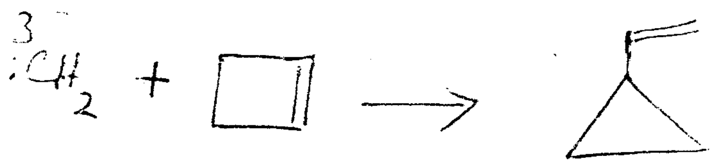
1

b)

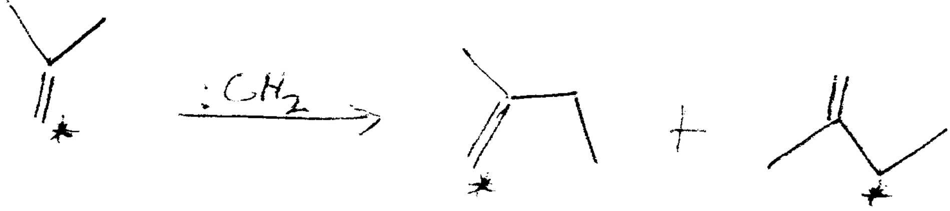



N
N
CH2
+
(2 Possibilities)

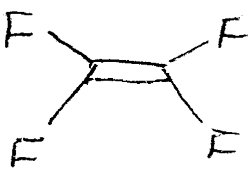
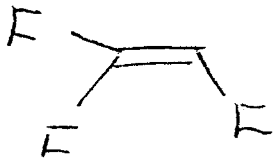
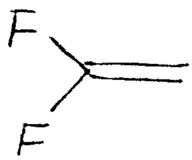
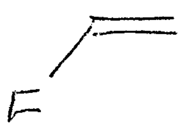

+ CHT3
+
CH2T3
CHT3


3
:CH2
+


+
3
:CH2
+ ((CH3)2CH)2


:CH2
+

b)

Alkene	Relative Reactivity towards Methylene
	0.10
	0.16
	0.33
	0.60
	1.0

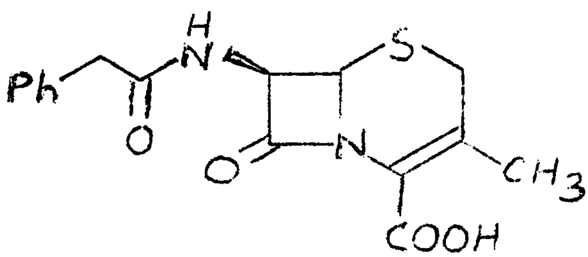
SECTION B

IME: ONE AND A HALF HOURS ($1\frac{1}{2}$ HRS).

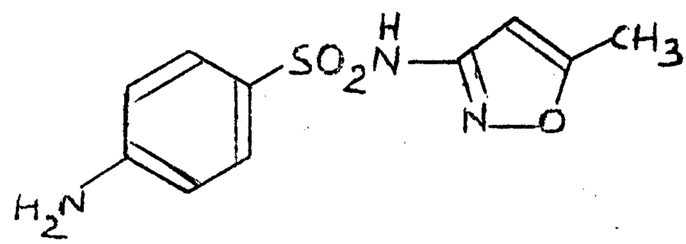
NSTRUCTIONS:

. ANSWER ANY TWO QUESTIONS.
. ANSWER THIS SECTION IN A SEPARATE ANSWER BOOK.

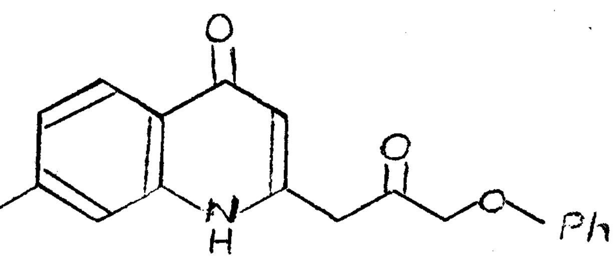
. (a) Identify the pharmacophore in the following anti-bacterial agents, A - D.



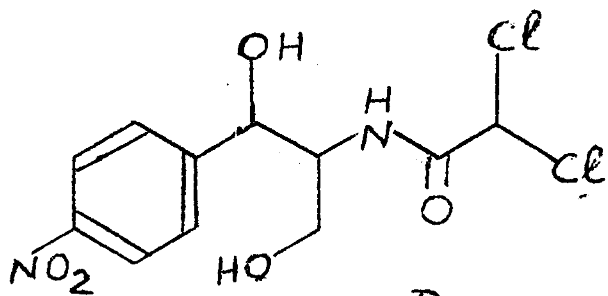
A



B



C

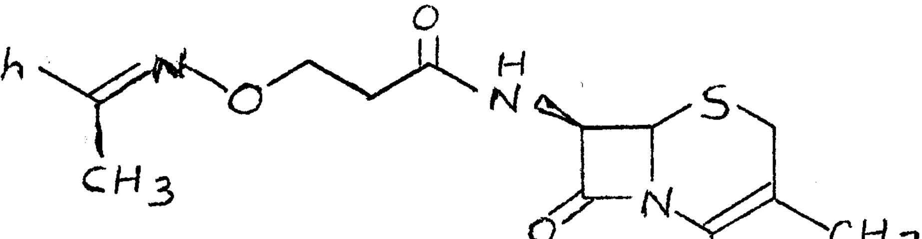


D

(b) Briefly explain how compound D, structure shown above, is inactivated by many Gram positive cocci.

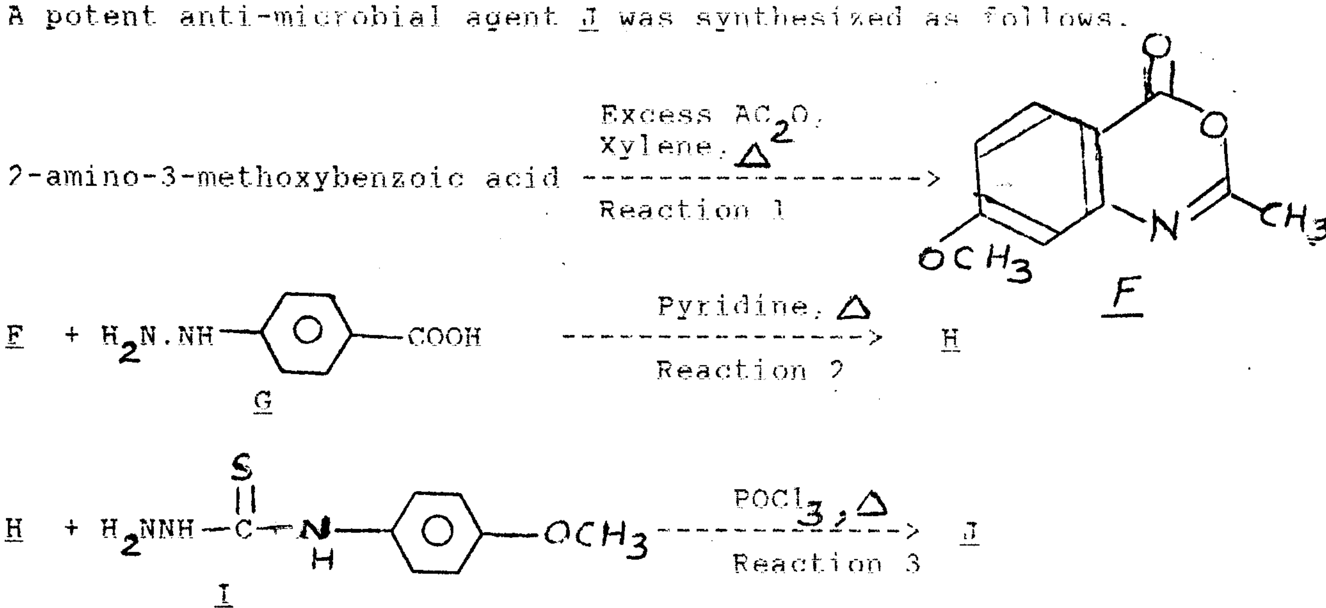
(7 marks)

(c) A molecule E, structure shown below, was designed to improve the anti-bacterial potency of compound A, shown in question 1 (a). Suggest a plausible sequence of reactions by which compound A can be transformed into compound E. State the reagents needed and special reaction conditions, if any, for each step. (12 marks)



E

A potent anti-microbial agent J was synthesized as follows.



(i) Identify compounds H and J in the above synthesis. (5 marks)

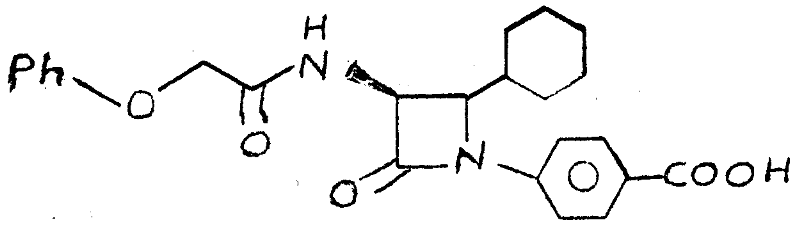
(ii) Give the mechanisms of the reactions 1 and 3. (9 marks)

(iii) Suggest the most likely mode of anti-bacterial action of compound J. (8 marks)

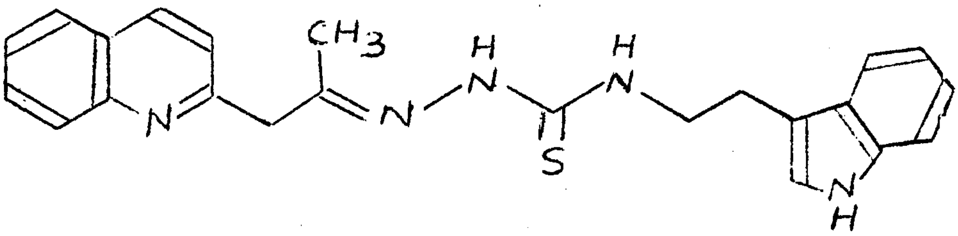
(iv) How would you prepare compound G used in the above synthesis from a mono-functionalized benzene. (3 marks)

. Propose a stepwise synthesis of TWO of the following biologically active compounds from readily available non-heterocyclic starting materials. Show the logic of your proposal.

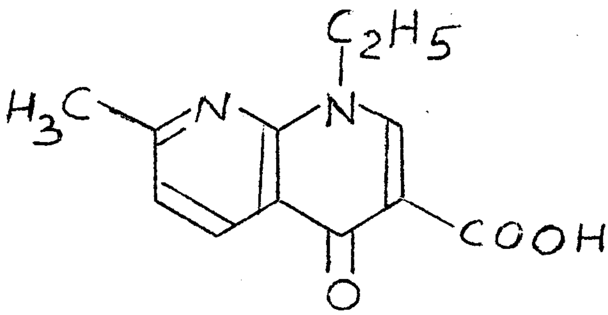
(i)



(ii)



(iii)



(25 marks)

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

CAV 251

ANALYTICAL/PHYSICAL/ORGANIC CHEMISTRY

TIME: THREE HOURS

INSTRUCTIONS

1. THERE ARE SEVEN QUESTIONS IN THIS EXAMINATION.
2. ANSWER QUESTION ONE AND ANY OTHER FOUR QUESTIONS.
3. QUESTION ONE CARRIES 20 MARKS AND 10 MARKS ARE ALLOCATED TO EACH OF THE OTHER QUESTIONS.
4. SHOW ALL YOUR WORKING FOR THOSE QUESTIONS INVOLVING CALCULATION.

Important Data Page

Universal Gas Constant, R = 0.02051 atm/mol K
R = 8.314 J/mol K

Values of F at the 95% Confidence Level.

	V_1 =	2	3	4	5	6
V_2 =	2	19.0	19.2	19.2	19.3	19.3
	3	9.55	9.28	9.12	9.01	8.94
	4	6.94	6.59	6.39	6.26	6.16
	5	5.79	5.41	5.19	5.05	4.95
	6	5.14	4.76	4.53	4.39	4.28

Values of t for V Degrees of Freedom for various Confidence Levels.

Degrees of Freedom (n - 1) V	Confidence Level 90%	95%	99%	99.5%
1	6.314	12.706	63.657	127.32
2	2.920	4.303	9.925	14.089
3	2.353	3.182	5.841	7.453
4	2.132	2.776	4.604	5.598
5	2.015	2.571	4.032	4.773
6	1.943	2.447	3.707	4.317
7	1.895	2.365	3.500	4.029
8	1.860	2.306	3.355	3.832
9	1.833	2.262	3.250	3.690
10	1.812	2.228	3.169	3.581

(a) Explain briefly how you would analyse a maize sample from a car load of ten 90 kg bags of maize.

(b) A new method of determining oxyphen butazone gave 99.53% recovery (variance 0.185). The standard method gave 99.35% recovery (variance 0.152). In each case three replicate measurements were made. Test whether the two means differ significantly at 95% confidence level.

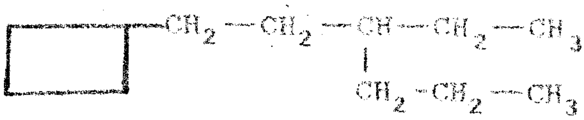
(c) Calculate the $[OH^-]$, the percent reaction and pH of a 0.050M solution of sodium acetate K_a for acetic acid = 1.75×10^{-5}.

(d) Define the rate determining step of a reaction mechanism.

(e) One mole of an ideal gas at 25°C is compressed adiabatically so that the temperature rises to 55°C. Calculate the ΔE, q, W and ΔH for the process. C_v for the gas is 1.5R.

(f) Give the IUPAC names of the following organic compounds.

(i)



(ii) $CH_3-CH{=}CH-CH(CH_3)_2$

(iii)

(g) Give explanations as to why dl-pairs and meso compounds are optically inactive.

(h) (i) Define pI (or IpH).
(ii) For an amino acid with pKa values 2.6 and 9.8, estimate its pI value.

(a) Distinguish between dry-ashing and wet-ashing.

(b) Explain the difference between accuracy and precision.

(c) A commercial farmer purchased a track load of stockfeed from the manufacturers. The analysis certificate made out while the track was being loaded showed 46.70% protein with a standard deviation of 0.07% for five (5) measurements. When the stockfeed arrived at the farm, it was analysed with the following results, % protein: 45.58, 45.61, 45.69 and 45.64. Should the farmer accept the stockfeed?

. (a) Calculate the pH and pOH of 0.14M $Ba(OH)_2$ solution.

(b) An acetic acid-sodium acetate buffer of pH 5.00 is 0.100M in sodium acetate, NaOAc. Calculate the pH after the addition of 10 ml of 0.100M NaOH to 100 ml of the buffer.

K_a for acetic acid = 1.76×10^{-5}.

(c) A 25.0 ml protein of 0.050M Na_2CrO_4 solution is mixed with 25.0 ml of 0.120M $AgNO_3$ solution. Calculate the molar solubility of Ag_2CrO_4 in the solution.

K_{sp} for Ag_2CrO_4 = 1.9×10^{-12}.

. (a) Derive the rate of formation (rate law) of CH_4 from the mechanism below.

$CH_3CHO \xrightarrow{K_1} CH_3 + CHO$

$CH_3 + CH_3CHO \xrightarrow{K_2} CH_4 + CH_3CO$

$CH_3CO \xrightarrow{K_3} CH_3 + CO$

$2CH_3 \xrightarrow{K_4} C_2H_6$

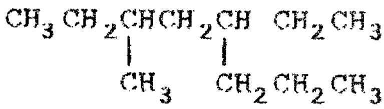
(b) Ammonia plays a major role in the production of nitrogenous fertilizers used in the farming industry. The free energy of formation of ammonia, ΔG (298K) is -16.5 kJ/mol.

(i) Calculate the equilibrium constant for the industrial important reaction of the formation of ammonia from its elements at 298K.

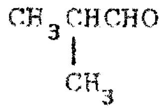
$\frac{1}{2} N_{2(g)} + 3/2\ H_2 \rightleftharpoons NH_{3(g)}$

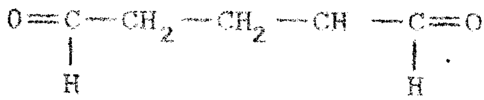
(ii) Given that the enthalpy of formation of ammonia at 298K is -46.1 kJ/mole. Compute the equilibrium constant at 400°C.

(a) Draw out the structural formula and give the IUPAC name of



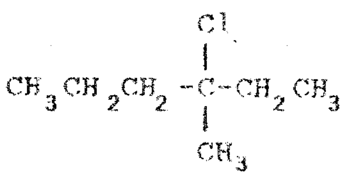
(b) Give the structure and name of the alkene that yields on ozonolysis:-

(i)  and CH_3CHO

(ii) only 

(c) (i) Discuss the mechanisms by which alkyl halides undergo nucleophilic substitution reactions.

(ii) With reference to the above mechanisms predict the product(s) of the reaction of compound (A) and of compound (B) with hydroxide ion (OH^-).



(A)

CH_3CH_2Cl

(B)

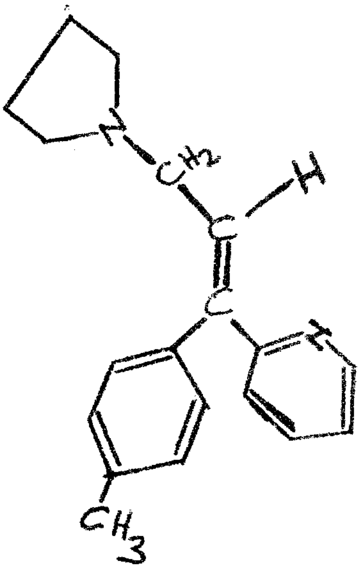
(a) Distinguish between stereoisomerism and optical isomerism.

(b) Draw Fischer projections of

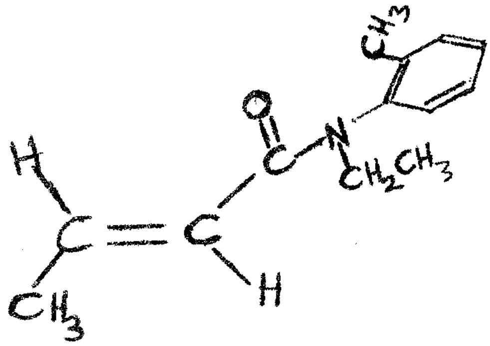
HOOC—CH(OH)—CH(OH)—COOH to illustrate.

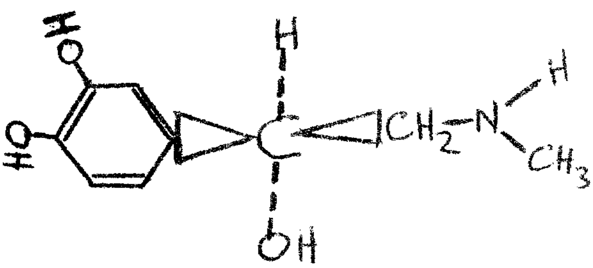
(i) a pair of enantiomers
(ii) a pair of diastereoisomers
(iii) a meso compound.

(c) Designate the following structures as either R/S or E/Z.

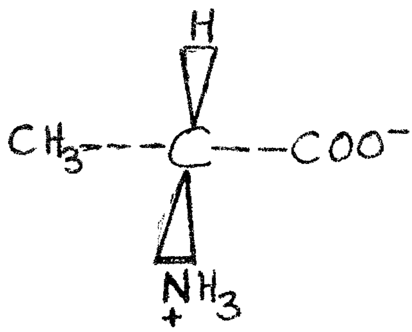


(ii)



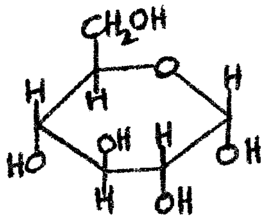


(iv)



7. (a) State and describe two functions of carbohydrates.

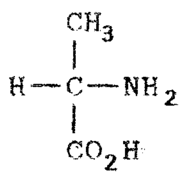
(b) The structure given below is that of α-D-glucose.



Draw the structures of:-

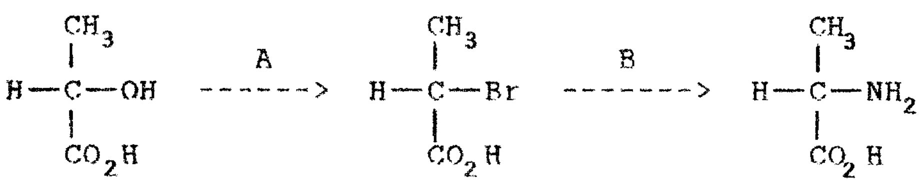
(i) β-D-glucose
(ii) α-L-glucose

(c) 2-aminopropanoic acid is an amino acid. It has the following formula



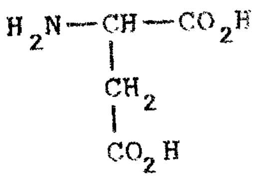
Amino acids are soluble in water since they exist as zwitterions and also form hydrogen bonds with water molecules. Draw the zwitterionic form of 2-aminopropanoic acid.

(d) The scheme below shows a suggested reaction scheme for the synthesis of 2-aminopropanoic acid from 2-hydroxy propanoic acid.

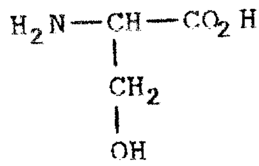


Suggest the reagents and conditions needed to carry out the two steps A and B.

(e) Two amino acids, aspartic acid and serine are:



Aspartic acid



Serine.

Draw the structural formula of a dipeptide formed from these two amino acids, showing the ionic form in which it would exist at pH 12.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

GEO 111

INTRODUCTION TO HUMAN GEOGRAPHY I

TIME ALLOWED: 3 (THREE) HOURS

ANSWER: QUESTION 1 (40%) AND ANY OTHER 3 (60%)

NOTE: ILLUSTRATE YOUR ANSWERS WHEREVER POSSIBLE
USE OF A SCIENTIFIC CALCULATOR IS ALLOWED

===

Q1 Using the map in Figure 1 determine the settlement pattern pertaining in the Copperbelt Province of Zambia covering 31,328 square kilometres.

Q2. Write short explanatory notes on each of the following:

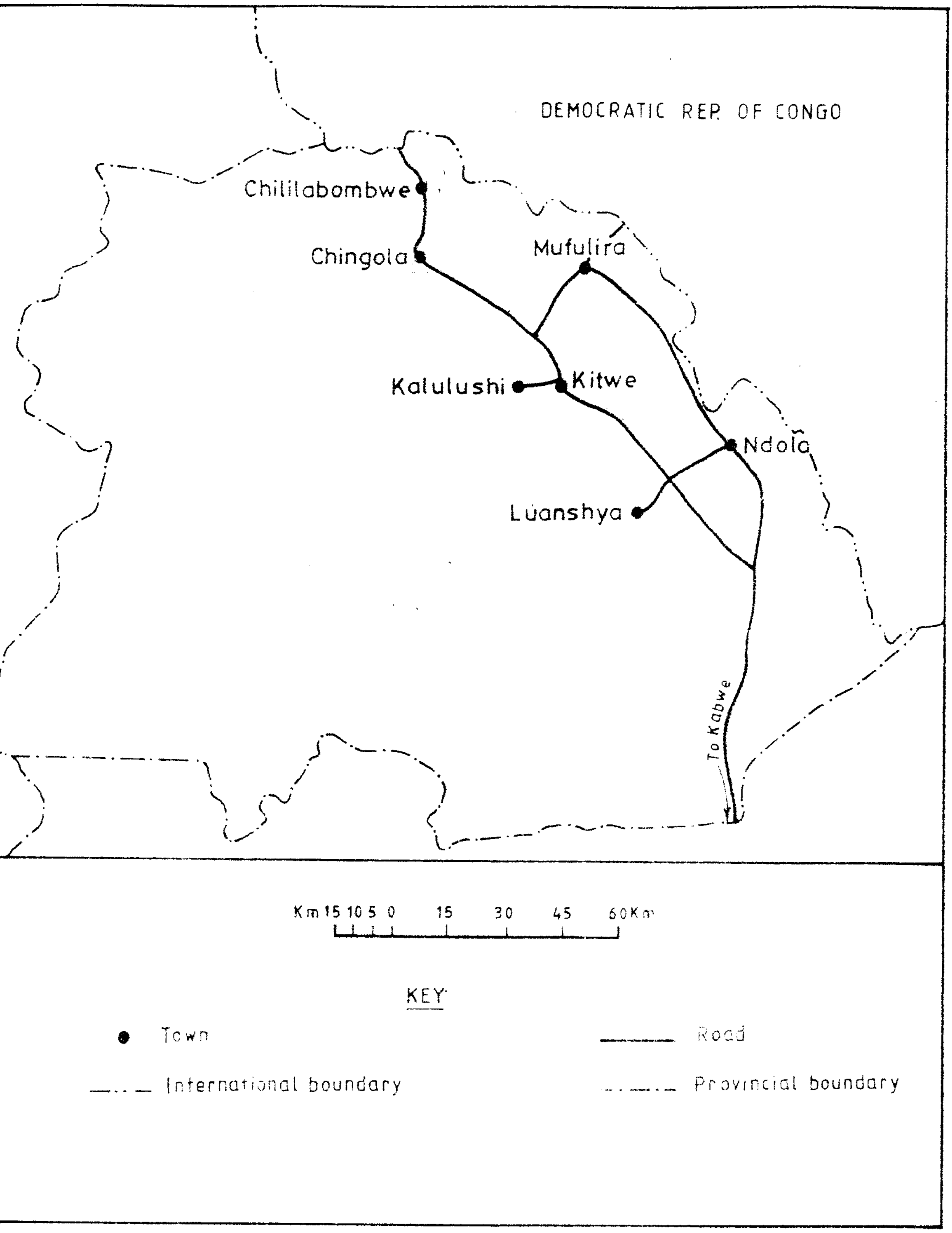
a) The Crop Theory and Intensity Theory
b) Barriers affecting diffusion
c) Least Transport Cost Location
d) The Rank Size Rule.
e) Situation in settlement Geography

Q3. Discuss the applicability of Hagerstrand's diffusion model with reference to Zambia.

Q4. Account for Zambia's high rate of urbanisation compared to other countries in Sub-saharan Africa.

Q5. Explain how the Regional Approach differs from the other two approaches found in the development of Human Geography.

Q6. 'Christaller's Central Place theory is too hypothetical to be of any relevance to the Zambian situation': Discuss.



g. 1. Copperbelt Province

UNIVERSITY FIRST AND SECOND SEMESTER
EXAMINATIONS NOV/DEC 1997

GEO 112

INTRODUCTION TO HUMAN GEOGRAPHY II

(DISTANCE EDUCATION)

TIME ALLOWED: THREE HOURS

ANSWER: FOUR QUESTIONS. ALL QUESTIONS CARRY EQUAL MARKS

NOTE: **Use of an approved atlas is allowed. Candidates are encouraged to use Maps and Diagrams wherever appropriate**

Q1. Show the relationship between the use of Natural Resources and Culture and comment on how this relationship was manifested in Africa during the pre-colonial period.

Q2. With the use of examples explain why it is important to study land tenure in Africa; and suggest ways of reforming traditional tenure.

Q3. Describe the Evolution of Industrial procedures in England in the 18th century.

Q4. How can the diffusion of the Industrial Revolution be further promoted in the developing countries of Africa?

Q5. 'Rostow's model of Economic Growth is still relevant to the developing countries of Africa in the 1990s and beyond'. Discuss.

Q6. Outline the components of culture according to Julian Huxley's Model, with particular reference to the role of technology in human subsistence.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

GEO 211

THE GEOGRAPHY OF AFRICA

TIME: THREE HOURS

ANSWER: ANY FOUR QUESTIONS

THE USE OF AN APPROVED ATLAS IS ALLOWED

Q1. 'Racial and Linguistic diversity in Africa can be a basis for unity in diversity.' Discuss.

Q2. Outline and discuss the ecological benefits of forests and woodlands on the African continent.

Q3. With the use of examples, suggest ways in which Africa's natural resource potential can be a basis for sustainable development.

Q4. Outline and explain the advantages of the tourist industry to the economy of Kenya.

Q5. Show how socio-economic development in Ghana has had a regional bias. Illustrate your answer with a sketch map.

Q6. Why are prospects for large scale industrialisation in East Africa bleak?

END OF EXAMINATION..GOOD LUCK!!

UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS, MARCH 1998

DEPARTMENT OF GEOGRAPHY

GEO 271: QUANTITATIVE TECHNIQUES IN HUMAN GEOGRAPHY I

ME: THREE (3) HOURS

STRUCTIONS: ANSWER ANY 4 QUESTIONS

. Write short explanatory notes on any 5 of the following:

(a) Participatory research
(b) Quasi-experimental design
(c) Observation techniques of data collection
(d) Scales of measurements
(e) Properties of scientific research
(f) Scheduled structural interview
(g) Hypothesis formulation

. Discuss the geographical sources of data. Illustrate your answer using examples.

. Outline the main elements of probability and non-probability sampling methods. State the advantages and disadvantages of the two sampling methods.

. Imagine you are the Director of the Institute of Social and Economic Research of the University of Zambia, and you have been asked by the Zambian government to conduct research on the 'Impact of Structural Adjustment on the Household economy in Lusaka Compounds'. Explain how you will go about writing a bankable research proposal to be presented to the Zambian government.

. During the last ten year period, the Department of National Parks and Wildlife Service has been implementing the community based - natural resource programme of Administrative Management Design for Game Management Area (ADMADE). Under the ADMADE Programme proportions of funds generated from various forms of wildlife utilization like safari hunting, non-resident hunting, culling, cropping programmes and certain tourism ventures are returned to the game management areas to support local community Development Projects. It is assumed that local people can support wildlife management programme if they see benefits accruing to their communities. How would you go about to design a questionnaire in order to ascertain the attitude and perception of local communities towards wildlife management and utilization in the game management areas where the ADMADE programme has been operational in the last ten years?

Q6. You have been hired as a consultant by an international donor agency to conduct an evaluation of a social-oriented development programme/project in Zambia which the agency has supported the last five years and is about to be closed down in early December, 1998. Explain how you would go about conducting an evaluation research of the development programme/project bearing in mind that the "process" approach was followed during the planning and implementation stages of the development programme/project?

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS – MARCH, 1998

GEO 381

ENVIRONMENT AND DEVELOPMENT I

TIME: THREE HOURS
ANSWER: QUESTION ONE AND ANY OTHER THREE

Q1. The Development Committee of the Luangwa District Council is considering a proposal for a sugar plantation in the district that is likely to boost development in the area. You have been asked as an environmental consultant to assess the viability and sustainability of the proposed sugar plantation in order to assist the council make an informed decision on the project.

a) Choose the most appropriate environmental planning technique and explain how you would go about assessing whether or not the proposed project should be sanctioned.

b) List the likely sources of impacts that you should consider and justify their significance.

c) What difficulties are you likely to face in carrying out this task?

Q2. 'The poor are both victims and agents of environmental damage.' Discuss.

Q3. Explain the assertion that, 'Some of the environmental problems that some countries face are associated with either lack of economic development or rapid economic growth.'

Q4. Write short explanatory notes on any five of the following:

i) Equity
ii) Baseline survey
iii) El nino
iv) Ecological sustainability
v) Performance bonds
vi) Agenda 21 and NEAP
vii) Impact prediction
viii) Economic growth and economic development.

Q5. Subsidies can either lead to environmental degradation or environmental protection. Using examples explain how subsidies can lead to:

a) environmental degradation
b) environmental protection

Q6. Explain how economic instruments work in promoting environmental protection and sustainable development.

END OF EXAMINATION

UNIVERSITY OF ZAMBIA

University First semester Examinations - March 1998

GEO 451

Land Resources Survey

Time: 3 Hours

Answer any Four Questions. All question carry equal marks. The use of illustrations and approved atlas is allowed.

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1. Write Short notes on all of the following

   (a) The length of the growing season

   (b) The importance of multi-disciplinary approanch in land use planning.

   (c) The matching process

   (d) The basic concepts of the land capability code of Zambia

   (e) Significance of land Tenure systems in resource evaluation

2(a) Land qualities and characteristics are attributes which can be used in assessing land suitability. Discuss these two attributes and give three examples for each.

(b) Which of the two attributes (land qualities and land characteristics) is recommended for assessing land suitability for rainfed agriculture. Give the advantages of the attribute selected and the disadvantages of the attribute not selected.

3. Study the following pedon from Chelstone Soil Series located at UNZA farm 20 km east of Lusaka

Soil Depth (cm)	Bulk Density (g/cm)	Water Content (%)	
		(-0.33 bar)	(-15 bar)
0-24	1.76	11.8	7.6
24-38	1.86	13.3	9.4
38-66	1.62	16.9	11.2
66-109	1.55	17.0	13.2
109-157	1.43	18.7	13.7
157-195	1.47	17.0	12.8

(Source: P. Woode (ed), 1985. Proceedings of the XI International Forum on Soil Taxonomy and Agrotechnology Transfer, Zambia. July 15 - August 1, 1985. pp 454. MAWD.)

(a) Assume the efficiency of utilisation is 1.0 in all horizons. Calculate the Total Readily Available Moisture (TRAM) for this soil.

(b) Write short notes on each of the stages you used to calculate the TRAM.

(c) Identify one use for the exercise you have done above.

4(a) What is the importance of using Participatory methods of Land Use Planning for Natural Resources Management.

(b) Explain the failures of social and technical approaches to rural land use planning.

(c) List in order, with short notes the stages used in Participatory Village Land Use Mapping.

5(a) What is a Land Utilization type (LUT)?

(b) Explain the attributes of LUTs.

(c) Give an example of a LUT which combines livestock and a perennial crop.

6(a) Explain the sequence of activities in the two stages of economic evaluation of a land use.

(b) Explain the situations where it is necessary to carry-out and not to carry out the two stages of economic analysis.

(c) Give reasons why it is not advisable in rural land evaluation to use economic evaluation as the only guide

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

GEO 481 - ENVIRONMENT AND DEVELOPMENT II

NSTRUCTIONS: Answer Question 1 and three other questions. All questions carry equal marks.

TIME: Three Hours.

. (a) Conservation often requires an analysis of the mortality patterns of the species concerned. The table below contains survivorship data for elephants in Tsavo National Park, Kenya. Compare and comment on the mortality patterns of the male and female elephants by drawing survivorship curves (both on one graph) using the data in the table.

Survivorship Data for Tsavo Elephants between 1961 and 1967

Age in years (x)	Female survivorship (l_x)	Male survivorship (l_x)
0 - 1	1000	1000
1 - 5	640	640
5 - 10	388	388
10 - 15	344	344
15 - 20	304	304
20 - 25	273	273
25 - 30	247	252
30 - 35	218	175
35 - 40	192	118
40 - 45	168	82
45 - 50	144	51
50 - 55	90	6
55 - 60	30	2

(Source: *East African Wildlife Journal*, 10(3): 159 - 164, November 1972)

(b) Explain the following in relation to elephant conservation in Zambia:

i. CITES
ii. ADMADE

2. Using a specific case study in Zambia, illustrate the conflict between environment and development.

3. Write short explanatory accounts on ALL of the following:

   a) Environmentally friendly pest and weed control.
   b) Urban population growth *versus* the natural pattern of population growth.
   c) Human threats to forests and the conservation requirements of forests.
   d) Eutrophication.
   e) How enriched carbon dioxide environments may alter biotic systems even in the absence of climate change.

4. How would you restore aesthetic quality to an environment scarred by mining induced dereliction?

5. Describe the various ways in which the *Chitemene* shifting cultivation system can be made sustainable.

6. Describe the main features of the tropical savannah biome, the threats posed to it by man, and the conservation requirements of tropical savannahs.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER FINAL EXAMINATIONS - MARCH 1998

GEO 911

Instructions: Time Allowed: THREE HOURS

Answer FOUR questions: Question 1 from Section 'A' and any other three from Section 'B'.

Question 1 accounts for 40 marks of this paper while the rest carry 20 marks each.

Use of any type of a desk calculator and a University Atlas is allowed.

SECTION 'A'

Q1. Study data that are presented in Tables 1 and 2 and attempt questions 1a - 1e.

(a) Calculate the ASFR for every cohort for both countries.

(b) Plot the results for the two countries by using the same graph and the same scale(s).

(c) Interpret your graphs

(d) Calculate the GRRs for both countries.

(e) Compare and contrast the results you got in d.

SECTION 'B'

Q2. Developing countries are experiencing 'a revolution of rising expectations'. Comment on this statement keeping in view the population and economic growth and development in the Third World.

Q3. The Demographic Transition Theory presents a generalisation of the twentieth century Third World experience. Discuss.

Q4. Discuss the Population Policy of Zambia while paying particular attention to modern approaches to Family Planning.

Q5. "The micro economic roots of fertility decline involve changes in the values and costs of children as well as costs of avoiding them" (Herrick and Kindlerberger, 1983). Analyse this statement in relation to any Zambia's rural area of your choice.

Q6. 'Migration and population transfer are two important factors in the economic development of a country.' Discuss this statement giving specific examples from Africa.

Q7. Account for the significant mortality transition in both the North and South between 1850 and mid - 20th century.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY SECOND SEMESTER EXAMINATIONS - SEPTEMBER 1998

GEO 932

URBAN GEOGRAPHY

TIME: THREE HOURS

ANSWER: ANY FOUR QUESTIONS

NOTE: CANDIDATES SHOULD USE DIAGRAMS AND EXAMPLES WHEREVER RELEVANT

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1. Write short explanatory notes on all of the following
   (a) The Keynesian theory of Urban Growth
   (b) Cost and Revenue in Urban Land Use
   (c) Ravensteins Laws of Migration
   (d) Alonso's Bid Rent Curve
   (e) Temporary Movements in the city

2 "Urban Planning is at best described as a form of state intervention in a development process dominated by the private sector" [Adams, 1994, p2]. Discuss the statement in relation to planning in Zambia.

3. Discuss the relationship between developments in transport technology and urban form and structure.

4 Answer Either
   (a) Shanty compounds in Zambia are best viewed as 'slums of hope' rather than as 'slums of despair'. Critically evaluate this assertion.

   OR

   (b) Explain why some governments have attempted to prevent the concentration of population within large urban settlements.

5. Evaluate previous Zambian government efforts aimed at providing cheap and affordable accommodation for the majority of the urban population and show how these differ from the current Housing Policy of 1996.

6. Discuss Burgess' 'Concentric Zone Model' outlining its major criticisms and modifications.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

GEO 951

CLIMATOLOGY

TIME: THREE HOURS

ANSWER: ANY FOUR QUESTIONS
THE USE OF ELECTRONIC CALCULATORS AND AN APPROVED ATLAS IS ALLOWED.

Q1. Write short explanatory notes on all of the following:

a) Weather associated with anticyclones

b) Urban heat islands

c) Lapse rates and their significance

d) Variables that determine the characteristics of air masses

e) Ozone depletion

Q2. Explain why Global Warming is an important environmental issues?

Q3. What is meant by the term 'heat budget'? Briefly explain how energy is transferred from areas of plenty to areas of shortage.

Q4. "There is great uncertainty as to how far the climate may change as a result of the greenhouse effect" (Gouldie & Viles 1997:95) Discuss the reasons for this uncertainly.

Q5. What factors determine the amount of isolation received at a particular place on the earth's surface?

Q6. Examine the data given in the table below and then answer the questions that follow:

UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - FEBRUARY, 1998

GEO 955

GEOMORPHOLOGY

TIME: Three Hours

ANSWER: Question One and three others.

NOTE: All questions carry equal marks. Illustrations and examples should be used wherever appropriate. Use of an atlas and calculator is allowed.

Q1. Write short explanatory notes on FIVE of the following:

a) Geomorphological mapping
b) Hysteresis
c) Etchplanation
d) Hydrothermal metamorphism
e) Laterization
f) Plate tectonics
g) Climamorphogenetic regions

Q2. Discuss the different approaches used in the study of various geomorphological phenomena.

Q3. Characterize the different types of dambos found in Zambia. What potentials do they offer for human sustenance and how can the use of these dambos be sustained?

Q4. State and explain the variations in dominant geomorphological processes found in tropical and periglacial environments.

Q5. Evaluate the value of sediment and discharge monitoring in a small tropical catchment.

Q6. Discuss the factors influencing the magnitudes of earthquake damage in any part of the world.

UNIVERSITY OF ZAMBIA

University First semester Examinations - March 1998

Geo 961

Soils Geography

Time: 3 Hours

Answer any Four Questions. All question carry equal marks. The use of illustrations and approved atlas is allowed.

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1. Write short notes on all of the following

   (a) Hydration in rock weathering

   (b) Criteria for identification of Cambic horizon

   (c) Soil Moisture Control Section

   (d) Influence of climate on soil formation

   (e) Relationship between Aquic moisture regime and reduction.

2. A soil profile has at the same time all the characteristics of a Vertisol and the diagnostic features of an Alfisol.

(a) Define the necessary characteristics to classify a soil as a Vertisol.

(b) Define the diagnostic horizons and other necessary properties of an alfisol.

(c) What is the final classification of the soil? Justify your choice. Give the corresponding name(s) according to the FAO legend.

3(a) Explain the influence of Basalt parent material on soil composition in a tropical environment with more than 1000mm of annual rainfall and another with 600mm of annual rainfall.

(b) What are the distinguishing features of a spodic horizon?

(c) Explain the important processes of soil formation in the genesis of a Spodic horizon. Make any assumptions

4 The Universal Soil Loss Equation (USLE) is used in predicting soil erosion on rangelands and forestland.

(a) Define the factors of the USLE including how they are derived, their units and influence on soil erosion.

(b) Discuss the factors of the USLE that can be manipulated to reduce soil erosion.

(c) Discuss one method of controlling erosion on sloping land.

5. During the soil survey procedures, a soil survey uses the knowledge learnt in various fields like Cartography, Geomorphology, Climatology, Remote sensing, Biogeography, and Pedology.

(a) Explain the procedures of carrying out a soil survey and the importance of the above mentioned fields during this procedure.

(b) What are the five types of soil surveys?

(c) What are the limitations of soil maps and how do they come about?

6(a) A relationship can be drawn between the type of clay minerals that are developed and climate. Discuss this relationship with reference to Zambia.

(b) The basic building blocks of clay are Silicon tetrahedral and Aluminium octahedral. Explain how Silicon forms a tetrahedral and Aluminium an octahedral shape.

(c) Using any example explain how Cation Exchange Capacity (CEC) develops on clays.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - NOVEMBER 1997

M 111

MATHEMATICS

DISTANCE EDUCATION

TIME ALLOWED: THREE (3) HOURS

INSTRUCTIONS: ANSWER ANY FIVE (5) QUESTIONS. CALCULATORS ARE NOT ALLOWED. CANDIDATES ARE ASKED TO PRINT THEIR COMPUTER NUMBERS AND THE NUMBER OF THE QUESTIONS ANSWERED ON THE ANSWER BOOK.

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1. a) Solve the following equation for integer values of x:

$$(x^2 - 3x)^2 - 9(x^2 - 3x) - 10 = 0.$$

b) (i) Define a quadratic polynomial f(x) where x is real.

(ii) The quadratic polynomial f(x) leaves a remainder −6 on division by x + 1, a remainder of −5 on division by x + 2 and no remainder on division by x + 3. Find f(x) and solve the equation f(x) = 0.

c) Given that x and y are real, find the values of x and y which satisfy the equation

$$(x + iy)^2 = \frac{1 + 7i}{1 - i}$$

2. a) Define a set of rational numbers. Hence show that 0.41414141...... is a rational number.

b) Given that $x * y = \sqrt{x}$, where x and y are real. Decide whether the operation * is:

(i) commutative

(ii) associative

c) Consider the function given by

$$f(x) = \begin{cases} \dfrac{x^2 - 36}{x - 6} & \text{if } x \neq 6 \\ 15 & \text{if } x = 6 \end{cases}$$

(i) Is f(x) continous at x = 6?

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

d) Given that k is a real constant such that $0 < k < 1$, show that the roots of the equation $kx^2 + 2x + (1 - k) = 0$ are:

(i) always real

(ii) always negative

3. a) (i) Does the following mapping define a function

$$x \longrightarrow \pm\sqrt{x}, \quad x \in IR.$$

If not why?

(ii) Given that $f: x \longrightarrow x^2$ for $x \in IR$, draw the graph of f and state its range. If the domain is redefined as $x \in IR^+$, sketch the graph that now represents f.

b) Let f and g be functions defined on IR such that

$f: x \longrightarrow 3 - x$

$g: x \longrightarrow \dfrac{3x}{x - 3}, \quad x \neq 3.$

(i) Show that each of the functions is its own inverse.

(ii) Find (g o f) (x) and verify that its inverse is (f o g) (x).

(iii) Show whether or not (f o g) (x) is even or odd or neither.

c) (i) Let B be any arbitrary non-empty set. Prove that $(B^C)^C = B$.

(ii) Prove that if a and b are any real numbers then

$a^2 + b^2 \geq 2ab.$

4. a) (i) Solve the equation

$$\sqrt{(3 - x)} - \sqrt{(7 + x)} = 2$$

(ii) Find the values of x real which satisfy the following inequality:

$$x^3 - 3x^2 \leq 10x.$$

b) (i) Given that $\text{Cos}^2x - \text{Sin}^2x = 2$, where

$0° < x < 90°$, find cos x and tan x.

(ii) Express Cos x + Sin x in the form r Cos (x - θ), where r is a positive real. Hence or otherwise, solve the equation Cos x + Sin x = 1, giving all values of x between 0° and 360° inclusive.

c) Prove the following identity:

$$\frac{\text{Sin } (\theta + 15°) + \text{Sin } (\theta - 15°)}{\text{Cos } (\theta - 15°) + \text{Cos } (\theta + 15°)} = \tan \theta$$

5. a) Differentiate the following with respect to x:

(i) $X(3x - 1)^5$

(ii) $\frac{\sqrt{(x^2 + 4)}}{x + 1}$

b) (i) If $x^2 - y^2 = 1$, prove that

$$y \frac{d^2y}{dx^2} + \left(\frac{dy}{dx}\right)^2 = 1$$

(ii) Find the limit as $x \longrightarrow 0$ of

$$\frac{1 - \text{Cos } 2x}{x^2}$$

c) (i) Write down the derivatives of Sin x and Cos x. Hence find the derivates of Cot x and Cosec x.

(ii) Given that $y = x\, e^{2x}$.

Find $\frac{dy}{dx}$

6. a) (i) Given that $x = \sec\theta + \tan\theta$ and $y = \text{Cosec}\,\theta + \text{Cot}\,\theta$, show that $x + \frac{1}{x} = 2\sec\theta$ and $y + \frac{1}{y} = 2\,\text{Cosec}\,\theta$.

(ii) If $x = \frac{1+t}{1-2t}$ and

$y = \frac{1+2t}{1-t}$, where

t is variable, find the value of $\frac{dy}{dx}$ when $t = 0$.

b) Two functions are defined on the domain $0 \leq x \leq \pi$ by

$f : x \longrightarrow \text{Sin}\,x$ and

$g : x \longrightarrow \text{Cos}\,x$.

(i) Sketch the graphs of f and g on two different diagrams.

(ii) Explain why one of these functions has an inverse while the other does not.

(iii) When the domain is restricted to $0 \leq x \leq \frac{1}{2}\pi$, calculate $f^{-1}g(\frac{1}{3}\pi)$.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
DEPARTMENT OF MATHEMATICS AND STATISTICS

M111 EXAMINATION MARCH 1998

INSTRUCTIONS:

1. **Write your computer number on all answer books you have used.**
2. Answer any five (5) questions out of the 7 given questions.
3. Write the number of the questions you solved on your front sheet of the answer book in the first column (of use for examiners).
4. Calculators are not allowed.
5. All working must be shown in your answers.

TIME ALLOWED: 3 HOURS

1.

a) If the polynomial $4x^3 + kx^2 + px + 2$ is divisible by $x^2 + 1$, find the values of p and k.

b) Simplify $(\sqrt{3} - 1)^3$ and hence rationalise the denominator of $\dfrac{1+\sqrt{3}}{(\sqrt{3}-1)^3}$ and express your answer in the form $a + b\sqrt{3}$ where $a, b \in \mathbf{Q}$.

2.

a) Given $z = x + \dfrac{1}{x}$.

Do the following:

i) Find z^2.

ii) Express $x^2 + \dfrac{1}{x^2}$ in terms of z^2.

iii) Divide both sides of the equation $3x^4 - 4x^3 - 14x^2 - 4x + 3 = 0$ by x^2 and rearrange to express it in terms of z.

iv) Find the real roots of the equation $3x^4 - 4x^3 - 14x^2 - 4x + 3 = 0$.

b) Given the equation $2\cos^2\theta = 1 + \sin\theta$.

i) Determine the general solution of the equation.

ii) Find all values of θ between 0 and 2π which satisfy the equation.

6.

a) Given $z = \dfrac{2+3i}{5+i}$

i) Express the complex number z in the form $a(1 + i)$, where a is a real number.

ii) Show that z^2 is imaginary.

b) Given the function $y = x^3 - 6x^2 + 9x$, find:

i) The range of values of x in which y increases.

ii) The range of values of x in which y decreases.

iii) The points at which the graph of y cuts the x-axis.

iv) The y-intercept of the graph

Sketch the graph **on the separately distributed graph sheet.**

7.

a) Given $f(x) = |x|$ and $g(x) = x^2 - 2x + 1$

i) Find $(f \circ g)(x)$ and $(g \circ f)(x)$.

ii) Redefine $|x|^2$ by removing the modulus.

iii) Determine the range of real values of x for which $(f \circ g)(x) = (g \circ f)(x)$.

b) Find the derivative of the following functions:

i) $g(x) = \dfrac{1}{x^{100} + 1}$

ii) $f(x) = x(2x^2 - 3)^4$

iii) $s(t) = \dfrac{7t^3 - t}{2\sqrt{t}}$

THE END

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

M 161

MATHEMATICS

TIME: THREE (3) HOURS

INSTRUCTIONS: ANSWER ANY FIVE (5) QUESTIONS. CALCULATORS, TABLES ARE NOT ALLOWED.

CANDIDATES ARE ASKED TO PRINT THEIR COMPUTER NUMBERS AND THE NUMBER OF QUESTIONS ANSWERED ON THE ANSWER BOX

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1. (a) Let $A = (2, 5)$, $B = [4, 6)$ and $(1, 3]$ be subsets of R, the set of reals. Find $A \cap (B \cup C)$..

   (b) Given that $p = x^{\frac{1}{2}} + x^{-\frac{1}{2}}$ and $q = x^{\frac{1}{2}} - x^{-\frac{1}{2}}$, find $p^2q^2 + 2$ in terms of x, giving your answer in its simplest form.

   (c) If $\log x + \log y = 2$, find xy. Hence solve the simultaneous equations. $\log x + \log y = 2, \quad x + y = 25$.

2. (a) Define a rational number. Hence show that $0.1\bar{3}$ is a rational number.

   (b) Find the real values of x and y when:

   (i) $\dfrac{x}{1-i} + \dfrac{y}{1+3i} = 2$

   (ii) $(x + iy)^2 = \dfrac{1+7i}{1-i}$

   (c) The polynomial $P(x) = x^3 + ax + b$ has remainder -94 when divided by $x - 1$. One factor of $P(x)$ is $x - 3$. Find a and b.

3. (a) Find the set of values of x for which $|x+1| < 2|x-1|$.

(b) Given that $f(x) = \frac{x+3}{x-1}$, find

(i) the domain of f,
(ii) the range of f,
(iii) $(f \circ f)(x)$,
(iv) $f^{-1}(x)$.

(c) (i) Show that the roots of the equation $ax^2 + bx + a = 0$ are reciprocals of each other.

(ii) Factorize completely the polynomial $P(x) = x^4 - 2x^2 + 1$. Hence solve the equation $P(x) = 0$.

4. (a) Show that at the points of intersection of the line $y = mx + c$ and the curve $y = x^2 + x + 4$, the relation $(c-4) + (m-1)x - x^2 = 0$ holds.

(b) Given that $c = 3$ in part (a), find the values of m such that the line $y = mx + c$ is tangent to the curve $y = x^2 + x + 4$.

(c) Resolve the rational function $\frac{2x}{x^3 - x^2 + x - 1}$ into partial fractions.

5. (a) Given $f(x) = 2x^2 + 4x + 5$,

(i) express f(x) in the form $2(x+A)^2 + B$,
(ii) find the minimum value of f(x),
(iii) show that f(x) is always positive

and

(iv) sketch the graph of f(x).

(b) When a certain car factory produces n cars per day its profit P in millions of kwacha is given by

$P = 5n^2 - 100n$.

How many cars per day must the factory produce

(i) to make a profit,
(ii) to make a profit of K220 million per day,
(iii) to make the worst possible loss.

6. (a) (i) Find e^x given that $2e^x - 2e^{-x} - 3 = 0$.

(ii) Find the value of $e^{\ln 2} + e^{-\ln 2}$.

(b) One root of the equation

$$6x^2 + 7x + K = 0$$

is $-\frac{1}{2}$.

(i) Find K.

(ii) With the value of K found in (i) above, find the other root.

(c) (i) Find the values of θ between 0° and 360° for which

$$2\sin^2\theta + \cos\theta = 1.$$

(ii) Show that

$$\frac{1}{1-\cos\alpha} + \frac{1}{1+\cos\alpha} = 2\csc^2\alpha.$$

7. (a) Find the term independent of x in the expansion of $\left(x+\frac{1}{x}\right)^{14}$. Leave your answer in factorial notation.

(b) Write down the first four terms in the expansion of $(1-x)^6$. Hence find an approximate value for $(0.99)^6$.

(c) In triangle ABC, $AB = x$, $BC = x+1$, and $AC = x+2$. Show that

$$\cos B = \frac{x-3}{2x}.$$

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - MARCH 1998
M211 MATHEMATICAL METHODS III

INSTRUCTIONS : ATTEMPT ANY **FIVE (5)** QUESTIONS ONLY
TIME ALLOWED : THREE (3) HOURS

1. (a) Evaluate the limits

(i) $\lim_{x \to \frac{\pi}{2}} \dfrac{1-\sin x}{1+\cos 2x}$ (ii) $\lim_{x \to 0^+} \left[1+\dfrac{5}{x}\right]^{2x}$

(b) Show that, at $(a\sec\theta, b\tan\theta)$, on the hyperbola

$$\frac{x^2}{a^2}-\frac{y^2}{b^2}=1,$$

the equation of the tangent lineis

$$bx - ay\sin\theta - ab\cos\theta = 0.$$

2. Discuss the graph of

$$x^2+2xy+y^2-8x+8y=0,$$

stating the focus/foci and directrix/directrices. Hence, or otherwise sketch the curve.

3. (a) Identify the conic

$$r=\frac{6}{3-4\cos\theta}$$

and give its eccentricity and distance of the directrix from the origin. Hence sketch the curve.

(b) (i) State (without proof) the theorem of the Mean.
(ii) Given that

$$f(x)=\sqrt{x-1}, \quad 1 \le x \le 3,$$

find the value/s x_o such that $1 < x_o < 3$, as prescribed by the theorem of the Mean.

4. (a) Express the polynomial

$$P(x)=3-2x+8x^2-x^3$$

in powers of $(x-2)$.

(b) Find the equation of the circle of curvature at the point $(0,1)$, of the curve $y=2x^2+1$.

5. (a) State whether the geometric series $\sum_{k=1}^{\infty} \frac{5.3^k}{4^{k+1}}$ is convergent.

If the series is convergent find its sum.

(b) If $y = \ln\cos x$, prove that

$$\frac{d^3y}{dx^3} + 2\frac{d^2y}{dx^2}\frac{dy}{dx} = 0.$$

Hence, or otherwise, obtain the Maclaurin expansion of y in powers of x up to and including the term in x^4. Using $x = \frac{\pi}{4}$ show that $\ln 2 \sim \frac{\pi^2}{16}(1 + \frac{\pi^2}{96})$.

6. Evaluate

(a) $\int x^2 \ln x \, dx$

(b) $\int \frac{dx}{1+e^x}$

(c) $\int \frac{dx}{1+\sin x}$.

7. (a) Given that $y = \sinh^{-1} x$, show that

$$\frac{dy}{dx} = \frac{1}{\sqrt{1+x^2}}.$$

Hence or otherwise find $\int \sinh^{-1} x \, dx$.

(b) Find the area of the surface S obtained by revolving the arc given by

$$\ell = \{(x, y) ; 0 \le x \le 2, y = \frac{1}{3}x^3\}$$

about the x- axis.

8. (a) Given that

$$I_n = \int_0^{\frac{\pi}{2}} \cos^n x \, dx, \quad n \in \aleph$$

show that $I_n = \frac{n-1}{n} I_{n-2}, \quad n \ge 2$.

Hence or otherwise find I_4.

(b) Find the length of the circumference of the astroid,

$$x = a\cos^3\theta, \quad y = a\sin^3\theta, \quad 0 \le \theta \le \frac{\pi}{2}.$$

END OF EXAM

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - NOVEMBER 1997

M 211

MATHEMATICAL METHODS III

DISTANCE EDUCATION

ME ALLOWED: THREE (3) HOURS

STRUCTIONS: ATTEMPT FIVE (5) QUESTIONS ONLY

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a) Evaluate the limit

i) $$\lim_{x \to 0} \frac{x + \sin 2x}{x - \sin 2x}$$

ii) $$\lim_{x \to \frac{\pi}{2}} (\tan x)^{\cos x}$$

b) Find the value of x_o as prescribed by Rolle's Theorem, given that

$$f(x) = \cos x, \ \frac{\pi}{2} < x < 3\frac{\pi}{2}$$

Discuss the graph of

$$2xy - 6y - 4x + 11 = 0,$$

stating the focus/foci and directrix/directrices.

a) Identify the conic

$$r = \frac{12}{2 + \sin \theta},$$

and give its eccentricity and distance of the directrix from the origin. Hence sketch the curve.

3. b) Show that at $(a \sec\theta, b \tan\theta)$ on the hyperbola

$$\frac{x^2}{a^2} - \frac{y^2}{b^2} = 1,$$

the equation of the tangent is

$$bx - ay \sin\theta - ab \cos\theta = 0$$

and the equation of the normal is

$$ax \sin\theta + by - (a^2 + b^2) \tan\theta = 0.$$

4. a) Find the equation of the circle of curvature at the point (0, 1), of the curve $y = 2x^2 + 1$.

b) Find the point of greatest curvature on the curve $y = \ln x$.

5. Evaluate

a) $$\int \frac{x^2 - 2x - 1}{x^2 - 4x + 4}\, dx$$

b) $$\int \frac{dx}{1 - \sin x}$$

c) $$\int x \sin^{-1} x \, d\, x.$$

6. a) Let $S_n = a + ar + ar^2 + \ldots + ar^{n-2} + ar^{n-1}$

Prove that $S_n = \dfrac{a(1 - r^n)}{1 - r}$.

Hence, or otherwise, evaluate $\sum\limits_{k=0}^{10} 15\left(\frac{2}{7}\right)^k$.

b) If $y = \ln \cos x$, prove that

$$\frac{d^3y}{dx^3} + 2\frac{d^2y}{dx^2}\frac{dy}{dx} = 0$$

Hence or otherwise, obtain the Maclaurin expansion of y in terms of x up to and including the term in x^4.

Using $x = \frac{\pi}{4}$ show that

$$\ln 2 \approx \frac{\pi^2}{16}\left(1 + \frac{\pi^2}{96}\right)$$

7. a) Given that

$$I_n = \int_0^{\frac{\pi}{2}} \cos^n x\,dx,$$

prove that $I_n = \frac{n-1}{n} I_{n-2}, \quad n \geq 2.$

Hence or otherwise find I_6.

b) Find the length of the circumference of the astroid,

$$x = a\cos^3\theta,\ y = a\sin^3\theta,\ 0 \leq \theta \leq \frac{\pi}{2}$$

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - NOVEMBER 1997

M 212

MATHEMATICAL METHODS IV

DISTANCE EDUCATION

TIME ALLOWED: THREE (3) HOURS

INSTRUCTIONS: ATTEMPT FIVE (5) QUESTIONS ONLY.

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1. a) Given that $\bar{A} = 2\hat{i} + 3\hat{j} + \hat{k}$ and $\bar{B} = \hat{i} + 2\hat{j} - 6\hat{k}$, find the projection of $\bar{A}$ onto $\bar{B}$.

   b) Find the distance from the point D(2,1,7) to the plane through the points A(3,-1,6), B(1,5,5) and C(4,-6,4).

   c) Find the curvative for the curve

   $$\bar{R} = 6t\hat{i} + 3\sqrt{2}t^2\hat{j} + 2t^3\hat{k}$$

   at t = 1.

2. a) For a gas formula $(p + \frac{a}{\nu^2})(\nu - b) = ct$, where a, b, c are constants, show that

   $$\frac{\partial p}{\partial \nu} = \frac{2a(\nu - b) - (p + a/\nu^2)\,\nu^3}{\nu^3(\nu - b)}$$

   b) If z = f(x, y) and x = u + av, y = u - av, prove that

   $$\left(\frac{\partial z}{\partial x}\right)^2 - \left(\frac{\partial z}{\partial y}\right)^2 = \frac{1}{a}\left(\frac{\partial z}{\partial u}\right)\left(\frac{\partial z}{\partial v}\right)$$

   c) Use the total differential to compute the volume of a box with square base 800.5mm and height 999.6mm.

3. a) Find dz/dt, in terms of t, given that

$z = \ln(x^2 + y^2)$; $x = e^{-t}$, $y = e^t$.

b) If $z = \dfrac{xy}{x - y}$, show that

$$x^2 \frac{\partial^2 z}{\partial x^2} + 2xy \frac{\partial^2 z}{\partial x \, \partial y} + y^2 \frac{\partial^2 z}{\partial y^2} = 0$$

c) For the formula R=E/C, find the maximum error and the percentage error if C = 20 with a possible error of 0.1 and E = 120 with a possible error of 0.05.

4. a) Solve the initial value problem

$y' + 2xy = 4x, \quad y(o) = 3$

b) Prove that the differential equation

$(3x^2y^2 + 2xy^4)\, dx + (2x^3 + 4x^2y^3 + 1)\, dy = 0$

is exact. Hence find its general solution.

c) The electric current in a certain circuit is given by

$$\frac{d^2I}{dt^2} + 4\frac{dI}{dt} + 2504I = 110,$$

$I = 0$ and $\dfrac{dI}{dt} = 0$ when $t = 0$, find I in terms of t.

5. a) By making a substitution y = vx or otherwise, solve the differential equation

$(9x - y)\, dx + (x - y)\, dy = 0$

b) Solve the equation

$$x\frac{d^2y}{dx^2} = 2 .$$

c) A weight attached to a spring moves up and down, so that the equation of motion is

$$\frac{d^2 5}{dt^2} + 165 = 0$$

Where s is the stretch of the spring at time t.
If $s = 2$ and $\frac{ds}{dt} = 1$, when $t = 0$, find s in terms of t.

6. Solve the following differential equations.

a) $2xydy = (x^2 - y^2)\, dx$

b) $\frac{dy}{dx} + y = xy^2$

c) $\frac{d^2y}{dx^2} - y = \text{Cos } 2x - 2 \text{ Sin } 2x.$

7. a) Find the coordinates of the point P in which the line $\frac{x-2}{3} = \frac{y-3}{4} = \frac{z+4}{2}$ intersects the plane

$$4x + 5y + 6z = 87$$

b) Find a symmetric equation of the line orthogonal to the vectors $\vec{AB}$ and $\vec{CD}$ and passes through the point (2, -1, 1), where A(1, 1, 0), B(-2, 3, 1), C(1, -1, 3) and D(0, 0, 0).

c) If $\vec{R} = (t^2 - 1)\hat{i} + (t^3 - 3t^2)\hat{j} + 5t\hat{k}$ is the position vector for a moving particle, and t denotes time, find where the particle is when the velocity vector is parallel to the xz-plane.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
DEFERRED/SUPPLEMENTARY EXAMINATION- FEB 1998
M212 MATHEMATICAL METHODS IV
DISTANCE EDUCATION

IME ALLOWED : THREE (3) HOURS
NSTRUCTIONS : ATTEMPT ANY FIVE (5) QUESTIONS ONLY.sd

. (a) Find p so that the vectors **i** +2**j** + 3**k** and 4**i** + 5**j**+ p**k** are perpendicular.
(b) Find the curvature for the curve

$$R = e^{t}i + \sqrt{2}\, tj + e^{-t}k$$

at $t = 0$.

. (a) Find the symmetric equation of a line joining the points $(1,2,3)$ and $(4,6,-9)$.
(b) Find the vector perpendicular to the plane which passes through the points $P_0(2,1,6)$, $P_1(5,-2,0)$ and $P_2(4,-5,-5)$.

. (a) Prove that if f is any differentiable function, then $z = f(x^2 - y^2)$ is a solution of the partial differential equation

$$x\frac{\partial z}{\partial y} + y\frac{\partial z}{\partial x} = 0.$$

(b) Use the total differential to compute the volume of a box with square base 880.5mm and height 999.6mm.

-. (a) Find the total differential of

$$z = x^3y + x^2y^2 + xy^3.$$

(b) Verify the Euler's theorem for a homogeneous function

$$f(x,y) = x^4 + 2x^3y - 3x^2y^2 + xy^3 - 4y^4.$$

5. (a) Find a simple differential equation satisfied by a family of curves given by

$$y = k(x-1)^2,$$

by eliminating the constant, k.

(b) Solve the differential equations:
(i) $(9x - y)dx + (x - y)dy = 0.$
(ii) $(6x^2 + 5y^2)dx + 10xydy = 0.$

5. (a) Solve the initial value problem

$$y' + 2xy = 4x, \quad y(0) = 3.$$

(b) Find the general solution of the differential equation

$$y'' + 6y' + 9y = 8\sin x + 6\cos x.$$

7. (a) Solve the equation

$$(2x-1)\frac{d^2y}{dx^2}-2\frac{dy}{dx}=0,$$

given that when $x=0$, $y=2$ and $\frac{dy}{dx}=3$.

(b) Find the first four nonzero terms in the Maclaurin's series for the solution of

$$(x+1)y'=3y.$$

END OF EXAM

UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER FINAL EXAMINATIONS - MARCH 1998

MATHEMATICS M221 - LINEAR ALGEBRA I.

INSTRUCTIONS: Attempt ANY five (5) questions.

TIME ALLOWED: Three (3) hours.

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1. What is meant by the following terms

   (i) a matrix B is *row equivalent* to a matrix A? (2 marks)
   (ii) the *row reduced echelon form* of a matrix A? (2 marks)

(a) Show that the matrix $\begin{pmatrix} 1 & 0 & -1 & 1 \\ 0 & 1 & -1 & 3 \\ 0 & 3 & 0 & 5 \end{pmatrix}$ is row equivalent to the

matrix $\begin{pmatrix} 1 & 0 & -1 & 1 \\ 2 & 1 & 0 & 1 \\ -1 & 1 & 0 & 2 \end{pmatrix}$. (3 marks)

(b) Reduce the matrix A to its row reduced form; where

$$A = \begin{pmatrix} 2 & 4 & 6 & 18 \\ 4 & 5 & 6 & 24 \\ 3 & 1 & -1 & 2 \end{pmatrix}.$$ (5 marks)

Hence, find the unique solution of the system

$$\begin{aligned} 2x + 4y + 6z &= 18 \\ 4x + 5y + 6z &= 24 \\ 3x + y - z &= 2 \end{aligned}$$ (3 marks)

of linear equations in unknowns x, y and z.

1. cont'd (c) For what value of k will the system

$$\begin{aligned} 3x + 4y &= k \\ 2x + y &= 5 \\ x - 3y &= -1 \end{aligned}$$

be consistent? For that value of k, find the complete solution.

(5 marks)

2. Define the following terms:

(i) An *invertible* matrix A; (1 1/2 marks)

(ii) An *orthogonal* matrix B. (1 1/2 marks)

(a) (i) Show that if a square matrix A is invertible, then its inverse is unique. (3 marks)

(ii) For the matrix $A = \begin{pmatrix} 2 & 4 & 3 \\ 0 & 1 & -1 \\ 3 & 5 & 7 \end{pmatrix}$, determine whether it is invertible or not. If it is invertible, calculate A^{-1}. (5 marks)

(b) Show that if A is an orthogonal matirx, then det $A = \pm 1$ (3 marks)

(c) Show that

(i) the 3×3 Vandermonde determinant is given by

$$\begin{vmatrix} 1 & 1 & 1 \\ x & y & z \\ x^2 & y^2 & z^2 \end{vmatrix} = (y - x)(z - x)(z - y);$$ (3 marks)

(ii) $$\begin{vmatrix} 1+x & y & z \\ x & 1+y & z \\ x & y & 1+z \end{vmatrix} = 1 + x + y + z.$$ (3 marks)

3. Define the following terms:

(i) a *skew-symmetric* matrix A; (2 marks)

(ii) *equivalent matrices* A and B. (2 marks)

(a) If A and B are skew-symmetric nxn matrices, show that $(AB)^t = BA$, so that AB is symmetric if and only if A and B commute, where A^t means the transpose of the matirx A.

(4 marks)

3. cont'd

(b) Find invertible matrices P and Q such that PAQ is in normal form, given that

$$A = \begin{pmatrix} 2 & -1 & 0 & 1 \\ 1 & 2 & 1 & -1 \\ 2 & 9 & 4 & -5 \end{pmatrix}$$

(7 marks)

(c) If

$$A(\alpha) = \begin{pmatrix} 1 & \alpha & \alpha^2/2 \\ 0 & 1 & \alpha \\ 0 & 0 & 1 \end{pmatrix},$$

show that $A(\alpha)A(\beta) = A(\alpha+\beta)$. (4 marks)

4. Define a *vector space* over the field K. (3 marks)

(a) Let V be a vector space over the field K. Show that

(i) the zero element $\mathbf{0} \in V$ is unique; (3 marks)

(ii) if $v \in V$, then $(-v)$ is unique. (3 marks)

(b) Let $V = \{(x, y): y = 2x + 1,\ x \in \mathbf{R}\}$. That is, V is the set of points lying on the line $y = 2x + 1$. Show that V is **not** a vector space over $\mathbf{R}$.

(4 marks)

(c) Let V be the set of all functions from a nonempty set X into a field K. For any functions $f, g \in V$ and any scalar $k \in K$, let $f+g$ and kf be functions in V defined by

$$(f+g)(x) = f(x) + g(x) \text{ and } (kf)(x) = kf(x), \text{ for every } x \in X.$$

Prove that V is vector space over K. (7 marks)

5. Briefly explain the meaning of each of the following:

(i) the set of vectors $S = \{w_1, w_2, ---, w_m\}$ *generates* a subspace W of V.

(2 marks)

(ii) W is a *subspace* of a vector space V (2 marks)

(a) Let $S = \{w_1, w_2, ---, w_k\}$ be a finite subset of a vector space V over K.

5. cont'd

Let $W = \left\{ \sum_{i=1}^{k} \alpha_i w_i : \alpha_i \in K \right\}$.

Prove that W is a subspace of V. (4 marks)

(b) (i) Let $W = \{(x, y, z) : x = at, y = bt, z = ct; a, b, c, t \in \mathbf{R}\}$. Verify that W is a subspace of $\mathbf{R}^3$. (4 marks)

(ii) Let $V = R^3$. Show that $W = \{(a, b, c): a \geq 0\}$, is not a subspace of V. (4 marks)

(c) Let W_1, W_2 and W_3 be subspaces of a vector space V over K. Show that $W_1 \cap W_2 \cap W_3$ is also a subspace of V. (4 marks)

6. Define the terms:

(i) a <u>*linearly dependent*</u> subset of a vector space V over K; (2 marks)

(ii) a <u>*K-linear combination*</u> of a subset S of a vector space V. (2 marks)

(a) Let V be a vector space over K. Prove that two vectors $u, v \in V$ are linearly dependent if and only if one is a scalar multiple of the other. (5 marks)

(b) Determine whether the vectors $u_1 = (1, -3, 0)$, $u_2 = (3, 0, 4)$ and $u_3 = (11, -6, 12)$ are linearly dependent or not. If they are linearly dependent, find the equation which relates them. (8 marks)

(c) Show that the vector $V = (-7, 7, 7)$ in $\mathbf{R}^3$ is a linear combination of $u_1 = (-1, 2, 4)$ and $u_2 = (5, -3, 1)$. (3 marks)

7. What is meant by the following terms:

(i) a <u>*basis*</u> of a vector space V over K? (2 marks)

(ii) the <u>*dimension*</u> of a vector space V over K? (2 marks)

(a) Find a basis for the set of vectors lying on the plane

$$W = \{(x, y, z): 2x - y + 3z = 0\}.$$ (4 marks)

(b) Find a basis and the dimension of the solution space S of the following homogeneous system:

$$x + 2y - z = 0$$
$$2x - y + 3z = 0.$$ (4 marks)

7. cont'd

(c) If W is a subspace of $V_4(\boldsymbol{R})$ which is generated by the set $\{u_1, u_2, u_3, u_4\}$ where $u_1 =$ [illegible], $u_2 = (0, 1, 3, 0)$, $u_3 = (2, -1, 4, -7)$, and $u_4 = (2, -5, -3, 6)$, determine an $\boldsymbol{R}$-basis for W.

Extend the basis for W to a basis for $V_4(\boldsymbol{R})$ which includes this $\boldsymbol{R}$-basis for W. (8 marks)

END OF EXAMINATION.

UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER FINAL EXAMINATIONS - MARCH 1998

MATHEMATICS M221 - LINEAR ALGEBRA I.

INSTRUCTIONS: Attempt ANY five (5) questions.

TIME ALLOWED: Three (3) hours.

1. What is meant by the following terms

   (i) a matrix B is *row equivalent* to a matrix A? (2 marks)

   (ii) the *row reduced echelon form* of a matrix A? (2 marks)

(a) Show that the matrix $\begin{pmatrix} 1 & 0 & -1 & 1 \\ 0 & 1 & -1 & 3 \\ 0 & 3 & 0 & 5 \end{pmatrix}$ is row equivalent to the

matrix $\begin{pmatrix} 1 & 0 & -1 & 1 \\ 2 & 1 & 0 & 1 \\ -1 & 1 & 0 & 2 \end{pmatrix}$. (3 marks)

(b) Reduce the matrix A to its row reduced form; where

$$A = \begin{pmatrix} 2 & 4 & 6 & 18 \\ 4 & 5 & 6 & 24 \\ 3 & 1 & -1 & 2 \end{pmatrix}.$$ (5 marks)

Hence, find the unique solution of the system

$$\begin{aligned} 2x + 4y + 6z &= 18 \\ 4x + 5y + 6z &= 24 \\ 3x + y - z &= 2 \end{aligned}$$ (3 marks)

of linear equations in unknowns x, y and z.

1. cont'd (c) For what value of k will the system

$$\begin{aligned} 3x + 4y &= k \\ 2x + y &= 5 \\ x - 3y &= -1 \end{aligned}$$

be consistent? For that value of k, find the complete solution.

(5 marks)

2. Define the following terms:

(i) An *invertible* matrix A; (1 1/2 marks)

(ii) An *orthogonal* matrix B. (1 1/2 marks)

(a) (i) Show that if a square matrix A is invertible, then its inverse is unique. (3 marks)

(ii) For the matrix $A = \begin{pmatrix} 2 & 4 & 3 \\ 0 & 1 & -1 \\ 3 & 5 & 7 \end{pmatrix}$, determine whether it is invertible or not. If it is invertible, calculate A^{-1}. (5 marks)

(b) Show that if A is an orthogonal matirx, then det $A = \pm 1$ (3 marks)

(c) Show that

(i) the 3×3 Vandermonde determinant is given by

$$\begin{vmatrix} 1 & 1 & 1 \\ x & y & z \\ x^2 & y^2 & z^2 \end{vmatrix} = (y-x)(z-x)(z-y);$$ (3 marks)

(ii) $$\begin{vmatrix} 1+x & y & z \\ x & 1+y & z \\ x & y & 1+z \end{vmatrix} = 1 + x + y + z.$$ (3 marks)

3. Define the following terms:

(i) a *skew-symmetric* matrix A; (2 marks)

(ii) *equivalent matrices* A and B. (2 marks)

(a) If A and B are skew-symmetric nxn matrices, show that $(AB)^t = BA$, so that AB is symmetric if and only if A and B commute, where A^t means the transpose of the matirx A.

(4 marks)

3. cont'd

(b) Find invertible matrices P and Q such that PAQ is in normal form, given that

$$A = \begin{pmatrix} 2 & -1 & 0 & 1 \\ 1 & 2 & 1 & -1 \\ 2 & 9 & 4 & -5 \end{pmatrix}$$ (7 marks)

(c) If

$$A(\alpha) = \begin{pmatrix} 1 & \alpha & \alpha^2/2 \\ 0 & 1 & \alpha \\ 0 & 0 & 1 \end{pmatrix},$$

show that $A(\alpha)A(\beta) = A(\alpha+\beta)$. (4 marks)

4. Define a *vector space* over the field K. (3 marks)

(a) Let V be a vector space over the field K. Show that

(i) the zero element $0 \in V$ is unique; (3 marks)

(ii) if $v \in V$, then $(-v)$ is unique. (3 marks)

(b) Let $V = \{(x, y): y = 2x + 1,\ x \in \mathbf{R}\}$. That is, V is the set of points lying on the line $y = 2x + 1$. Show that V is **not** a vector space over $\mathbf{R}$. (4 marks)

(c) Let V be the set of all functions from a nonempty set X into a field K. For any functions $f, g \in V$ and any scalar $k \in K$, let $f+g$ and kf be functions in V defined by

$$(f+g)(x) = f(x) + g(x) \text{ and } (kf)(x) = kf(x), \text{ for every } x \in X.$$

Prove that V is vector space over K. (7 marks)

5. Briefly explain the meaning of each of the following:

(i) the set of vectors $S = \{w_1, w_2, \text{---}, w_m\}$ *generates* a subspace W of V. (2 marks)

(ii) W is a *subspace* of a vector space V (2 marks)

(a) Let $S = \{w_1, w_2, \text{---}, w_k\}$ be a finite subset of a vector space V over K.

5. cont'd

Let $W = \left\{ \sum_{i=1}^{k} \alpha_i w_i : \alpha_i \in K \right\}$.

Prove that W is a subspace of V. (4 marks)

(b) (i) Let $W = \{(x, y, z) : x = at, y = bt, z = ct;\ a, b, c, t \in \mathbf{R}\}$. Verify that W is a subspace of $\mathbf{R}^3$. (4 marks)

(ii) Let $V = R^3$. Show that $W = \{(a, b, c): a \geq 0\}$, is not a subspace of V. (4 marks)

(c) Let W_1, W_2 and W_3 be subspaces of a vector space V over K. Show that $W_1 \cap W_2 \cap W_3$ is also a subspace of V. (4 marks)

6. Define the terms:

(i) a *linearly dependent* subset of a vector space V over K; (2 marks)

(ii) a *K-linear combination* of a subset S of a vector space V. (2 marks)

(a) Let V be a vector space over K. Prove that two vectors $u, v \in V$ are linearly dependent if and only if one is a scalar multiple of the other. (5 marks)

(b) Determine whether the vectors $u_1 = (1, -3, 0)$, $u_2 = (3, 0, 4)$ and $u_3 = (11, -6, 12)$ are linearly dependent or not. If they are linearly dependent, find the equation which relates them. (8 marks)

(c) Show that the vector $V = (-7, 7, 7)$ in $\mathbf{R}^3$ is a linear combination of $u_1 = (-1, 2, 4)$ and $u_2 = (5, -3, 1)$. (3 marks)

7. What is meant by the following terms:

(i) a *basis* of a vector space V over K? (2 marks)

(ii) the *dimension* of a vector space V over K? (2 marks)

(a) Find a basis for the set of vectors lying on the plane

$$W = \{(x, y, z): 2x - y + 3z = 0\}.$$ (4 marks)

(b) Find a basis and the dimension of the solution space S of the following homogeneous system:

$$x + 2y - z = 0$$
$$2x - y + 3z = 0.$$ (4 marks)

7. cont'd

(c) If W is a subspace of $V_4(\mathbf{R})$ which is generated by the set $\{u_1, u_2, u_3, u_4\}$, where $u_1 = (1, -2, 0, 3)$, $u_2 = (0, 1, 3, 0)$, $u_3 = (2, -1, 4, -7)$, and $u_4 = (2, -5, -3, 6)$, determine an $\mathbf{R}$-basis for W.

Extend the basis for W to a basis for $V_4(\mathbf{R})$ which includes this $\mathbf{R}$-basis for W. (8 marks)

END OF EXAMINATION.

UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

M 231

SECOND YEAR MATHEMATICS

TIME: THREE (3) HOURS

INSTRUCTIONS: ANSWER ANY FIVE (5) QUESTIONS

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1. (a) Let A and B be subsets of X and let $f : X \to Y$ be a function. Prove that

   (i) $f(A \cap B) \subseteq f(A) \cap f(B)$;

   (ii) $f(A \cap B) \nsupseteq f(A) \cap f(B)$.

   (10 marks)

   (b) Find an example for each of the following functions:

   (i) f is onto

   (ii) f is one-to-one

   (iii) f is one-to-one and onto

   (iv) f is neither one-to-one nor onto.

   (10 marks)

2. (a) If $x \in \mathbb{R}$, prove that there exists $n \in \mathbb{N}$ such that $x < n$.

   (10 marks)

   (b) Let y and z be strictly positive real numbers. Prove that

   (i) there exists $n \in \mathbf{N}$ such that $z < ny$;

   (ii) there exists $n \in \mathbb{N}$ such that $0 < \frac{1}{n} < y$.

   (10 marks)

3. (a) If $\limsup \left| \frac{x_{n+1}}{x_n} \right| < 1$, prove that $x_n \to 0$ as $n \to \infty$.

   (10 marks)

   (b) Let $x_n = 1 + \frac{1}{1!} + \frac{1}{2!} + \dots + \frac{1}{n!}$.
   Prove that $\lim x_n$ exists and lies between 2 and 3.

   (10 marks)

4. (a) Let $f : A \to B$ be a function. Define:

   (i) Direct image of $E \subseteq A$ under f.

   (ii) Inverse image of $F \subseteq B$ under f.

   (8 marks)

(b) Let $f : R \to R$ be defined by $f(x) = x^2 + 1,\ x \Leftarrow R$, and let $E = \{x : 0 \le x \le 2\}$.

(i) Find the direct image of E under f and the inverse image of f(E) .

(ii) Prove that f is not injective.

(12 marks)

5. (a) If (x_n) converges to l, prove that every subsequence of (x_n) converges to the same limit l.

(10 marks)

(b) If (x_n) converges to l, prove that $\left((-1)^n x_n\right)$ does not coverage.

(10 marks)

6. (a) Prove that a sequence of real numbers is convergent if and only if it is a Cauchy sequence.

(12 marks)

(b) Prove that the sequence

$$x_n = 1 + \frac{1}{2} + \frac{1}{3} + \ldots\ldots + \frac{1}{n}$$

does not coverage.

(8 marks)

7. (a) Let (S_n) be a sequence of real numbers. If $\limsup S_n = \infty = \liminf S_n$, prove that (S_n) diverges to ∞.

(12 marks)

(b) If P is real and $|x| < 1$, prove that $n^p x^n \to 0$ as $n \to \infty$.

(8 marks)

END OF THE EXAMINATION

THE UNIVERSITY OF ZAMBIA

FIRST SEMESTER SESSIONAL EXAMINATION MARCH 1998

M241 - INTRODUCTION TO COMPUTER PROGRAMMING

TIME ALLOWED: THREE (3) HOURS

INSTRUCTIONS: ANSWER ANY FIVE (5) QUESTIONS, INDICATING THE ATTEMPTED QUESTIONS ON THE ANSWER BOOKLET.

Q1. a. (i) What is a conditional statement?

(ii) Name the two conditional statements in Pascal.

b. What is a repetitive statement used for in Pascal?

c. What is the difference between the FOR..TO..DO statement and the REPEAT..UNTIL and the WHILE..DO statements?

d. Write a complete Pascal program that allows a user to enter a mark, out of 10, obtained by a student in an M241 assignment. The program should then output the mark and an appropriate message as follows:

mark obtained		message to print
above 8	-	'Excellent'
7,8	-	'Very good'
5,6	-	'Good'
3,4	-	'Fair'
below 3	-	'Useless'

The program should also calculate and output the percentage (%) mark obtained by the student.

Q2. a. Define the following terms as applied to computer science.

(i) program

(ii) logical error

(iii) object code

(iv) compiling

(v) run-time error

b. Give one function of each of the following five main parts of a computer.

(i) memory

(ii) secondary storage device

(iii) input device

(iv) output device

(v) central processing unit

c. Draw a sketch of the above parts showing the flow of information by using arrows.

Q3. a. Write a complete Pascal program that reads three real numbers a, b, and c from the keyboard. The numbers represent the sides of a triangle. The program should determine whether the numbers define a right angled triangle, an isosceles triangle, an equilateral triangle or an ordinary triangle. Assume that the sides really do represent a triangle. It should then print an appropriate message to indicate the type of triangle determined.

b. Write a complete Pascal program to evaluate the following:

$1 + \frac{1}{3} + \frac{1}{5} + \ldots + \frac{1}{2n+1}$ where n is a positive integer to be supplied by

the user. That is, the program should evaluate $S = \sum_{m=0}^{n} \frac{1}{2m+1}$.

Q4. a. (i) Name two situations when a goto statement would be appropriate to use.

(ii) Re-write the following Pascal program by replacing the goto statements with appropriate structured types.

```
program power(input,output);
label   100, 200;
var     i,product,n:integer;
        x:real;
begin
        writeln('Enter a real number x and a positive integer n');
        readln(x,n);
        if (n<=0) then
                goto 200
        else
        begin
                i:=1;
                product:=1;
          100:  product:=product*x;
                i:=i+1;
                if (i<=n) then goto 100;
                writeln(x,' to the power of ',n,' is ',product);
200:    end;
end.
```

Q5. a. When would a CASE statement be better to use than an IF statement?

b. Re-write the following segment using an IF statement.

```
CASE station OF
        5,6,10: writeln('Unidentified TV station');
        1:      writeln('BBC 1');
        2:      writeln('BBC 2');
        3:      writeln('ITV');
        4:      writeln('CHANNEL 4');
        7:      writeln('SKY Sports 1');
        8,9:    writeln('Movie Channels');
end;
```

c. Make an appropriate declaration for **station** using a **var** declaration.

d. The following program segment is supposed to count the number of integers entered before a 0 is entered but contains a bug.

(i) What is the bug?

(ii) Classify the bug as either syntactic or semantic.

```
{This segment counts the number of non-zero integers read}
readln(number);
count:=count+1;
while (number<>0) do
begin
        count:=count+1;
end;
```

Q6. a. What is an algorithm?

b. When is an algorithm said to be efficient?

c. An algorithm of $O(N^2)$ which has 100 statements, takes 2 seconds to execute. How long will it take if the number of statements is increased to 300? Justify your answer.

d. Consider the following Pascal program.

```
program SumSeries(input,output);
var n, total:integer;
begin
        readln(n);
        total:=n*(n+1)/2;
        writeln('The total is ',total:4);
end.
```

How long will it take to execute when: (i) n=10; (ii) n=20 (iii) n=100 if takes 1 ms (micro second) for n=5? Justify your answer.

END OF EXAMINATION. GOOD LUCK.

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER FINAL EXAMINATIONS - MARCH 1998

M261

TIME: THREE (3) HOURS

INSTRUCTIONS: ANSWER ANY FIVE (5) QUESTIONS ALL NECESSARY WORK MUST BE SHOWN FOR FULL CREDIT.

CALCULATORS ARE ALLOWED. STATISTICAL TABLES WILL BE PROVIDED.

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1. The following scores represent the final examination grade for an elementary statistics course:

47	62	61	60	39	34	37
46	81	72	74	62	65	53
47	52	38	25	42	40	70
63	62	83	19	26	59	49
53	52	88	91	51	52	24

(a) Construct a stem and leaf plot,

(b) Construct a box-plot for the above scores. Are there any outlying observations?

(c) Comment on the shape of the distribution from the stem and leaf plot of part (a). Does your conclusion agree with the box plot of part (b)? Explain.

2. (a) Define the following terms:

(i) type I error.
(ii) the power of a test.

(b) The lifetime of a brand of flashlight battery is normally distributed with a mean of 30 hours and a standard deviation of 5.6 hours. Let X be the lifetime of a randomly selected flashlight battery of this brand. Determine

(i) $P(X > 20)$
(ii) $P(15 < X < 45)$

(c) Given two random samples of size $n_1 = 10$ and $n_2 = 10$, from two independent normal populations, with $\bar{x}_1 = 35, \bar{x}_2 = 31, s_1^2 = 17.2$ and $s_2^2 = 19.1$.

(i) Find a 90% confidence interval for $\mu_1 - \mu_2$, assuming equal variances.
(ii) Are we justified in assuming that $\sigma_1^2 = \sigma_2^2$? Test at the 0.1 level of significance.

3. (a) Define the following terms:

(i) a random sample of size n
(ii) a parameter
(iii) a statistic

(b) A new rocket-launching system is being considered for deployment of small short-ranges launches. The existing system has $p = 0.8$ as the probability of a successful launch. A sample of 40 experimental launches is made with the new system and 34 are successful. Let p be the probability of a successful launch.

(i) construct a 95% confidence interval for p.
(ii) would you conclude that the new system is better?

(c) The probability that a patient recovers from a delicate operation is 0.67. Of the next 200 patients having their operation, what is the probability that:

(i) exactly 140 survive?
(ii) between 120 and 130 inclusive survive?

4. (a) (i) Define a type II error.
(ii) State the Central Limit Theorem.

(b) A random sample of size five is taken from a normal distribution with mean 200 and variance 80, find the probability that the sample mean

(i) is greater than 207.
(ii) lies between 201 and 209.

(c) The heights of a random sample of 50 college students showed a mean of 174.5cm and a standard deviation of 6.9cm.

(i) find 98% confidence interval for the mean height of all college students.
(ii) how large should our sample be if we wish to be 98% confident that our sample mean will be within 1.5cm of true mean.

5. (a) Suppose that 20 young ladies are chosen at random in order to estimate the mean weight, μ, of all such ladies. The resulting data are shown below (weight in kg).

44	44	47	46	38
42	46	41	50	43
40	51	47	43	47
48	48	45	41	46

Assuming the weights of all young ladies to be normally distributed, find a 95% confidence interval for the population

(i) mean
(ii) variance

(b) An experiment was conducted to compare the yield of two varieties of tomatoes, A and B. Forty plants of each variety were randomly selected and planted within the same field. The yields recorded in kilograms of tomatoes produced for each plant, possessed means of 10.5kg per plant for variety A and 9.3kg per plant for variety B. The variances for samples A and B were 2.1 and 2.8, respectively. Do the data provide sufficient evidence to conclude that there is a difference between the mean weights of tomatoes produced per plant for two varieties? Test using $\alpha = 0.05$.

(c) A study was conducted to determine whether the treatment a psychiatric patient receives it determined by the patient's social status. One hundred psychiatric patients were randomly sampled from each of four social classes and each was classified according to the type of treatment received. Determine whether the data given in the table support the theory that type of psychiatric treatment and social status are dependent. Test at the $\alpha = 0.10$ level.

		SOCIAL CLASS			
		Upper	Upper Middle	Lower Middle	Lower
TREATMENT	Psychotherapy	78	53	31	17
	Organic	13	27	38	33
	No Treatment	9	20	31	50

6. Three strains of rats were studied under two environmental conditions for their performance in a maze test. The error scores for 48 rates were recorded and analysed.

(a) For the above data, copy and complete the following Analysis of variance table:

Source	Sum of squares	Degrees of freedom	Mean square	f
Environment	14876	1		
Strain		2		
Interaction	1235			
Error	42193			
Total	76457	47		

(b) Is there a difference in error scores for the different strains? Test using $\alpha = 0.01$.

(c) The grades of a class of 9 students on a midterm report (x) and on the final examination (y) are as follows:

x	77	50	71	72	81	94	96	99	67
y	82	66	78	34	47	85	99	99	68

(i) calculate r

(ii) Estimate the linear regression line $y = \alpha + \beta x$

(iii) Estimate the final examination grade of a student who received a grade of 85 on the midterm report.

$$\left[\Sigma x = 707, \Sigma y = 658, \Sigma x^2 = 57557, \Sigma y^2 = 51980, \Sigma xy = 53258\right]$$

END OF EXAMINATION

UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER FINAL EXAMINATIONS - MARCH 1998

MATHEMATICS M325 - GROUP AND RING THEORY

INSTRUCTIONS: Attempt ANY three (3) questions from Section A and ANY two (2) from Section B.
TIME ALLOWED: Three (3) hours.

SECTION A

Attempt ANY three (3) questions from this section.

1. Define the following terms

   (i) the *centre* $Z(G)$ of a group G; (2 marks)
   (ii) a *p-group* G. (2 marks)

   (a) Let G be a group with Centre $Z(G)$. Prove that $Z(G)$ is a normal abelian subgroup of G. (4 marks)

   (b) If G is a non-abelian group with Centre $Z(G)$, prove that $G/Z(G)$ can not be cyclic. (5 marks)
   Hence or otherwise, prove that

   (i) a p-group of order p^2, p a prime, is necessarily abelian; (4 marks)
   (ii) the Symmetric group S_3, of degree 3, has a trivial Centre. (3 marks)

2. What is meant by the following:

   (i) a *cyclic* group G? (2 marks)
   (ii) a *homomorphism* $\theta : G \to H$ of a group G into a group H? (2 marks)

   (a) Let G be a group. Show that
   (i) if G is cyclic, then G is abelian. (4 marks)
   (ii) if $(x^{-1}y^{-1})^2 = x^{-2}y^{-2}$, for all $x, y \in G$, then G is abelian. (3 marks)

   (b) Show that if N is a normal subgroup of a group G, then the canonical (or natural) map $\theta : G \to G/N$ given by $\theta(g) = gN$, for $g \in G$, is a homomorphism. (4 marks)

(c) Prove that a homomorphism $\theta : G \rightarrow H$ is *injective* if and only if the kernel of θ is $\{ e \}$. (5 marks)

3. What is meant by

(i) the *centralizer* of an element g in a group G? (2 marks)
(ii) the *conjugacy class* of an element g of a group G? (2 marks)

(a) Show that the centralizer of an element g in a group G is a subroup of G. (4 marks)

(b) Write down the multiplication table of a group g of order 6 which is given by

$$G = \langle x, y : x^3 = y^2 = e, yx = x^2y \rangle.$$ (2 marks)

From the multiplication table of G, determine:

(i) the centralizer of each element g in G; (2 marks)
(ii) the centre $Z(G)$ of G; (1 mark)
(iii) the conjugacy classes of elements of G and write down the class equation; (3 marks)
(iv) a subgroup H of order 3 in G; (1 mark)
(v) all the distinct cosets of H in G, where H is as in (iv); (2 marks)
(vi) whether H is normal or not. Justify your answer. (1 mark)

4. What is meant by the following terms

(i) a *simple* group G? (2 marks)
(ii) a *factor group*? (2 marks)

(a) Let H be a subgroup of index 2 in G. Prove that H is a normal subgroup of G. (5 marks)

(b) Prove that a factor group of a cyclic group is cyclic. (5 marks)

(c) Let $\mathbf{Z}_4$ and $\mathbf{Z}_6$ be the additive groups of integers modulo 4 and 6 respectively. Let $\mathbf{Z}_4 + \mathbf{Z}_6$ be the group of ordered pairs (a,b), with $a \in \mathbf{Z}_4$, $b \in \mathbf{Z}_6$. Let $H = \langle (0, 1) \rangle$ be the cyclic subgroup of $\mathbf{Z}_4 + \mathbf{Z}_6$ generated by the element $(0,1)$.

(i) Write down all the elements of H. (2 marks)
(ii) Compute the elements of the factor group $(\mathbf{Z}_4 + \mathbf{Z}_6)/H$ and determine the group Isomorphic to $(\mathbf{Z}_4 + \mathbf{Z}_6)/H$. (4 marks)

SECTION B

Attempt ANY two(2) questions from this section.

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5. Define the terms

(i) an *ideal* of a ring R; (2 marks)
(ii) a *zero-division* in a ring R. (2 marks)

(a) Given that ϕ is a ring homomorphism: $R \to S$, show that

(i) $Ker\ \phi$ is an ideal of R; (4 marks)
(ii) $R/ker\ \phi \cong Im\phi$. (4 marks)

(b) Verify that if $n \in \mathbf{Z}$, the ring of integers, then $n\mathbf{Z}$ is an ideal of $\mathbf{Z}$. (3 marks).

If a map $\phi : \mathbf{Z}_n \to \mathbf{Z}/n\mathbf{Z}$ is given by $\phi(\bar{z}) = z + n\mathbf{Z}$, show that ϕ is an isomorphism. (3 marks)

Find a condition on n in order that $z + n\mathbf{Z}$ is not a zero divisor in $\mathbf{Z}/n\mathbf{Z}$. (2 marks)

6. Define the terms:

(i) an *integral domain* R; (2 marks)
(ii) a *unique factorization domain.* (2 marks)

(a) Show that if R is an integral domain, then every prime element is irreducible. (4 marks)
When would every irreducible element in R be prime? Explain your answer clearly. (2 marks)

(b) Given an integral domain

$$\mathbf{Z}[\sqrt{-3}\,] = \{a + b\sqrt{-3} : a, b \in \mathbf{Z}\},$$

verify that the element $1+\sqrt{-3}$ is

(i) irreducible in $\mathbf{Z}[\sqrt{-3}\,]$; (6 marks)
(ii) not prime in $\mathbf{Z}[\sqrt{-3}\,]$. (3 marks)

Hence, deduce that $\mathbf{Z}[\sqrt{-3}\,]$ is not a unique factorization domain. (1 mark)

7. What is meant by each of the followig terms:-

(i) an *evaluation homomorphism* as applied to polynomial rings? (2 marks)

(ii) an *external direct* sum of rings $R_1, R_2, ---, R_n$. (2 marks)

(a) Let $\phi_1: \boldsymbol{Z} \to \boldsymbol{Z}/2\boldsymbol{Z}$ $(\cong \boldsymbol{Z}_2)$ and

$\phi_2 \boldsymbol{Z} \to \boldsymbol{Z}/3\boldsymbol{Z}$ $(\cong Z_3)$

be natural maps from $\boldsymbol{Z}$ to $\boldsymbol{Z}/2\boldsymbol{Z}$ and $\boldsymbol{Z}/3\boldsymbol{Z}$, respectively, and define a map $\theta: \boldsymbol{Z} \to \boldsymbol{Z}_2 \oplus \boldsymbol{Z}_3$ by $\theta(z) = (\phi_1(z), \phi_2(z))$.

(i) Verify that θ is a homomorphism from $\boldsymbol{Z}$ to the external direct sum $\boldsymbol{Z}_2 \oplus \boldsymbol{Z}_3$; (5 marks)

(ii) Determine $ker\theta$. (3 marks)

Hence, deduce that $\boldsymbol{Z}_6 \cong \boldsymbol{Z}_2 \oplus \boldsymbol{Z}_3$. (2 marks)

(b) For each real number $\alpha \in \boldsymbol{R}$, define

$\phi_\alpha: \boldsymbol{Q}[x] \to \boldsymbol{R}$ by $\phi_\alpha f(x) = f(\alpha)$.

Determine

(i) $ker\ \phi_3$ (3 marks)

(ii) $\boldsymbol{Q}[x]/ker\phi_3$. (3 marks)

END OF EXAMINATION.

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

M 331

REAL ANALYSIS III

TIME: THREE (3) HOURS

INSTRUCTIONS: ATTEMPT ANY FIVE (5) QUESTIONS

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1. (a) For each $x \in (0, 1)$, show that there is an open interval, with centre x, which is a subset of $(0, 1)$.

   (b) Let $A_1 = (\frac{1}{2}, 2)$ and for $n > 1$ let $A_n = \left(\frac{1}{n+1}, \frac{1}{n-1}\right)$. Show that $\left(0, 1\right] \subset \bigcup_{n \in N} A_n$.

2. (a) Let $I = [0, 1]$ be the closed unit interval. Suppose that f is a continuous mapping of I into I. Prove that $f(x) = x$ for at least one $x \in I$.

   (b) Show that the function f, defined for $x \in \Re$ by $f(x) = \frac{1}{1+x^2}$, is uniformly continuous on $\Re$.

3. (a) (i) Define an open set in $\Re$.
   (ii) Define an closed set in $\Re$.

   (b) Let $A \subset \Re$. If A is both open and closed in $\Re$, show that either $A = \varnothing$ or $A = \Re$

4. (a) (i) Define a covering of a subset of $\Re$.
   (ii) Define a compact subset of $\Re$.

   (b) State and prove the Heine-Borel theorem.

5. (a) Give the $\varepsilon - \delta$ definition of a continuous function defined on a subset of $\Re$ to $\Re$.

   (b) Let f be a function defined on its domain $D(f) \subset \Re$. Prove that f is continuous on its domain if and only if for any open set G in $\Re$ there exists an open set G_1 in $\Re$ such that $G_1 \cap D(f) = f^{-1}(G)$.

6. (a) Define a step function with domain and range in $\Re$.

(b) Let f be a continuous function whose domain is a closed interval in $\Re$ with range in $\Re$. Prove that f can be uniformly approximated on its domain by step functions.

7. (a) Let a function f be defined on a closed interval $[a, b]$ in $\Re$ to $\Re$. When is f said to be of bounded variation?

(b) Let f be of bounded variation on a closed interval $[a, b]$ in $\Re$ into $\Re$ and assume that $c \in (a, b)$. Prove that f is of bounded variation on $[a, c]$ and on $[c, b]$ and find a relationship between the total variations of f on $[a, b]$ on $[a, c]$ and on $[c, b]$.

END OF THE EXAMINATIONS

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER FINAL EXAMINATIONS - MARCH 1998

M361

MATHEMATICAL STATISTICS

TIME: THREE (3) HOURS

INSTRUCTIONS: ATTEMPT ANY THREE (3) QUESTIONS. ALL QUESTIONS CARRY EQUAL MARKS. FULL CREDIT WILL ONLY BE GIVEN IF ALL ESSENTIAL STEPS ARE SHOWN.

STATISTICAL TABLES WILL BE PROVIDED AND CALCULATORS ARE ALLOWED.

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1. (a) Define the following terms:

   (i) Moment generating function (*mgf*) of a random variable x.

   (ii) Jacobian of the transformation $(x,y) \to (z,u)$.

   (iii) Chi-square distribution.

   (b) Prove the following

   (i) If $\bar{x}$ is a sample mean of a random sample of size n from $N(\mu,\sigma^2)$ then $\bar{x} \sim N\left(\mu, \frac{\sigma^2}{n}\right)$.

   (ii) If X and Y are jointly distributed continuous random variables with density $f_{x,y}(x,y)$ and $W = X + Y$ then

   $$f_w(w) = \int_{-\infty}^{\infty} f_{x,y}\left(w-y, y\right)dy.$$

   (iii) If X is a random variable with the following density

   $$f_x\left(x,\alpha,\lambda\right) = \frac{1}{2\lambda}e^{-\frac{1}{\lambda}|x-\alpha|}, \quad -\infty < x < \infty, \quad -\infty < \alpha < \infty, \quad \lambda > 0,$$

   then

   $$M_x(t) = \frac{e^{\alpha t}}{1-\lambda^2 t^2}, \qquad \text{for } t \in \left(-\frac{1}{\lambda}, \frac{1}{\lambda}\right).$$

(c) (i) Let X have an exponential density with mean λ. Find the density of $Y = X^{\frac{1}{3}}$.

(ii) Let X and Y have a joint density given by

$$f_{x,y}(x, y) = \frac{3}{8}(x + y^2), \quad \begin{matrix} 0 < x < 2 \\ 0 < y < 1 \end{matrix}.$$

Find the joint density of Z and W where $Z=X+Y$ and $W=\frac{X}{Y}$.

2. (a) Define the following terms:

(i) An estimator.
(ii) Sufficient statistics.
(iii) Consistent estimator.

(b) Prove the following:

(i) The mean-squared error of an estimator is equal to the variance of the estimator and its bias squared.
(ii) If $X_1, X_2, \ldots, X_n$ is a random sample from Bernoulli with parameter $\theta = p(X = 1)$, then $S = \sum_{i=1}^{n} X_i$ is sufficient statistics for (use definition of sufficient statistics).
(iii) An estimator T for a parameter θ is said to be asymptomally unbiased if $\lim_{n \to \infty} E(T) = \theta$. Let $X_1, X_2, \ldots, X_n$ be a random sample from uniform over the interval $(0, \theta)$; then $Y = \max(X_1, \ldots, X_n)$ is asymptomatically unbiased for θ. .

(c) Let $X_1, X_2, \ldots, X_n$ be a random sample from normal distribution with mean zero and variance σ^2..

(i) Find the sufficient statistics for σ^2.
(ii) Find the maximum likelihood estimator (MLE) for σ^2.
(iii) Find the expectation of the MLE for σ^2.
(iv) Find the Cramer-Rao lower bound for σ^2.
(v) Show that the MLE for σ^2 is UMVUE. .

3. (a) Define the following terms:

(i) The power function of a test
(ii) The size of a test
(iii) Most powerful test.

(b) (i) State the Neyman-Pearson Lemma.
(ii) Prove the Neyman-Pearson Lemma.

(c) (i) Consider a random sample of size n from a distribution with pdf

$$f_x(x,\theta) = \frac{3x^2}{\theta} e^{-\frac{x^3}{\theta}}.$$

Derive the form of the critical region for a uniformly most powerful (ump test of size α for testing $H_0 : \theta = \theta_0$ against $H_1 : \theta > \theta_0$.

(ii) Let X be a discrete random variable whose density values under H_0 and H_1 are given by the table below:

X	1	2	3	4	5	6	7
$f(x \mid H_0)$	0.01	0.02	0.03	0.05	0.05	0.07	0.77
$f(x \mid H_1)$	0.03	0.09	0.10	0.10	0.20	0.18	0.30

List all the critical regions of size $\alpha = 0.10$. Find the critical region of siz $\alpha = 0.10$ with the largest power.

4. (a) Let x_1 and x_2 denote a random sample of size 2 form a probability density functio $f_x(x) = \frac{1}{x^2}$ $1 < x < \infty$.

(i) Find the joint density function of u and v where $U=X_1X_1$ and $V=X_1$.
(ii) Find the marginal density function of U in (i) above.

(b) Let $X_1, X_2, \ldots, X_n$ be a random sample from Poisson.

(i) Find the most powerful test for testing
$H_0 : \lambda = 0.1$ versus $H_1 : \lambda = 0.2$ at $\alpha = 0.143$, for $n = 20$.

(ii) Find the power of the test derived in (i) above.
Hint: If x_j $P(\lambda)$, then $\sum_{j=1}^{n} x_j$ $P(n\lambda)$.

(c) Let $X_1, X_2, \ldots\ldots, X_n$ be a random sample from

$$f_x(x,\theta) = (\theta+3)(1-x)^{\theta+2}, \quad 0 < x < 1.$$

(i) What is the parameter space for θ?
(ii) Find the sufficient statistics for θ.
(iii) Find the MLE for θ.
(iv) Find the Cramer-Rao lower bound for θ.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER FINAL EXAMINATIONS - MARCH 1998

M 411

TIME: THREE (3) HOURS

INSTRUCTIONS: ATTEMPT ANY FIVE QUESTIONS. ALL QUESTIONS CARRY EQUAL MARKS.

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1. (a) State and Prove De Moivre's theorem for any positive integer n.

(b) Show that $\left(\dfrac{1+i\sqrt{3}}{1-i\sqrt{3}}\right)^{10} = -\dfrac{1}{2} + i\dfrac{\sqrt{3}}{2}$.

(c) Prove that if f(z) is analytic in D, then

$$\left(\frac{\partial}{\partial x}|f(z)|\right)^2 + \left(\frac{\partial}{\partial y}|f(z)|\right)^2 = |f'(z)|^2$$

in D.

2. (a) Show that $\sin^{-1} z = -i\ln\left(iz + \sqrt{1-z^2}\right)$

(b) Let $z = x + iy$. By considering z and $\bar{z}$ to be independent variables, show that

$$\frac{\partial}{\partial z} = \frac{1}{2}\left(\frac{\partial}{\partial x} - i\frac{\partial}{\partial y}\right),\quad \frac{\partial}{\partial \bar{z}} = \frac{1}{2}\left(\frac{\partial}{\partial x} + i\frac{\partial}{\partial y}\right).$$

(c) Hence show that if ϕ satisfies Laplace's equation, then in terms of z and $\bar{z}$, Laplace's equation becomes $\dfrac{\partial^2\phi}{\partial z\partial\bar{z}} = 0$.

3. (a) Give necessary and sufficient conditions for analyticity of a function $f(z) = U(x,y) + iV(x,y)$ in some domain D.

(b) Prove that the function

$$f(z) = \frac{x^4 - y^4}{x^3 + y^3} + i\frac{x^4 + y^4}{x^3 + y^3}, \quad \text{with } f(0)=0,$$

is not analytic at the origin.

(c) Given that $U = \cosh x \sin y$, show that U is harmonic and find its corresponding harmonic conjugate. Hence write down the corresponding analytic function $f(z) = U + iV$ in terms of z.

4. (a) Definee a conformal map. Hence show that the mapping $f(z) = z^2$ is conformal.

(b) Show that the transformation $w = iz + i$ maps the half-plane $x > 0$ onto the half plane $v > 1$ and the region $y > -1$ onto the region $u < 1$. Sketch the regions.

(c) Find the Moebius transformation that maps the points $i, -i$ and 1 into the points $0, 1, \infty$ respectively. Determine the region in the w-plane which is the image of the interior of the circle defined by the three points in the z-plane.

5. (a) State without proof Green's theorem for a simple region. Hence prove that if $f(z)$ is analytic in a simply connected domain D and also on its boundary C which is a piece-wise smooth closed simple curve, then, assuming that $f'(z)$ is continuous in D, $\int_c f(z)dz = 0$.

(b) Show that

$$\left|\int_c \frac{\sinh 2z}{z^2}dz\right| \leq \frac{2\pi \cosh 2R}{R},$$

where C is the circle $|z| = R$.

(c) Use contour deformation to evaluate

$$\int_c \frac{4z^2 + 9iz + 27}{z\left(z^2+9\right)}dz$$

where C is the perimeter common to the circles

$|z-3| = 4$ and $|z+2| = 3$.

6. (a) Simplify $\left(1+i\sqrt{3}\right)^{2-5i}$

(b) Evaluate $\int_0^{2\pi} \frac{dx}{2+\cos x}$ by means of contour integration.

(c) The real variable Legendre polynomial $P_n(x)$ may be defined by means of Rodrigues' formula

$$P_n(x) = \frac{1}{2^n n!}\frac{d^n}{dx^n}\left[\left(x^2-1\right)^n\right].$$

Show that in the complex plane

$$P_n(z_0) = \frac{1}{2\pi i}\int_c \frac{(z^2-1)^n}{2^n(z-z_0)^{n+1}}dz,$$

where C is any simple closed contour about the point z_0.

7. (a) Evaluate $\int_c \frac{dw}{(w-z)^n}$, $n = 2, 3, 4, \ldots\ldots$ where $w = z$ is inside the simple closed curve C.

(b) Evaluate $\int_c \frac{\sin 2z}{(z-\frac{\pi}{4})^3(z^2+9)}dz$, where C is the square with corners at $2+2i, -2+2i, -2-2i$ and $2-2i$.

(c) State the mean value therorem and verify it by using $f(z) = 3 + 2z$ and $z_0 = 0$.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER FINAL EXAMINATIONS - MARCH 1998

M421

TIME: THREE (3) HOURS

INSTRUCTIONS: ATTEMPT FOUR (4) QUESTIONS IN ALL AND AT LEAST TWO (2) QUESTIONS FROM SECTION A PLUS AT LEAST ONE (1) QUESTION FROM SECTION B.

SECTION A (STRUCTURE OF GROUPS)
(ATTEMPT AT LEAST TWO (2) QUESTIONS FROM THIS SECTION)

1. Define each of the following terms:

(i) a solvable group G.

(ii) a nilpotent group G.

(a) (i) Given that a group G contains a solvable normal subgroup N such that G/N is solvable, show that G is a solvable group.

(ii) Given that a nilpotent group G contains a normal subgroup N, prove that G/N is nilpotent.

(b) (i) Show that the symmetric group S_5 of degree 5 is not solvable.

(ii) Show that every finite p–group is nilpotent.

2. Let G be a permutation group acting on a set Ω. What is meant by each of the following:

(i) the stabilizer G_α of $\alpha \in \Omega$ in G.

(ii) G is transitive on Ω.

(a) (i) Show that for each $\alpha \in \Omega$, the subset G_α is a subgroup of G, and that if G is a primitive transitive group on Ω then G_α is maximal for each α.

(ii) If for $\alpha_i, \alpha_j \in \Omega$ and some $x \in G$ the condition $\alpha_j = \alpha_i^x$ holds, show that $G_{\alpha_j} = xG_{\alpha_i}x^{-1}$. Hence deduce that if G is transitive on Ω then all the stabilizer subgroups G_α are conjugate in G.

(b) (i) Show that if G is a primitive regular permutation group of finite degree, then it has prime power order.

(ii) Let G be an arbitrary group and let Ω be a set for which for each $\alpha \in \Omega$ and each $x \in G$, the element $\alpha^x \in \Omega$ has property that the map $\phi_x : \alpha \to \alpha^x$ is a permutation of Ω. Then show that ϕ is a homomorphism with kernel = $\bigcap_{\alpha \in \Omega} G_\alpha$.

3. Define each of the following terms

(i) a <u>sylow p-subgroup</u> of a group G.
(ii) the <u>semi-direct product</u> of two groups H and K.

(a) (i) Let p^r be the highest power of a prime p which divides the order of a group G. Show that G has a subgroup of order p^r.

(ii) Prove that a semidirect product of two groups H and K is a direct product if and only if K is normal in G.

(b) (i) Let G be a group of order $p^{\alpha}k$, where p is a prime and let H be its subgroup of order $p^{\alpha}l$, where $(k, l) = 1$. Then show that H contains all the sylow p-subgroups of G.

(ii) Let G be a group of order pq, where p and q are primes and such that $p > q$, and q does not divide $p - 1$. Then show that G is a direct product of a sylow p-subgroup and a sylow q-subgroup.

4. What is the meaning of each of the following terms:

(i) the <u>direct product</u> of groups $H_1, H_2, \ldots\ldots, H_r$.

(ii) the <u>projective special linear group</u> $PSL(m, k)$.

(a) (i) Show that if G is a group with normal subgroups $H_1, H_2, \ldots, H_r$ and such that the following conditions hold

$$G = H_1 H_2 \ldots H_r$$
and
$$H_1 H_2 \ldots H_{i-1} \cap H_i = \{1\}$$

then each element of G has a unique expression of the form $g = g_1 g_2 \ldots g_r$, where $g_i \in H_i$.

(ii) Let $GL(m, q)$ denote the group of $m \times m$ non-singular matrices over the Galois field $GF(q)$, where $q = p^n$. Let σ be a generator of $GF(q)$. Show that for each divisor t of $q - 1$, the set

$$M(t) = \{A \in GL(m, q) \mid \det A = \text{power of } \sigma^t\}$$

is a normal subgroup of $GL(m, q)$ of order $\dfrac{|GL(m, q)|}{t}$

Show that $GL(m, q)$ is of order $(q^m - 1)(q^m - q)\ldots(q^m - q^{m-1})$ and deduce the order $|SL(m, q)|$ of $SL(m, q)$. Hence confirm that $PSL(m,q)$ is of order $\frac{(q^m - 1)(q^m - q)\ldots\ldots(q^m - q^{m-1})}{d(q-1)}$, where $d = (m, q-1)$.

(b) (i) Show that if each sylow subgroup of a finite group G is normal then G is a direct product of its sylow subgroups.

(ii) Compute the orders of the linear groups $PSL(2, 4)$ and $PSL(2, 5)$. Hence by using the fact that the alternating group A_5 of degrees 5 is the only simple group of order 60 or otherwise, confirm that $PSL(2, 4)$ is isomorphic to $PSL(2, 5)$.

SECTION B (REPRESENTATIONS OF GROUPS)
(ATTEMPT AT LEAST ONE (1) QUESTION FROM THIS SECTION)

5. Define each of the following terms:

(i) a completely reducible representation T of a group G.
(ii) the group algebra KG of G over the field K.

(a) (i) Prove that over an algebraically closed field K whose characteristic does not divide the order of a group G, all matrix representations of G are completely reducible.

(ii) Show that there is a bijection between the representation of a finite group G and the representations of its group algebra KG.

(b) (i) Show that the mapping $T : G \to GL(2, C)$ of the group $G = \langle \alpha | \alpha^3 = 1 \rangle$ to $GL(2, C)$ given by $T(\alpha) = \begin{pmatrix} 0 & 1 \\ -1 & -1 \end{pmatrix}$ is an irreducible representation of G over the set of reals.

(ii) Show that the symmetric group S_3 degree 3 has exactly three irreducible characters.

Show that the map $X : S_3 \to \{1, -1\}$ defined by

$$X(g) = \begin{cases} 1 \text{ if } g \text{ is even in } S_3 \\ -1 \text{ if } g \text{ is odd in } S_3 \end{cases}$$

is an irreducible representation of S_3 of degree 1. Hence determine the character table of S_3.

6. Define each of the following terms:

(i) equivalent representations

(ii) the character of a representation of a finite group G.

(a) (i) State and prove Schur's lemma.

(ii) Prove that equivalent representations have the same character.

Let H be a normal subgroup of G and T' a representation of G/H. Show how a representation T of G may be lifted from T'. If T is a representation of G with character x, show that $K = \{g \in G / x(g) = x(e)\}$ is a normal subgroup of G and that T is a representation of G/K.

(b) (i) Let $V = < x, y | x^2 = y^2 = 1, xy = yx >$. Then by assigning to x and y in turn the numbers 1 and −1 or otherwise, determine the character table of V.

(ii) Let $Q_8 = < a, b | a^4 = e, a^2 = b^2, b^{-1}ab = a^3 >$, the quaternion group of order 8. Then determine the five conjugacy classes of Q_8. Show that $N = \{1, a^2\}$ is a normal subgroup of Q_8 and determine Q_8/N, and confirm that $Q_8/N \cong V$, where V is the group in b(i). Hence by using the character table in V or otherwise, determine the character table of Q_8.

END OF EXAMINATION

THE UNIVESITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS MARCH 1998

M 431

FOURTH YEAR MATHEMATICS

TIME: THREE (3) HOURS

INSTRUCTIONS: ANSWER ANY FIVE (5) QUESTIONS

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1. (a) Define partially ordered set and give two examples of that.

(5 marks)

(b) State Zorn's lemma and indicate how it can be applied in a particular situation.

(5 marks)

(c) State and prove Minkowski's inequality for l_p^n, $1 \le p < \infty$.

(10 marks)

2. (a) Let l^∞ denote the set of all bounded sequences of real numbers. Define $d\left(x, y\right) = \sup\limits_{1 \le n \le \infty} |x_n - y_n|$.
Prove that l^∞ is a metric space.

(10 marks)

(b) Prove that l^∞, the space of all bounded sequences, is not separable.

(10 marks)

3. (a) Prove that $C[a, b]$ is a complete metric space.

(12 marks)

(b) Let $\left(X, d\right)$ be a complete metric space and let E be a closed subset of X. Prove that $\left(E, d\right)$ is complete.

(8 marks)

4. (a) Prove that the subset E of the metric space $\left(X, d\right)$ is totally bounded if and only if for every $\varepsilon > 0$, E contains a finite subset - which is ε-dense in E.

(10 marks)

(b) If the subset E of the metric space (X, d) is totally bounded, prove that E is bounded.

(10 marks)

5. (a) Prove that the metric space (X, d) is compact if and only if every sequence of points in X has a subsequence converging to a point in X

(12 marks)

(b) Let E be a subset of a metric space (X, d). If (E, d) is compact, then prove that E is a closed subset of (X, d).

(8 marks)

6. (a) Let E be a bounded and closed set in R. Prove that every open covering of E has a finite sub-covering.

(10 marks)

(b) Prove that a compact metric space is separable.

(10 marks)

7. (a) Let (X, d_1) and (Y, d_2) be metric spaces. Let $f : X \to Y$ be a continuous function. If X is compact then prove that $f(x)$ is also compact.

(10 marks)

(b) Let $f : X \to Y$ be a uniformly continuous function. Let (x_n) be a Cauchy sequence in X. Prove that $f((x_n))$ is also a Cauchy sequence in Y.

(10 marks)

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER FINAL EXAMINATIONS - MARCH 1998

M465

TIME: THREE (3) HOURS

INSTRUCTIONS: ANSWER FOUR (4) QUESTIONS

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1. (a) Give 2 advantages and 2 disadvantages of nonparametric procedures.

(b) What measurement scale is used in the following:

(i) telephone area codes
(ii) postal zip codes
(iii) Your student identification number
(iv) In a certain sporting event a trophy is awarded to the team that accumulates the most points. A team receives 5,3, or 1 point each time a member of that team finishes first, second or third, respectively in competition. (What measurement scale is used in awarding points?)

(c) The 'tidal volume' of adults suffering from disease of the arteries was recorded. Some of the adults were suffering from high blood pressure while others were not.

Use a Mann-Whitney test to assess whether the tidal volume is lower in patients without high blood pressure than for those with high blood pressure. (The 0.95 quantile is 180)

The data recorded are as follows:

Without HBP

652	556	618	500	500
526	511	538	440	547
605	500	437	481	572

With HBP

876	556	493	348
530	780	569	546
766	819	710	

2. (a) (i) Define the empirical distribution function

(ii) Six married women were selected at random from among the married women in a ladies civic club and the number of children belonging to each was recorded. These numbers were 0, 2, 1, 2, 3, 4.

Graph the empirical distribution function.

(b) An experiment was conducted at a particular shop concerning the arrival of customers. The times between successive arrivals over a two hour period one morning were recorded.

The data are given below in minutes

3.6	14.2	10.8	22.4	1.4	6.2
6.1	4.2	3.3	8.2	38.0	

Test at the 5% significance level whether inter-arrival times are exponentially distributed with mean $\lambda = 0.1$. (The 0.95 quantile is 0.391).

3. (a) The ratio of soluble starch to enzyme level was determined from saliva specimens for 11 subjects. The data are as follows:

0.78	0.86	0.82	1.10	0.71	1.00
0.65	0.85	0.64	0.86	0.70	

Using a sign test, test at the 5% significance level whether the population upper quartile is greater than 0.80.

(b) (i) A random sample of ten companies have reported their rate of change in advertising expenses, x, and their rate of change in sales, y, for last year as compared with the previous year.

x:	4	62	31	-11	47	88	16	-1	74	21
y:	10	33	39	-14	37	39	18	-8	45	33

Calculate Spearman's coefficient of rank correlation between x and y.

(ii) Is there any relationship between the rate of change in advertising expenses and sales based on Spearman's coefficient of rank correlation? The 0.025 and 0.975 quantiles for spearman's rho are -0.6364 and 0.6364 respectively.

4. Four different methods of growing corn were randomly assigned to a large number of different plots of land and the yield per acre was computed for each plot.

Method

1	2	3	4
83	91	101	78
91	90	100	82
94	81	91	81
89	83	93	77
89	84	96	79
96	83	95	81
91	88	94	80
92	91		81
90	89		
	84		

Determine whether there is a difference in yields as a result of the method used, using

(a) The Median test

(b) The Kruskal-Wallis test.

5. (a) Let (x_i, y_i), $i = 1, 2, \ldots\ldots, n$ be a bivariate random sample of size n. Show that if all pairs are discordant the value of Kendall's tau is -1.

(b) The following are the scores on a certain test given to 13 pairs of nonidentical female twins

	1	2	3	4	5	6	7	8	9
x_i :	277	169	157	139	108	213	232	229	114
y_i :	256	118	137	144	146	221	184	188	97

10	11	12	13
232	161	149	128
231	114	187	230

(i) Calculate Kendall's Tau.

(ii) Use Kendall's test statistic to test the hypothesis of independence against the alternative of postive dependence at the 5% significance level. (The 0.95 quantile is 26).

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER FINAL EXAMINATIONS - MARCH 1998

M 491

MATHEMATICS

TIME: THREE (3) HOURS

INSTRUCTIONS: ANSWER ANY FIVE (5) QUESTIONS.

MATHEMATICAL TABLES AND CALCULATORS ARE ALLOWED.

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1. (a) A positive integer z is selected with $p(z = n) = \left(\frac{1}{2}\right)^n$, $n = 1, 2, \ldots$
If z takes the value n, a coin with probability e^{-n} of heads is tossed once.
Find the probability that the resulting toss is a head.

(b) Suppose that the continuous random variable x has pdf
$f(x) = \frac{1}{2}e^{-|x|}$, $-\infty < x < \infty$.

(i) Obtain the moment generating function of x.
(ii) Using the moment generating function found in (i), find E(x) and Var(x).

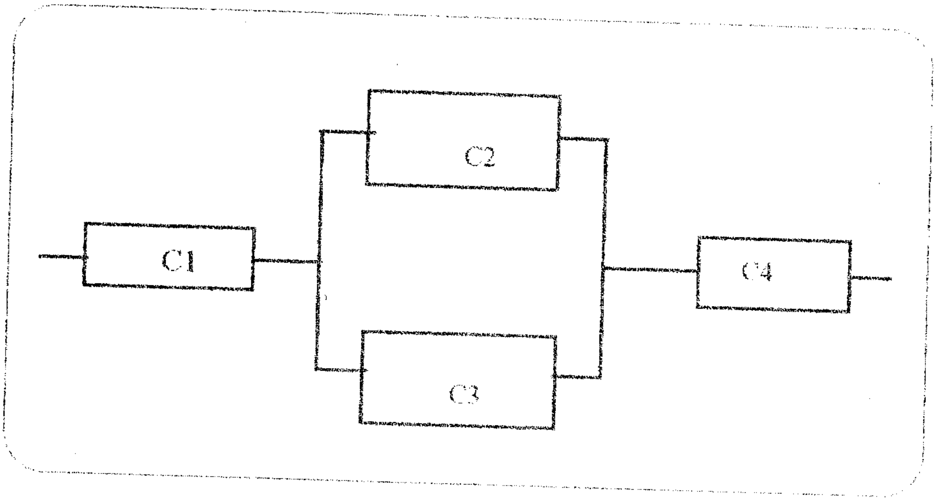
(c) Let x be a random variable with pdf and cdf.
[Assume that $f(x) = 0$, $x \notin (a, b)$].
Let Y be the random variable defined by $Y = F(x)$. Prove that Y is uniformly distributed over [0,1].

2. (a) An electronic system has three components C_1, C_2, and C_3 which function independently of each other. Let $R_i(t)$, $i = 1, 2, 3$ be the reliability of the system at time t.

Suppose the system fails if at least one of the components fails.

(i) Draw the structure of this system showing the arrangement of the three components.
(ii) Find the reliability of the system.
(iii) Assume that the components have exponential lifetime distributions with failure rates $\lambda = 0.03$, $\lambda_2 = 0.01$, $\lambda_3 = 0.04$, and that the system has failed. Compute the probability that component C_2 is the cause of the system failure.

(b) Consider the following system:



(i) Determine the minimal paths and minimal cuts for this system.

(ii) Write down two expressions (one cut-based and one path-based) for the structure function of this system.

(iii) By multiplying out the two expressions in (ii) above, verify that they are equivalent.

(iv) Suppose that each of the four components has a failure law given by an exponential distribution with parameters $\lambda_1, \lambda_2, \lambda_3$ and λ_4.

α Obtain an expression for R(t), the reliability of the system.

β Obtain an expression for the pdf of T, the time to failure of the system.

γ Find the mean time to failure of the system.

θ Find $\lim_{t\to\infty} R(t)$. Explain your answer in words.

3. (a) Random variables x and y are said to be orthogonal if and only if $E[xy] = 0$.

(i) If x and y are orthogonal determine the conditions under which they are uncorrelated.

(ii) If x and y are uncorrelated, determine the conditions under which they are orthogonal.

(b) Consider n repetitions of an experiment and let x be the number of times some event, say A, occurs. Let $p(A) = p$ and assume that this number is constant for all repetitions.

Define the auxillary random variables as follows:

$Y_i = 1$ if the event A occurs on the ith repetition.
$= 0$ elsewhere.

If $x = Y_1 + Y_2 + \ldots Y_n$, show that $E(x) = np$.

(c) Let $f(x) = \lambda\alpha x^{\alpha-1} e^{-\lambda x^{\alpha}}, x > 0$.

Find the $E(x)$ and $E(x^2)$

Hence show that

$$Var(x) = \left(\frac{1}{\lambda}\right)^{2/\alpha} \left\{ \Gamma(1 + \tfrac{2}{\alpha}) - \left[\Gamma\left(1 + \frac{2}{\alpha}\right)\right]^2 \right\}$$

4. (a) Let X be a random variable with finite $E(x) = \mu$.
Prove the Markov inequality given by

$P[x \geq t] \leq \mu/t, \qquad t > 0.$

(b) (i) State the relationship between the moment generating function and the Laplace transform.

(ii) State two advantages which the characteristic function has over the moment generating function.

(iii) Let x be a continuous random variable whose Laplace transform is given by

$$L_x(s) = \frac{1}{(a+s)(b+s)}$$

Find the pdf of x.

(c) Prove that if h is the characteristic function of the bounded distribution function F, and $F(a, b] = F(b) - F(a)$ then

$$F(a, b] = \lim_{c \to \infty} \frac{1}{2\pi} \int_{-c}^{c} \frac{e^{-iva} - e^{-ivb}}{iv} h(v)dv$$

for all points a, b $(a < b)$ at which F is continuous. If in addition h is Lebesgue integrable on $(-\infty, \infty)$ then the function

$$F(x) = \frac{1}{2\pi}\int_{-\infty}^{\infty} e^{-ivx}h(v)dv$$

is a density for F.

5. (a) Define the following:

   (i) the Laplace transform of the continuous random variable x,
   (ii) the characteristic function of the continuous random variable x.

   (b) Let $X_i, i = 1, 2$ be independent exponentially distributed random variables with parameters λ_i. Assuming that $\lambda_1 \neq \lambda_2$, find the Laplace transform $L_T(s)$ where $T = x_1 + x_2$. Hence find the probability density function of T.

   What is the name of this function?

   (c) Let X be normally distributed with parameters μ and σ^2 such that

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}}\exp\left[-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2\right], \quad -\infty < x < \infty.$$

   (i) Derive the characteristic function of x.
   (ii) Using the characteristic function found in (i) above, confirm that $E(x) = \mu$ and find $E(x^2)$.

6. (a) Let ε be an experiment and let A be an event associated with ε. Consider n independent repetitions of ε, let n_A be the number of times A occurs among the n repetitions and let $f_A = \frac{n_A}{n}$. Assume $p(A) = p$ to be the same for all repetitions.

   Prove that for every positive number ε, we have

$$p[\,|f_A - p| \geq \varepsilon\,] \leq \frac{p(1-p)}{n\varepsilon^2}$$

   or equivalently,

$$p[\,|f_A - p| < \varepsilon\,] \geq 1 - \frac{p(1-p)}{n\varepsilon^2}.$$

   (b) A production process is operated in such a manner that there is a probability p that each item is defective, and p is unknown. A random sample of n items is to be selected to estimate p. The estimator to be used is $\hat{p} = y/n$, where

$$X_i = \begin{cases} 0 \text{ if the jth item is good} \\ 1 \text{ if the jth item is defective} \end{cases}$$

and $Y = X_1 + X_2 + \ldots + X_n$.
How large should n be so that the probability be at least 0.95 that the error, $|\hat{p} - p|$, not exceed 0.01?

(c) Let T, the time to failure, be a continuous random variable with probability distribution function f.

Prove that if F(0)=0, where F is the cumulative distribution of T, then
$f(t) = z(t)e^{-\int_0^t z(s)ds}$

where z is the failure rate.

7. (a) Define the following:

(i) A sequence $\{x_n\}$, $n \geq 1$ is a martingale.

(ii) A sequence $\{x_n\}$, $n \geq 1$ is a submartingale.

(b) Let $Y_1, Y_2, \ldots$ be independent random variables with mean zero. Let
$X_n = \sum_{k=1}^{n} Y_k$, $\beta_n = \beta(Y_1, \ldots Y_n)$, $n = 1, 2, \ldots$

Prove that $\{X_n, \beta_n\}$ is a martingale.

(c) Let $\{x_n, \beta_n\}$ be a submartingale and let $\varepsilon_1, \varepsilon_2, \ldots$ be random variables defined by

$$\varepsilon_k = \begin{cases} 1 \text{ if } (x_1, \ldots, x_k) \in A_k \\ 0 \text{ if } (x_1, \ldots, x_k) \notin A_k \end{cases}$$

where the A_k are arbitrary sets in R^n.

Set $Y_1 = x_1$

$Y_2 = x_1 + \varepsilon_1(x_2$

.

.

$Y_n = x_1 + \varepsilon_1(x_2 - x_1) + \ldots + \varepsilon_{n-1}(x_n - x$

Prove that $\{Y_n, \beta_n\}$ is a submartingale.

END OF EXAMINATION

UNIVERSITY OF ZAMBIA

UNIVERSITY SECOND SEMESTER FINAL
EXAMINATIONS - AUGUST/SEPTEMBER 1998.

MATHEMATICS M492 - SYSTEMS ANALYSIS AND DESIGN

INSTRUCTIONS: Answer ANY Five(5) Questions.

TIME ALLOWED: Three(3) Hours.

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1. a) HIPO Charts are developed basically to aid the technical aspects of computer Systems Design. List down the three main types of diagrams found in HIPO Charts.

   b) List down two main disadvantages of HIPO Charts over other techniques in Systems Design.

   c) Suppose that, as a Systems Analyst, you have been asked by the Head of Department, Mathematics and Statistics, to design a system that would be providing student information. The system should be able to:

      i) create a permanent Student-File from Data fields entered,
      ii) load the Student-File,
      iii) create a temporary Updated-Student-File from the loaded Student-File (Additions, Deletions, Changes),
      iv) create a permanent Backup-Student-File from the loaded Student-File, and
      v) inquire into the loaded Student-File and display student records.

   Design an Overview Diagram for the system described above.

2. a) What do you understand by the term ORDINARY FLOWCHART as applied to Systems Design and Analysis?

   b) List down four main disadvantages of Ordinary Flowcharts over other types of Flowcharts in Systems Design and Analysis.

   c) The Manager of MDM Commercial Bank Ltd wants to introduce a cash-point withdrawing system which would be operating as follows:

2(c)\cont..

Firstly, the system should asks for the customer's card. If he enters an invalid card, it should be rejected, otherwise the system should ask for his PIN (Personal Identification Number). If he enters an incorrect PIN, the system should give him another chance to enter his PIN. If he enters an incorrect PIN four times, the system should 'swallow' the card. If the customer entered the correct PIN, the system should ask for the amount. If he enters an amount which is beyond his balance, the system should give him another chance to enter the amount. If he enters too much an amount three times, the system should swallow his card. If he entered an amount within his balance, he should get his card, and then his cash.

Suppose that the Manager has hired you, as a Systems Analyst, to design and implement the system described above. Draw a clearly labelled Ordinary Flowchart for the system.

3. a) Decision Tables and Decision Trees are two of the techniques used in describing process specifications and structured decisions. List down two factors that would let you choose a Decision Tree rather than a Decision Table.

b) Suppose that the following procedure describes how the four possible comments are decided for the examination results of students doing M942:

If a student gets at least 50% in the final exam and if he gets at least 40% in the continuous assessment, which includes a Project, then he has a clear pass, else he has an arrear. But if a student gets below 50% in the final exam and if he gets at least 40% in the continuous assessment, then he goes on part-time, else he is excluded from UNZA.

If a student doesn't do the M942 Project, then he is excluded from UNZA.

Prepare a Decision Table for the procedure described above.

c) Prepare a Decision Tree for the procedure described in (b) above.

4. a) Nassi-Shneiderman(N-S) Charts and Warnier-Orr(W-O) Diagrams are two of the techniques used in Systems Design and Development. Which of the two techniques is better? Give two reasons.

b) The following is the Newton-Raphson Algorithm for finding a solution to $f(x) = 0$ given an initial approximation P_o:

4(b)\cont..

INPUT Initial Approximation Po, Tolerance TOL,
Maximum Number of Approximations N.
OUTPUT Approximate Solution P or Message of Failure.
STEP 1 Set i = 1.
STEP 2 While i ≤ N DO steps 3-6.
STEP3 set P = Po - f(Po)/f'(Po)
STEP 4 If | P- Po | < TOL Then
OUTPUT(P).
STOP.
STEP 5 set i = i + 1.
STEP 6 set Po = P
STEP 7 OUTPUT Message of Failure.
STOP.

Draw an N-S Chart for the above algorithm.

c) Draw a W-O Diagram for the Newton-Raphson procedure described in (b) above.

5. a) Define the following terms as applied to Data, Databases and Database Management Systems.

i) Entity (ii) Primary Key (iii) Relationship

b) List down the three main types of Relationships, giving two examples (diagrams) in each case.

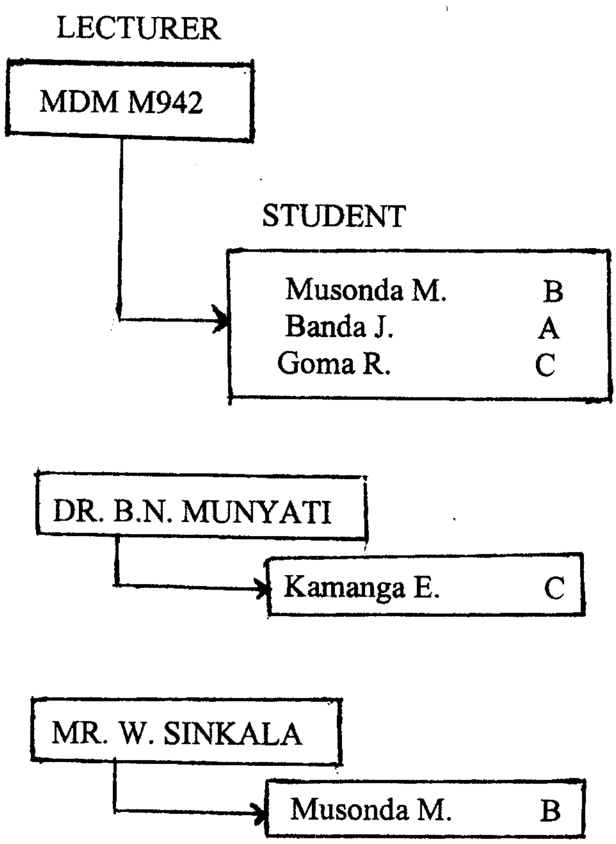
c) Consider a STUDENT-COURSE Relationship with the attributes as shown below:

STUDENT{Compno, Sname, DOB, Address}
COURSE{Coursecode, Coursename, Dept}
ATTENDS{Compno, Coursecode, Mark}

i) State the Entries/Entity in each of the above three Relations.
ii) Identity the Primary Key in each of the above three Relations.
iii) Draw an Entity-Relationship Diagram for the STUDENT-COURSE Relationship.

6. a) Hierarchical, Network and Relational Data Models are the three main types of logically Structured Databases. Which of the three types is most widely used in Database design? Give two reasons.

b) The user view below is an example of a Hierarchical Data Structure showing some student grades:



Draw a Network Data Structure for the above user view.

c) Draw a Relational Data Structure for the user view given in (b) above.

END OF EXAMINATION.

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

M 911

MATHEMATICAL METHODS

TIME: THREE (3) HOURS

INSTRUCTIONS: ATTEMPT ANY FIVE (5) QUESTIONS

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1. (a) Find the directional derivative of $2x + 3y^2 - yz^2$ at the point $(2, -1, 5)$ along a line whose directional ratios are $[1, 1, 2]$. State whether the function is decreasing or increasing in this direction.

   (b) A tank is in the form of a cylinder with plane ends. Using Lagrange multipliers, show that the volume is maximum for a given surface area when the height is equal to the diameter of the plane ends.

2. (a) Examine the function $x^3 + 3x^2 + 2y^2 + z^2 - y^2z$ for maximum and minimum values.

   (b) Find the point(s) on the curve of intersection of $x^2 + z^2 = 4$ and $x - y = 8$ that is (are) furthest from the origin.

3. (a) Prove that $\text{curl}\left(\bar{r}r^n \times \hat{K}\right) = nr^{n-2}z\bar{r} - (n+2)r^n\hat{k}$ where $\bar{r}$ is the position vector.

   (b) Show in general that the surfaces $3x^2 + 4y^2 + 8z^2 - 36$ and $x^2 + 2y^2 - 4z^2 - 6$ intersect at right angles.

4. (a) Let $z = \frac{x}{\sqrt{x^2 + y^2}}$ represent a surface. Obtain
   (i) the parametric representation of the surface.
   (ii) the normal vector to the surface at any point,
   (iii) the Cartesian equation of tangent plane,
   (iv) equation of the normal line.

   (b) Let $x = u^2 + v^2 + w^2$, $y = u + v + w$ and $z = uvw$.
   Show that $J(u, v, w) = (u - v)(v - w)(u - w)$.

5. (a) For the space curve $x = e^t \sin t$, $y = e^t \cos t$, $z = e^t$, obtain the following at the point $t = 0$:

(i) the unit tangent vector $\bar{T}$.

(ii) the principal normal vector $\bar{n}$ and curvature K.

(iii) the binormal vector $\bar{B}$.

(b) Find the length of the space curve above from $t = 0$ to $\pi/2$.

(c) Evaluate $\int_c \left(x^2 + y^2\right) ds$ where c is the path $y = -x$ from $\left(1,-1\right)$ to $\left(2,-2\right)$.

6 (a) Show that the third degree Taylor polynomial of $\cos\left(x + 2y\right)$ at the point $\left(0,0\right)$ is $1 - \frac{(x+2y)^2}{2!}$.

(b) By obtaining the parametric representation of the surface $z = x^2 + y^2$ where $0 \le z \le 1$, find the total surface area of S.

END OF THE EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

M 981

NUMERICAL ANALYSIS I

TIME: THREE (3) HOURS

INSTRUCTIONS: ATTEMPT ANY FIVE (5) QUESTIONS.

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1. (a) Write an algorithm to find a solution to $f(x) = 0$ given the continuous function f on the interval $[a, b]$ where $f(a)$ and $f(b)$ have opposite signs.

   (b) Use the algorithm in part (a) to find an approximation to $x - \sin x - 1 = 0$, to within 10^{-3}. Find a bound for the number of iterations needed to achieve this accuracy.

2. The following data has been experimentally collected:-

x	0.2	0.4	0.6	0.8	1.0
f(x)	0.9798652	0.9177710	0.8080348	0.6386093	0.3843735

   (a) Approximate $f(0.25)$ using the Newton forward divided-difference formula.

   (b) Use methods of error $0(h^2)$ to approximate $f'(0.2)$, $f'(1.0)$ and $f'(0.6)$.

3. (a) Derive the Newton-Raphson formula.

   (b) Use the Newton-Raphson method to approximate, to within 10^{-4}, the value of x that produces the point on the graph of $y = x^2$ that is closest to $(1, 0)$.

4. (a) Given the function f at the following values

x	1.8	2.0	2.2	2.4	2.6
f(x)	3.12014	4.42569	6.04241	8.03014	10.46675

   approximate $\int_{1.8}^{2.6} f(x)dx$ using Simpson's rule

   (b) The arclength of the graph of a function g on $[a, b]$ is given by the integral

$L = \int_a^b (1+[g'(x)]^2)^{\frac{1}{2}} dx$. Compute the arclength of the graph of

$g(x) = \tan x$ on $\left[0, \frac{\pi}{2}\right]$ using the trapezoidal rule over 5 intervals.

5. (a) Given that $f(0.25) = f(0.75) = \alpha$, find α if the composite trapezoidal rule with $n = 2$ gives the value 2 for $\int_0^1 f(x)dx$ and gives the value 1.75 with n=4.

(b) Determine the values of n and h required to approximate $\int_0^{\pi} \sin x dx$ with an absolute error less that 2×10^{-5} using the composite Simpson rule.

(c) Let $P_3(x)$ be the interpolating polynomial for the data (0.0), (0.5, y), (1,3) and (2, 2). Find y if the coefficient of x^3 in $P_3(x)$ is 6.

6. (a) Derive the Richardson extrapolation formula.

(b) Apply the Richardson extrapolation process to determine $L_3(h)$, an approximation to $f'(x_o)$ for the function $f(x) = xe^x$, with $x_o = 2.0$ and $h = 0.2$.

7. (a) Determine by Lagrange's formula the percentage number of criminals under 35 years given the following data:

Age	% Number of criminals
Under 25 years	52
Under 30 years	67.3
Under 40 years	84.1
Under 50 years	94.4

(b) Find the polynomial of the lowest degree which assumes the values 3, 12, 15, −21 when x has the values 3, 2, 1, −1 respectively.

END OF THE EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

M 981

NUMERICAL ANALYSIS I

TIME: THREE (3) HOURS

INSTRUCTIONS: ATTEMPT ANY FIVE (5) QUESTIONS.

---

1. (a) Write an algorithm to find a solution to $f(x) = 0$ given the continuous function f on the interval $[a, b]$ where $f(a)$ and $f(b)$ have opposite signs.

   (b) Use the algorithm in part (a) to find an approximation to $x - \sin x - 1 = 0$, to within $10^{-[illegible]}$. Find a bound for the number of iterations needed to achieve this accuracy.

2. The following data has been experimentally collected:-

x	0.2	0.4	0.6	0.8	1.0
f(x)	0.9798652	0.9177710	0.8080348	0.6386093	0.3843735

   (a) Approximate f(0.25) using the Newton forward divided-difference formula.

   (b) Use methods of error $O(h^2)$ to approximate $f'(0.2)$, $f'(1.0)$ and $f'(0.6)$.

3. (a) Derive the Newton-Raphson formula.

   (b) Use the Newton-Raphson method to approximate, to within 10^{-4}, the value of x that produces the point on the graph of $y = x^2$ that is closest to $(1, 0)$.

4. (a) Given the function f at the following values

x	1.8	2.0	2.2	2.4	2.6
f(x)	3.12014	4.42569	6.04241	8.03014	10.46675

   approximate $\int_{1.8}^{2.6} f(x)dx$ using Simpson's rule

   (b) The arclength of the graph of a function g on $[a, b]$ is given by the integral

$L = \int_a^b (1 + [g'(x)]^2)^{\frac{1}{2}} dx$. Compute the arclength of the graph of

$g(x) = \tan x$ on $\left[0, \frac{\pi}{2}\right]$ using the trapezoidal rule over 5 intervals.

5. (a) Given that $f(0.25) = f(0.75) = \alpha$, find α if the composite trapezoidal rule with $n = 2$ gives the value 2 for $\int_0^1 f(x)dx$ and gives the value 1.75 with n=4.

(b) Determine the values of n and h required to approximate $\int_0^{\pi} \sin x dx$ with an absolute error less that 2×10^{-5} using the composite Simpson rule.

(c) Let $P_3(x)$ be the interpolating polynomial for the data (0.0), (0.5, y), (1, 3) and (2, 2). Find y if the coefficient of x^3 in $P_3(x)$ is 6.

6. (a) Derive the Richardson extrapolation formula.

(b) Apply the Richardson extrapolation process to determine $L_3(h)$, an approximation to $f'(x_0)$ for the function $f(x) = xe^x$, with $x_0 = 2.0$ and $h = 0.2$.

7. (a) Determine by Lagrange's formula the percentage number of criminals under 35 years given the following data:

Age	% Number of criminals
Under 25 years	52
Under 30 years	67.3
Under 40 years	84.1
Under 50 years	94.4

(b) Find the polynomial of the lowest degree which assumes the values 3, 12, 15, −21 when x has the values 3, 2, 1, −1 respectively.

END OF THE EXAMINATION

UNIVERSITY OF ZAMBIA

UNIVERSITY SECOND SEMESTER FINAL
EXAMINATIONS - AUGUST/SEPTEMBER 1998.

M982 - NUMERICAL ANALYSIS II

INSTRUCTIONS: Attempt any **five(5)** Questions

TIME ALLOWED: Three (3) hours

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1. Apply the Adams-Bashforth three-step method to obtain the numerical solution to the initial-value problem

$$y' = t^2 + y^2, \ y(0) = 1$$

performing one step with $h = 0.1$.

The method is given by

$$w_0 = \alpha, \ w_1 = \alpha_1, w_2 = \alpha_2$$

$$w_{i+1} = w_i + \frac{h}{12}\left[23f(t_i, w_i) - 16f(t_{i-1}, w_{i-1}) + 5f(t_{i-2}, w_{i-2})\right]$$

(Use a method of $0(h^4)$ for the necessary start)

2. a) Prove that if λ is an eigenvalue of arbitrary nxn matrix

$A = (a_{ij})$, then for some integer k, $(1 \le k \le n)$

$$|a_{kk} - \lambda| \le \sum_{\substack{j=1 \\ j \neq k}}^{n} |a_{kj}|$$

b) Milne's method of solving the initial-value problem $y' = f(t,y)$ $a \le t \le b$, $y(a) = \alpha$, consists of applying the predictor formula

$$w_{i+1} = w_{i-3} + \frac{4h}{3}\left[2f(t_i, w_i) - f(t_{i-1}, w_{i-1}) + 2f(t_{i-2}, w_{i-2}\right]$$

and the corrector formula

$$w_{i+1} = w_{i-1} + \frac{h}{3}\left[f(t_{i+1}, w_{i+1}) + 4f(t_i, w_i) + f(t_{i-1}, w_{i-1}\right].$$

Why are they called 'predictor' and 'corrector'? Can they be applied in any order? Explain why. At how many points t, must the value of y be known initially to apply the method?

3. a) Consider the system of n linear equations in n unknowns $x_1, x_2, \ldots, x_n$

E_1: $a_{11}x_1 + a_{12}x_2 + \ldots + a_{in}x_n = b_1$

$\vdots$

E_n: $a_{n1}x_1 + a_{n2}x_2 + \ldots + a_{nn}x_n = b_n$

where $b_1, b_2, \ldots, b_n$ and a_{ij}, $1 \le i \le n$, $1 \le j \le n$, are given numbers. Describe the Jacobi iterative method for solving the system for the unknowns as an iterative technique.

b) Given the system of linear equations

$$\begin{aligned} 10x_1 + 5x_2 \qquad\qquad &= 6 \\ 5x_1 + 10x_2 - 4x_3 \qquad &= 25 \\ -4x_2 + 8x_3 - x_4 &= -11 \\ -x_3 + 5x_4 &= -11 \end{aligned}$$

Find the first three(3) iterations of the Gauss-Seidel method using

$X^{(0)} = (0,0,0,0)^t$

4. a) Show that the given initial-value problem has a unique solution

$$y' = \frac{-2}{t}y + t^2e^t, \quad 1 \le t \le 2, \quad y(1) = \sqrt{2}e$$

b) Apply Taylor's method of order four(4) to solve the initial value problem

$$y' = y - t^2 + 1, \quad 0 \le t \le 1, \quad y(0) = 0.5$$

using stepsize $h = 0.2$.

5. Let $a = \begin{bmatrix} 2 & 1 & 1 \\ 1 & 2 & 1 \\ 1 & 1 & 2 \end{bmatrix}$

a) Determine the region containing the eigenvalues of A.
b) Find the spectral radius of A
c) Find the first three iterations obtained by the power method applied to A using $X^{(0)} = (1,-1,2)^t$.

6. a) Given the linear system

$$\begin{aligned} 2x_1 - 6\alpha\, x_2 &= 3 \\ 3\, x_1 - x_2 &= 3/2 \end{aligned}$$

i) Find the value(s) of α for which the system has no solutions

ii) Find the value(s) of α for which the system has a infinite number of solutions.

iii) Assuming a unique solution exists for a given α, find the solution.

b) Given the initial value problem

$y' = \frac{y}{t} - \left(\frac{y}{t}\right)^2$, $1 < t < 2$, $y(1) = 1$, with $h = 0.1$, use the Runge-Kutta method of order 4 to approximate the value of y(1.2) correct to four decimal places.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
PHYSICS DEPARTMENT

UNIVERSITY EXAMINATIONS : NOVEMBER - DECEMBER 1997
PARTIAL ENTRY EXAMINATION IN PHYSICS

All questions carry equal marks. The marks are shown in brackets. Attempt five questions. Question one is compulsory. Attempt four more questions, including two from each section. Indicate clearly which questions you have attempted.

Time : Three hours. **Maximum marks : 100**

Wherever necessary, $g = 9.8\ m/s^2$, 1 cal. = 4.186 J, $k = 9.0 \times 10^9\ N.m^2/C^2$

Answer Q1 in the following manner:

a) (?) b) (?)........j) (?). Write the number i, ii, iii, or iv as the case may be in place of the question mark.

Q 1. a) The acceleration of gravity on Mars is $3.7\ m/s^2$. Compared with his mass and weight on earth, an astronaut on Mars has :

i)less mass and less weight
ii)less mass and more weight
iii)the same mass and less weight
iv)less mass and the same weight.

b)In a perfectly elastic collision between two objects, their relative speed after the collision is :

i)zero
ii)less than the relative speed before the collision
iii)equal to their relative speed before the collision
iv)more than their relative speed before collision.

c)The centripetal acceleration of a particle in circular motion

i)is less than its tangential acceleration
ii)is equal to its tangential acceleration
iii)is more than its tangential acceleration
iv)may be more or less than its tangential acceleration.

d)If the sum of the torques on an object in equilibrium is zero about a certain point, it is :

i)zero about no other point
ii)zero about some other points
iii)zero about all other points
iv)any of the above, depending on the situation.

e)The pressure at the bottom of a vessel filled with a liquid does not depend on the :

i)acceleration due to gravity
ii)density of the liquid
iii)height of the liquid
iv)area of the liquid surface.

f)Two waves meet at a certain moment when one has the instantaneous amplitude A, and the other one has the instantaneous amplitude B. Their combined amplitude at that moment is :

i)A + B
ii)A - B
iii)between (A + B) and (A - B)
iv)indeterminate.

g)Two point charges of unknown magnitude and sign are a distance d apart. The electric field is zero at one point located between the charges on the line joining the two charges. It can be concluded that the two charges must have :

i)the same sign
ii)the opposite sign
iii)the same sign and the same magnitude
iv)the opposite sign and the same magnitude.

h)The magnetic flux through a wire in a magnetic field $\vec{\mathbf{B}}$ does not depend on :

i)the magnitude B of the field
ii)the area of the loop
iii)the shape of the loop
iv)the angle between the plane of the loop and the direction of B.

i)The voltage cannot be exactly in phase with the current in a circuit that contains :

i)only a capacitance
ii)only a resistance
iii)inductance and capacitance
iv)inductance, capacitance and resistance.

j)An object is placed at a distance d in front of a converging lens with focal length f. The image will be virtual and larger than the object size if :

i)d < f
ii)d = f
iii)d > f
iv)d = 2f.

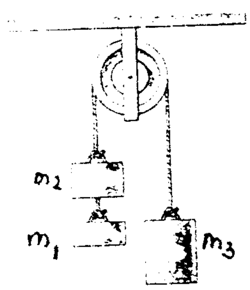
Marks : 10 × 2 = 20.

SECTION A

Answer any two questions from this section!

(a) A person wants to travel a distance of 400 m with his new car. If he starts at rest and can accelerate at 3 m/s^2 , what minimum time will it take to cover this distance if the maximum speed is 30 m/s? [8]

(b) A small girl is pulling a wagon of mass 20 kg along the road. The girl is pulling on the wagon's handle with a force of 20 N. The handle makes an angle of 20^0 with the horizontal. Find the coefficient of kinetic friction between the wagon and the road if the wagon is maintaining a constant velocity. [12]



Consider the system shown in the figure with m_1 = 0.5 kg, m_2 = 0.8 kg and m_3 = 1.0 kg. The pulley is massless and frictionless. The system is released from rest. After the right-hand mass has risen 80 cm, the mass m_1 is cut loose from the system What is the speed of mass m_3 when it returns to its original position? [10]

(b) A 5 kg lump of clay that is moving at 10 m/s to the left, strikes a 6 kg lump of clay moving at 12 m/s to the right. The two lumps stick together after they collide. Find the final speed of the composite object, and the kinetic energy dissipated in the collision. [10]

The University of Zambia
Physics Department
University Examinations. March 1998.
P-191 : Introductory Physics

All questions carry equal marks. The marks are shown in brackets.
Maximum marks = 100. Answer question 1 and any other four questions only.
Clearly indicate which questions you have attempted.
Time : Three hours.

Wherever necessary, use g = 9.8 m/s^2. P_A = 1.01 × 10^5 N/m^2. 1 cal. = 4.18 J.
ρ_{water} = 1000kg/m^3 . $\rho_{benzene}$ = 879kg/m^3.

Some equations you may find useful :

$v_f = v_o + at$ $v_f^2 = v_o^2 + 2ax$ $x = v_o t + (1/2)at^2$ $f = \mu F_N$ $W = mg$

$Ft = m(v_f - v_o)$ kin.energy = $(1/2)mv^2$ grav. pot.energy = mgh work = F.s.cosθ

$\Delta PE + \Delta KE + \Delta TE = 0$ power = work/time $v = (1/2)(v_o + v_f)$ $x = v t$

$v_T = \omega r$ $\omega_f = \omega_o + \alpha t$ $\omega_f^2 = \omega_o^2 + 2\alpha\theta$ $\theta = \omega_o t + (1/2)\alpha t^2$ $Ft = \Delta \mathbf{p}$

$\mathbf{p} = mv$ $a_T = \alpha r$ $L = I\omega$ $\tau = I\alpha = Fr$ Kin. energy = $(1/2)mv^2 + (1/2)I\omega^2$

1 rev = 360° = 2π radians $F_c = (mv^2)/r$ $I = \Sigma mr^2$ $F = (Gm_1m_2)/r^2$

$Y = (F/A)/(\Delta L/L_o)$ $B = -\Delta P/(\Delta V/V_o)$ $W_{app.} = mg - B.F.$ $P = \rho gh$

$W_{app.} = W[1 - (\rho_f/\rho)]$ $F = -kx$ $[(1/2)mv^2]_{avg.} = (3/2)kT$ $\Delta Q = cm\Delta T = nC\Delta T$

$\Delta L = \alpha L\Delta T$ $\Delta V = \gamma V\Delta T$ $\Delta W = P\Delta V$ $P_1V_1^\gamma = P_2V_2^\gamma$ $(\Delta Q/\Delta t) = (kA\Delta T)/\Delta L$

$\Delta Q = \Delta U + \Delta W$ $a_{max.} = kx_o/m$ $a_c = \omega^2 x_o$ P.E. = $(1/2)kx^2$

$(1/2)kx^2 + (1/2)mv^2 = (1/2)kx_o^2$ $a = -kx/m$ $\omega = \sqrt{(k/m)}$ $v = \pm\sqrt{[(k/m)(x_o^2 - x^2)]}$

$v = \sqrt{(Y/\rho)}$ $f = (1/2\pi)\sqrt{(k/m)}$ $f = (1/2\pi)\sqrt{(g/L)}$ $v = \sqrt{[T/(m/L)]}$ $v = \sqrt{(B/\rho)}$

$PV = nRT$ $v = \sqrt{(\gamma RT/M)}$ $f = 1/\tau$ $\omega = 2\pi f$ $I_1\omega_1 = I_2\omega_2$ $\Delta T.E. = f.s$

area of a sphere = $4\pi r^2$ area of a right cylinder = $2\pi rl$

Question 1 : **Marks : 10 × 2 = 20**

A) Ball A is thrown horizontally, and ball B is dropped vertically from the same height at the same moment. If we neglect air friction :

(a) ball A reaches the ground first
(b) ball B reaches the ground first
(c) ball A has the greater speed when it reaches the ground
(d) ball B has the greater speed when it reaches the ground.

B) An engine block is supported by a rope hoist attached to an overhead beam. When the block is pulled to one side by a horizontal force exerted by another rope, the tension in the rope hoist :

(a) is greater than before
(b) is lesser than before
(c) is unchanged
(d) may be any of the above, depending on the magnitude of the horizontal force.

C) A stone is thrown upward from a roof at the same time as an identical stone is dropped from there. The two stones :

(a) reach the ground at the same time
(b) have the same acceleration when they reach the ground
(c) have the same velocity when they reach the ground
(d) none of the above.

D) A cake of soap placed in a bathtub of water sinks. The buoyant force on the soap is :

(a) zero
(b) more than its weight
(c) equal to its weight
(d) less than its weight.

E) A cable stretches by the amount x under a certain load. If the cable is replaced by a cable of the same material but half as long and having half the diameter, the same load will stretch it by :

(a) 2x (b) x/4 (c) x (d) x/2

F) An object undergoes simple harmonic motion. Its maximum speed occurs when its displacement from its equilibrium position is :

(a) zero (b) a maximum
(c) half its maximum value (d) none of the above.

G) Evaporation cools a liquid because :

(a) the slowest molecules tend to escape
(b) the pressure on the liquid increases
(c) the pressure on the liquid decreases
(d) the fastest molecules tend to escape.

H) A pressure cooker cooks food more rapidly than an ordinary pot with a loose lid because :

(a) the pressure forces heat into the food
(b) the higher pressure lowers the boiling point of water
(c) the higher pressure raises the boiling point of water
(d) the higher pressure increases the specific heat capacity of water.

I) A road slopes upward so that it climbs 1.0m per each 12m of distance along the road. A car with a weight of 10kN moves up the road at a constant speed of 24m/s. The maximum power the car develops is :

(a) 1.7kW (b) 20kW
(c) 2.0kW (d) 240kW

J) An empty plastic bag is placed on a spring balance and a first reading is taken. After this the bag is filled with air at room temperature and a second reading is taken. Which one of the following statements is correct ?

(a) the second reading is larger than the first one
(b) the second reading is smaller than the first one
(c) the second reading is equal to the first one
(d) the second reading might be larger than or equal to the first one, depending on whether the scale on the balance indicates mass or weight.

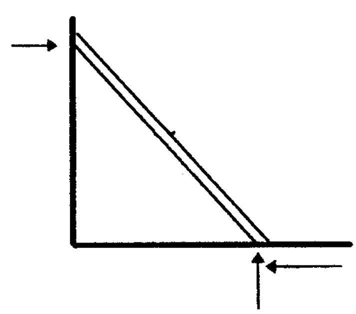
Q2.(a) Define bulk modulus and compressibility [3]

(b) A bus travels 400m between 2 stops. It starts from rest and accelerates at $1.5 m/s^2$ until it reaches a velocity of 9.0m/s. The bus continues at this velocity for some time and then decelerates at $2.0 m/s^2$ until it comes to a halt. Find the total time required for the journey. [8]

(c) 0.020kg of ice and 0.10kg of water at 0°C are in a container. Steam at 100°C is passed in until all the ice has just melted. How much water is now in the container ? Given, specific heat capacity of water = 4.2×10^3 J/kg.K. H_f of ice = 3.4×10^5 J/kg; H_v of water = 2.3×10^6 J/kg. Neglect any other type of heat loss. [9]

Q3.(a) Define moment of inertia. [3]

(b) A uniform ladder 5m long weighing 200N is leaning against a frictionless vertical wall with its base 3m from the wall. The coefficient of static friction between the bottom of the ladder and the ground is 0.45. How far, measured along the ladder from its bottom, can a 600N man climb before the ladder starts to slip ? [10]

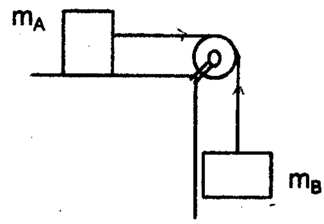


(c) A horizontal disc rotating freely about a vertical axis through its centre makes 100rev/min. A small piece of wax of mass 10g falls vertically on the disc and sticks to it at a distance of 9cm from the axis. If the number of revs/min is thereby reduced to 90, calculate the moment of inertia of the disc.

Given, moment of inertia of a disc of radius r = $(1/2)mr^2$, and moment of inertia of a point mass at a distance "a" from the axis of rotation = ma^2. [7]

Q4.(a) Explain the meaning of the terms (i) isothermal change and (ii) adiabatic change for a thermodynamic system. [4]

(b) Two masses m_A and m_B with $m_A = m_B$ are connected by a massless string going over a massless and frictionless pulley. The system is released from rest.



Find the coefficient of kinetic friction between the table and m_A if it is given that the masses have a speed of 3.7m/s after m_B has descended by 2.0m. (use conservation of energy). [10]

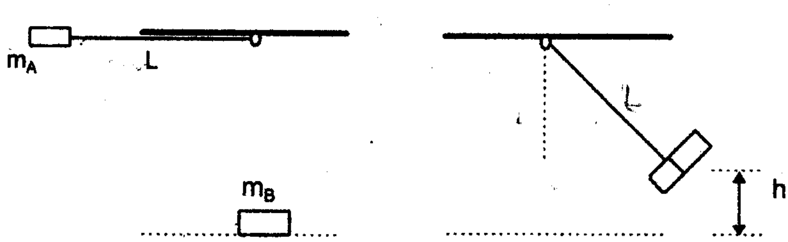
(c) It is desired to measure the density of an oil by using Archimedes' principle. An irregularly shaped piece of metal, of unknown composition, is available. The following data are taken :

i)	weight of metal in air	= 1.55N
ii)	weight of metal in water	= 0.75N
iii)	weight of metal in oil	= 0.85N

Calculate (a) the density of the metal,
(b) the density of the oil. [6]

Q5.(a) State Archimedes' principle. [3]

(b)



A magnet of mass $m_A = 0.5$kg is attached to a massless string of length L = 2m. The magnet is pulled out to one side so that the string is horizontal. When the magnet is released, it swings down and strikes an iron cube B of mass m_B that is resting on a frictionless surface. The two stick together and swing upward on the other side to a height h = L / 9. Find m_B. [9]

(c) A glass tube is bent into a U-shape. Water is poured into the tube until it stands 12cm high in each side. A 3.0cm column of benzene is slowly poured into one side. How far will the water in the other side rise ? Given $\rho_{benzene} = 879kg/m^3$ [8]

Q6.(a) Define simple harmonic motion and state the relation between displacement from its mean position and the restoring force when a body executes simple harmonic motion. [2 + 1]

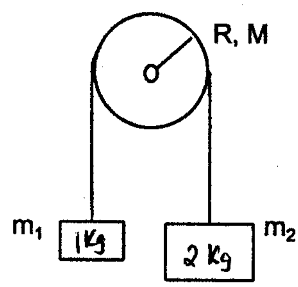
(b) A volume of air initially at a temperature of 27°C and 1.0×10^5 N/m² pressure is compressed isothermally until its volume is halved. It is then expanded adiabatically until its original volume is restored. Assuming the changes to be reversible, find the final pressure and temperature. Given $\gamma = C_p/C_v = 1.4$. [10]

(c) A small mass rests on a horizontal platform which vibrates vertically in simple harmonic motion with a period of 0.50 second. Find the maximum amplitude of the motion which will allow the mass to remain in contact with the platform throughout the motion. [7]

Q7.(a) Define Young's modulus. [3]

(b) Consider the system in the figure. With m_1 = 1kg, m_2 = 2kg, M =1kg, R = 30cm, find the speed of the masses once the mass m_2 has descended by 2m after the system has been released from rest.

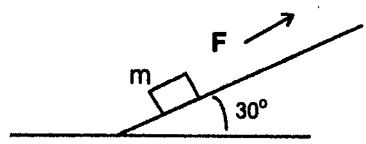
Find the linear acceleration of the mass m_2 and the angular acceleration of the pulley.
$I_{solid\ disk} = (1/2)MR^2$.
(Hint : use conservation of energy). [10]



(c) A piece of copper wire has twice the radius of a piece of steel wire. Young's modulus for steel is twice Young's modulus for copper. One end of the copper wire is joined to one end of the steel wire so that both can be subjected to the same force along the length. By what fraction of its length will the steel wire have stretched when the length of the copper wire has increased by 1% ? [7]

Q8.(a) Briefly explain the principle of heat transfer by convection. [4]

(b) Consider a mass m = 10kg on an incline making an angle of 30° with the horizontal. The coefficients of static and kinetic friction, μ_s and μ_k respectively between the incline and the mass are 0.25 and 0.15 :



(i) what force is needed to start upward motion ?
(ii) what force is needed to move the block up the incline at constant velocity once it has been set into motion ? [8]

(c) A copper pipe having an external diameter of 12cm and a wall thickness of 0.30cm carries steam at 150°C through a vat of circulating water at 20°C. How much heat is lost per meter of pipe in 1 second ? Given, k_{copper} = 400W/K.m.
(Hint : It may help to draw a sketch). [8]

End of Examination

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS

1996/97 ACADEMIC YEAR

ATOMIC PHYSICS

(P 212)

Time allowed : THREE (3) HOURS

INSTRUCTIONS: Answer any FIVE(5) questions only. They are of equal marks. The marks are shown in brackets.

Wherever necessary, the following constants and formulas can be used:

Speed of light	$c = 3 \times 10^{8}$ m/s
	$1\ eV = 1.6 \times 10^{-19}$ J
electronic charge	$e = 1.6 \times 10^{-19}$ C
electronic mass	$m = 9.1 \times 10^{-31}$ kg
1 atomic mass unit	$1u = 931.3$ MeV
Avogadro's constant	$N_A = 6.02 \times 10^{23}$ / mol
Planck's constant	$h = 6.625 \times 10^{-34}$ J.s
Photon energy	$E = h\nu$
1 Angstrom	$1\ Å = 10^{-10}$ m
	$e^{x} = 1 + x,\ x << 1$
	$I = I_o(1 - e^{-t/\tau})$
Rayleigh-Jeans's law	$I(\lambda)d\lambda = \frac{8\pi kTd\lambda}{\lambda^4}$
Wien's formula	$I(\lambda)d\lambda = \frac{C_1\lambda^{-5}d\lambda}{e^{C_2/\lambda T}}$
Stefan's law	$E = \sigma T^4$
Isotopic masses	$^{27}Al = 26.98153$
	$^{23}Na = 22.98977$
	$^{4}He = 4.00260$
	$^{226}Ra = 226.0254$
	$^{222}Rn = 222.0175$

Q1 (a) Planck's radiation law for the distribution of intensity of radiation in the spectrum of a black-body is stated as

$$I(\lambda)d\lambda = \frac{8\pi hcd\lambda}{\lambda^{-5}(e^{hc/kT} - 1)}$$

(i) Re-write this expression in terms of frequency showing all steps you take. [4]

(ii) Show that the expression reduces to the Rayleigh-Jean's law at long wavelengths and to Wien's law at short-wave lengths. [8]

(b) A star is determined to have a temperature of 300K and radiates 400 times as much as the sun. What is the radius of the star in sun radii? (Use 6000K for the surface temperature of the sun). [8]

Q2 (a) What is meant by the following terms as applied in atomic physics? [4]

(i) stopping potential;

(ii) threshold frequency.

(b) Calculate the value of Planck's constant from the following data, assuming that the electronic charge has a value of 1.6×10^{-19}C

A surface when irradiated with light of wavelength 5696 Å emits electrons for which the stopping potential is 0.12 volts. When the same surface is irradiated with light of wavelength 2830 Å, it emits electrons for which the stopping potential is 2.20 volts [10]

(c) Calculate the work- function and threshold frequency for the surface cited in part (b) above. [6]

Q3 (a) Explain the reason why Bohr's derivation of expressions for the quantization of orbits for hydrogen is termed as "semi-classical" [5]

(b) Starting with the centripetal force on the orbiting electron in hydrogen i.e.

$$\frac{mv^2}{r} = \frac{e^2}{4\pi\varepsilon_0 r^2}$$

and Bohr's second postulate,

$$mvr = \frac{nh}{2\pi}$$

show that the radii of the orbits are quantized and are given by

$$r = \frac{n^2h^2\varepsilon_0}{\pi m_e e^2}$$

where m_e = the electronic mass and e = the electronic charge. [8]

(Q3. continued)

(c) Calculate the ionisation energy of the hydrogen atom from the following data: The wavelength of the Balmer series limit is 3645Å and the wavelength of the first line in the Lyman series is 1215Å [7]

Q4 (a) What are x-rays and how are they produced? [3]

(b) An x-ray tube is operating at a potential difference of 150 000 volts and 10 mA current.

(i) How many electrons are hitting the target every second? [2]

(ii) If only 1% of the electric power is converted into x-rays, at what rate is the target being heated in joules per second? [4]

(iii) If the target has a mass of 300 gram and a specific heat capacity of $0.146J / g^{\circ} C$ at what average rate would its temperature rise if there were no heat losses? [5]

(iv) State three desirable physical properties of a practical target material. and give two examples of suitable target elements. [3]

(c) (i) What is meant by the term " half-value layer" as applied in x-ray absorption? [1]

(ii) How many half-value layers are necessary to reduce the intensity of an x-ray [2] beam to 1/64 of its original value?

Q5 (a) (i) What is meant by the term "Compton Wavelength"? [2]

(ii) An x-ray quantum that has a wavelength of 0.15 Å undergoes a Compton collision and is scattered through a an angle of 37°

1) What are the energies of the incident and scattered photons and of the ejected electrons? [6]

2) What is the magnitude of the momentum of each photon? [3]

(b) (i) What are "matter waves " ? [1]

(ii) Show that the de Broglie wavelength, in Ångstroms, associated with an electron accelerated from rest through a potential difference of V volts is classically equal to

$$\lambda = \frac{12.27}{V^{1/2}}$$ [4]

(iii) An alpha particle is ejected from the nucleus of a radium atom with 5.78 MeV of kinetic energy. What is the de Broglie wavelength of this particle? [4]

Average nucleonic mass = 1.67×10^{-27} kg

Q6 (a) Define the following terms as understood in radioactive decay: [4]

(i) Half-life

(ii) Disintegration constant;

(iii) Daughter nuclide;

(iv) Parent nuclide.

(b) A certain radioactive nuclide has a half-life of 20 days.

(i) How long will it take for 3/4 of the atoms originally present to disintegrate? [3]

(ii) How long will it take until only 1/8 of the atoms originally present remain unchanged? [3]

(iii) What are the disintegration constant and the mean life of this nuclide? [2]

(c) If a radioactive material initially contains 3.00 mg of ^{234}U ,($T_{1/2}$=2.48 x 10^5yr),

(i) how much material will remain unchanged after 62 000 years? [6]

(ii) what will be its activity at the end of that time? [2]

Q7 (a) Define the following terms as understood in nuclear reactions:

(i) " Q-value " of a reaction [2]

(ii) " exoergic" and " endoergic" nuclear reactions [2]

(b) Find the Q-values of the following nuclear reactions and determine whether they are endoergic or exoergic:

(i) $^{27}Al \rightarrow {}^{23}Na + {}^{4}He + Q$

(ii) $^{226}Ra \rightarrow {}^{222}Rn + {}^{4}He + Q$ [6]

(c) (i) Define the following and give two examples of each:

1) isotopes

2) isotones

3) isobars [6]

(ii) Draw a well labelled diagram of a typical gas filled chamber (a radiation detector) and describe how it works. [4]

END OF EXAMINATION

HAVE YOU WRITTEN YOUR COMPUTER NUMBER?

THE UNIVERSITY OF ZAMBIA
PHYSICS DEPARTMENT

FIRST SEMESTER UNIVERSITY EXAMINATION - MARCH, 1998

P231 (PROPERTIES OF MATTER AND THERMAL PHYSICS)

TIME: THREE HOURS MAX. MARKS: 100

NOTE: *ANSWER TWO QUESTIONS FROM SECTION A AND TWO QUESTIONS FROM SECTION B AND ONE QUESTION FROM EITHER SECTION TO MAKE TOTAL FIVE QUESTIONS.*

Please check that this question paper contains 5 printed pages.

SECTION A: ANSWER TWO QUESTION FROM THIS SECTION

QUESTION 1.

(1a) Derive the formula for the volume of a liquid which flows through a narrow tube in unit time and explain the limitations of the formula. **(8 Marks)**

(1b) Water flows through a horizontal tube of length 20 cm and internal radius 0.081 cm. under a constant head of the liquid 20 cm. high. In 12 minutes 864 c.c. of liquid issues from the tube. Calculate the viscosity coefficient for water. The density of water is1 gm. per c.c. and g = 981 m/s^2 **(6 Marks)**

(1c) A square plate of 10 cm. side moves parallel to another plate with a velocity of 10 cm. per sec., both plates being immersed in water. If the viscous force between them is 200 dynes, and the viscosity of water is 0.01 gm/cm sec., what is their distance apart **(6 Marks)**

QUESTION 2.

(2a) Show that excess pressure inside the soap bubble of radius r over the atmospheric pressure outside it is equal to 4T/r where T is the surface tension of the soap solution. **(5 Marks)**

(2b) The pressure inside a soap bubble of radius 1 cm balances a 1.4 mm column of oil with density of 0.80 gm/c.c. Calculate the surface tension of the soap solution. (5 Marks)

(2c) Derive an expression for the height h through the liquid of surface tension T will rise
in a capillary tube of radius r (5 Marks)

(2d) A U tube with limbs of diameters 5 mm and 2 mm respectively contains water of surface tension 7×10^{-2} N m^{-1}, angle of contact zero and density of 1000 kg m^{-3}. Find the difference in levels given that acceleration due to force of gravity equals 10 m/s . (5 Marks)

QUESTION 3

(3a) Show that the bending moment for a rectangular plate with cross-section area b dz where b is its length and dz its breadth is given by

$$(Y\, b\, d^3)/(12R) \qquad \text{(6 Marks)}$$

whereY is the Young's modules of the material of the rectangular plate and R is the radius of curvature.

(3b) Derive the expression for the depression of a square beam supported at the ends and loaded at the centre. (4 Marks)

(3c) calculate the Young's modules for brass bar 1cm. square in cross-section supported on two knife edges 100 cm apart if a load of 1 kg at the centre of the bar depresses that point by 2.51 mm. (6 Marks)

(3d) Find the work done in joules in stretching a wire of cross-section 1 sq. mm. and length 2 metres through 0.1 mm, if Young's modules for the material of the wire is 2×10^{12} dynes/cm^2 . (4 Marks)

QUESTION 4.

(4a) Show that the deflection at the free end of a light horizontal beam of length L and negligible weight clamped at one end and loaded at the other is given by

$$(W\, L^3)/(3\, Y\, I_g) \qquad \text{(8 Marks)}$$

where W is the weight of the load at the free end, Y is the Young's modules of the material of the beam, I_g is the geometrical moment of inertia of the material of the beam.

(4b) A light bar of length 1m. and rectangular cross-section 5×10^{-3} m^2. is supported at two ends and loaded in the middle with a load of 0.1 kg. The depression observed is $1 \times 96 \times 10^{-3}$ m. Calculate the Young's modules of the material of the light bar (Note that rectangular cross-section are a = bd, $k^2 = d^2/12$ where k is the radius of gyration, $I_g = ak^2$ is the geometrical moment of inertia of the material of the beam). (8 Marks)

(4c) A copper wire 3m. long for which Young's modules is 12.5×10^{11} dynes per square cm, has a diameter of 1 mm. If the weight of 10 kg is attached to one end, what extension is produced? If Poisson's ratio is 0.26, what lateral compression is produced? (4 Marks)

SECTION B: ANSWER TWO QUESTIONS FROM THIS SECTION

QUESTION 5

(5a) Using the postulates of the Kinetic theory of gases, derive the expression for Kinetic pressure. (7 Marks)

(5b) Show that

(i) Equal volumes of ideal gases existing under the same conditions of temperature and pressure contain equal number of molecules.

(ii) Average Kinetic energy per molecule is proportional to the thermal dynamic temperature.

(iii) The rate of diffusion of a gas is inversely proportional to the square root of its density. (9 Marks)

(5c)

(i) Given that the gas constant R is 8.3×10^7 ergs per 1°C, and the atomic weight of chlorine is 35.5, find the root mean square (r.m.s.) velocity of the chlorine molecules at 0.°C. (2 Marks)

(ii) If the density of nitrogen is 1.25 gm/litre at normal temperature and pressure, calculate the root mean square velocity of its molecule (4 Marks)

QUESTION 6

(6b) Show that the relationship between temperature and volume of a gas for the temperature change during a reversible adiabatic process is

$$TV^{\gamma-1} = \text{constant}$$ (5 Marks)

(6c) Show that the heat equivalent of the mechanical work done in an isothermal expansion of a gas is

$$Q = W + RT\ \ell n\left(\frac{V_2}{V_1}\right)$$ (5 Marks)

where T is the absolute temperature, W is the mechanical work, R is the universal gas constant and the gas expands from volume V_1 to volume V_2

(6d)

(i) During an adiabatic expansion of an ideal gas, the pressure at any moment is given by $PV^{\gamma} = k$ where γ and are constants. If the initial pressure and volume are 10 At m and 10^{-3} m^3 and the final values are 2 At m and 3×10^{-3} m^3, how many joules of work is done by a gas whose $\gamma = 1.4$. (1 Atm = $1.0\ 13 \times 10^5$ pa)

(5 Marks)

(ii) Helium ($\gamma = 5/3$) at 300K and at a pressure of 1 atmosphere is compressed adiabatically to a pressure of 5 atmospheres. Assuming that helium behaves like an ideal gas, what is the final temperature? (5 Marks)

QUESTION 7

(7a) A carnot engine is made to work between 200°C and 0°C first and then between 0°C and -200°C. Compare the values of the efficiencies in the two cases.

(4 Marks)

(7b) A carnot's cycle ABCDA is performed by 1 litre of air ($\gamma = 1.4$) initially at 327°C and a pressure of 12 atmosphere each state represents a compression or expansion in the ratio 1 to 6. The changes along AD and BC are adiabatic and along AB and DC are isothermal. Calculate the lowest temperature and the efficiency of the cycle.

(4 Marks)

(7c) If a carnot cycle is run backward, we have an ideal refrigerator. A quantity of heat Q_2 is taken in at the lower temperature T_2 and the quantity of heat Q_1 is given out at higher temperature T_1. The difference is the work W that must be supplied to run the refrigerator;

(i) Show that

$$W = Q_1 (T_1 - T_2)/T_1$$ (4 Marks)

(ii) Find the work that must be done to extract 1.0 joules of heat from a reservoir at 7°C and transfer it to one at 27°C. (4 Marks)

(7d) A Carnot engine has an efficiency 50% when its sink temperature is 27°C. What must be the change in its source temperature so that its efficiency may become 60%. (4 Marks)

QUESTION 8

The Van der Wall's equation of state is given by $(p + a/v^2)$ $(v - b)$ RT where a and b are constants.

(a) Find the equation for the locus of maxima and minima and hence the expressions for the critical volume, pressure and temperature. (8 Marks)

(b) Show that Boyle's temperature $T_B = a/(b\,R)$ (6 Marks)

(c) 10g of steam at 100°C is blown into 90g of water at 0°C in a calorimeter of water equivalent of 10g. The whole of steam is condensed. Calculate the change in entropy of the system (L = 540 calories/gm)

Make sure that you have written your computer number on your answer sheet.

END OF THE EXAMINATIONS

GOOD LUCK

UNIVERSITY OF ZAMBIA
UNIVERSITY EXAMINATIONS
CLASSICAL MECHANICS
P 251

MARCH, 1998

IMPORTANT INFORMATION:

Answer **any five** questions. All questions carry equal marks.

Marks are indicated in square brackets [ ]

Time: Three Hours

$$\mathbf{a} \times (\mathbf{b} \times \mathbf{c}) = \mathbf{b}(\mathbf{a} \cdot \mathbf{c}) - \mathbf{c}(\mathbf{a} \cdot \mathbf{b})$$

$$\mathbf{a} \cdot (\mathbf{b} \times \mathbf{c}) = \mathbf{c} \cdot (\mathbf{a} \times \mathbf{b})$$

$$\frac{d^2u}{d\theta^2} = -u - \frac{m}{L^2u^2}F(1/u), \text{ with } u = 1/r.$$

$$\frac{d\mathbf{r}}{dt} = \dot{r}\hat{\mathbf{r}} + r\,\dot{\theta}\hat{\boldsymbol{\theta}}$$

$$\frac{d^2\mathbf{r}}{dt^2} = (\ddot{r} - r\,\dot{\theta}^2)\,\hat{\mathbf{r}} + (r\,\ddot{\theta} + 2\,\dot{r}\dot{\theta})\,\hat{\boldsymbol{\theta}}$$

Q1 (*a*) Prove that for a central force :

(*i*) the angular momentum $\mathbf{L}$ is conserved [3]

(*ii*) the magnitude of angular momentum is $mr^2\,\dot{\theta}$ [3]

(*iii*) the total energy E is conserved [4]

(*b*) By use of Newton's second law and for an attractive inverse square force $-\lambda/r^2$,

(*i*) show that the Laplace-Lenz-Runge vector $\mathbf{K}$ is a constant of motion and it is given by

$$\mathbf{K} = \dot{\mathbf{r}} \times \mathbf{L} - \frac{\lambda}{r}\mathbf{r}; \qquad [5]$$

(*ii*) show that $\mathbf{K}$ is orthogonal to the angular momentum $\mathbf{L}$ and hence $\mathbf{L}$ is orthogonal to $\mathbf{K} \times \mathbf{L}$; [2]

(*iii*) show that $|\mathbf{K}|^2$ is related to the total energy E by

$$|\mathbf{K}|^2 = \frac{2L^2E}{m} + \lambda^2. \qquad [3]$$

Q2 (*a*) Show that for a system of N particles moving under the influence of internal as well as external forces, $\mathbf{F} = \frac{d\mathbf{P}}{dt}$, where $\mathbf{F}$ is the total external force acting on the system and $\mathbf{P}$ is the total linear momentum of the system. [10]

(*b*) Four particles of masses 2.0kg, 4.0kg, 6.0kg, and 8.0 kg are rigidly joined by massless rods so as to lie on the corners of a 2.0 meter long square with position coordinates (1, 1, 0), (1, −1, 0), (−1, −1, 0) and (−1, 1, 0) respectively.

(*i*) Find the position of the centre of mass of the system [4]

(*ii*) If a force (2, 2, 0) starts acting on the system (which is free to move in the x−y plane) find the position of the centre of mass of the system after 2.0 seconds. [4]

(*iii*) Find the velocity after 2.0 seconds. [2]

Q3 (*a*) What is a central force? Give two examples of central forces. A particle of mass m moves in a path of constant radius r_0. Show that the force acting on the particle is the centrifugal force. [5]

(*b*) A particle of mass m moving with angular momentum L and velocity v_0 describes an orbit

$$\frac{1}{r} = \frac{1}{r_0}(1 + e\cos\theta),$$

where e is the eccentricity and r_0 is a constant.

(*i*) Obtain the force $F(r)$ and the corresponding potential $V(r)$. Make plots of $V(r)$ and $F(r)$. [4]

(*ii*) Make a plot of the effective potential $V_{eff}(r)$ for a particle moving with energy E. Describe the motion of the particle without solving the equations of motion. [4]

(*iii*) Calculate E and L if the particle moves in a circle of radius r_0. [4]

(*iv*) Calculate the period for circular motion. Also calculate the period of small oscillations if the particle is slightly perturbed from the circular orbit. [3]

Q4 (*a*) State the principle of conservation of energy. [1]

(*b*)The magnitude of the force of attraction between the positively charged nucleus and the negatively charged electron in the hydrogen atom is

$$F = \frac{kq^2}{r^2}$$

where q is the electronic charge, k is a constant, and r is the separation between the electron and the nucleus. Assume that the nucleus is fixed. The electron, initially moving in a circle of radius R_1 about the nucleus, jumps suddenly into a circular orbit of smaller radius R_2.

(*i*) Calculate the change in kinetic energy of the electron. [7]

(*ii*) Calculate the decrease in potential energy of the atom. [6]

(*iii*) Calculate by how much the total energy of the atom has decreased in this process (This is the energy given off in the form of radiation) [6]

Q5 (*a*) State Newton's law of universal gravitation. {Descriptive and mathematical statements are both required}. [2]

(*b*) A particle of mass m moves along the axis of a fixed uniform ring of mass M and radius r. Assume that the only force acting on the particle is the gravitational attraction of the ring. The position of the particle at any time is specified by its distance y from the center of the ring.

(*i*) Draw a diagram of this arrangement. [2]

(*ii*) Show, using symmetry considerations, that the force on the particle is along the axis through the center of the ring. [2]

(*iii*) Determine the potential energy of the particle as a function of y [5]

(*iv*) Obtain the magnitude of the force acting on the particle as a function of y. [4]

(*v*) If the particle is "projected" from the center of the ring, show that its escape velocity is $\sqrt{\frac{2GM}{r}}$. [5]

Q6 (*a*) (*i*) Distinguish between an elastic and an inelastic collision? [2]

(*ii*) In terms of momenta, explain briefly the difference between the laboratory coordinate system and the center of mass coordinate system. [4]

(*b*) A particle of mass m_1 and kinetic energy T_1 collides elastically with a particle of mass m which is at rest. The particle of mass m leaves the collision at an angle θ with respect to the original direction of motion of the particle of mass m_1.

(*i*) Obtain an expression for the kinetic energy T in terms of m, m_1, θ and T_1, with which the particle of mass m leaves the collision. Show that, for a given value of T_1, this energy is maximum for a head-on collision. [6]

(*ii*) Show that in this case the energy lost by the particle of mass m_1 is given by $\frac{4m_1 m}{(m_1+m)^2}T_1$. [3]

(*c*) Show that the kinetic energy of a system of two particles relative to their center of mass is equal to the kinetic energy of one of the particles calculated as if the other particle were fixed, provided that the mass of the first particle is replaced by its reduced mass. [5]

Q7 (*a*) State Kepler's three laws of planetary motion. Show how each law can be obtained from orbit theory. [5]

(*b*) A particle of mass m_0 is moving in such a way that it describes an orbit given by

$$\mathbf{r}(t) = (x_0 + at^2)\mathbf{i} + (y_0 + bt^3)\mathbf{j} + (z_0 + ct)\mathbf{k}$$

where a, b, c, x_0, y_0 and z_0 are constants.

(*i*) What is the position of the particle at $t = 0$? [1]

(*ii*) What is the force acting on the particle at any time t? [2]

(*iii*) Find the angular momentum at any time t [3]

(*iv*) Is angular momentum conserved? [2]

(*v*) Compute $\mathbf{r} \times \mathbf{F}$, where $\mathbf{F}$ is the force found in (*ii*). Compare the results in (*iv*) and (*v*) and comment on them. [3]

(*c*) A particle moves along the parabola $y^2 = 4f_0^2 - 4f_0 x$, where f_0 is a real constant. Show that the equation of the parabola in plane polar coordinates is

$$r \cos^2\left(\frac{\theta}{2}\right) = f_0. \qquad [4]$$

Q8 (*a*) What are the principle features of simple harmonic motion? Give an example of a system that executes simple harmonic motion. [3]

(*b*) Show that the speed and acceleration of a pendulum of length l released at an angle θ_0 to the vertical are

$$v = \sqrt{2gl(\cos\theta - \cos\theta_0)} \qquad \text{and} \qquad a = g\sin\theta,$$

where θ is the angle at any other time. [8]

(*c*) A particle is subjected to two simple harmonic motions at right angles along the x and y axes respectively,

$$x = x_0 \cos\omega t, \qquad y = y_0 \cos(\omega t + \delta),$$

where x_0 and y_0 are amplitudes, ω is the frequency of both motions and δ is the phase difference. The particle has both components of velocity equal to zero at $t = 0$. Find and sketch the trajectory for $\delta = 0$, $\pi/2$ and π. [9]

END OF EXAMINATION

UNIVERSITY OF ZAMBIA
UNIVERSITY EXAMINATIONS
P 252
CLASSICAL MECHANICS II

SEPTEMBER 1998

ANSWER ANY FIVE QUESTIONS

TIME: THREE HOURS

1 (a) Can there be two-dimensional motion with acceleration only in one-dimension? Explain. If so, give an example. [3]

(b) A particle of mass m moves near the surface of the earth. The acceleration due to gravity is g and its position is given by $(r\cos\theta, r\sin\theta)$ in the $x-y$ plane, both θ and r being functions of time.

(i) Calculate the kinetic energy T. [4]

(ii) Obtain the potential energy V and write down the Lagrangian function for the system. [3]

(iii) Obtain the equations of motion. Under what condition(s) will this kind of motion have acceleration in one-dimension only? [4]

(c) Show for the particle in (b), the quantity

$$\frac{p_r^2}{2m} + \frac{p_\theta^2}{2mr^2} + mgr\sin\theta$$

is a constant of the motion and the p's are the respective momenta. Write down the Hamiltonian and the total energy of the system. [6]

2 (a) What are generalized coordinates? Hence define the generalized momenta. [4]

(b) Name two main properties of an inertial frame. What are the respective consequences of each of these properties of an inertial frame? Show how these symmetry properties lead to the conservation laws. [6]

(c) A simple pendulum of mass m and length l hangs from a trolley of mass M running on smooth horizontal rails. The pendulum swings in a plane parallel to the rails. The mass M is attached to a horizontal spring which has spring constant k.

(i) Sketch the system and obtain the Hamiltonian function. [5]

(ii) Obtain the equations of motion of the system. [3]

(iii) Are there any ignorable coordinates? Hence, are there any constants of the motion? [2]

3 (a) What is the effect on its amplitude and period of doubling the length of a pendulum? [2]

(b) Consider a simple pendulum of length l. Show that if the displacement ($\theta = \theta_0$) is not small, then to the *fourth order* T^2 the square of the period of the pendulum is given by

$$T^2 = \frac{4\pi^2 l}{g}\left(1 + \frac{1}{2}\sin^2(\frac{\theta_0}{2}) + \frac{1}{16}\sin^4(\frac{\theta_0}{2})\right)$$

where g is the acceleration due to gravity. [10]

(c) Compute the centre of mass of a uniform solid hemisphere of radius b. [8]

4 (a) State the basic postulates of the special theory of relativity. [3]

(b) Show that the Lorentz transformation equations for the S and S' systems in uniform relative motion may be expressed as

$$\begin{aligned} x_1' &= x_1 \cosh\alpha - ct\sinh\alpha \\ x_2' &= x_2 \\ x_3' &= x_3 \\ t' &= t\cosh\alpha - \frac{x_1}{c}\sinh\alpha \end{aligned}$$

where $\tanh\alpha = \frac{v}{c}$. [8]

(c) Given that $x' = \gamma(x - vt)$ and $t' = \gamma(t - vx/c^2)$, where the symbols have their usual meaning, derive the equations for x and t in terms of x' and t'. [9]

5 (a) What is the essential difference between a transverse and a longitudinal wave? [4]

(b) Prove that $u = A\sin(kx)\cos(\omega t)$ is a solution of the wave equation for a stretched string

$$\frac{\partial^2 u}{\partial t^2} = v^2\frac{\partial^2 u}{\partial x^2},$$

where k is the wave number, ω is the angular frequency, and v is the velocity of the wave. [8]

(c) Show that if the string, in (b), is of length L and is clamped at both ends, then

$$k = \frac{n\pi}{L},$$

where $n = 1, 2, 3....$ Hence or otherwise, show that the string vibrates only with frequencies

$$f_n = \frac{nv}{2L}. \qquad [8]$$

6 (a) State the parallel axis theorem. Prove the theorem for a two-dimensional object? [4]

(b) A disk of uniform density has radius r_0 and mass m. Calculate its moment of inertia about an axis perpendicular to its plane and passing through its centre. Hence or otherwise obtain its moment of inertia about an axis perpendicular to its plane and through a point on its rim. [7]

(c) A wheel of moment of inertia I and radius r is free to rotate frictionlessly about a horizontal axis. A weightless string wound round the wheel carries a particle of mass m hanging vertically. The system is released from rest and the mass m starts to descend. Sketch the system and write down the equations of motion of the mass m and the wheel. Hence show that in time t the wheel rotates through an angle

$$\theta = \frac{mgrt^2}{2(I + mr^2)}. \qquad [9]$$

7 (a) What are normal coordinates ? [2]

(b) Two horizontal harmonic oscillators are coupled to each other via a spring of spring constant k. Each of the harmonic oscillators is of mass m and spring constant k. Sketch the system and obtain the kinetic energy T and potential energy V. Hence obtain the corresponding Lagrangian $\mathcal{L}$. [4]

(c) Obtain the differential equations of motion for the system in (b). Solve them by use of $x_i = A_i \exp(i\omega t)$ as trial solutions ($i = 1$ and 2). Show that these trial solutions lead to

$$\begin{aligned} (2k - m\omega^2)A_1 - kA_2 &= 0 \\ -kA_1 + (2k - m\omega^2)A_2 &= 0 \end{aligned}$$

By solving these simultaneous equations, show that the system oscillates with natural frequencies

$$\begin{aligned} f_1 &= \frac{1}{2\pi}\sqrt{\frac{k}{m}} \\ f_2 &= \frac{1}{2\pi}\sqrt{\frac{3k}{m}} \end{aligned}$$

Interpret these frequencies in physical terms. Obtain the equations of motion in terms of the normal coordinates. [14]

END OF EXAMINTION

THE UNIVERSITY OF ZAMBIA
PHYSICS DEPARTMENT
UNIVERSITY EXAMINATIONS 1996/7
P332
STATISTICAL AND THERMAL PHYSICS

TIME: THREE HOURS
ANSWER: ANY FOUR QUESTIONS
ALL QUESTIONS CARRY EQUAL MARKS
TOTAL MARKS: 100

Useful Formulas

$\beta = \frac{\partial \ln \Omega}{\partial E}$

$c_V = \left(\frac{\partial E}{\partial T}\right)_V$

$S = k ln \Omega$

$kT = \frac{1}{\beta}$

$\overline{y} = \frac{\sum_r y_i P_i}{\sum_r P_i}$

$\frac{\partial \ln \Omega}{\partial x_\alpha} = \beta \overline{X_\alpha}$

$dQ = dE + pdV$

$pV = \nu RT$

$Z = \sum_r e^{-\beta E_r}$

1.(**a**) Two insulated systems A and A' are in weak thermal interaction only. Show that they achieve equilibrium when their temperature parameters are equal. (10 marks)

(**b**) The number of states in the energy range from E to $E + \delta E$ of an ideal gas of N molecules in a volume V is

$$\Omega(E) = BV^N E^{3N/2}$$

where B is a constant.

(**i**) Obtain the equation of state of such a gas. (3 marks)

(**ii**) Consider two such gases, one with N_1 molecules in a volume V_1 with energy E_1 and the other with N_2 molecules in a volume V_2 and energy E_2.

Suppose that the two gases are brought into thermal contact, so they form an insulated composite system. Show that when equilibrium is achieved between them, the distribution of energy is such that

$$\widetilde{E_1} = \frac{N_1(E_1 + E_2)}{N_1 + N_2},$$

$$\widetilde{E_2} = \frac{N_2(E_1 + E_2)}{N_1 + N_2}$$

(9 marks)

(iii) Calculate the amount of heat absorbed by each gas in the process. (3 marks)

2. **(a)** Explain the significance of the entropy S and hence show that spontaneous processes are characterised by the condition $\Delta S \geq 0$. (10 marks)

(b) A system consists of N non-interacting spin $\frac{1}{2}$ particles in a weak magnetic field H. Each particle has magnetic moment μ.When the spin of a particle lies parallel to the field, its magnetic moment is μ and its energy is $-\mu H$; when the particle is anti-parallel to the field, the energy is μH, and its magnetic moment is $-\mu$. Suppose that n_1 particles have their spins parallel to H and n_2 have their spins anti-parallel to H.

(i) What is the energy of the system? (3 marks)

(ii) What is the spin entropy of the system? (5 marks)

(iii) Explain why the spin temperature of the system can be negative and give the range of energies for which the temperature is positive and the range for which it is negative.. (7 marks)

3. **(a)** Explain what is meant by a quasi-static process and explain the importance of such processes in statistical mechanics. (5 marks)

(b) Show that when a body at absolute temperature T absorbs an infinitesmal amount of heat dQ, its entropy increases by

$$dS = dQ/T$$ (10 marks)

(c) 500g of ice at 0^0C are placed in thermal contact with a heat bath at 50^0C. Obtain the change in entropy of the total system when equilibrium has been re-established. (10 marks)

The specific heat capacity of water is 4.2J/(g.^{0}C). The latent heat of fusion of ice is 333 J/g.

4.(a) What is the postulate of equal a priori probabilities? (2 marks)

(b) Derive the canonical distribution

$$P_r = \frac{e^{-\beta E_r}}{\sum e^{-\beta E_r}} \qquad \text{(10 marks)}$$

(c) A system consists of N weakly interacting subsystems. Each subsystem possesses only two non-degenerate energy levels $E_1$and E_2. Show that the heat capacity of the system is

$$C = \frac{Nkx^2e^x}{(e^x+1)^2}$$

where $x \equiv \beta\epsilon$ and $\epsilon = E_2 - E_1$. (13 marks)

5. (a) Show that in a quasi-static adiabatic compression or expansion the pressure p of an ideal gas is related to the temperature T by

$$p^{1-\gamma}T^{\gamma} = \text{cons tan t}$$

where $\gamma = c_p/c_V$. (10 marks)

(b) Prove the equipartition theorem

$$\overline{bp_i^2} = \overline{cx_i^2} = \frac{1}{2}kT$$

where the total energy of a system described by the canonical distribution is

$$E = bp_i^2 + E'$$

or

$$E = cx_i^2 + E'$$

(10 marks)

(c) Hence, show that the molar heat capacity at constant volume of a classical solid is

$c_V = 3R$ (5 marks)

6.(**a**) According to the Maxwell distribution of speeds in a dilute gas, the mean number of molecules per unit volume with speed $v = |\mathbf{v}|$ in the range between v and $v + dv$ is

$$F(v)dv = 4\pi n \left(\frac{m}{2\pi kT}\right)^{3/2} v^2 e^{-mv^2/2kT} dv$$

Find the most probable speed of a nitrogen molecule in a volume of gas at an absolute temperature of 300K. (5 marks)

Note:$k = 1.3 \times 10^{-23}$J/K and for an N_2 molecule, $m = 4.67 \times 10^{-26}$kg

(**b**) The quantum mechanical wave function of fermions (i.e., particles with half-integral spin) is anti-symmetric. Show that two such particles cannot be in the same quantum state. (5 marks)

(**c**) A quantum system consists of two particles, each of which can be in any one of three quantum states of respective energies 0, ϵ and 3ϵ. The system is in contact with a heat reservoir at temperature $T = (k\beta)^{-1}$. Write down the partition function Z of the particles in the following three cases:

(**i**) The particles obey Maxwell-Boltzmann statistics and are considered distinguishable. (5 marks)

(**ii**) The particles obey Bose-Einstein statistics. (5 marks)

(**iii**) The particles obey Fermi-Dirac statistics. (5 marks)

****END OF EXAMINATION****

THE UNIVERSITY OF ZAMBIA

Physics Department

UNIVERSITY EXAMINATIONS -March 1998

P341

Introduction to Electronics

TIME: THREE(3) HOURS

ATTEMPT ANY FOUR QUESTIONS. ALL QUESTIONS CARRY EQUAL MARKS.

MARKS ARE INDICATED AGAINST EACH QUESTION.

You may use the following where necessary:

magnitude of electronic charge $e = q = 1.6 \times 10^{-19}$ C

free electron rest mass $= 9.11 \times 10^{-31}$ kg

Q. 1 State:

(a) Thevenin's theorem as applied to a two-terminal network of resistors and sources of emf. [*2 marks*]

(b) Norton's theorem as applied to a two-terminal network of resistors and sources of emf. [*2 marks*]

For the circuit shown in Figure 1, find:

(c) the resistance between A and B [*7 marks*]

(d) the open circuit voltage between A and B [*8 marks*]

(e)(i) the resistance R_L that would result in the maximum delivery of power to the load, and (ii) the current in the load, R_L. [*3 + 3 marks*]

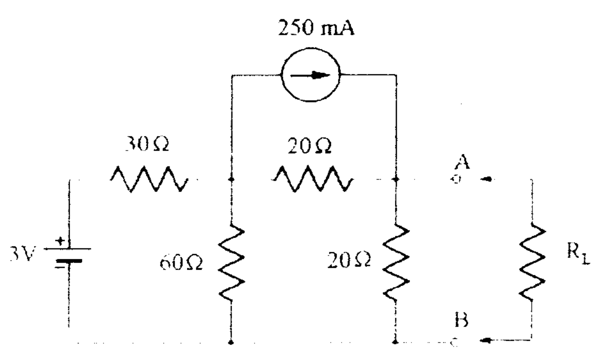


Figure 1

Q. 2. (a) Explain the origin of the difference in behaviour in the electrical conductivity of semiconductors and metals. In particular state what happens in each case as T approaches absolute zero temperature. [$3\frac{1}{2}+3\frac{1}{2}$ marks]

At room temperature germanium of reasonable purity has an electron mobility of 0.36 m^2/V-s, hole mobility of 0.17 m^2/V-s and charge carrier concentrations $n=p=2.5\times10^{19}$ m^{-3}. The effective masses for the electrons and holes are respectively, $m_n^*/m = 1$, and $m_p^*/m = 1$.

Calculate:

(b) the electrical conductivity of Ge, [*6 marks*]

(c) the average collision time of the electrons and holes [*3 + 3 marks*]

(d) the current density in an electric field of 100 V m^{-1} [*2 marks*]

(e) the average drift velocity of the electrons and the holes in an electric field of 100 Vm^{-1}. [*2 + 2 marks*]

Q. 3. (a) Determine the transfer function of a high-pass RC filter. [*7 marks*]

A voltage wave-form is given by:

$$v(t) = \begin{cases} -4V_P\left(\frac{t}{T}\right) + V_P, & -\frac{T}{2} \le t \le 0 \\ 4V_P\left(\frac{t}{T}\right) - V_P, & 0 \le t \le \frac{T}{2} \end{cases}$$

where V_P is the peak voltage, T is the period in second and t is the time in second.

Suppose that this voltage is applied to a high-pass RC filter,

(b) sketch the input wave-form [*3 marks*]

(c) explain the action of the filter for $\omega RC \ll 1$, where $\omega = 2\pi/T$, and [*7 marks*]

(d) sketch the output wave-form in this case. [*5 marks*]

(e) If R=1000Ω and C=0.02μF, determine the range of frequencies for which $\omega RC \ll 1$. [*3 marks*]

Q. 4. A full-wave rectifier constructed using a centre-tapped transformer and two diode is required to supply an unfiltered average(i.e. dc) current of 800 mA to a 25-ohm load.

(a)Draw (i) a diagram of the circuit and, (ii) the input (into rectifier) and output wave-forms [3+2+2 *marks*]

(b)calculate the peak current that flows in the circuit [5 *marks*]

(c)calculate the average voltage across the load, and determine: [3*marks*]

(d) the specifications for the transformer, and [7 *marks*]

(e) the specifications for the diodes to be used in the circuit. [3*marks*]

Q. 5. A Ge pnp transistor (V_{BE}=0.2 V) is used in a common-emitter amplifier that

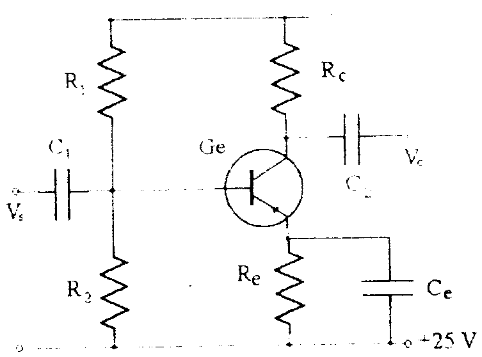


Figure 2(a)

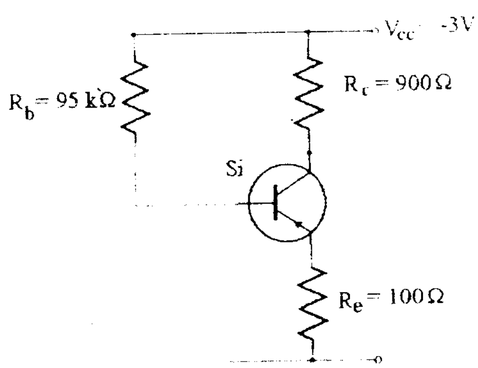


Figure 2(b)

includes a voltage divider bias and an emitter swamping resistor as shown in Figure 2(a). The quiescent emitter current is 5 mA, the quiescent base current is 0.2 mA and the emitter supply voltage is 25V.

Determine:

(a) the required value of the emitter swamping resistor [5 *marks*]

(b) the values of both resistors in the voltage divider R_1 and R_2. [3 *marks*]

Figure 2(b) shows the circuit of a grounded emitter pnp transistor amplifier. Assuming that $\beta >> 1$ and $V_{BE} = 0$, find:

(c) the load line of this amplifier [6 *marks*]

(d) the bias equation(i.e. an expression for the base current) , and [6 *marks*]

(e)comment on the behaviour of the base current for values of I_c from 0 to -2 mA. [5 *marks*]

Q. 6. (a) State the properties of an ideal operational amplifier. [4 *marks*]

(b) Determine an expression for the voltage gain for the circuit in Figure 3(a) constructed using an ideal operational amplifier. [6 *marks*]

Figure 3(b) shows an ideal operational amplifier used to construct an operational adder.

(c) Determine:

(i) an expression for v_{out}, and [5 *marks*]

(ii) show that if $R_1=R_2=R_f$, then,

$$v_{out} = -(v_1 + v_2)$$ [2 *marks*]

(d) (i) Determine an expression for the voltage gain for the circuit in Figure 4, and

(ii) state what kind of analogue operation can be performed by such a circuit [6+ 2 *marks*]

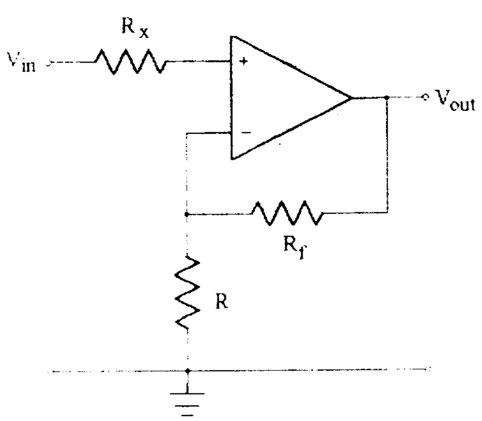


Figure 3(a)

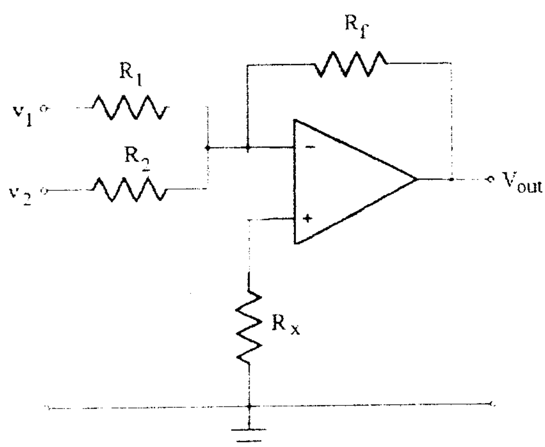


Figure 3(b)

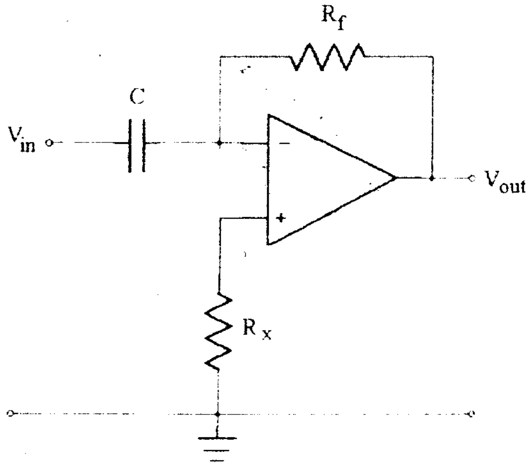


Figure 4

END OF P341 EXAMINATION

THE UNIVERSITY OF ZAMBIA
PHYSICS DEPARTMENT
UNIVERSITY EXAMINATIONS - 1997
P361 - ELECTROMAGNETISM

TIME: 3 HOURS MAX MARKS: 100

ATTEMPT ANY **FOUR** QUESTIONS. ALL QUESTIONS CARRY EQUAL MARKS.

You may use the following information:

$\varepsilon_0 = 8.85 \times 10^{-12}$ farad/meter;
$\mu_0 = 4\pi \times 10^{-7}$ N/A^2

$$\int_0^\pi \sin^3\theta \, d\theta = \frac{4}{3}$$

$$\sqrt{-i} = \frac{1}{\sqrt{2}}(1-i) \; ; \quad \textit{where} \quad i = \sqrt{-1}$$

$$B = \nabla X A \; ; \qquad \vec{A} = \frac{\mu_0 I}{4\pi}\oint\frac{\vec{dl}}{r}$$

Divergence of a vector A in spherical coordinates (r, θ, ϕ) is given by

$$\nabla . A = \frac{2}{r}A_r + \frac{\partial A_r}{\partial r} + \frac{A_\theta}{r}\cot\theta + \frac{1}{r}\frac{\partial A_\theta}{\partial \theta} + \frac{1}{r\sin\theta}\frac{\partial A_\phi}{\partial \phi}$$

Laplacian in spherical polar coordinates (r, θ, ϕ) is given by

$$\nabla^2 = \frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial}{\partial r}\right) + \frac{1}{r^2\sin\theta}\frac{\partial}{\partial\theta}\left(\sin\theta\frac{\partial}{\partial\theta}\right) + \frac{1}{r^2\sin^2\theta}\frac{\partial^2}{\partial\phi^2}$$

In cylindrical coordinates (ρ, ϕ, z)

$$\vec{\nabla}\times\vec{A} = \frac{1}{\rho}\begin{vmatrix} \hat{\rho} & \rho\hat{\phi} & \hat{z} \\ \frac{\partial}{\partial\rho} & \frac{\partial}{\partial\phi} & \frac{\partial}{\partial z} \\ A_\rho & \rho A_\phi & A_z \end{vmatrix}$$

Poisson Equation

$$\nabla^2 V = -\frac{\rho}{\epsilon_0}$$

The vector **r** is directed from P'(x', y', z') to P(x, y, z). If P' is fixed and P is allowed to move, then the gradient under this condition is given by

$$\nabla\left(\frac{1}{r}\right) = -\frac{\hat{r}}{r^2}$$

If P is fixed and P' is allowed to move, then the gradient is

$$\nabla'\left(\frac{1}{r}\right) = \frac{\hat{r}}{r^2}$$

The vector identities

$$\nabla \times (\nabla \times A) = -\nabla^2 A + \nabla(\nabla . A)$$

$$\nabla .(fA) = f\, \nabla . A + A . \nabla f$$

$$\nabla(V . \nabla V) = (\nabla V)^2 + V\, \nabla^2 V$$

For a long solenoid of length L, $B = \mu_0 N I / L$ inside; $= 0$ outside

The magnetic induction at a point on the axis of a circular current carrying loop is

$$B = \frac{\mu_0 I a^2}{2(a^2+z^2)^{3/2}}$$

Maxwell's Equations are

$$\nabla . D = \rho_f \quad ; \qquad \nabla . B = 0$$

$$\nabla \times E + \frac{\partial B}{\partial t} = 0 \quad ; \qquad \nabla \times H - \frac{\partial D}{\partial t} = J_f$$

Q.1 (a) The energy W for an electric charge distribution of density $\rho(x, y, z)$ is given by

$$W = \frac{1}{2}\int_{\tau} V\rho\, d\tau$$

Use the above expression to show that the energy density associated with an electric field is given by

$$\frac{dW}{d\tau} = \frac{\epsilon_0}{2}E^2 \text{ joules/m}^3$$

[10 marks]

(b) Show that the electric potential energy of a sphere of radius R carrying a charge Q uniformly distributed over its volume is equal to $3Q^2/20\pi\varepsilon_0 R$.

[15 marks]

Q.2 (a) Show that the electric potential due to a polarized material at a point away from the material is given as the sum of the potentials due to a bound surface charge of density $\sigma_b = \mathbf{P}.\hat{\mathbf{n}}$ and a bound volume charge of density $\rho_b = -\nabla.\mathbf{P}$. [11 marks]

(b) A sphere of radius R is polarized uniformly with polarizaion **P**

(i) Calculate the bound surface and volume charge densities. [2+2 marks]

(ii) Show that the sphere stays neutral overall. [4 marks]

(iii) Calculate the electric field intensity at the centre of the sphere due to the bound charges. [6 marks]

Q.3 A conducting sphere of radius R is charged to a potential V and spun about a diameter at an angular velocity ω. Show that

(a) the surface current density is $\varepsilon_0\omega V \sin\theta$, where θ is the spherical polar angle of a point on the surface if the axis of rotation is taken as the z-axis and the centre of the sphere as the origin. [8 marks]

(b) the magnetic induction B at the centre is $(2/3)\mu_0\varepsilon_0\omega V$. [8 marks]

(c) the magnetic dipole moment is $(4/3)\pi R^3 M\hat{\mathbf{k}}$ where $M = \varepsilon_0\omega V$. [9 marks]

Q.4 (a) Define mutual inductance and show that $M_{ab} = M_{ba}$. [2+5 marks]

(b) Obtain an expression for the mutual inductance between two long coaxial solenoids of nearly the same radius R, the lengths L_a and L_b ($L_a > L_b$) and the total number of turns N_a and N_b, respectively. [8 marks]

(b) Two long parallel rectangular loops lying in the same plane have lengths L_1 and L_2 and widths w_1 and w_2, respectively. The loops do not overlap, and the distance between the near sides is *s*. Show that the mutual inductance between the loops is

$$M = \frac{\mu_0 L_2}{2\pi} \ln\left[\frac{s + w_2}{s\left(1 + \frac{w_2}{s + w_1}\right)}\right]$$

if $L_2 < L_1$ and if the loops have a single turn. Neglect end effects.

[10 marks]

Q.5. A long wire of radius *a* carries a current I and is surrounded by a long coaxial hollow iron cylinder. The inner radius of the cylinder is *b* and the outer radius *c*. Assuming the material to be isotropic and linear,

(a) Calculate the flux of B inside a section of the cylinder L meters long. [6 marks]

(b) Find the equivalent surface current density on the inner and outer iron surfaces, and find the direction of the equivalent currents relative to the current in the wire. [5+2 marks]

(c) Find the equivalent current density inside the iron. [6 marks]

(d) Find B at distances $r > c$ from the wire. How would this value be affected if the iron cylinder is removed? [5+1 marks]

Q.6 In a homogeneous, linear, isotropic and stationary medium, in the absence of free charges, the **E** vector obeys the following wave equation

$$\nabla^2 E - \epsilon\mu \frac{\partial^2 E}{\partial t^2} - \sigma\mu \frac{\partial E}{\partial t} = 0$$

(a) Using complex notation for a plane sinusoidal wave travelling along the positive z-direction, show that in a good conductor the wave number is complex and is equal to $(\omega\sigma\mu/2)^{1/2}$ (1 - i). Hence show that the amplitude of the electric field vector is attenuated exponentially as $E \sim \exp(-z/\delta)$, where z is the thickness of the medium traversed by the wave and $\delta = (2/\omega\sigma\mu)^{1/2}$.

[15 marks]

(b) If the average value of the Poynting vector at a distance z inside a good conductor is given by

$$S_{av} = \frac{1}{2}\left(\frac{\sigma}{2\omega\mu}\right)^{\frac{1}{2}} E_0^2 \exp\left(-\frac{2z}{\delta}\right),$$

what fraction of the power is dissipated inside a nickel sheet of thickness 0.5 mm when it is placed perpendicular to the direction of propagation of electromagnetic waves of frequency 1 kilohertz?

(For nickel $\sigma = 1.3 \times 10^7$ mho/meter, $\mu_r = 100$).

[10 marks]

.... **END OF THE EXAMINATION** ....

THE UNIVERSITY OF ZAMBIA

PHYSICS DEPARTMENT

UNIVERSITY EXAMINATIONS-1998

P-401

(Computational Physics-II)

Time: Three Hours **Max.Marks:** 100

Answer:(i) Question **1** is *compulsory*.
(ii) Any **Three** questions from **2,3,4,5** and **6**.

All questions carry equal marks.
(Marks are shown in the Square Brackets)

INSTRUCTION: Whenever necessary, use the information given in the Appendix.

Q.1. (A) Identify the errors if any in the following [5]

(i)
```
      WRITE (*,10) X
   10 FORMAT(2X,F6.5,,'VALUE OF X ' , // )
```
(ii)
```
      CHARACTER*5 NAME, SCHOOL*17
      NAME= 'PHYSICS'
      SCHOOL= 'NATURAL SCIENCES'
```
(iii)
```
      IF( X . EQ . 7.0 )
         THEN STOP
      ENDIF
```
(iv)
```
      FUNCTION SUM(X)
      DO 10 J=1,5
        X(J)=X(J)+1
   10 CONTINUE
      END
```
(v)
```
      COMMON/A(10),X(5),Y/BK1/ X(10),Z/
```

(B) Write a program to read and print a FORTRAN program devoid of all comment lines The program is to be read from a data file which contains a FORTRAN program having many comment lines [5]

(C) Write a program to read the data given below and write on a file 'EX1.DAT' [5]

PHYSICS PAPER 4091 FOURTH YEAR

and then to read the data from file 'EX1.DAT' and write on output file 'EX1.OUT' as follows

491 FOURTH YEAR PHYSICS PAPER

(D) Given (x_i, y_i) for i= 1,2,......10 , [5]
use DO-loops to write a program to evaluate

$$\sum x_i \ , \ \sum x_i^2 \ , \ \sum x_i y_i \ , \ \sum x_i^2 y_i^2$$

(E) The normal probability function ϕ is defined as: [5]

$$\phi(x) = \frac{1}{\sqrt{2\pi}} \exp(-x^2/2)$$

Write a program to evaluate $\phi(x)$ for values of x from -3.0 to 3.0 in steps of 0.2 and store them in an array. Display the results in a table with five values to a line.

Q.2.: (A) The following data are given [10]

m1 = 2.56 , m2= 7.56 , theta= 23.5 and cross= 2.14E-24

Write a program to
(i) write the data on a file whose name is to be given through a default device,
(ii) read the data from the file and write on an output file whose name is to be given through a default device. The output should contain the corresponding variable names m1, m2, theta and cross.

(B) Write a program to calculate $f(x_k)$ at $x_k = 400$ using the data given below [15]

$f(x_k)$	80	90	210	450	840
x_k	100	130	300	650	1200

Use Lagrange's Interpolating Polynomial *P(x)* given by

$$P(x) = \sum_{k=0}^{n} f(x_k) L_{n,k}(x)$$

where

$$L_{n,k} = \frac{(x-x_0)(x-x_1)..........(x-x_{k-1})(x-x_{k+1}).......(x-x_n)}{(x_k-x_0)(x_k-x_1)..........(x_k-x_{k-1})(x_k-x_{k+1}).......(x_k-x_n)}$$

for $k = 0,1,2,........n$

Q.3. The sample data of ambient room light obtained by an optical multi-channel analyzer are given in the following table

λ	Intensity I(λ)	λ	Intensity I(λ)
4357.84	40.0	4358.39	168.0
4357.94	41.0	4358.49	111.0
4358.04	7.0	4358.59	64.0
4358.14	66.0	4358.69	51.0
4358.24	129.0	4358.79	46.0
4358.34	165.0	4358.84	41.0

It is proposed to fit the data to a theoretical Lorentzian line shape function given by

$$I(\lambda) = \frac{I_0}{1+4(\lambda-\lambda_0)^2/\Gamma^2}$$

The merit function is given by

$$\chi^2 = \sum_{j=1}^{N}[I_j - B - I(\lambda_j)]^2$$

where I_j measured intensities, B = 30.0 and I_0 = *168.5*.

By minimising χ^2 the best value of λ_0 and Γ are given.

Write a program to

(i) to create a data file for the data given above with the file name 'INTEN.DAT' [5]

(ii) to calculate χ^2 for $0.1 \le \Gamma \le 0.6$ with increment $\Delta\Gamma$=0.05 and $4358.2 \le \lambda_0 \le 4358.5$ with increment $\Delta\lambda$=0.01 [15]

(iii) to tabulate χ^2 as a function of Γ and λ_0 on an output file with any name given through a default device [5]

Q.4. Consider a two dimensional lattice with 200 lattice points along the x-direction and 40 lattice points along the y-direction forming a set of square lattices each of side of unit length. The total number of lattice points is 200 x 40 . Assume that all the lattice points at (x,y=20) and (x,y=-20) for all x have reflecting property. That is if a walker reaches y=20 the next step is towards south or if the walker reaches y=-20, the next step is towards north. Here we have assumed y-direction to be north-south.

Write a program to find the mean displacement of a walker taking 100 steps in 50 trials starting from (x=0,y=0). [25]

Assume that you have a subroutine RN(N,S,RD) which generates N-number of random numbers RD(N) for a given seed S.

Q.5.(a) Define autocorrelation and show that autocorrelation of a signal S with noise n will be a signal on a constant background due to noise. [5]

(b)Explain the difference between Fourier, Discrete Fourier and Fast Fourier Transforms. [5]

(c) The Duffing Oscillator differential equation is given by [15]

$$\frac{d^2x}{dt^2} + k\frac{dx}{dt} + x^3 = B\cos t \qquad where\ B = constant$$

Assume initial conditions to be at $t=0$, $x(t=0)=0.5$ and $\left.\frac{dx}{dt}\right|_{t=0} = 0$

Write an algorithm in pseudo code to

(i) find the solution x(t) on the interval $0 \le t \le 25$ at 200 points ,

(ii)find the frequency spectrum using solutions of (i). Assume that the subroutine for FFT is given with the name FOUR1(DATA,NN,ISIGN) where DATA is the input data of 2*NN points and with ISIGN=1. The returned values of DATA will be the Fourier Transform of the original data points.

Q.6.: (a) Explain the term Chaos and Deterministic Chaos. [5]

(b) In the presence of damping and driving force the Simple Pendulum is described by the differential equation

$$\frac{d^2x}{dt^2} + c\frac{dx}{dt} + [1 + F\cos(\varpi t)]\sin x = 0$$

where $\omega = 2\pi f$, f= frequency of the driving force,
F= amplitude of driving force and c = damping constant=0.1.
Mass of the pendulum is assumed to be unity and L/g=1
where L=length of the pendulum and g=acceleration due to gravity.

Consider the initial conditions to be

$$\text{at } t=0,\ x(0)=1 \text{ and } \left.\frac{dx}{dt}\right|_{t=0}=0$$

Write a pseudo code to solve the above equation to find [15]

(i) $x(t)$ and $p(t)=\dfrac{dx}{dt}$ for $0 \le t \le 8\pi/\omega$

with increment $\Delta t = 8\pi/150\,\omega$ and for F=1.51, 1.79 and 1.9, given $\omega = 2.0$.

(c) Explain the terms Poincare' Section and Fractal with reference to the solutions of (b). [5]

@@@END OF EXAMINATION@@@

APPENDIX

1.Non-Linear Equations:

Newton-Raphson method:

$$x_n = x_{n-1} - \frac{f(x_{n-1})}{f'(x_{n-1})}$$

2.Integration:

(a) Trapezoidal Rule:

$$\int_a^b f(x)\,dx = 0.5\,h\left[f(a) + f(b) + 2\sum_{j=1}^{m-1} f(x_j) \right]$$

with $x_j = a + j\,h$ with $j = 1,2,3,\ldots\ldots\ldots,m$.

(b) Simpson Rule:

$$\int_a^b f(x)\,dx = \frac{h}{3}[\, f(a) + f(b) + 4\,(f_1 + f_3 + f_5 + \ldots\ldots + f_{2n-1})$$
$$+ 2\,(\, f_2 + f_4 + f_6 + \ldots\ldots + f_{2n})\,]$$

(c) Monte Carlo Method:

$$\int_a^b f(x)\,dx = \frac{(b-a)}{N}\sum_{i=1}^{N} f(x_i)$$

3. Solution of Differential Equation:

(a) First Order Differential equation with initial conditions:

$$\frac{dy}{dx} = f(x, y)$$

(i) Euler Method:

$$y_{i+1} = y_i + h\,f(x_i, y_i) \qquad \text{where } h = x_{i+1} - x_i$$

(ii) Fourth Order RK-Method:

$$y_{i+1} = y_i + (k_1 + 2k_2 + 2k_3 + k_4)/6$$

where

$$k_1 = h\, f(x_i, y_i)$$

$$k_2 = h\, f(x_i + 0.5\,h,\ y_i + 0.5\,k_1)$$

$$k_3 = h\, f(x_i + 0.5\,h,\ y_i + 0.5\,k_2)$$

$$k_4 = h\, f(x_i + h,\ y_i + k_3) \qquad \text{, where } h = x_{i+1} - x_i$$

(b) Second Order Differential Equation:

(i) A second -order differential equation

$$\frac{d^2y}{dx^2} + q(x)\frac{dy}{dx} = r(x)$$

can be written as two first-order equations

$$\frac{dy}{dx} = z(x) \quad \text{and} \quad \frac{dz}{dx} = r(x) - q(x)\,z(x)$$

where z is a new variable.

(ii) Numerov Method:

$$\frac{d^2y}{dx^2} + k^2(x)y = S(x)$$

$$\left(1 + \frac{h^2}{12}k_{n+1}^2\right)y_{n+1} - 2\left(1 - \frac{5h^2}{12}k_n^2\right)y_n + \left(1 + \frac{h^2}{12}k_{n-1}^2\right)y_{n-1}$$

$$= \frac{h^2}{12}\left(S_{n+1} + 10S_n + S_{n-1}\right)$$

........@@@.........

UNIVERSITY OF ZAMBIA

PHYSICS DEPARTMENT

UNIVERSITY EXAMINATION MARCH 1998

P421

SOLID STATE PHYSICS 1

TIME: THREE (3) HOURS

ANSWER: ANY FOUR (4) QUESTIONS

ALL QUESTIONS CARRY EQUAL MARKS

<u>DATA YOU MAY FIND USEFUL</u>

Planck's constant (reduced)	$\hbar = 1.0546x10^{-34}\,Js$
Boltzmann's constant	$k_B = 1.38x10^{-23}\,JK^{-1}$
Permittivity of free space	$\varepsilon_o = 8.85x10^{-12}\,Fm^{-1}$
Electronic charge	$e = 1.6x10^{-19}\,C$
Electronic rest mass	$m_e = 9.11x10^{-31}\,kg$
Avogadro's Number	$N = 6x10^{26}$ per kg mole

$$\int_{-\infty}^{\infty} \frac{x^2 e^2}{(e^x - 1)^2} dx = \frac{\pi^2}{3}$$

$$\int_0^{\frac{\theta}{T}} \frac{x^4 e^x}{(e^x - 1)^2} dx = \frac{4\pi^4}{15}$$ at low temperatures.

$$= \frac{1}{3}\left(\frac{\theta_D}{T}\right)^3$$ at high temperatures.

(a) Define the Brillouin zone. Draw the second and third Brillouin zones for a square lattice. (5 marks)

(b) The basis of the fcc structure referred to the cubic cell has identical atoms at $000; 0\frac{1}{2}\frac{1}{2}; \frac{1}{2}0\frac{1}{2}; \frac{1}{2}\frac{1}{2}0$.
Show that the structure factor of this crystal lattice type is zero for (100) and (110) reflections but non -zero for (111) reflections. (6 marks)

(c) On an X-ray powder photogragh of a cubic substance taken with copper K_α, radiation ($\lambda = 1.5\ \mathring{A}$) lines are observed corresponding to $(h^2 + k^2 + l^2)$ values of 3, 4, 8, 11, 12, 16, 19, 20, respectively. Assign indices to these lines and determine whether the lattice is sc,bcc or fcc.
The density of the substance is 8 g cm^{-3} and its molecular weight is 300. The atomic mass unit may be taken as 1.6×10^{-24} g.
Taking $(h^2 + k^2 + l^2) = 16$, and $\sin\theta = 0.5$, calculate the number of atoms per unit cell. (14 marks)

a) Comment, briefly, on whether the Debye temperature is a constant. (3 marks)

b) In the Debye approximation, the density of states for each polarization is given by

$$D(\omega) = \frac{V\omega^2}{2\pi^2 \upsilon^3}$$

in the usual notation.

(i) Using this, obtain an expression for the heat capacity of solids. (10marks)

(ii) Show that the heat capacity at low temperatures is proportional to T^3. (2 marks)

(iii) Show that at high temperatures the Debye theory gives the Dulong - Petit values. (2 marks)

) At low temperatures the Debye temperature of NaCl and KCl, which have similar crystal structure, are 300K and 250K respectively.
The lattice heat capacity of KCl at 4K is 4×10^{-2} mol^{-2} deg^{-1}.
Estimate the lattice heat capacity of NaCl at 4K and that of KCl at 2K. (8marks)

a) (i) Describe the origin of the Hall effect and derive the expression for the Hall coefficient R_H . Illustrate your answer with the help of a diagram. (9 marks)

(ii) What information can we gain from the measurement of the Hall coefficient? (3 marks)

(iii) In what way is the free electron theory inadequate in explaining the variations between Hall coefficients of different metals. (3 marks)

b) The electronic contribution to the heat capacity of metals at low - temperatures is experimentally found to be linear in temperature and can be written as

$$C_{el} = \gamma\ T$$

where γ is a constant.

Using the free electron gas model, obtain an expression for γ . (12 marks)
The density of states for a free electron gas is given by

$$D(\varepsilon) = \frac{3N}{2\varepsilon}$$

where the symbols have their usual meaning.

Do the calculated values of γ agree well with the observed values? If not, why? (3 marks)

a) What is a Fermi sphere as defined in the free electron theory? (5 marks)

b) Using your knowledge of the free electron model, show that for a cubic sample of a metal the Fermi energy at 0K is given by

$$\varepsilon_F = \frac{\hbar^2}{2m}(3\pi^2 n)^{\frac{2}{3}}$$

where n is the concentration of electrons and all the other symbols have their usual meaning. (10 marks)

(c) Calculate the Fermi energy for sodium in which the nearest neighbour distance is 3.66 $\overset{o}{A}$. Sodium has a bcc structure. (10marks)

(a) State and prove Bloch's theorem. (7 marks)

b) (i) With the help of suitable diagrams, describe the origin of the gap between energy bands in a solid. (4 marks)

(ii) What is the energy difference, in the first order, at the zone boundary between the two bands? (10 marks)

(iii) How is the gap energy related to the crystal potential? (4 marks)

a) In semiconductors there are two types of carriers. Is there any relationship between their concentrations and if so what does it depend on? (5 marks)

b) A sample of germanium shows no Hall effect. The mobility of electrons is 2.1 times the mobility of holes in the sample.

(i) Show that the Hall coefficient for the two types of carriers is given by

$$R_H = \frac{p\mu_h^2 - n\mu_e^2}{e(p\mu_h + n\mu_e)^2},$$

where p, n are the concentrations of holes and electrons respectively, μ_h and μ_e are the respective mobilities. (10 marks)

(ii) What is the ratio of the number density of conduction electrons to the number density of holes for the sample described above? (5marks)

(iii) What fraction of the current is carried by holes? (5marks)

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
PHYSICS DEPARTMENT
UNIVERSITY EXAMINATION
MARCH 1998
P441
ANALOG ELECTRONICS

TIME: 3 HOURS MAXIMUM MARKS 100

ANSWER 4 QUESTIONS
ALL QUESTIONS CARRY EQUAL MARKS

Laplace transform pairs

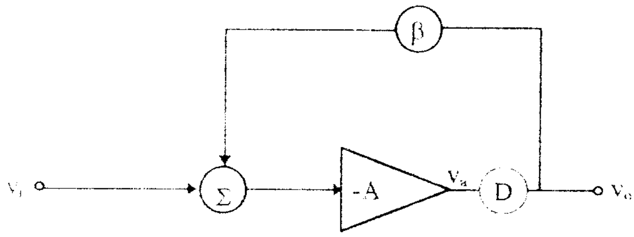
$f(t)$	$F(s)$
e^{at}	$\frac{1}{s-a}$
$\frac{d^n f(t)}{dt^n}$	$s^n F(s) - s^{n-1} f(0) - s^{n-2} f'(0) \ldots\ldots f^{(n-1)}(0)$

Q.1. What is meant by the term "Power Rating" of an operational amplifier? [2]

a) Derive the expressions for the general transfer function of an amplifier with Negative Feedback. [5]

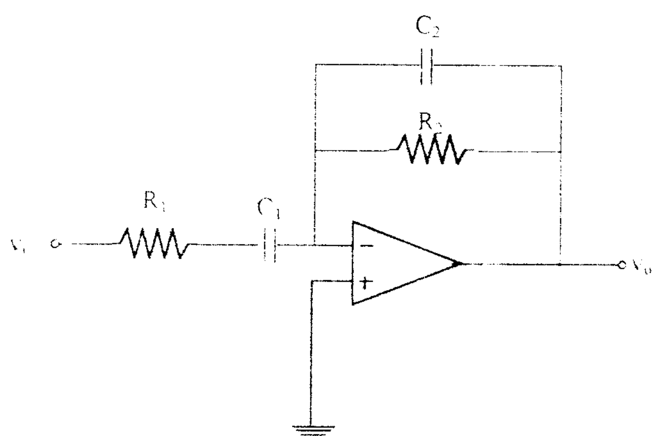
b) For the non-inverting op-amp amplifier determine the gain v_o/v_i of the circuit and thus find an expression for β (the feedback factor). [9]

c) Using the equivalent circuit for an amplifier with a distortion signal as shown, demonstrate that the negative reduces distortion. [9]



Q.2 What information can be obtained form a polar plot? [2]

a) For the circuit below find the transfer function. [10]



b) Given that the components for the above circuit have the values $C_1 = C_2 = 1\mu F$, $R_1 = 100K$ and $R_2 = 1K$. Derive the bode plot clearly indicating the cut-off frequencies in rad/s. [13]

3 What is the advantage of an active filter compared to a passive filter? [2]

a) Design a second order butterworth low pass filter with cut-off frequency of 5kHz. Draw the circuit [10]

b) For the active bandpass filter below find the midband gain A_m, Q value and the midband frequency ω_m. [13]