THE UNIVERSITY OF ZAMBIA SCHOOL OF NATURAL SCIENCES

FIRST SEMESTER 2008

1. BS211- CELL MOLECULAR BIOLOGY AND GENETICS
2. BS221- FORM FUNCTION AND DIVERSITY OF PLANTS
3. BS319- BIOSTATISTICS
4. BS321- ETHOLOGY AND EVOLUTION
5. BS331- PLANT PHYSILOGY
6. BS349- MICROBIOLOGY
7. BS361- MOLECULAR BIOLOGY
8. BS375- INVERTEBRATES
9. BS411- INSECT BEHAVIOUR AND ECOLOGY
10. BS425- IMMUNOLOGY
11. BS431- ADVANCED PARASITOLOGY I
12. BS441- ADVANCED MOLECULAR BIOLOGY I
13. BS471- ENVIRONMENTAL MICROBIOLOGY
14. BS475- POPULATION ECOLOGY
15. BS491- FRESHWATER BIOLOGY
16. BS915- BIOLOGY OF SEED PLANTS
17. BS935- PLANT PATHOLOGY
18. C101- INTRODUCTION TO CHEMISTRY I
19. C205- ANALYTICAL AND INORGANIC CHEMISTRY
20. C225- ANALYTICAL CHEMISTRY I
21. C251- ORGANIC CHEMISTRY I
22. CAV251- AGRICULTURAL AND VETERNARY CHEMISTRY
23. C252- ORGANIC CHEMISTRY II

24. C491- ORGANIC INDUSTRIAL CHEMISTRY I
25. C311- BIOCHEMISTRY I
26. C312- BIOCHEMISTRY II
27. C321- ANALYTICAL CHEMISTRY II
28. C341- INORGANIC CHEMISTRY II
29. C421- APPLIED ANANLYTICAL CHEMISTRY
30. C441- ADVANCED INORGANIC CHEMISTRY I
31. C451- ADVANCED ORGANIC CHEMISTRY
32. CST3011- ALGORITHMS AND DATA STRUCTURES
33. CST3031- INTRODUCTION TO SOFTWARE ENGINEERING
34. CST3141- OBJECT ORIENTED ANALYSIS AND DESIGN
35. CST4241- ELECTRONICS FOR COMPUTING III
36. GEO111- INTRODUCTION TO HUMAN GEOGRAPHY I
37. GEO111- INTRODUCTION TO HUMAN GEOGRAPHY I
38. GEO155- INTRODUCTION TO PHYSICAL GEOGRAPHY
39. GEO271- QUANTITATIVE TECHNIQUES IN GEOGRAPHY
40. GEO381- ENVIRONMENT AND DEVELOPMENT I
41. GEO481- ENVIRONMENT AND DEVELOPMENT II
42. GEO911- POPULATION GEOGRAPHY
43. GEO915- MEDICAL GEOGRAPHY
44. GEO921- ECONOMIC GEOGRAPHY
45. GEO971- AERIAL PHOTOGRAPHY AND AIR PHOTO INTERPRETATION
46. GEO971- AERIAL PHOTOGRAPHY AND AIR PHOTO INTERPRETATION
47. M111- MATHEMATICAL METHODS I
48. M161- INTRODUCTION TO MATHEMATICS, PROBABILITY AND STATISTICS I

49. M211- MATHEMATICAL METHODS III
50. M211- MATHEMATICAL METHODS III
51. M221- LINEAR ALGEBRA I
52. M231- REAL ANALYSIS I
53. M261- INTRODUCTION TO STATISTICS
54. M331- REAL ANALYSIS III
55. M335- TOPOLOGY
56. M361- MATHEMATICAL STATISTICS
57. M411- THEORY OF FUNCTIONS AND A COMPLEX VARIABLE I
58. M421- STRUCTURE AND REPRESENTATIONS OF GROUPS
59. M431- REAL ANALYSIS V
60. M911- MATHEMATICAL METHODS V
61. P191- INTRODUCTORY PHYSICS I
62. P231- GENERAL PROPERTIES OF MATTER AND THERMAL PHYSICS
63. P261- ELECTRICITY AND MAGNETISM
64. P341- ANALOG ELECTRONICS I
65. P351- INTRODUCTION TO QUANTUM MECHANICS
66. P361- ELECTROMAGNETISM
67. P401- COMPUTATIONAL PHYSICS II
68. P421- SOLID STATE PHYSICS I
69. P441- ANALOG ELECTRONICS II

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2008 ACADEMIC YEAR FIRST SEMESTER
FINAL EXAMINATIONS

BS 211: CELL MOLECULAR BIOLOGY AND GENETICS
THEORY PAPER

INSTRUCTIONS: ANSWER **FIVE** QUESTIONS. ANSWER AT LEAST TWO QUESTIONS FROM EACH SECTION, WHILE THE FIFTH QUESTION MAY BE CHOSEN FROM ANY SECTION. USE SEPARATE ANSWER BOOKS FOR EACH SECTION.

SECTION A – Cell Molecular Biology

1. The steady state kinetics of an enzyme are studied in the absence and presence of an inhibitor (Inhibitor A). The initial rate is given as a function of substrate concentration in the following table:

	V [(m mol/ L) min $^{-1}$]	
[S] (m mol/ L)	No inhibitor	Inhibitor A
1.25	1.72	0.98
1.67	2.04	1.17
2.50	2.63	1.47
5.00	3.33	1.96
10.00	4.17	2.38

(a) Use the Lineweaver-Burk double reciprocal plot to determine if the inhibition is competitive or noncompetitive.

(b) Determine V_{max} and K_M in the absence and presence of inhibitor.

(c) Explain how the value of K_M affects the catalytic efficiency of an enzyme.

Turn over

2. (a) Describe the flow of electrons from NADH and $FADH_2$ in mitochondrial oxidative phosphorylation.

   (b) Summarize the chemiosmotic coupling mechanism of ATP synthesis in the mitochondria.

3. Summarize the major steps in the chemical reactions involved in the hydrolysis of glucose to pyruvate in cellular glucose metabolism. Indicate the enzymes involved at each step.

4. Free energy changes under intracellular conditions differ markedly from those determined under standard conditions. $\Delta G^{0\prime}$ for ATP hydrolysis to ADP and Pi is -30.5 kJ/ mol. Calculate the free energy change under intracellular conditions ($\Delta G'$) for ATP hydrolysis in a cell at 37 ^{0}C that contains ATP at 3 mM, ADP at 0.2 mM and Pi at 50 mM. (R= 8.31451 J/ ^{0}K. mol).

SECTION B – Genetics

5. Explain chromosomal aberrations in terms of number, giving specific details and their influence especially in humans and plants.

6. State the Hardy-Weinberg principle and indicate its usefulness in population genetics. Assuming a scenario where genotypes A_1A_1, A_2A_2 and A_1A_2 have the following frequencies: 0.1, 0.5 and 0.4 respectively;

   (a) Use these values to illustrate that random mating will produce Hardy-Weinberg proportions in one generation.

   (b) Suppose that there were 200 individuals in the population, use a chi-square test to determine whether this population is statistically different from Hardy-Weinberg proportions.

7. Discuss gene linkage, highlighting the importance of the experiments performed by Bateson and Punnett and the phenomenon of crossing over.

8. Discuss regulation of gene action, emphasizing the importance of the operon system.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2008 ACADEMIC YEAR FIRST SEMESTER
FINAL EXAMINATIONS

BS 221: FORM, FUNCTION AND DIVERSITY OF PLANTS
THEORY PAPER

TIME: THREE HOURS

INSTRUCTIONS: ANY **FIVE** QUESTIONS. USE ILLUSTRATIONS WHEREEVER NECESSARY

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1. Explain why *Chara* is considered an aberration among green algae and describe its unique botanical characters and relationships with other plant groups.

2. State the salient features of the Volvocales. Describe structure and reproduction in *Chlamydomonas.*

3. Describe the thallus structure and methods of reproduction in *Ulothrix*. Give evidence in support of origin of sex shown by this alga.

4. Describe characteristic features of Oomycetes. Describe sporangiophore structure in *Phytophthora* and *Peronospora* and the common name of plant diseases caused by these two fungi.

5. Describe characteristics, structure and the reproductive process in a named lycophyte.

6. Describe alternation of generations and full life cycle of *Riccia*.

7. Describe structure and reproduction and economic importance of diatoms.

8. Write detailed notes on any TWO of the following:

(a) Apical Caps
(b) *Spirulina*
(c) Diffuse growth in algae
(d) *Cladophora*

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2008 ACADEMIC YEAR FIRST SEMESTER
FINAL EXAMINATIONS

BS319: BIOSTATISTICS

TIME: THREE HOURS

INSTRUCTIONS: ANSWER QUESTION **ONE** IN SECTION A AND **TWO** QUESTIONS FROM SECTION B AND ANOTHER **TWO** QUESTIONS FROM SECTION C AND USE ILLUSTRATIONS WHEREVER POSSIBLE.

SECTION A (COMPULSORY)

1. In a study to determine above ground grass biomass production at four miombo woodland sites, the following biomass was found at the end of the rainy season:

Site	Above ground grass biomass (g per sq. cm)								
A	59	137	64	39	64	47	72	117	44
B	48	41	40	36	98	103	20	44	41
C	98	33	66	68	43	92	34	86	46
D	39	45	30	66	27	16	27	15	40

Determine whether the grass biomass at the four sites was significantly different.

SECTION B

2. Discuss the main sources of variability in biological observations and how such variability can be estimated.

3. Distinguish parametric tests from nonparametric tests.

4. Explain the usefulness of replication in experimental design.

5. Define Analysis of Variance and explain why it is considered to be more efficient than the two-sample t-test.

Turn over

SECTION C

6. A researcher weighed seeds of the wild orange tree, *Strychnos spinosa*, recovered from three different elephant dung in Kasanka National Park in Serenje district. The results were as follows:

Dung	Seed dry weight (g)			
A	0.292	0.243	0.237	0.333
B	0.124	0.168	0.147	0.222
C	0.254	0.033	0.355	0.398

Using the Kruskal-Wallis H statistic (H =[12/(N(N+1) $\sum_{j=1}^{k}(R_j^2/n_j)]-3(N+1)$)

determine if the seed samples came from the same tree.

7. A researcher enumerated lesions caused by a disease on each half of 16 leaves of the savanna tree *Erythrina abyssinica*, and obtained the following results:

Half leaf	Lesions per half leaf															
Right half	8	3	7	11	29	0	1	26	5	6	4	3	4	10	42	30
Left half	11	9	0	5	34	32	31	27	18	5	8	26	0	0	3	5

Use the Sign test to test whether the disease affected the two halves of each leaf in the same way and justify your decision.

8. A researcher measured the girth (circumference) at 1.3 m above ground and leaf biomass of *Uapaca kirkiana* (musuku) trees at the end of the rainy season in March and obtained the following results:

Girth (cm)	24	27	45	52	54	35	16	16	17	37
Leaf (kg)	1.5	2.3	4.5	4.5	4.9	1.9	0.2	0.3	0.2	1.3

Determine whether there is correlation between tree girth and leaf biomass. If there is, develop a model that can be used to predict leaf biomass from girth measurements.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2008 ACADEMIC YEAR FIRST SEMESTER FINAL EXAMINATIONS

BS 321: ETHOLOGY AND EVOLUTION

THEORY PAPER

TIME: THREE (3) HOURS

INSTRUCTIONS: ANSWER QUESTIONS ONE AND ANY OTHER FOUR QUESTIONS. ILLUSTRATE YOUR ANSWERS WHERE NECESSARY.

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1. Charles Darwin proposed that evolution by natural selection was the basis for the differences that he saw in similar organisms as he traveled and collected specimens in South America and on the Galapagos Islands.

   a) Explain the theory of evolution by Natural Selection as presented by Darwin.
   b) Explain Natural Selection and the insecticide-resistant insects

2. Summarize the following terms as used in evolution of species:
   a) Teleology
   b) Continental drift
   c) Handicap principle
   d) Genetic drift

3. If success in passing on genes determines the evolution of a species, explain why do not all organisms grow rapidly, reproduce shortly after birth, produce many offspring, reproduce frequently, and take extensive care of young?

4. Discuss chemical communication in animal species, and explain how such communication could be an essential mechanism in prey species.

5. Discuss why behavior can be assumed to be adaptive and evolving, as exhibited by the nest-building behavior of weaver birds.

6. Discuss how imprinting behavior could be useful in both offspring and parents in precocial species, where offspring are mobile upon hatching. Should we expect that kind of imprinting in mammals such as domestic dog or a human?

Turn over

7. Contrast character displacement and habituation, and explain why each one is significant to the evolution of species

8. Contrast Lamarckism and Darwinism as they relate to the evolution of altruistic behaviour in social species?

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2008 ACADEMIC YEAR FIRST SEMESTER
FINAL EXAMINATIONS

BS331: PLANT PHYSILOGY
PRACTICAL PAPER

TIME: TWO HOURS

INSTRUCTIONS: ANSWER BOTH QUESTIONS

1. The table below shows results of analysis for K^+ and Ca^{2+} in *Avena* (oat) roots grown in nutrient solution:

Mineral ion	Ionic concentration in nutrient solution (mol m^{-3})	Concentration of ion in root tissue (mol m^{-3})
K^+	1.0	66.0
Ca^{2+}	1.0	1.5

Measured membrane potential E = -84 mV

(a) From this data calculate the Nernst potentials for K^+ and Ca^{2+} across the root membranes of *Avena.*

(b) Explain the mechanism(s) which were involved in the uptake of K^+ and Ca^{2+}.

2. Use the method of limiting plasmolysis and solutions of sucrose provided to determine the solute potential of the epidermal cells of *Rhoeo* leaves which have been provided.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2008 ACADEMIC YEAR FIRST SEMESTER
FINAL EXAMINATINS

BS 331: PLANT PHYSIOLOGY
THEORY PAPER

TIME: THREE HOURS

INSTRUCTIONS: ANSWER ANY **FIVE** QESTIONS

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1. (a) Explain why accumulation of a high concentration of K^+ and other cations in root cells relative to the soil environment is not necessarily an indication of the direct involvement of active transport in their uptake.
   (b) Apply the Nernst equation to distinguish between diffusional and active transport.

2. Compare and contrast the processes of CO_2 assimilation in the three C_4 carbon cycle variants of photosynthesis.

3. Discuss the process of photophosphorylation and mechanism of ATP synthesis *in vivo.*

4. Critically discuss the cohesion-tension theory in relation to the physical structure of the conducting cells of the xylem and other factors which bear upon the operation of the system.

5. Darwin, Boysen-Jensen, Paál and Went are credited with having made significant contributions to the development of the concept of auxin. Discuss in brief the contributions made by each of these physiologists to the understanding of auxin concept.

6. Discuss the biosynthesis of indole-3-acetic acid (IAA) in plants.

7. Summarise each of the following:

   (a) Triple response of etiolated seedlings.
   (b) ACC oxidase.
   (c) Chemiosmotic transport of auxin.
   (d) Auxin mediated phototropism.

8. Compare and contrast biosynthesis of cytokinins *in vivo* and in plant tissue infected with *Agrobacterium tumefaciens.*

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2008/2009 ACADEMIC YEAR FIRST SEMESTER
FINAL EXAMINATION

BS349: MICROBIOLOGY

THEORY PAPER

TIME: THREE HOURS

INSTRUCTIONS: ANSWER ANY **FIVE** QUESTIONS. USE DIAGRAMS AND TABLES WHERE POSSIBLE TO ANSWER QUESTIONS

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1. Discuss the structure and function of the outer membrane of the gram negative cell wall of bacteria. Illustrate using labeled diagrams
   a) The outer membrane and show how it is linked to the peptidoglycan layer
   b) The structure and chemical composition of the lipopolysaccharide layer

2. a) Discuss bacterial conjugation with particular reference to F^+, F^- and Hfr strands of *Escherichia coli*
   b) Explain i) $F^+ \times F^-$ conjugation
   ii) Hfr x F^- conjugation
   c) What are the end products of the above conjugations?
   d) How does the F factor replicate during $F^+ \times F^-$ mating

3. Discuss the growth dynamics of a bacterial culture in a closed system

4. Describe the various responses of microorganisms to oxygen. How do microorganisms detoxify the harmful effects of oxygen.

5. Discuss the conditions that influence the effectiveness of an antimicrobial agent

6. a) Describe the composition and function of the various media used for culture of bacteria
   i) general
   ii) selective
   iii) differential
   iv) enrichment
   b) Explain three techniques that are used to obtain pure cultures

7. Discuss the structure and classification of viruses.

8. Summarize any **four** of the following

   a) generation time
   b) sterilization
   c) oxidative phosphorylation
   d) macroelements
   e) cardinal temperatures

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2008 ACADEMIC YEAR FIRST SEMESTER
FINAL EXAMINATIONS

BS 361: MOLECULAR BIOLOGY
THEORY PAPER

TIME: THREE HOURS

INSTRUCTIONS: ANSWER TWO QUESTIONS FROM SECTION A AND TWO FROM SECTION B AND THE FIFTH QUESTION FROM EITHER SECTION. USE A SEPARATE ANSWER BOOKLET FOR EACH SECTION. USE ILLUSTRATIONS AND TABLES WHEREVER POSSIBLE.

SECTION A

1. (a) Explain why cancer cells are able to divide indefinitely while normal cells have a limited life span.
   (b) Explain the link between an individual's longevity and the structure of their telomeres.

2. (a) Explain the presence of a minor and a major groove in B-DNA
   (b) State one functional difference between the major and the minor grooves of B-DNA.
   (c) Compare and contrast between the structure of B-DNA and Z-DNA.

3. (a) Describe the Southern blotting technique of DNA-DNA hybridization.
   (b) Explain one application of the Southern blotting technique.

4. Describe the processes which eukaryotic mRNA molecules undergo after transcription has been completed and before translation starts.

SECTION B

5. (a) Discuss the various lines of research which indicate that codons are three bases long.
   (b) Explain the structure and function of each major class of RNA.

6. (a) Differentiate between prokaryotes and eukaryotes in the mechanisms of translation.

   (b) Use the genetic code shown in Table 1 to identify which of the following nucleotide sequence would code for the polypeptide sequence: Arginine-Glycine-Aspartate.
   (i) 5′-GGG-AAA-GCA-3′ (ii) 5′-ACA-CGC-GAC-3′
   (iii) 5′-AGA-GGA-GAU-3′ (iv) 5′-CGG-GGU-GAC-3′

Turn Over

7. (a) Discuss the roles of elongation factors in the mechanism of protein synthesis.
   (b) Compare and contrast between components of prokaryotic and eukaryotic ribosomal subunits.

8. Discuss the mechanism of regulation of the Lac Operon in *Escherichia coli.*

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2008 ACADEMIC YEAR FIRST SEMESTER
FINAL EXAMINATIONS

TIME: THREE (3) HOURS

BS 375: INVERTEBRATES
THEORY PAPER

INSTRUCTIONS: ANSWER ANY **FIVE (5)** QUESTIONS. **TWO** QUESTIONS FROM SECTION A, **TWO** FROM SECTION B AND THE **LAST QUESTION** FROM **EITHER SECTION**. USE EXAMPLES AND ILLUSTRATIONS WHERE POSSIBLE.

SECTION A (LOWER INVERTEBRATES)

1. Describe the main features that distinguish the Phylum Cnidaria from the phylum Platyhelminthes.

2. Describe the variety of locomotory mechanisms employed by lower invertebrates.

3. Compare and contrast the reproductive strategies in phylum Protozoa and phylum Nematoda.

4. Describe morphological polymorphism as it occurs in phylum Cnidaria. Explain the function of each type of individual within the colony.

SECTION B (HIGHER INVERTEBRATES)

5. Describe the following aspects of the Phylum Annelida;
   (a) Adult body form
   (b) Feeding
   (c) Hemal system and coelom
   (d) Reproduction

6. Discuss adaptations in the Phylum Mollusca to the various habitats.

7. Discuss the main characteristics that distinguish Chelicerates from Mandibulates.

8. Describe the nature of the circulatory system in the Phylum Echinodermata.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2008 ACADEMIC YEAR FIRST SEMESTER
FINAL EXAMINATIONS

TIME: THREE (3) HOURS

BS 375: INVERTEBRATES
PRACTICAL PAPER

INSTRUCTIONS: ANSWER **ALL** QUESTIONS

SECTION A (LOWER INVERTEBRATES)

1. Make slide preparations of specimens **A** and **B** provided. Examine each slide preparation under low and high power magnification.

   (a) Draw and label the slide preparation of each specimen at high power magnification
   (b) Name the Phylum and Class to which each specimen belongs.
   (c) Contrast the key features used to place these specimens into different Phyla.
   (d) Discuss the modes of locomotion observed in these organisms.

2. Examine specimens labeled **C** to **H** and answer the following questions.

   (a) Draw and label the key features you have observed for each specimen.
   (b) Name the Phylum and Class to which each specimen belongs.
   (c) Summarize the methods of reproduction for each specimen.
   (d) Discuss the public health and economic importance (if any) of each specimen.

SECTION B (HIGHER INVERTEBRATES)

3. Examine the specimens **I** and **J** and answer the following questions.

   (a) Draw and label the specimens provided.
   (b) Assign the Classes to which these specimens belong.
   (c) Describe the key features that distinguish these specimens from other members in the same phylum.
   (d) Name the major respiratory pigment(s) in each specimen and discuss the type(s) of respiratory systems found in these organisms.

Turn Over

4. Examine the specimens labelled **K** to **P**, and answer the following questions.

   (a) Draw and label the specimens.
   (b) Name the Phylum and Class to which they belong.
   (c) Describe the features used to separate these specimens into their respective Classes.
   (d) Discuss the forms of skeleton found in each specimen

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2008 ACADEMIC YEAR FIRST SEMESTER
FINAL EXAMINATIONS

BS 411: INSECT BEHAVIOUR AND ECOLOGY
THEORY PAPER 11

TIME: THREE HOURS

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

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1. Discuss factors affecting insect population dynamics in an ecosystem.
2. Contrast intra- and inter-specific competition using named examples.
3. Contrast host/parasite and host/parasitoid relationships giving examples in each case.
4. Describe a sampling programme and discuss methods used to sample ground crawling beetles.
5. Summarize the following:
   a). Degree –day method
   b). Insect outbreak
   c). Survivorship curves
   d). Dispersion
6. Compare and contrast natural ecosystems and agro-ecosystems with examples.
7. Given two competing hypothetical species 1 and species 2, discuss the circumstances under which:
   a). the two species will co-exist
   b). species 1 will eliminate species 2.
8. Discuss methods you would use to construct insect life tables, pointing out the advantages and disadvantages.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2008 ACADEMIC YEAR FIRST SEMESTER
FINAL EXAMINATIONS

BS 411: INSECT BEHAVIOUR AND ECOLOGY
THEORY PAPER I

TIME: THREE HOURS

INSTRUCTIONS: ANSWER ANY **FIVE** QUESTIONS AND USE ILLUSTRATIONS WHERE POSSIBLE.

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1. Discuss four mechanisms of orientation behaviour in named insects.

2. Explain the major steps involved in the acquisition of food by herbivorous insects.

3. Describe the common forms of passive defence in named insects.

4. Give a detailed account of migratory behaviour in the desert locust (*Schistocera gregaria* Forskal).

5. Explain the common mode of communication in the forager honey bee (*Apis mellifera* L).

6. Discuss the dominant forms of sound production and their significance among the orders Orthoptera, Hemiptera and Coleoptera.

7. Explain the mechanisms that lead to mate location and rivalry in named insect group(s).

8. Compare and contrast the major characteristics between the highly social termites and eusocial Hymenoptera.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2008 ACADEMIC YEAR FIRST SEMESTER
FINAL EXAMINATIONS

BS 425: IMMUNOLOGY

THEORY PAPER I

TIME: THREE HOURS

INSTRUCTIONS: ANSWER ANY **FIVE** QUESTIONS AND USE ILLUSTRATIONS WHEREVER POSSIBLE

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1. Compare and Contrast the innate and adaptive components of the immune system.

2. Discuss the roles of the MAJOR HISTOCOMPATABILITY. COMLEX (MHC) and how they are regulated in on-going immune responses.

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

4. Discuss the complement system under the following:
   a. Activation/Triggering factors.
   b. C3 Convertase
   c. Common terminal pathway of complement activation.
   d. Regulation of complement activation.

5. Discuss the concept of active and passive immunization with reference to the following types of acquired immunity:
   a. Immunity following the infection of diphtheria toxoid.
   b. Immunity following an infection.
   c. A newborn's immunity to yellow fever.
   d. Immunity following an injection of anti-rabies serum.

6. Explain the nature, structure, function and classes of antibodies.

7. Discuss the various vaccines by type and describe their characteristics. Explain the risks of vaccines.

8. Discuss the role of Antibodies and Natural Killer (NK) cells in Antibody – Dependent Cell Mediated Cytotoxicity (ADCC). Explain why ADCC is an important protection against parasitic protozoa and helminthes.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2008 ACADEMIC YEAR FIRST SEMESTER
FINAL EXAMINATIONS

BS 431: **ADVANCED PARASITOLOGY I**

THEORY PAPER

TIME: **THREE HOURS**

INSTRUCTIONS: ANSWER ANY **FIVE** QUESTIONS AND USE ILLUSTRATIONS WHEREVER POSSIBLE

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1. (a) Discuss the concept of parasitism. Explain how it differs from commensalism and mutualism. Give example of each.

   (b) Compare and contrast the following:

   (i) Control and elimination of disease
   (ii) Endemic and epidemic
   (iii) Descriptive and analytical epidemiology.

2. Discuss the niche concept with particular reference to *Capillaria hepatica* and *Dracunculus medinensis*.

3. Discuss the mechanisms by which the infective stages of monogeneans and digeneans locate their hosts.

4. Discuss Chronological adaptations in blood parasites to the host's habit for successful transmission.

5. Discuss the roles of various stages of *Fasciola hepatica* in the overall life of the parasite.

6. The worm *Trichinella Spiralis* would behave like a virus and use host cells for its own benefit. Discuss how this behaviour contribute to the parasite's success.

7. Explain the following terms as used in epidemiology:

   (a) Host and parasite populations.
   (b) Parasitic infection as a unit of study.
   (c) Morbidity, Prevalence and Mortality rates.

8. Discuss the use of epidemiological information in community health assessment, individual decision and clinical medicine.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2008 ACADEMIC YEAR FIRST SEMESTER
FINAL EXAMINATIONS

BS 431: **ADVANCED PARASITOLOGY I**

PRACTICAL PAPER

TIME: **THREE HOURS**

INSTRUCTIONS: ANSWER **ALL** QUESTIONS

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1. You are provided with Specimen A, a stage micrometer, an ocular micrometer (eye piece) and a microscope. Examine the slide and

a. identify the parasite
b. measure the size of parasite A after calibrating the microscope eye piece at X10 and X40 magnification.
c. briefly, outline the steps taken in calibrating the eye piece. (6 marks)

2. Assuming you are a laboratory scientist stationed at a highly endemic area for malaria. 2000 individuals were to be examined for malaria parasite. Your technicians had to conduct laboratory tests to confirm the infection with malaria parasite, but as a quick diagnosis, fever can be evaluated as a reliable substitute for positive slide. Your second task was to analyze the reported results.

a. For malaria diagnosis, write out clear instructions to technicians on the following:

i. Type of blood sample that should be taken and what the technicians should check for.
ii. The procedure they should follow for processing the samples.
iii. The classification of the "plus" system to determine the intensity for malaria infection.

b. For your second task, you had received the following results:

- Out of 700 who had a fever, 670 had malaria positive slides.

Calculate malaria prevalence in this population.

c. Discuss whether the results of slide examination should be the only basis for treatment or detection of fever can be used as well. (8 marks)

3. You are provided with a prepared slide B. Examine the slide, identify the parasite and determine the intensity of infection. (2 marks)

4. a. Describe the KATO/KATZ procedure to examine a stool sample for parasite infection.

b. Examine slide preparation C, identify the parasite and give the name of its species. (4 marks)

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2008 ACADEMIC YEAR FIRST SEMESTER
FINAL EXAMINATIONS

BS 441: ADVANCED MOLECULAR BIOLOGY I
THEORY PAPER

TIME: THREE HOURS

INSTRUCTIONS: ANSWER **TWO QUESTIONS FROM SECTION A** AND **TWO FROM SECTION B** AND THE **FIFTH QUESTION FROM EITHER SECTION**. USE A SEPARATE ANSWER BOOKLET FOR EACH SECTION. USE ILLUSTRATIONS AND TABLES WHEREVER POSSIBLE.

SECTION A

1. (a) With respect to radioisotope use in molecular biology, explain the terms specific activity and biological half-life.

   (b) Describe the principle of the test to diagnose suspected infection with *Helicobacter pylori,* causative agent for ulcers.

   (c) Using the given properties of some of the commonly used radionuclides in **Table 1** below, calculate the total dosage in REM of 10 μCi of the isotope that should be prescribed to a 70 Kg patient in the test for *Helicobacter pylori* infection, given that ln2 = 0.7, and the fact that 1 eV = 1.602×10^{-12} ergs.

Table 1: Selected properties of some of the commonly used radionuclides

Property	^{3}H	^{14}C	^{125}I
Half life	12.4 years	5730 years	59.408 days
Biological half life	12 days	12 days	42 days
Critical organ	Whole body	Whole body	Thyroid
Decay energy	19 Kev	156 KeV	186 V

2. Critically discuss using specific examples and experimental evidence the hypothesis that the mitochondrion arose when a free-living microorganism capable of oxidative phosphorylation was engulfed by another cell.

Turn over

3. Summarize the principles of the following techniques:
   (a) Ion Exchange Chromatography.
   (b) Cryo-electron microscopy.
   (c) Isoelectric focusing.
   (d) Salting out.

4. Discuss the stages at which oxidative phosphorylation can be inhibited as well as the molecular and biochemical mechanisms underlying the inhibition.

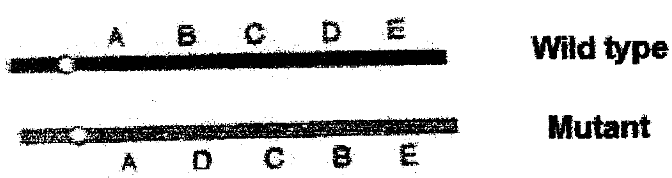
SECTION B

5. (a) Explain the various types of DNA damage and describe 4 named diseases which may result due to failure of repair of DNA damage.

   (b) (i) Explain briefly how the mismatch repair system recognises the wrong base between the two in the mispair.
   (ii) Briefly describe the mechanism of repair of UV- damaged DNA.

6. (a). Explain the evolution of proteins with special reference to globins.
   (b). Describe the enzyme-driven events taking place during prophase I of meiosis.

7. Below is a homologous pair of chromosomes, illustrating a certain type of mutation.



(a) Name the type of mutation.
(b) Draw the pairing configuration that would be observed in the chromatids of this pair at metaphase I of meiosis.
(c) Assuming that a crossover takes place between B and C on one chromatid of the wild type and another chromatid of the mutant, draw the early anaphase I structure that would result.
(d) Draw and comment on the gametes produced at telophase II.

Turn over

8. (a) In the immune system of vertebrates, having a different set of antibodies is crucial if a robust immune response is to be generated.

(i)Explain the significance of clonal expansion in the vertebrate immune system.
(ii) Explain allelic exclusion and suggest why it is crucial to the immune response.

(b) The mouse is estimate to have 350 variable segments and 4 joining segments for immunoglobulin light-chain genes, and 1000 variable, 5 joining and 10 diversity segments for heavy-chain genes. If all light-chain and heavy-chain rearrangements occur randomly, how many possible antibody molecules could be generated by the immune system?

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2008 ACADEMIC YEAR FIRST SEMESTER
FINAL EXAMINATIONS

BS 471: ENVIRONMENTAL MICROBIOLOGY
PRACTICAL PAPER

TIME: THREE HOURS

INSTRUCTIONS: ANSWER **ALL** QUESTIONS. USE SPECIFIC EXAMPLES AND ILLUSTRATIONS WHERE POSSIBLE.

1. (a) Describe how you can prepare and set a Winogradsky Column. **(15 marks)**

   (b) Explain the importance of the Winogradsky Column in microbiological studies. **(5 marks)**

2. (a) Explain the importance of the specimen labelled **A** in the sanitary analysis of water. **(4 marks)**

   (b) An experiment was carried out to check the presence of indicator organisms of faecal origin in wastewater and tap water. A set of five test tubes of lactose broth containing bromocresol purple were treated with 10 cm^3 of wastewater. In a second treatment five test tubes of lactose broth containing bromocresol purple were treated with 1 cm^3 of wastewater. In a third treatment a set of five test tubes of lactose broth containing bromocresol purple were treated with 0.1 cm^3 of wastewater sample. The procedure was repeated using tap water. The tubes were labelled and incubated at 37°C for 24 hours. The results obtained were as indicated in the table below.

Table of results

Sample	**Five tubes of 0.1 cm^3 each**					**Five tubes of 1 cm^3 each**					**Five tubes of 10 cm^3 each**				
Wastewater	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Tap water	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-

Key:
\+ lactose fermentation and gas formation
\- either lactose fermentation and no gas formation or no lactose fermentation and no gas formation.

Determine the quality of the water samples analysed in this experiment. (The MPN index table is given as an appendix to this paper). **(6 marks)**

3. (a) Examine specimen **B** and identify the specimen. Give two major sources of this microorganism. **(5 marks)**
   (b) Draw and labell specimen **B**. **(5 marks)**
   (c) Explain the economic importance of specimen **B** in 3 (b) above. **(5 marks)**

4. Examine specimens labelled **C** and **D**.

   (a) Describe one method used to enumerate these microorganisms from air by using a named medium. **(7.5 marks)**
   (b) Describe how ultraviolet light can be used to sterilize a pharmaceutical warehouse. Explain the effect of ultraviolet light on microorganisms. **(7.5 marks)**

END OF EXAMINATION

APPENDIX

MPN TABLE:
The MPN index per 100 ml for combinations of positive and negative presumptive test results when five 10-ml, five 1-ml and five 0.1-ml portions of sample are used.

Number of tubes with positive results				Number of tubes with positive results			
Five of 10 ml each	Five of 1 ml each	Five of 0.1 ml each	MPN index per 100 ml	Five of 10 ml each	Five of 1 ml each	Five of 0.1 ml each	MPN index per 100 ml
0	0	0	<2	4	2	1	26
0	0	1	2	4	3	0	27
0	1	0	2	4	3	1	33
0	2	0	4	4	4	0	34
1	0	0	2	5	0	0	23
1	0	1	4	5	0	1	31
1	1	0	4	5	0	2	43
1	1	1	6	5	1	0	33
1	2	0	6	5	1	1	46
2	0	0	6	5	1	2	63
2	0	1	7	5	2	0	49
2	1	0	7	5	2	1	70
2	1	1	9	5	2	2	94
2	2	0	9	5	3	0	79
2	3	0	12	5	3	1	110
3	0	0	8	5	3	2	140
3	0	1	11	5	3	3	180
3	1	0	11	5	4	0	130
3	1	1	14	5	4	1	170
3	2	0	14	5	4	2	220
3	2	1	17	5	4	3	280
3	3	0	17	5	4	4	350
4	0	0	13	5	5	0	240
4	0	1	17	5	5	1	350
4	1	0	17	5	5	2	540
4	1	1	21	5	5	3	920
4	1	2	26	5	5	4	1600
4	2	0	22	5	5	5	≥2400

Source: pp. 9-51, Standard methods for the examination of water and wastewater, 20th edition (1998). M. J. Taras, A.E.Greenberg, R.D. Hoak, and M.C. and American Public Health Association, Washington, D.C. Copyright 1998, American Public Health Association.

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2008 ACADEMIC YEAR FIRST SEMESTER
FINAL EXAMINATIONS

BS 471: ENVIRONMENTAL MICROBIOLOGY
THEORY PAPER

TIME: THREE HOURS

INSTRUCTIONS: ANSWER **ANY FIVE** QUESTIONS. ALL QUESTIONS CARRY EQUAL MARKS. USE SPECIFIC EXAMPLES AND ILLUSTRATIONS WHERE POSSIBLE.

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1. Discuss the microbial decomposition of starch and cellulose in aerobic and anaerobic environments.

2. Describe the biological methods used to concentrate a metal whose concentration in the ore is low.

3. Describe the non-bacterial mutualistic relationships. Discuss the contributions made by each partner organism in the association.

4. Discuss the significance of biodegrading xenobiotic compounds in the environment.

5. (a) Compare and contrast aerobic and anaerobic secondary treatment of wastewater.
   (b) Discuss the factors that help to bring about the purification of wastewater in stabilisation ponds.

6. Using named examples, explain the levels of application of biological control in pest management programmes.

7. (a) Discuss the different modes of spore transport in the environment.
   (b) Explain the significance of enumerating the types and numbers of air borne fungal flora for a given dwelling locality.

8. (a) Describe the importance of enumerating fungal air spora of a typical open land from a medical point of view.
   (b) Describe the advantages and disadvantages of using a settle plate method for sampling air borne fungal flora, using Rose-Bengal streptomycin agar.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

200~~7~~8 ACADEMIC YEAR FIRST SEMESTER
FINAL EXAMINATIONS

BS475: POPULATION ECOLOGY
THEORY PAPER II

TIME: THREE HOURS

INSTRUCTIONS: ANSWER **FIVE** QUESTIONS. USE ILLUSTRATIONS WHEREVER POSSIBLE.

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1. Discuss a population as a biological system.

2. Identify the features of the animal shown below that can be used to determine the genetic structure of a population and explain to what extent these features are manifestations of polymorphism.

3. Discuss the ecological structure of a population.

4. Contrast morphological and phenetic approaches to defining populations.

5. Discuss the effects of selective hunting on the population structure of mammals.

6. Discuss the concept of a population as a unit of conservation.

7. Explain how a population can be used as a unit of bio-monitoring.

8. Discuss the characteristics of *r* and *K* ecological strategies.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2008 ACADEMIC YEAR: FIRST SEMESTER
FINAL EXAMINATIONS

BS 491: FRESHWATER BIOLOGY:

PRACTICAL PAPER

TIME: THREE HOURS

INSTRUCTIONS: ANSWER ALL QUESTIONS

1 Table 1 below shows results of an ecological investigation for a lake where temperature measurements were recorded for one year at different depths. Using the results given in Table 1below, answer the questions (a) to (d).

Table 1 Results of temperature measurements in different months and depths of a lake

Month	**Values of Temperature in °C at different depths**																
Jan	0	0	0	0	0	1	2	3	3	3	3	3	3	3	3	3	3
Feb	0	0	0	0	1	2	3	3	3	3	3	3	3	3	3	3	3
Mar	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Apr	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
May	10	8	8	6	5	4.5	4	4	4	4	4	4	4	4	4	4	4
Jun	18	15	10	8	6	5	4	4	4	4	4	4	4	4	4	4	4
Jul	15	15	12	12	10	8	5	4	4	4	4	4	4	4	4	4	4
Aug	12	12	12	10	8	5	5	4	4	4	4	4	4	4	4	4	4
Sep	10	8	8	6	5	4.5	4	4	4	4	4	4	4	4	4	4	4
Oct	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Nov	0	0	0	0	1	2	3	3	3	3	3	3	3	3	3	3	3
Dec	0	0	0	0	0	1	2	3	3	3	3	3	3	3	3	3	3
Depth (m)	**0.5**	**1**	**2**	**5**	**8**	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**60**	**70**	**80 Bottom**

a) Construct an appropriate depth- time diagram that could be used to describe the thermal regime of the lake;
b) Using the diagram constructed in (a) above, provide detailed description of the thermal regime for the lake under investigation;
c) According to the classification of lakes based on thermal regime name the type of lake that is being investigated and give reasons for your answer.
d) Name geographical areas where such a lake could be found giving reasons for your answer.

Please Turn Over

2

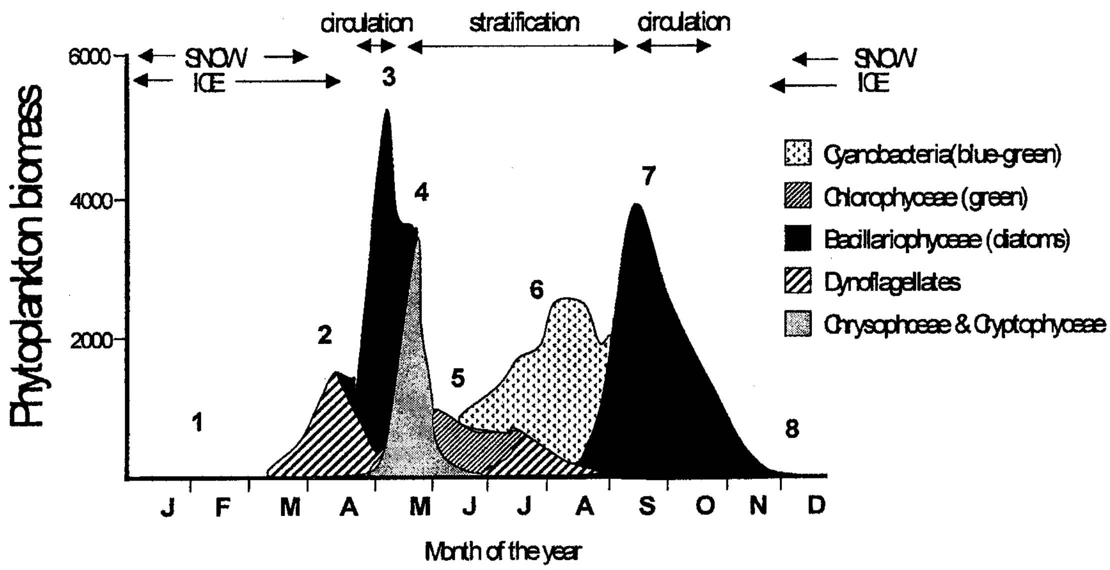


Fig. 1 Seasonal succession of phytoplankton in a lake

Fig 1 above is a simplified seasonal pattern of phytoplankton biomass for a eutrophic lake. Note that physical conditions in the lake are indicated across the top of the figure. Numbers (1-8) above portions of the graph refer to different periods during the year. Diatoms for instance comprise a dominant proportion of the phytoplankton biomass during time periods 3 and 7.

a) Explain the physical conditions of the lake that correspond to diatom abundance
b) Give two reasons why diatoms are abundant in the water column during these periods
c) Time period 5 corresponds to the Clearwater Phase in the lake. Give reasons for the low biomass of phytoplankton during this time
d) During time period 6, Cyanobacteria are the dominant phytoplankton. Name two characteristics of Cyanobacteria that allow them to dominate during this time of the year. Explain why those characteristics are useful.

Please Turn Over

3 A freshwater ecologist is assigned to provide a detailed description of a given lake. He chooses to take the following measurements in summer: temperature; light penetration; dissolved oxygen concentrations; and concentrations of the most abundant phytoplankton species during the early summer phytoplankton bloom *Melosira granulata*. The results obtained are shown in the table 2 below.

Table 2 Values of temperature °C light as percentage of surface radiance, dissolved oxygen and concentrations of *Melosira granulata* (cells per cm^3)

Depth (m)	0.1	1	2	5	7	10	12	15	20	25	30	40	50	60	70	80	90
Temp °C	25.5	25	25	25	25	25	25	24	20	16	15.5	15.5	15.5	15.5	15.5	15.5	15.5
Light (lx)	100	80	50	15	8	6	4	3	1.5	1	0.5	0	0	0	0	0	0
O_2 mg l^{-1}	4	4.5	5	6	8	8	12	14	8	7	2	1	0	0	0	0	0
Melosira granulata	19	25	28	30	50	60	84	98	150	75	30	15	15	15	15	15	15

a) Construct appropriate diagrams and curves that would assist to explain characteristics of the lake
b) Based on curves constructed in (a) above assess the relative productivity of the lake being described
c) Explain the effect of light intensities on phytoplankton abundance of the lake during the period of the investigation.

END OF THE EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2008 ACADEMIC YEAR FIRST SEMESTER
FINAL EXAMINATIONS

BS 915: BIOLOGY OF SEED PLANTS
THEORY PAPER

TIME: THREE HOURS

INSTRUCTIONS: ANY **FIVE** QUESTIONS. WHERE APPROPRIATE USE EXAMPLES AND ILLUSTRATIONS

1. Compare and contrast development of gametophytes in conifers and flowering plants.

2. Describe the features characterizing fertilization and the role of double fertilization in the angiosperms.

3. Describe *Cycas* plant habit. Describe anatomy of *Cycas* leaf-let and explain its features of significance with the help of labeled diagrams.

4. Describe structure of the pollen in angiosperms and explain the usefulness of pollen study in determining the past climate and vegetation type of a geographical area.

5. Describe grafting and its types in plant propagation. Explain why this practice is commonly used in the cultivation of only certain types of plants.

6. Describe the structure and vegetation types found in Zambia.

7. Discuss structural adaptations of hydrophytes to aquatic life.

8. Summarize any TWO of the following:

(a) Endemism
(b) Pseudo-cereals
(c) Sporophyll
(d) Bi-collateral vascular bundle

EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2008 ACADEMIC YEAR FIRST SEMESTER
FINAL EXAMINATIONS

BS 935: PLANT PATHOLOGY
THEORY PAPER

TIME: THREE HOURS

INSTRUCTIONS: ANSWER ANY **FIVE** QUESTIONS. USE ILLUSTRATIONS WHEREEVER NECESSARY

1. Describe primary disease cycle and the different infection sources known to initiate the primary disease cycle in plants. Discuss disease cycles using suitable pathogen types.

2. Describe the characteristics of viroids and explain their role in plant disease using two examples of diseases caused by viroids.

3. Compare and contrast dispersal adaptations in downy mildews, late blight and rust fungi.

4. Discuss the role of natural plant products in plant defence against infection.

5. Compare and contrast fungal pathogen types that cause disease in plants with reference to mode of infection.

6. Discuss host-pathogen interactions in disease development.

7. Discuss the mechanism of vascular wilt disease in plants, their causes and management.

8. Compare and contrast diseases caused by *Puccinia* and *Phytophthora*.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2008 ACADEMIC YEAR FIRST SEMESTER
FINAL EXAMINATIONS

C101: INTRODUCTION TO CHEMISTRY I

TIME: THREE (3) HOURS

INSTRUCTIONS:

1. Indicate your **student ID number** (computer number) and **TG number** on **ALL** your answer booklets.

2. This examination paper consists of two (**2**) sections: **A** and **B**

3. Section **A** has ten **(10)** short answer questions (Total marks = **40**). **ANSWER ALL QUESTIONS**. Questions carry equal marks.

4. Section **B** has five **(5)** long answer questions. (Total marks = **60**). **ANSWER QUESTION B1 and ANY THREE QUESTIONS, EACH IN A SEPARATE ANSWER BOOKLET**. Questions carry equal marks.

5. **YOU ARE REMINDED OF THE NEED TO ORGANISE AND PRESENT YOUR WORKING CLEARLY AND LOGICALLY.**

Information to the candidates:

1. **Useful data** is printed on **page 2**.

2. **Periodic Table** is printed on the **last page** of this question paper.

DATA

Avogadro's constant, N_A	6.022×10^{23} mol^{-1}
Molar volume of gas at S.T.P	22.4 dm^3 mol^{-1}
Universal gas constant, R	8.314 J K^{-1} mol^{-1}
	0.0821 L atm K^{-1} mol^{-1}
	8.314 k Pa L K^{-1} mol^{-1}
Planck's constant, h	6.63×10^{-34} J s
Rhydberg constant, R_H	109678 cm^{-1}
Velocity of light, c	3.00×10^{8} ms^{-1}
Electron volt, 1 eV	1.602×10^{-19} J
Faraday, 1 F	96485 C mol^{-1}
Joule, 1 J	1 kg m^2 s^{-2}
Mass of proton, m_p	1.00727 amu
Mass of Neutron, m_n	1.008665 amu
Mass of electron, m_e	0.000548593 amu

Standard Electrode Potentials:

$O_2(g) + 4H^+(aq) + 4e^- \rightleftharpoons 2H_2O(l)$; $E^o = +1.23$ V
$Br_2(aq) + 2e^- \rightleftharpoons 2Br^-(aq)$; $E^o = +1.07$ V
$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$; $E^o = +0.80$ V
$O_2(g) + 2H_2O(l) + 4e^- \rightleftharpoons 4OH^-(aq)$; $E^o = +0.401$ V
$Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s)$; $E^o = +0.34$ V
$2H^+(aq) + 2e^- \rightleftharpoons H_2(g)$; $E^o = 0.00$ V
$Pb^{2+}(aq) + 2e^- \rightleftharpoons Pb(s)$; $E^o = -0.13$ V
$Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s)$; $E^o = -0.76$ V
$2H_2O(l) + 2e^- \rightleftharpoons H_2(g) + 2OH^-(aq)$; $E^o = -0.83$ V

SECTION A **ANSWER ALL QUESTIONS**

QUESTION A 1

Silver has two stable isotopes, $^{107}_{47}Ag$ and $^{109}_{47}Ag$ with isotopic masses of 106.90509 u and 108.80476 u respectively and their isotopic abundances 51.83 % and 48.17% respectively.

(a) Calculate the relative atomic mass of Ag.

(b) How many protons, electrons, and neutrons are in $^{109}_{47}Ag^{+}$?

[4 Marks]

QUESTION A 2

One gram sample of disilane, Si_2H_x contains 90.28 % Si by mass. What is the value of x in this compound?

[4 Marks]

QUESTION A 3

Gaseous silane, SiH_4, ignites spontaneously in air according to the **unbalanced** reaction

$$SiH_4(g) + O_2(g) \rightarrow SiO_2(s) + H_2O(l)$$

Assume all gases are measured at the same temperature and pressure of 298.15 K and 1 bar.

(a) If 5.2 L SiH_4 is treated with O_2 what volume in liters of O_2 is required for complete reaction?

(b) Calculate the number of moles of O_2 required in (a) above.

[4 Marks]

QUESTION A 4

Microwaves are used to heat food in microwave ovens. The microwave radiation is absorbed by moisture in food. This heats the water, and as the water becomes hot, so does the food. How many photons having a wavelength of 3.00 mm would have to be absorbed by 1.00 g of water to raise its temperature by 1.00 °C Specific heat capacity of water is 4.18 J / g °C.

[4 Marks]

QUESTION A 5

The electron affinities for oxygen are given below.

Electron affinity/kJ mol^{-1}	1st	2nd
	– 142	+844

(i) Write equations representing the changes to which the 1st and 2nd electron affinities of oxygen relate.

(ii) Explain the relative magnitudes of the 1st and 2nd electron affinities of oxygen

[4 Marks]

QUESTION A 6

(a) Write the electron configuration for an element X with Z = 7. Based on its electron configuration explain why the element is likely to have extra stability.

(b) Will the anion X^{3-} exhibit paramagnetism. Give an explanation for your answer.

[4 Marks]

QUESTION A 7

Sulphur dioxide can be produced according to the equation

$S(s) + O_2(g) \rightarrow SO_2(g)$

Calculate the enthalpy change, $\Delta H°$, for the reaction using the following thermochemical equations;

$2\ SO_2(s) + O_2(g) \rightarrow 2\ SO_3(g)$ $\Delta H° = -196$ kJ

$2\ S(s) + 3\ O_2(g) \rightarrow 2\ SO_3(g)$ $\Delta H° = -790$ kJ

[4 Marks]

QUESTION A 8

Calcium carbide can be made by heating calcium oxide (lime) with carbon (charcoal).

$CaO(s) + 3C(s) \rightarrow CaC_2(s) + CO(g)$ $\Delta H° = +464.8$ kJ

How many kilojoules of heat are absorbed in a reaction in which 76.5 g C(s) is consumed?

[4 mks]

QUESTION A 9

(a) A dilute aqueous solution of $CuBr_2$ is electrolyzed. What are the products at each electrode?

(b) How many moles of electrons are required in the following reaction in an ***acidic*** solution?

$$Cr_2O_7^{2-}(aq) \rightarrow Cr^{3+}(aq)$$

[4 mks]

QUESTION A 10

Calculate the voltage of the cell: $Pb(s)\ |\ Pb^{2+}(0.025\ M)\ ||\ Cu^{2+}(2\ M)\ |\ Cu(s)$ at $25°C$

[4 mks]

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

QUESTION B1

In C101 Experiment VII: Analysis of hydrogen peroxide, the following half cell reaction below were taking place in an acidic media:

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

$$H_2O_2(aq) \rightarrow \quad O_2(g) + 2H^+(aq) + 2e^-$$

(a) Which of the reactions above is an oxidation and reduction reaction? Explain your answer?

(b) Balance the reactions above and obtain an overall redox reaction.

(c) In the redox titration, 25.00 mL of acidified H_2O_2 of solution required exactly 7.60 mL of 0.009972 M of the standardized $KMnO_4$ solution. Calculate the concentration of H_2O_2.

[TOTAL =15 mks]

QUESTION B 2

Gold can be dissolved from gold bearing rock by treating the rock with sodium cyanide in the presence of oxygen in the air

$$4Au(s) + 8NaCN(aq) + O_2(g) + 2H_2O \rightarrow 4NaAu(CN)_2(aq) + 4NaOH(aq)$$

Once gold is in solution in the form of $Au(CN)_2^-$ ion, it can be precipitated as a metal according to the following equation:

$$Au(CN)_2^-(aq) + Zn(s) \rightarrow Zn^{2+}(aq) + Au(s) + 2CN^-(aq)$$

(a) How many liters of 0.0750 M NaCN will you need to extract gold from 1000 kg of rock if the rock contains 0.0190 % gold?

(b) How many kilogram of metallic Zn will you need to recover the gold from the $Au(CN)_2^-$ obtained from the gold in the rock?

[TOTAL =15 mks]

QUESTION B 3

(a) Using simple calculations show that the effective charge increases from magnesium to phosphorus. Use this data to predict the trend in atomic size and ionisation energy across the period.

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

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

(ii) For the molecule described in **c (i)** above show whether the molecule is polar or non-polar.

[TOTAL =15 mks]

QUESTION B 4

(a) The reaction of barium hydroxide, $Ba(OH)_2$ with oxalic acid, $H_2C_2O_4$, releases heat and forms a precipitate of barium oxalate, BaC_2O_4 and water. The molar enthalpy change for this process is - 88.0 kJ/mol of BaC_2O_4 formed. 200.0 mL of 0.103 mol/L $Ba(OH)_2(aq)$ is added to 100.0 mL of 0.213 mol/L $H_2C_2O_4$ (aq) in a coffee cup calorimeter with a heat capacity of 40.0 J/ °C. The initial temperature for both solutions before mixing was 22.0 °C. Assume that the specific heat capacity for the mixed solution is 4.08 J/g°C and that its density is 1.02 g/mL.

(i) Calculate the number of moles of barium hydroxide added.
(ii) Calculate the number of moles of oxalic acid added.
(iii) Write the balanced equation for the reaction and deduce the number of moles of BaC_2O_4 formed.
(iv) Calculate the heat evolved (in Joules) in the reaction.
(v) Calculate the maximum solution temperature reached.

(b) Consider the combustion of liquid methanol, $CH_3OH(l)$:

$$CH_3OH(l) + \frac{3}{2}O_2(g) \rightarrow CO_2(g) + 2H_2O(l) \quad \Delta H° = -726.5 \text{ kJ}$$

(i) What is the enthalpy change for the reverse reaction?
(ii) What is ΔH for the reaction represented by the reaction:
$2CH_3OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(l)$

(iii) If the reaction were written to produce $H_2O(g)$ instead of $H_2O(l)$, would you expect the magnitude of ΔH to increase, decrease, or stay the same? Explain.

[TOTAL = 15 Marks]

QUESTION B 5

A galvanic cell is constructed of one half cell in which a silver wire is placed into a 1.00 *M* aqueous solution of silver nitrate and the other half cell is made of a zinc wire in a 1.00 *M* aqueous solution of zinc nitrate.

(a) Write the reaction that occurs in this cell under standard state conditions.
(b) Calculate E°.
(c) Calculate $\Delta G°$.
(d) Write this cell in shorthand notation and indicate the flow of current.
(e) Calculate the voltage of the cell at 35 °C if the concentrations of $[Ag^+(aq)]$= 0.50 *M* and $[Zn^{2+}(aq)]$ = 1.00 *M*.

[TOTAL = 15 mks]

END OF EXAMINATION

PERIODIC TABLE OF THE ELEMENTS

KEY

Atomic number
X
Atomic mass
Name of the element X

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** 1.01 Hydrogen																1 **H** 1.01 Hydrogen	2 **He** 4.00 Helium
3 **Li** 6.94 Lithium	4 **Be** 9.01 Beryllium											5 **B** 10.81 Boron	6 **C** 12.01 Carbon	7 **N** 14.01 Nitrogen	8 **O** 16.00 Oxygen	9 **F** 19.00 Fluorine	10 **Ne** 20.18 Neon
11 **Na** 23.00 Sodium	12 **Mg** 24.31 magnesium											13 **Al** 26.98 Aluminium	14 **Si** 28.09 Silicon	15 **P** 30.99 Phosphorus	16 **S** 32.07 Sulphur	17 **Cl** 35.45 Chlorine	18 **Ar** 39.95 Argon
19 **K** 39.10 Potassium	20 **Ca** 40.08 Calcium	21 **Sc** 44.96 Scandium	22 **Ti** 47.88 Titanium	23 **V** 50.94 Vanadium	24 **Cr** 52.00 Chromium	25 **Mn** 54.94 Manganese	26 **Fe** 55.85 Iron	27 **Co** 58.93 Cobalt	28 **Ni** 58.69 Nickel	29 **Cu** 63.65 Copper	30 **Zn** 65.39 Zinc	31 **Ga** 69.72 Gallium	32 **Ge** 71.61 Germanium	33 **As** 74.92 Arsenic	34 **Se** 78.96 Selenium	35 **Br** 79.90 Bromine	36 **Kr** 83.80 Krypton
37 **Rb** 85.47 Rubidium	38 **Sr** 87.62 Strontium	39 **Y** 88.91 Yttrium	40 **Zr** 91.22 Zirconium	41 **Nb** 92.91 Niobium	42 **Mo** 95.94 Molybdenum	43 **Tc** 97.91 Technetium	44 **Ru** 101.07 Ruthenium	45 **Rh** 102.91 Rhodium	46 **Pd** 106.42 Palladium	47 **Ag** 107.87 Silver	48 **Cd** 112.41 Cadmium	49 **In** 114.82 Inidum	50 **Sn** 118.71 Tin	51 **Sb** 121.76 Antimony	52 **Te** 127.60 Tellurium	53 **I** 126.90 Iodine	54 **Xe** 131.29 Xenon
55 **Cs** 132.91 Caesium	56 **Ba** 137.33 Barium	57 – 71	72 **Hf** 178.49 Hafnium	73 **Ta** 180.95 Tantalum	74 **W** 183.84 Tungsten	75 **Re** 186.21 Rhenium	76 **Os** 190.23 Osmium	77 **Ir** 192.22 Iridium	78 **Pt** 195.08 Platinum	79 **Au** 196.97 Gold	80 **Hg** 200.59 Mercury	81 **Tl** 204.38 Thallium	82 **Pb** 207.2 Lead	83 **Bi** 208.98 Bismuth	84 **Po** 208.98 Polonium	85 **At** 209.99 Astatine	86 **Rn** 222.02 Radon
87 **Fr** (223.02) Francium	88 **Ra** 226.03 Radium	89 - 103	104 **Unq** 261.11	105 **Unp** 262.11	106 **Unh** 263.12	107 **Uns** 262.12	108 **Uno** 265.00	109 **Une** 265									

57 **La** 138.91 Lanthanum	58 **Ce** 140.12 Cerium	59 **Pr** 140.91 Praseodymium	60 **Nd** 144.24 Neodymium	61 **Pm** 144.91 Promethium	62 **Sm** 150.36 Samarium	63 **Eu** 151.97 Europium	64 **Gd** 157.25 Gadolinium	65 **Tb** 158.93 Terbium	66 **Dy** 162.50 Dysprosium	67 **Ho** 164.93 Holmium	68 **Er** 167.26 Erbium	69 **Tm** 168.93 Thulium	70 **Yb** 173.04 Ytterbium	71 **Lu** 174.97 Lutetium
89 **Ac** 227.03 Actinium	90 **Th** 232.04 Thorium	91 **Pa** 231.04 Protactinium	92 **U** 238.03 Uranium	93 **Np** 237.05 Neptunium	94 **Pu** 244.0 Plutonium	95 **Am** 243.06 Americium	96 **Cm** 247.07 Curium	97 **Bk** 247.07 Berkelium	98 **Cf** 251.08 Californium	99 **Es** 252.08 Einstienium	100 **Fm** 257.10 Fermium	101 **Md** 260 Mendelevium	102 **No** 259.10 Nobelium	103 **Lr** 262.11 Lawrencium

Department of Chemistry-UNZA

The University of Zambia
School of Natural Sciences
Department of Chemistry
2008 Academic Year Final Examinations
First Semester
C 205: Analytical and Inorganic Chemistry
December 2008.

Time: 3 Hours.

Instructions:

[This Paper Contains Six (06) Questions; each Carrying 15 Marks].
Answer Both Questions In Section A; And, any Two (02) from Section B.

Section A.
Question 1.
a). A photon of wavelength 4000 Å strikes a metal surface, the work function of the metal being 2.13 eV. Calculate (i) the energy of the photon in eV (ii) the kinetic energy of the emitted photon electron and (iii) the velocity of photoelectron. Given that mass of electron = 9.109×10^{-31} kg, h = 1.626×10^{-34} J, C = 3×10^{8} m/s, 1eV = 1.602×10^{-10} J

b). State the hybridization involved and make sketches of (i) lone pair electron orbital of PH_3 and (ii) lone pair orbitals of ClF_3 (iii) IF_5

c). Briefly discuss expected variations of 1st Ionization energies across the elements of period 3.

Question 2.
a). Describe the changes that occur in a complex's properties when weak field ligands are replaced by strong field ligands.

b). The magnetic moment of complex $[Mn(NCS)_6]^{4-}$ is 6.06 μB. What is its electronic configuration? Calculate the magnetic moment and CFSE of the complex in terms of their Dq parameters. Given 10 Dq from $[FeF_6]^{4-}$ is 25,000 cm^{-1}, evaluate its CFSE in cm^{-1}

c). What is Borazine? How does it react with hydrochloric acid? Show the structure of the product formed. Give a balanced equation showing the hydrolysis of Borazine.

Section B.
Question 1.
a). i). What is a standard solution?

ii). What is meant by the equivalence point of a titration? How much 0.1 N Na OH would you have added to 30 mL of 0.1N HCl, at the equivalence point?

b). The precision of a method is being established; and the following data are obtained: 22.23; 22.18; 22.25; 22.09 and 22.17%. Is 22.09 a valid measurement at the 95% confidence level? Using the data above, estimate the range within which the true value falls at 99%CL

c). Write balanced equations, and decide which of the following may be regarded as redox reactions:

i). $BaCl_2 + H_2SO_4 \Rightarrow BaSO_4 + HCl$ ii). $Ag + Cl_2 \Rightarrow AgCl$

iii). $I^- + NO_3^- + H^+ \Rightarrow I_2 + NO_2$ iv). $PbO_{s)} + CO_{(g)} \Rightarrow Pb_{(s)} + CO_{2(g)}$

Question 2.

a). In dilute aqueous solution, sulphuric acid can be regarded as totally dissociated to H_3O^+ and HSO_4^-. The hydrogensulphate ion, HSO_4^-, is itself a weak acid with a dissociation constant of 1.20×10^{-2}. Calculate the concentration of H_3O^+, HSO_4^-, SO_4^{2-} and OH^- in a solution prepared by dissolving 1.00 mole H_2SO_4 in enough water to make 1.00 litre of solution.

b). Phosphorus was determined in urine by phosphomolybdate method, and the results were as follows:

Standard solution (ppm)	:	1.0	2.0	3.0	4.0	5.0
Absorbance	:	0.205	0.410	0.615	0.820	1.025

From the data obtained, determine the regression line and calculate the phosphorus concentration in the urine sample if the absorbance was 0.550.

c). A solution contains 2.50×10^{-4} M Cu $(NO_3)_2$. What is this copper nitrate concentration in ppm; and, what is the concentration of NO_3^- in this solution given that $Cu(NO_3)_2$ is a strong electrolyte.

Question 3.

a). Orthoarsenic acid, H_3AsO_4, is a triprotic acid with $pK_{a1} = 2.22$, $pK_{a2} = 6.98$ and $pK_{a3} = 11.53$. By writing appropriate equations, indicate i). What is meant by the term 'triprotic', and ii). What is the value of K_a for H_3AsO_4?

b). A sample was analysed several times using two different methods. The following two sets of results for % ethanol content were obtained:

Method I (%ethanol): 13.5; 13.3; 12.9; 13.0;

Method II (%ethanol): 12.7; 12.6; 13.3; 13.3

Does Method I give the same results as Method II at 95% confidence level?

c). A 0.1M solution of a weak monoprotic acid (HA) is found to be 5% ionized. Calculate the ionisation constant (Ka), and pH of the solution.

Question 4.

a). What is a buffer solution?

i). Calculate the pH of a buffer prepared by adding 10 ml of 0.20 M acetic acid (for acetic acid, $K_a = 1.75 \times 10^{-5}$) to 40 ml of 0.50 M sodium acetate.

ii). What is the pH and degree of hydrolysis of a 0.10 M solution of sodium acetate, $NaC_2H_3O_2$? For acetic acid, $K_a = 1.75 \times 10^{-5}$.

b). Calcium in blood is determined by two methods (AAS and Colorimetry). Determine, using the 'Pooled t-test', whether there is significant difference in the precision of the AAS method and the newly tried colorimetric method; at 95% CL. The data is:

AAS (mg/dL):	10.9; 10.1; 10.6; 11.2; 9.6; 10.0
Colorimetry (mg/dL):	9.2; 10.5; 9.7; 11.5; 11.6; 9.3; 10.1; 11.2

c). Calculate the mass of $KMnO_4$ that needs to be dissolved in 250 cm^3 of water to produce a solution of 0.500 N.

................................END OF EXAMINATION................................

The University of Zambia
School of Natural Sciences
Department of Chemistry
2008 Academic Year Final Examinations
First Semester.

C 225: Analytical Chemistry 1.

December 2008.

Time: 3 Hours.

Instructions:
[This Paper Contains Five (05) Questions. Each Question carries 20 Marks].
ANSWER ANY THREE (03) QUESTIONS ONLY.

Question 1.

a). i). Distinguish between:
- Complete and partial analysis
- Qualitative and quantitative analysis

ii). A batch of cough mixture bottles was weighed to determine if they fell within acceptable standard control guidelines. Individual weights were: 127.2 g; 128.4 g; 127.1 g; 129.0 g and 131.1 g. Determine whether the last bottle weight is an outlier datum at 99% CL.

b). Given the fact that acetic acid is 1.34% ionised, what will be the concentration of hydronium ion in a 0.10 M solution of acetic acid, (CH_3COOH), that has been made 0.15 M in sodium acetate, ($NaCH_3COO$)?

c). To 40.0 mL of 1.00 M $AgNO_3$ is added 20.0 mL of 0.500 M $AlCl_3$.What is the molarity of the resulting silver nitrate solution?

d). 0.420 g potassium permanganate, $KMnO_4$, is exactly reduced by 40.0 cm^3 of an acidified solution containing Fe^{2+}. Calculate the molarity of the Fe^{2+} ion?

e). Give three (03) problems encountered in precipitate formation, and state briefly how you would minimise the effect of each problem.

Question 2.

a). The sodium content of a water sample was determined by flame photometry methodology; and, the results were as follows:

Standard solution (ppm):	0	10	20	30	40	50
Transmittance:	0.00	2.05	4.10	6.15	8.20	10.25

From the data obtained, determine the regression line and calculate the sodium concentration in the water sample, if the transmittance of the sample was 5.50.

b). Determinate errors may be attributed to three main causes, namely Instrumental error, Operative error, and Errors of the Method. Briefly explain the meaning of each of the three categories of errors.

c). Write balanced ionic equations for the following reaction: potassium dichromate solution being decolourised by acidified iron(II) sulphate solution.

d). i). What is the difference between (a) galvanic and electrolytic cells (b) iodometric and iodimetric titrations?

ii). What concentrations should be used to prepare a cyanic acid-cyanate ($HCNO/CNO^-$) buffer solution of pH = 3.50? (K_a= 1.2 x 10^{-4} for HCNO).

e). Calculate the complex formation constant for the two-coordinate $Fe(SCN)^{2+}_2$ complex ion from the following data:

$Fe^{3+}_{(aq)} + SCN^-_{(aq)} \rightarrow Fe(SCN)^{2+}$; $K_{f1} = 890$

$Fe(SCN)^{2+}_{(aq)} + SCN^-_{(aq)} \rightarrow Fe(SCN)^+$; $K_{f2} = 2.6$

Question 3.

a). i. Distinguish between reproducibility and repeatability

ii. Define accuracy and precision

b). The three dissociation constants for the successive ionisation of a triprotic acid, H_3A, are Ka_1 = 7.42 x 10^{-4}; Ka_2 = 1.75 x 10^{-5} and Ka_3 = 3.99 x 10^{-6}. Determine the equilibrium concentrations of the species listed below at pH 2 in a 0.500 M H_3A solution:

a). molecular acid b). A^{3-} ion

c). A C 229 student determined the molarity of an acid by titrimetry, and obtained the following results 0.1067; 0.1071; 0.1066 and 0.1050. Can we discard either the second or the fourth result as being due to accidental error at 95% CL?

d). What do you understand by the terms: complec formation constant and complex dissociation constant? Show how the two terms are related.

e). i). Calculate the pH and pOH of a solution obtained by mixing equal volumes of a strong acid of pH 3.0 and a strong base of pH 12.0

ii). Complete and balance the following redox reactions which occur in acid aqueous solution:

a). $I_2 + H_2S \rightarrow H^+ + I^- + S_{(s)}$

b). $CuS + NO_3^- \rightarrow Cu^{++} + SO_4^= + NO$

Question 4.

a). What must be the concentration of added Ag^+ to just stsart precipitation of AgCl in a 1.0 x 10^{-10}M solution of NaCl? (for AgCl, K_{sp} = 1.0 x10^{-10})

b). Absorbance readings of a blank were made in a spectrophotometric method as follows: 0.002; 0.000; 0.006; 0.008; 0.003 and 0.000. A standard solution of 1ppm analyte solution gave an absorbance reading of 0.069. What is the detection limit for the method under test?

c). One gram of an acid (HA) of unknown formula is dissolved in water; and 20.72 mL of 0.588 M NaOH solution is added. The reaction may be represented as: HA + NaOH $\rightarrow$ NaA + H_2O. If 7.82 mL of 0.510 M HCl is required to neutralize the excess base, what is the formula weight of the acid?

d). In dilute aqueous solution, sulphuric acid can be regarded as totally dissociated to H_3O^+ and HSO_4^-. The hydrogensulphate ion, HSO_4^-, is itself a weak acid with a dissociation constant of 1.20 x 10^{-2}. Calculate the concentration of H_3O^+, HSO_4^-, SO_4^{-2} and OH^- in a solution prepared by dissolving 1.00 mole H_2SO_4 in enough water to make 1.00 litre of solution.

e). Riboflavin (vitamin B_2) is determined in cereal samples by measuring fluorescence intensity in a 5% acetic acid solution. From analytical data given below, use the method of least squares to:

Standards concentration (ppm):	0.000; 0.100; 0.200; 0.400; 0.800
Fluorescence intensities (I):	0.000; 5.8; 12.2; 22.3; 43.3

i). obtain the equation for the best-fit line for the calibration curve

ii). calculate the concentration of riboflavin in a sample for I was found to be 15.4

Question 5.

a). The three dissociation constants for the successive ionisation of arsenic acid, H_3AsO_4, are Ka_1 = 5.65 x 10^{-3}; Ka_2 = 1.75 x 10^{-7} and Ka_3 = 2.54 x 10^{-12}. Calculate the equilibrium concentrations of the hydrogen arsenate ion ($H_2AsO_4^-$) and its conjugate base at pH 3 in a 0.200 M arsenic acid solution.
b). Explain the sampling protocol you would use to sample a highly heterogeneous 10-acre farm. State any three problems you might encounter if you decided to crush and grind our sample to a suitable laboratory analysis sample size.
c). Justify why Cu^{2+} easily forms a complex with NH_3; and, explain how your answer is related to Lewis acids and bases.
d). Calculate the pH of a solution obtained by dissolving 50ml of 0.15 M concentrated ammonia solution (M_{wt} = 17.0g/mol; density 0.90 g/mL; 28.0% w/w) and 2.00 g ammonium chloride (M_{wt} = 53.5 g/mol) in water and diluting to exactly 250 mL (for ammonia, pK_b = 4.76)
e). Absorbance readings of a blank were made in a spectrophotometric method as follows: 0.002; 0.000; 0.006; 0.008; 0.003 and 0.000. A standard solution of 1ppm analyte solution gives an absorbance reading of 0.069. What is the detection limit for the method?

..........................END OF EXAMINATION...........................

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
DEPARTMENT OF CHEMISTRY
2008 ACADEMIC YEAR FIRST SEMESTER
FINAL EXAMINATION

CAV 251 AGRICULTURAL AND VETERNARY CHEMISTRY
TIME: 3 HOURS

INSTRUCTIONS:
ANSWER ANY 4 QUESTIONS FROM THE 5 QUESTIONS IN THIS PAPER
ALL QUESTIONS CARRY EQUAL MARKS
SHOW ALL YOUR WORKING AND REASONING CLEARLY

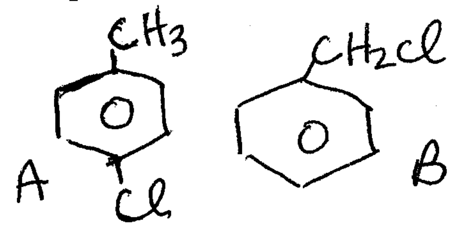
QUESTION 1

(a) Establish any differences between: chiral molecule, enantiomers, and disstereomers.
(b) A solution of 1.250g of a non-electrolyte in 20g water freezes at -1.06^0C. Calculate the molecular weight of the solute.
(c) Absorbance readings of a blank were made in a spectrometric method as follows: 0.002; 0.000; 0.006; 0.008; 0.003 and 0.000. A standard solution of 1ppm analyte solution gives an absorbance reading of 0.069. What is the detection limit for the analyte?
(d) Fe(11) in an acid solution is titrated with 0.02 M solution of $KMnO_4$. If the titration needed 40.2ml, how many mg Fe are in the solution? What indicator if any was used in the titration? (Fe = 55.8).
(e) Explain the Volhard and Fajan titrations and explain why acidic environment is needed during titration. Explain also the principles of operation of adsorption indicators.

(15 MARKS)

QUESTION 2

(a) Methylbenzene reacts with chlorine under 2 different sets of conditions to give compound A and compound B. Describe conditions used to produce A and B respectively.



(b) The freezing point of a 0.10m solution of $NaHCO_3$ is -0.38^0C. On the basis of this information, decide whether this compound ionizes in water as: $NaHCO_3(s) \rightarrow Na^+ + HCO_3^-$, n = 2 or $NaHCO_3(s) \rightarrow Na^+ + H^+ + CO_3$, n = 3.

(c) A solution is 10^{-3} M in $Cr_2O_7^{2-}$ and 10^{-2}M in Cr^{2+}. If the pH is 2.0, what is the potential of the half reaction? (E^0 =3.3v)

(d) A batch of cough mixture bottles was weighed to determine if they fell within acceptable standard control guidelines. The individual weights were: 127.2; 128.4; 127.1; 129.0 and 131.1 g. i) Calculate the mean ii) Determine whether the last weight is an outlier datum at 99% CL.

(e) What do you understand by the terms: tautomerism; Markowmikoff's rule and racemic mixture

(15 MARKS)

QUESTION 3

(a) Which of the following molecules would you expect to be polar? CF_4; P_4; CH_2Cl_2; CH_3Cl; CO_2 and $BeBr_2$. What is an exergonic reaction and what is a reducing sugar?

(b) The E^0 for the reaction $Fe + Zn^{2+} \rightarrow Zn + Fe^{2+}$ = -0.24v. What is the equilibrium concentration of Fe^{2+} reached if a piece of Fe is placed in a 1.0M solution of Zn^{2+}?

(c) State the 3 necessary criteria for a compound to be aromatic.

(d) Vitamin B2 is determined in cereal samples by measuring its fluorescence intensity in 5% acetic acid solution. A calibration curve was constructed using fluorescence intensities of a series of standards of increasing concentration. The data is:

Fluorescence Intensity (I):	0.00	5.80	12.20	22.30	43.30
Riboflavin (mg/ml)	0.000	0.100	0.200	0.400	0.800

Use the method of least squares to determine i) the best straight line for the calibration curve and ii) calculate the concentration of riboflavin for the fluorescence intensity of 28.4.

(e) Calculate the freezing point and boiling point at 760 mm Hg of a solution of 2.60g urea, $CO(NH_2)_2$ (fw = 60) in 50g of water.

(15 MARKS)

QUESTION 4

(a) Calculate the vapour pressure lowering and the vapour pressure of a solution containing 100g sugar $C_{12}H_{22}O_{11}$ (MW = 342) in 500ml of water at 25^{0}C. (Vapour pressure for water is 23.76mm hg).

(b) Show why the hydroxyl group in phenol directs the bromination to take place at para rather meta position. What is meant by the terms S_N1 and S_N2?

(c) Calculate the free energy change ΔG^0 at 25^{0}C for the reaction: $4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(l)$ and identify the type of reaction that may occur. (ΔG_f for NH_3 = -4.0; H_2O = -56.7 and NO = 20.7 kcal).

(d) What do you understand by the terms: geometric isomerism; entropy and electrophilic sbstitution?

(e) The first and second acidity constants of H_2S are 10^{-7} and 10^{-15} respectively. Calculate: a) the equilibrium constant (Ka) for the reaction $H_2S + 2H_2O \rightarrow 2H_3O^+ + S^{2-}$, b) the concentration of S^{2-} ion in a 0.1MH_2S solution at pH 2, c) what is meant by the term 'triprotic' and d) write appropriate equations for the first two dissociation constants of H_3AsO_4.

(15 MARKS)

QUESTION 5

(a) When the compound F, $C_6H_5CH_2Cl$, reacts with hot ethanoic KOH, two products are formed: compound G, C_7H_8O and compound H, $C_6H_5CH_2OCH_2CH_3$. Suggest an identity for compound G and state the type of reaction undergone by F, explaining how G and H are formed.

(b) Explain what the following terms mean: colligative properties, Rauolt's rule and activation potential.

(c) Given that k_p for the reaction $PCl_5(g) \rightarrow PCl_2(g) = Cl_2(g)$ is 1.87×10^{-7} at 25^{0}C and that ΔH is 22.2 kcal, calculate k_p at 250^{0}C. (R = 1.99).

(d) 2.0cm3 of 14.0 M HNO_3 is made up to 400cm^3 of solution of water.Calculate, a) the molarity of the solution b) H_3O^+ concentration of the solution and c) pH of the solution.

(e) O_2 gas is formed by decomposition of nitric oxide ($2NO(g) \rightarrow O_2(g) + N_2(g)$). If the rate of formation of O_2 is 0.054M/s, what is the rate of decomposition of NO?

(15 MARKS)

($Cr_2O_7^{2-}$ $14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$;
$5Fe^{2+} + MnO_4^- + 8H^+ \rightarrow 5Fe^{3+} + Mn^{2+} + 4H_2O$).

END OF EXAMINATION QUESTIONS

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2008 ACADEMIC YEAR FIRST SEMESTER
FINAL EXAMINATIONS

C251: ORGANIC CHEMISTRY I

TIME: THREE HOURS

INSTRUCTIONS:

1. **Answer any four questions.** **Max. Marks: 120**
2. **Marks allocation for questions is shown [x]**

QUESTION ONE

(a) Compound **A**, $C_8H_{15}Cl$, exists as a racemic form. Compound **A** did not react with solution of bromine in carbon tetrachloride and aqueous permanganate solution. Upon treatment with zinc/acetic acid and subsequent separation of the reaction mixture by gas chromatography, compound **A** gave two optically inactive fractions, **B**, C_8H_{16}, and **C**, C_8H_{16}. Fraction **B** was found to be a racemic mixture and it was resolved. Fraction **C** could not be resolved. Upon treatment with sodium hydroxide in ethanol, compound **A** gave a compound **D**, C_8H_{14}. Ozonolysis of **D** followed by treatment with zinc dust and acetic acid gave 2,7-octanedione. Hydrogenation of **D** using platinum catalyst gave **C**.

(i) Propose the structures, including stereochemistry where pertinent, for compounds **A**, **B**, **C** and **D**. Briefly show your reasoning.

(ii) Give mechanisms of the reactions involved in the formation of 2,7-octanedione from **D**.

[20]

(b) Cholic acid, the major steroid found in bile, was observed to have a specific rotation of +2.22° when a 3.0 gram sample was dissolved in 5.0 mL alcohol and the solution was placed in a sample tube with a 1.0 cm path length. Calculate $[\alpha]_D$ for cholic acid.

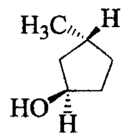
[6]

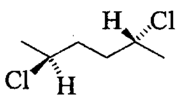
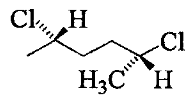
(c) A C251 student wanted to resolve 2*R*, 3*S*-butane-2, 3-diol. What advice would you offer to the student in carrying out this experiment?

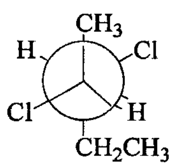
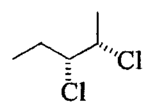
[4]

QUESTION TWO

(a) State the relationship between the following pairs of structures as identical, non-isomers, conformers, constitutional isomers, enantiomers, or diastereomers.

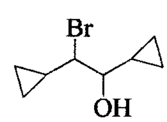
(i)  VS 

(ii)  VS 

(iii)  VS 

[9]

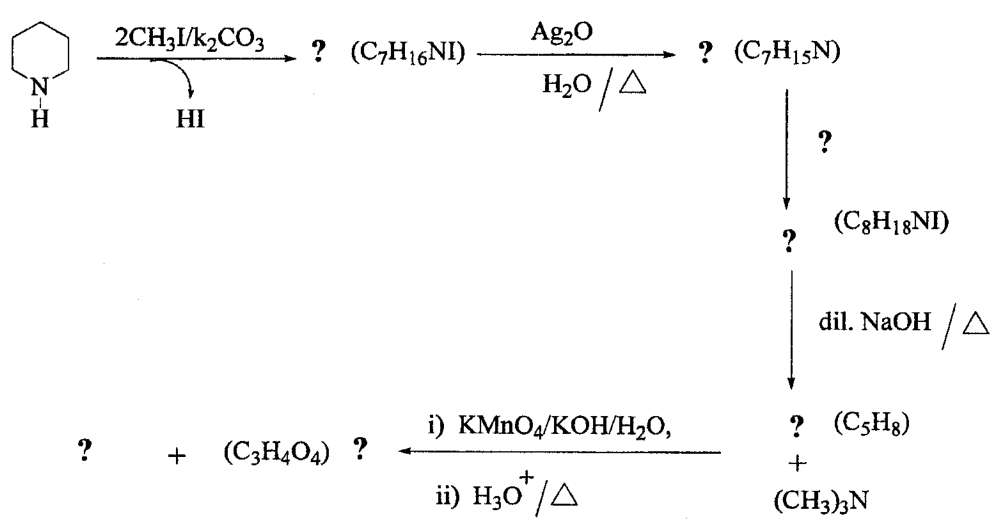
(b) Using only ethyne and any alcohols containing not more than five carbons as the only sources of carbon atoms, show how would you synthesise a compound **E**, structure shown below. Give reagents, including solvents, if any, and reaction conditions for each step of your proposed synthesis. Reaction mechanisms are **not** required to be shown.



Compoud E

[10]

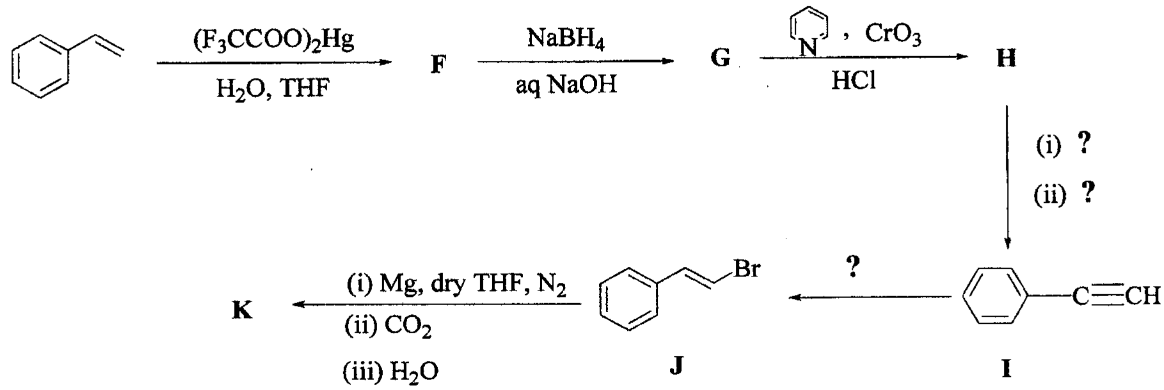
(c) Provide the missing products and reagents of the following reaction sequence.



NOTE: Ag_2O/H_2O is a source of OH^- ions. [11]

QUESTION THREE

(a) A synthesis of a bioactive compound **K** is shown below:



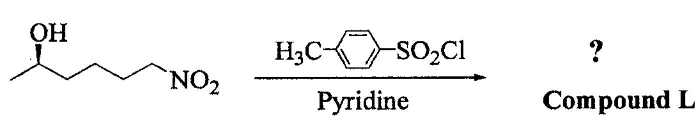
(i) Identify compounds **F, G, H** and **K** in the above synthesis.

(ii) Provide the missing reagents for the reactions typed bold, including solvents, if any, in the above synthesis (formation of **I** from **H;** and formation of **J** from **I**).

(iii) Give the mechanism of the reactions involved in the formation of **K** from **J**.

[20]

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

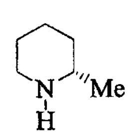


[6]

(c) Nitro compounds can be reduced by a variety of reagents to give primary amines, for example

$$RNO_2 \xrightarrow[HCl]{Sn} RNH_2$$

However, reduction of compound **L in Q3 (b) (i)** above gave a heterocyclic compound **M,** structure shown below, as the only product. Suggest a reaction mechanism to account for the formation of **M** from **L.**



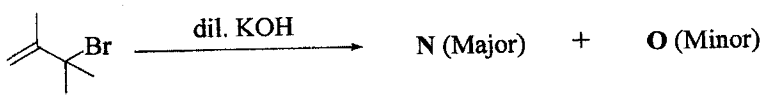
Compound M

[4]

QUESTION FOUR

(a) Tertiary halides are unreactive towards S_N2 but very reactive towards S_N1.

(i) On the basis of the above statement, write possible structures of **N** and **O** for the reaction shown below.



(ii) Show the mechanism for the reaction in (i) above.

(iii) Give a reason why **N** should be a major product. **[12]**

(b) Draw conformations for each of the following compounds and point out which one has the lowest energy. Give reason(s) for your choice.

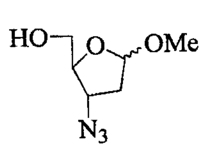
(i) *Cis*-1- tert-butyl-4-ethylcyclohexane

(ii) *Trans*-1- tert-butyl-4-ethylcyclohexane **[10]**

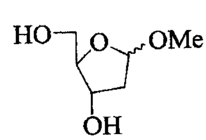
(c) Upon refluxing with phosphoric acid, 2,2,4- trimethylcyclopentanol gave 1,2,3-trimethylcyclopentene in good yield. Provide a mechanistic explanation for this experimental result. **[8]**

QUESTION FIVE

(a) Propose a synthesis for the following compound from indicated starting material and readily available reagents. State all reagents, including solvents, and reaction conditions for each step of your proposed synthesis. Reaction mechanism is **not** required to be shown.

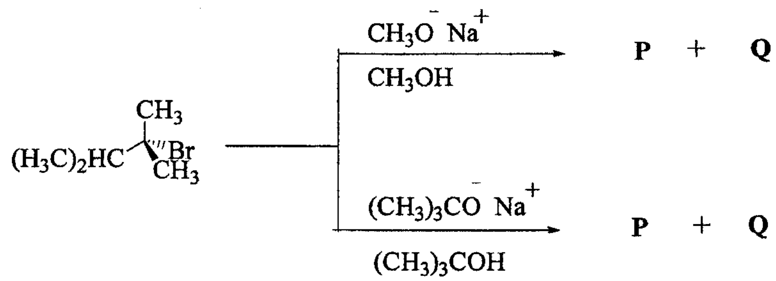


From

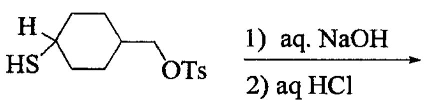


[10]

(b) (i) Predict the products **P** and **Q** in each of the following reactions. In each case **indicate** the major product and give reasons for your choice.

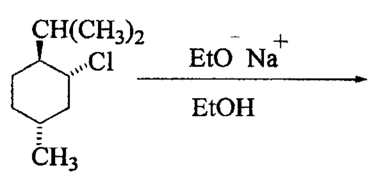


(ii) The reaction shown below is an intramolecular S_N2 type reaction. Give the product and propose a suitable mechanism for this reaction.

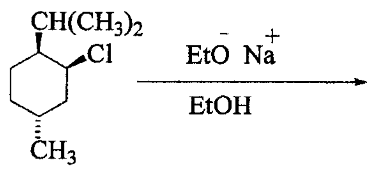


[12]

(c) When menthyl chloride and neomenthyl chloride isomers are treated with sodium ethoxide in ethyl alcohol, the menthyl chloride gives a single product while neomenthyl chloride gives a mixture of products. On this basis, show the products and give mechanism of the following reactions.



Menthyl chloride



Neomenthyl chloride

[8]

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2008 ACADEMIC YEAR FIRST SEMESTER
FINAL EXAMINATIONS

C252: ORGANIC CHEMISTRY II

TIME: THREE HOURS

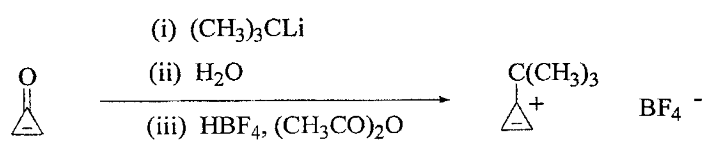
INSTRUCTIONS:
1. **Answer any four questions.**
2. **Marks allocation for questions is shown [x]**

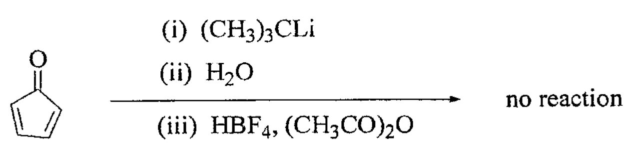
QUESTION 1

(a) Given that the heat of hydrogenation of cyclooctene to cyclooctane is -23.3 Kcal/mole and the heat of hydrogenation of cyclooctatetraene to cyclooctane is -100.9 Kcal/mole, calculate the empirical resonance energy for cyclooctatetraene and interpret your result in relation to the resonance energy of benzene.

[6]

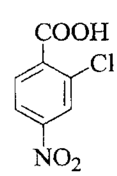
(b) The following known reaction of cyclopropenone does not occur with the corresponding five-membered ring analog. Explain why?



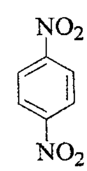


[8]

(c) Starting from benzene, show how each of the following compounds can be prepared. Assume that the ortho- and para- substitution products can be separated.

(i) 

2-Chloro-4-nitrobenzoic acid

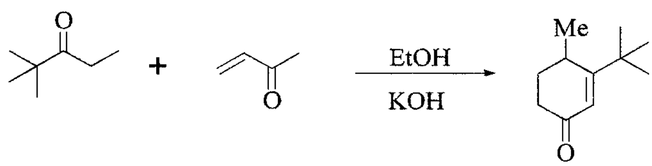
(ii) 

1,4-Dinitrobenzene

[16]

QUESTION 2

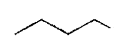
(a) Cyclohexenones can be prepared by Robinson annulation. For example:



Give the mechanisms of all steps that occur in this reaction.

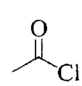
[12]

(b) Deduce the structure of the sex pheromone of the Egyptian cotton leafworm, **E**, from the following synthesis and show the structures of the intermediates **A** – **D**.

9-Bromo-1-nonanol $\xrightarrow[\text{Conc. } H_2SO_4]{\text{DHP}}$ **A**, $C_{14}H_{27}O_2Br$ $\xrightarrow[\text{(ii)}]{\text{(i) } Ph_3P}$  Li, THF **B**, $C_{32}H_{41}O_2PLi$

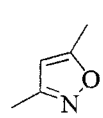
B $\xrightarrow{(E)\text{-2-penten-1-al}}$ **C**, $C_{19}H_{34}O_2$

C, $C_{19}H_{34}O_2$ $\xrightarrow[\text{warm}]{HCl/H_2O}$ **D**, $C_{14}H_{26}O$

D, $C_{14}H_{26}O$ $\xrightarrow[\text{Pyridine}]{}$  **E**, $C_{16}H_{28}O_2$

[8]

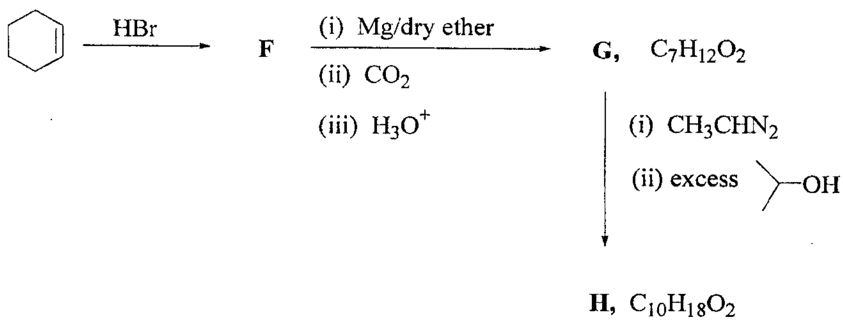
(b) Suggest plausible reaction mechanisms to account for the observed product of the following reaction.

$CH_3COCH_2COCH_3$ $\xrightarrow[\Delta]{H_2NOH.HCl}$ 

[10]

QUESTION 3

(a) Consider the following reaction sequence:

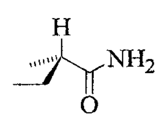


(i) Provide the structures for the compounds **F** – **H**.

(ii) Give the reaction mechanisms for the transformation of **F** into **G**; and **G** into **H** .

[15]

(b) The reaction of (S)-2-methylbutanamide, structure shown below, with sodium hydroxide & Bromine followed by aqueous hydrolysis gave an optically active amine.



(*S*)-2-Methylbutanamide

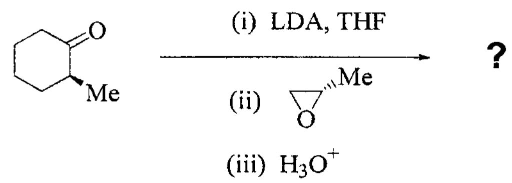
(i) Give the stereochemical structure, including the configurational label, of the amine and the mechanism of its formation.

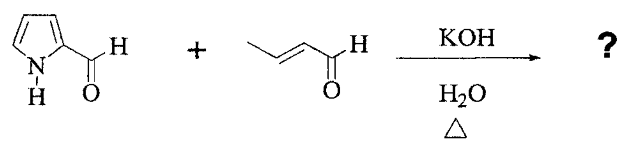
(ii) What product would you expect to obtain, if the optically active amine was treated with benzenesulfonyl chloride in the presence of pyridine? Show the reaction mechanism.

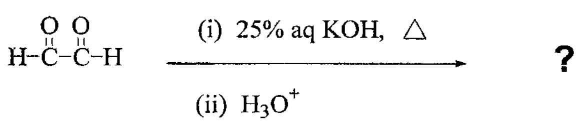
[15]

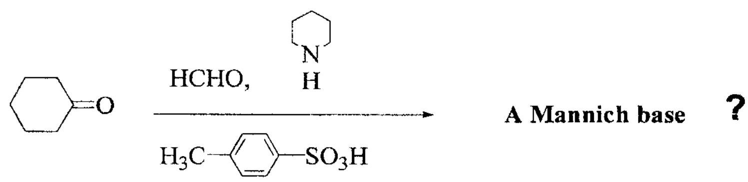
QUESTION 4

Predict the major organic products and give the mechanisms of the following reactions.

(i) 

(ii) 

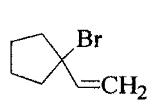
(iii) 

(iV) 

[30]

QUESTION 5

(a) Ethanol is allowed to react with 1-(1-bromocyclopentyl)ethene, structure shown below.



1-(1-Bromopentyl)ethene

(i) Show the products and provide the reaction mechanisms for their formation.

(ii) State which is the kinetic product and which is the thermodynamic product.

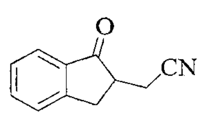
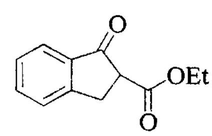
[8]

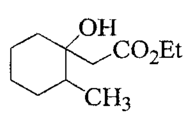
Chloride

(b) When 1, 3-butadiene is allowed to react with hydrogen ~~bromide~~ in acetic acid at room temperature, there is produced a mixture of 22 % 1-chloro-2-butene and 78 % 3-chloro-1-butene. On treatment with ferric chloride, this mixture is converted into 75 % 1-chloro-2-butene and 25 % 3-chloro-1-butene. Explain.

[8]

(c) Propose a synthesis of the following compounds from the indicated starting materials. Show the reagents, including solvents, if any, and the reaction conditions for each step of your proposed synthesis clearly. Reaction mechanisms are not required to be shown.

(i)  **from** 

(ii)  **from** any alcohol containing up to six carbon atoms as the source of carbons

[14]

END OF THE EXAMINATION

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

2008 ACADEMIC YEAR FIRST SEMESTER

FINAL EXAMINATION

C 311: BIOCHEMISTRY I

TIME: THREE HOURS

INSTRUCTIONS:

1. THERE ARE 3 SECTIONS IN THIS EXAMINATION PAPER
2. ANSWER ANY FIVE QUESTIONS

SECTION A

- **Question 1**
  A sample of an unknown peptide was divided into two aliquots. One aliquot was subjected to trypsin treatment, and the other to cyanogens bromide (CNBr). Given the following sequences (N-terminal to C-terminal) of the resulting fragments, **deduce** the sequence of the original peptide.

  Trypsin treatment:
  asn-thr-trp-met-ile-lys
  gly-tyr-met-gln-phe
  val-leu-gly-met-ser-arg

  CNBr treatment:
  gln-phe
  val-leu-gly-met
  ile-lys-gly-tyr-met
  ser-arg-asn-thr-trp-met

[20 marks]

Please turnover the page

- **Question 2**

a) Adult hemoglobin (HbA) has histidine at position 143 while fetal hemoglobin (HbF) has serine at this position. As a biochemist, **explain** how this change accounts for the transfer of oxygen from mother to child during pregnancy.

b) Your classmate in C 311 tells you that in the lungs hemoglobin binds oxygen and releases protons; as result pH increases. In actively metabolizing tissue hemoglobin releases oxygen and binds protons and, as a result the pH decreases. Do you agree with this statement? Why or why not?

[20 marks]

SECTION B

- **Question 3**

Intermediary metabolism focuses on the intermediates in metabolic pathways.

a) **Define** intermediary metabolism and state the major functions it serves.

b) **Define** a metabolic pathway and state and briefly explain the characteristics of a metabolic pathway.

c) Intermediary metabolism is usually symbolized by two functional blocks. **Name** these two functional blocks and briefly explain each one of them. **Name** 2 metabolic pathways in each functional block.

d) **What** are the two most important levels at which enzymes in metabolic pathways and intermediary metabolism are regulated?

e) Given that in end-product inhibition, the first enzyme in the pathway or the first reaction enzyme after the branch point are inhibited by the specific products, **sketch** three possible patterns for end-product inhibition, one for the unbranched and two for branched metabolic pathways.

[20 marks]

Please turnover the page

SECTION C

- **Question 4**

Differentiate with examples and illustrations between regulation of enzyme activity by

a) Allosterism and covalent modification
b) Feedback control and product inhibition

[20 marks]

- **Question 5**

a) How does the cell produce 38 moles of ATP from 1 mole of glucose? Include all enzymes involved in the pathway.
b) What is the fate of pyruvate in carbohydrate metabolism?

[20 marks]

- **Question 6**

Identify the following:

i. Reversible inhibition of enzyme activity
ii. Three-point attachment mechanism in enzyme specificity
iii. RNA enzymes
iv. Transition state in enzyme activity
v. Prosthetic group

[20 marks]

End of examination

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
2008 ACADEMIC YEAR FIRST SEMESTER
FINAL EXAMINATIONS

C321 ANALYTICAL CHEMISTRY 11
TIME: 3 HOURS
INSTRUCTIONS

1. Answer any **FOUR** of the questions in this paper.
2. All questions carry equal marks (15 Marks)
3. Show all your working and reasoning clearly

QUESTIONS :

1. (a) Transferrin is the iron-transport protein found in blood. It has a molecular weight of 81 000 and carries two Fe^{3+} ions. Desferrioxamine B is a potent iron chelator used to treat patients with iron overload. It has a molecular weight of about 650 and can bind one Fe^{3+}. Desferrioxamine can take iron from many sites within the body and is excreted (with its iron) through the kidneys. The molar absorptivities of these compounds (saturated with iron) at two wavelengths are given below. Both compounds are colourless (no visible absorption) in the absence of iron.

	ε [M^{-1} cm^{-1}]	
λ (nm)	Transferrin	Desferrioxamine
428	3540	2730
470	4170	2290

A solution of transferring exhibits an absorbance of 0.463 at 470 nm in a 1.000 cm cell. Calculate the concentration of transferring in milligrams per millilitre and the concentration of iron in micrograms per millilitre.

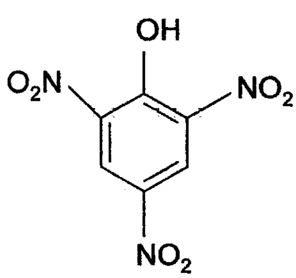
(b) Complex formation by 3-aminopyridine and picric acid in chloroform solution gives a yellow product with an absorbance maximum at 400 nm. Neither starting material absorbs significantly at this wavelength. Stock solutions containing 1.00 x 10^{-4} M of each compound were mixed as follows and the absorbances of the mixtures were recorded

Picric acid (mL)	3-Aminopyridine	Absorbance at 400 nm
2.70	0.30	0.106
2.40	0.60	0.214
2.10	0.90	0.311
1.80	1.20	0.402
1.50	1.50	0.442
1.20	1.80	0.404

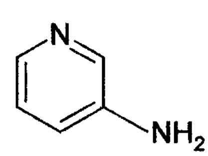
0.90	2.10	0.318
0.60	2.40	0.222
0.30	2.70	0.110

Prepare a graph of absorbance versus mole fraction of 3-aminopyridine and find the stoichiometry of the complex.

Picric acid



3-aminopyridine



(c) With the aid of ketches, describe the operation of charge coupled devices (CCD) in absorption spectrometry.

(d) Draw a block diagram of a typical absorption spectrophotometer. Give two types of monochromators that are used in these instruments and describe their purpose.

(e) What is chemiluminescence? Give an example of a reaction that cheluminesces.

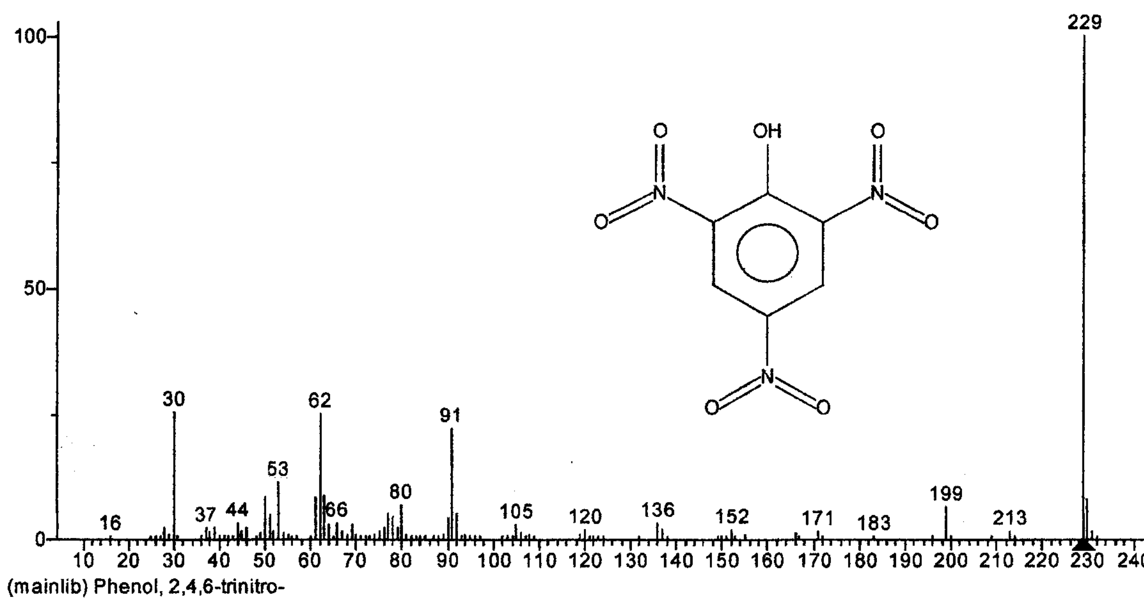
(15 Marks)

2. (a) Use a sketch to outline what happens when a molecule absorbs light energy (no description necessary).

(b) There is an emission process that occurs within $10^{-9} - 10^{-6}$ seconds usually referred to as an allowed transition, which one is it? Sketch and label completely the instrumentation used to carry out measurements for this process.

(c) With the aid of sketches, describe the operation of a quadrupole mass spectrometer found in the Department of Chemistry. Include, ionisation techniques, mass analysis and detection.

(d) Below is a mass spectrum of picric acid (MM= 229) obtained by Electron Ionization (EI). Assign plausible fragment structures for m/z ratio peaks at 229, 199, 183 and 91. It would have been expected that the molecular ion in this case should have fragmented extensively but did not why?



Mass Spectrum of Picric acid **(15 Marks)**

3(a) Why are echelle gratings better than echellette gratings as used in emission determinations.

(b) Explain the 2 types of nuclear relaxation and their implication in NMR.

(c) Describe the terms: Magnetic anisotropy, Coupling constant and Diamagnetic shielding.

(d) An analyst notes that a 1ppm solution of Na gives a flame emission signal of 110, while the same solution containing also 20ppm K gives a reading of 125. It was determined that a 20ppm solution of K showed no blank reading. Explain the results.

(e) The drug tolbutane)MW = 270) has molar absorptivity of 703 at 260nm. One tablet is dissolved in water and diluted to a volume of 2L. If the solution exhibits an absorbance in the UV region equal to 0.687 in a 1 cell, how many grams of the drug are in a tablet? **(15 Marks)**

4 (a) What do you understand by the terms: phosphorescence, isosbetic point and Doppler broadening.

(b) Describe the premix chamber burner and total consumption burner and compare them with respect to efficiency and sensitivity.
(c) Give a description of the components of an AA spectrometer you can use in elemental analysis of alkali metals found in serum,, include the types of elements that can be done by this technique and why the technique is preferred.
(d) Over what concentration range in mg/L could analyses be done for Fe(II) chelate which possesses a molar absorptivity of 12000 if it is desired to confine the transmittance readings within the range 0.200 to 0.650. Assume an optical length of 1.00cm. (Fe = 55.4).
(e). Describe radiation sources and detectors for the UV, Visible and IR regions of the spectrum. **(15 Marks)**

5 (a) IR is a very useful technique in analysis. How does the IR instrument work and give two examples of substances that can be done by this instrument.
(b) Describe and compare different causes of deviations from Beer's law.
(c) What do you understand by the terms: Raleigh scattering, Raman effect fingerprint area in IR?
(d) 0.131g of pure caffeine is dissolved in 1L, exactly 10ml of the solution is diluted to 100ml and the solution gave an absorbance of 0.854 in a 1cm cell. What is the concentration of the solution? An unknown aqueous solution of caffeine gave an absorbance of 1.022 in a 2cm cell at 272nm. What is the concentration of the solution (MW caffeine = 194.2).
(e) In an experiment to determine Na, two approaches were used, that is, using direct intensity method and internal standard method, which method should be better and why? **(15 Marks)**

END OF EXAMINATION QUESTIONS

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS – FEBRUARY 2008

GG322: STRATIGRAPHY AND REMOTE SENSING

PRACTICAL

PAPER II

TIME: THREE HOURS
ANSWER: ALL QUESTIONS. NEATLY DRAWN SKETCHES/ DIAGRAMS RECOMMENDED FOR A FULL MARK.

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1 (a) What does following abbreviations stand for?
(i) UTM (2 marks)
(ii) TIFF (2 marks)
(iii) EMR (2 marks)
(iv) GPS (2 marks)

(b) Differentiate between the following:
(i) TIFF and GeoTIFF .... (4 marks)
(ii) Spectral Signature and Spectral Response .... (4 marks)
(iii) Path and Row.. (4 marks)
(iv) Cross-track and Along-track scanners.................................. (4 marks)

(c) With neatly labeled sketches, where possible differentiate between the following:
(i) Vector Model and Raster Model (4 marks)
(ii) Aerial photographs and satellite images (4 marks)
(iii) Transmission and Reflection (4 marks)
(iv) Passive and Active Sensors (4 marks)
(v) Energy and Radiation (4 marks)

2. (a) List the sensor systems known today .... (5 marks)
(b) How many satellites are required to get an accurate GPS position? Explain your answer...(4 marks)
(c) In what ways can you improve accuracy in a GPS set-up?................ (2 marks)
(d) List the data sources i.e. various forms of data that you could enter into a GIS project ....(5 marks)

3. As a Geologist, you have been assigned to undertake a research study in Zambia.

(a) You decide to select 2 aerial photos so that you can undertake an initial photo-geological interpretation. You are therefore required to:

(i) Provide a fully annotated photogeological interpretation on the portion that you are able to obtain a stereo vision i.e. able to see in three dimensions. ....(30 marks)

(ii) Provide a description of the photogeology i.e. the geology of the annotated area..(10 marks)

END -- GOOD LUCK

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2008 ACADEMIC YEAR FIRST SEMESTER
FINAL EXAMINATIONS

C 341: INORGANIC CHEMISTRY II

TIME: THREE HOURS

INSTRUCTIONS: ANSWER ANY FOUR QUESTIONS

QUESTION 1. For production of fertilizers on a large scale they use sulphuric and nitric acids and ammonia. State the industrial methods production of:

(a). Sulphuric acid.

(b). Ammonia.

(c). Dilute nitric acid

QUESTION 2. (a) How do dilute and concentrated nitric acids react with: Cu, Zn and Fe.

(b). Describe the laboratory methods and write down the reactions for preparations of Hydrogen peroxide using barium peroxide and sodium peroxide.

(c). Give three commercial uses of each of the following: ammonia, nitric and sulphuric acids.

QUESTION 3. Write down the reactions:

(a). Production of hexamminecobalt(III) chloride, $[Co(NH_3)_6]Cl_3$, from $CoCl_2.6H_2O$, NH_4Cl, concentrated ammonia solution and H_2O_2 at room temperature in presence of light and charcoal (H_2O_2 is used as an oxidizing agent to shorten the time of the preparation).

(b). Give an account of the general properties of Carbon group.

(c). State the basic oxides of the group VIA of the periodic Table of the elements.

QUESTION 4. (a). Show that for d^4 high spin ions the relative energy of an octahedral over tetrahedral field is -3/5(10Dq) + 2/5(10Dq).

(b). Show that the spin only magnetic moment for a d^6 ion is normally 4.90 or 0.0 B.M in an octahedral field but 4.90 or 2.83 B.M in tetrahedral field.

(c). The magnetic moments of two Mn^{2+} compounds are given. Account for the observation.

$K_4[Mn(NCS)_6].3H_2O$	6.06 B.M
$K_4[Mn(CN)_6].3H_2O$	2.13 B.M

QUESTION 5. (a) Draw all possible isomers for the complexes:

(i) $RuCl_3(H_2O)_3$

(ii)Tetraaminedichloro Cobalt (111) cation.

(b) Name the given complexes

(i) $[(CH_3)_4N]_2[Co(NCS)_4]$

(ii) $Ni(PF_3)_4$

(c) (i) Sketch the NMR spectra for the following:

(1) 1, 1, 2 Trichloroethane

(2) 1, 1, 1 Trichloroethane

(ii) Explain briefly the appearance of the spectrum of RCH_2Cl and RCH_2F. What causes the protons to show up in different parts of spectrum?

Question 6. (a). What factors affect the intensity of an electronic spectrum?

(b) In a tetrahedral environment Mn^{2+} has a green yellow color, much more intense than normal pink color of octahedrally co-ordinated ion. Comment.

(c) Absorption spectra of both hydrated Cu^{2+} and Ti^{3+} do not consist of one simple band. Suggest why this may be so?

END OF EXAMINATIONS

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
DEPARTMENT OF CHEMISTRY
2008 ACADEMIC YEAR FIRST SEMESTER
FINAL EXAMINATIONS.

C 421: APPLIED ANALYTICAL CHEMISTRY.

DECEMBER, 2008.

TIME: THREE HOURS.

INSTRUCTIONS: [This Paper Contains Five (05) Questions]. ANSWER ANY FOUR (04) QUESTIONS. Each Question Carries 15 marks.

Question 1.

a. Discuss the Winkler method used for the determination of dissolved oxygen (DO) in water.

b. A sample of copper ore (0.20g) was analysed by iodometry. Cu (II) was reduced to Cu (I) by iodide [$2Cu^{2+} + 4I^- \rightarrow 2CuI + I_2$].What is the copper content (%) of the ore if 20.0 cm^3 of 0.2 M $Na_2S_2O_3$ is used up for titrating the liberated iodine [$I_2 + 2S_2O_3^{2-} \rightarrow 2I + S_4O_6^{2-}$]

c. Describe 2 methods used to separate Pb from rocks and one technique used to determine it from a solution of the rock.

d. Account for characteristics of a 16-55-15 fertilizer. What is the content of ballast in this fertiliser?

e. Given that the analysis of a certain fertiliser yielded the following elemental analysis results: 22.67% P, 22.00% N and ballast 8.00% how would you report this result officially according to the N-P-K Convention?

Question 2.

a. The fertiliser plant at Nitrogen Chemicals of Zambia Ltd. in Kafue produces urea, one of many chemical fertilisers manufactured world-wide. Classify the NCZ product as a fertiliser, and then detail five basic parameters that you would analyse for in this product.

b. Photometric methods are not ideal for the determination of metals in rocks. Why is this so, and how would you overcome such difficulties?

c. How would you determine organic C as well as "alkalinity of sash" in soils?

d. What methods would you use for the analysis of the following, in the atmosphere?

i). Nitrogen oxides

ii). SO_2

e. A solid mixture of $Ca(OH)_2$ and $CaCl_2$ is analysed by titration with HCl. It is found that a sample weighing 0.60 g needs 25.0 cm^3 of 0.2 M HCl. Determine the % $Ca(OH)_2$ and %$CaCl_2$ and in the mixture.

Question 3.

a. The chloride content of several aliquots of a pooled blood serum sample was reported as follows: 103, 106, 107, and 114 milli equivalents /L.,Upon evaluation of the results, one value (114) appears suspect. Determine whether the suspect value could be attributed to accidental error if the table value at 90% confidence limit for four observations is 0.76.

b. In flame Spectrophotometry, discuss the differences between emission and absorption spectrometry, giving examples to illustrate them.

c. What does the acronym LIDAR mean in remote sensing and very briefly discuss this technique?

d. Discuss 2 schemes used to determine silica in rocks.

e. The determination of many of the trace elements in fertilisers is amenable to both physico-chemical and wet chemical methods. Name two elements which you can be determined for by the former; and one, you could determine for by the latter. Which of the two techniques would you prefer if you were to submit your results urgently?

Question 4.

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

b. Given that the analysis of a certain fertiliser yielded the following elemental analysis results: 22.67% P, 22.00% N and ballast 8.00% how would you report this result officially according to the N-P-K Convention?

c. Describe how to determine "Base Saturation" and "alkalinity of ash" in soils.

d. Distinguish between 'good ozone' and 'bad ozone'. In which parts of the atmosphere do these two occur?

e. A soda ash sample is analysed by titration with 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? ($t = 4.303$ for $\nu = 2$)

Question 5.

a. Name all the major nutrients in a fertiliser, and, state the specific one that promotes a good roots system in plants?

b. An ore is analysed for the Mn content by converting Mn to Mn_3O_4 and weighing it. If a 2.1 g sample yields Mn_3O_4 weighing 1.5 g, what would be the % MnO_3 in the sample, and %Mn?

c. Discuss the determination of C and K in soils.

d. What is COD and how do you determine it in water?

e. How would you determine total N in soils?

.......................END OF EXAMINATION..........................

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

UNIVERSITY EXAMINATIONS

2008 ACADEMIC YEAR FIRST SEMESTER

C441 ADVANCED INORGANIC CHEMISTRY 1

TIME: THREE HOURS

INSTRUCTIONS:

All questions carry equal Marks.

Answer Any Four Questions.

Answer Each Question on a Fresh Page.

Character Table and the Periodic Table of Elements are Provided.

Question 1.

(a) A C_{4v} molecule has reducible representations as 5 1 1 3 1. Determine the σ-hybridization scheme of this molecule.

(b) The infrared spectrum of a nitrate, NO_3^-, ion has the peaks below

Frequency/cm^{-1}	*Band Intensity*	*Frequency/cm^{-1}*	*Band Intensity*
2900	very weak	850	strong
2400	weak	700	medium
1690	weak	308	very weak
1450	medium		

A Raman spectra of this compound has distinct peak at 1010cm^{-1}.

(i) Identify the i.r. fundamental bands in this spectrum.

(ii) Account for the existence of these peaks.

Question 2.

(a) Predict the isotopic mass spectrum distribution for BBr_3.
Given the following abundances: $^{10}B = 20\%$, $^{11}B = 80\%$, $^{79}Br = 50\%$, and $^{81}B = 50\%$.

(b) ScL_3 and GaL_3, where L = $PhCOCHCOCF_3$ mass spectra when compared show distinct peaks due to atom or group migration. What migrations are expected in GaL_3? Show mechanisms leading to a peak at m/e = 349 units.
^{69}Ga=60%,, $^{71}Ga = 40\%$, $^{45}Sc = 100\%$,

Question 3

(a) Determine the ground state RS term Sm^{3+}, hence or otherwise account for the discrepancy that $\mu_{cal.}$ is $0.84\mu_B$ while μ_{exp} is $1.54\mu_B$.

(b) What are the differences between ferromagnetic and anti-ferromagnetic materials?

(c) Why is it important to always consider effects of diamagnetic corrections in magneto-chemistry? Calculate the total diamagnetic corrections arising from this $PhCOCHCOCF_3$ ligand given the following Pascal's constants and constitutive corrections:-

Atom	**$10^{-6}\chi_A$/cgs**	**Atom**	**$10^{-6}\chi_A$/cgs**	**Bond**	**$10^{-6}\chi_A$/cgs**
H	-2.93	C	-6.00	C=C	5.5
C(ring)	-5.76	O	-4.61	C=C-C=C	10.6
O (carbonyl)	+1.73	O (carboxyl)	-3.36		
F	-6.30	Cl	-20.1		

Question 4.

(a) A hydrocarbon has the following secular equations:

$$c_1x + c_2 + c_3 = 0$$

$$c_1 + c_2x + c_3 = 0$$

$$c_2 + c_3 + c_1x = 0$$

where $x = \dfrac{\alpha - E}{\beta}$.

(i) Write down the formula of the hydrocarbon.

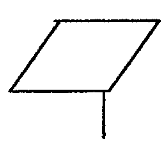
(ii) Compute the energies of its ψ_n orbitals and show their shapes.

(iii) Propose appropriate metal orbital(s) available for metal – ligand overlap.

(b) Sketch the molecular orbital diagram for PH_3 molecule given that the three hydrogen atom uses the LCAO of symmetry a_1 and e symbols. Discuss the paramagnetism of the molecule.

Question 5.

(a) State the point group of the following compounds



p- dichlorobenzene

(i) (ii)

(b) The Cr-Cr bond length in metallic chromium is 2.498Å but in the complex $Cr_2(OOCR_3)_4.2H_2O$ it is found to be 2.362Å. Account for the reduction in the bond length.

(c) Using group Theory, construct an MO energy level diagram for CH_4. What electronic transition is predicted by the MO in the VIS and UV region?

END OF EXAMINATION

Appendix III*

A. Character Tables for Chemically Important Symmetry Groups

1. The Nonaxial Groups

C_1	E
A	1

C_s	E	σ_h		
A'	1	1	x, y, R_z	x^2, y^2, z^2, xy
A''	1	-1	z, R_x, R_y	yz, xz

C_i	E	i		
A_g	1	1	R_x, R_y, R_z	x^2, y^2, z^2 xy, xz, yz
A_u	1	-1	x, y, z	

2. The C_n Groups

C_2	E	C_2		
A	1	1	z, R_z	x^2, y^2, z^2, xy
B	1	-1	x, y, R_x, R_y	yz, xz

C_3	E	C_3	C_3^2		$\varepsilon = \exp(2\pi i/3)$
A	1	1	1	z, R_z	$x^2 + y^2, z^2$
E	$\{1$	ε	$\varepsilon^*\}$	$(x, y)(R_x, R_y)$	$(x^2 - y^2, xy)(yz, xz)$
	$\{1$	ε^*	$\varepsilon\}$		

* Appendix IIIA is presented in two places: (1) here, in its proper location in the sequence of appendices, and (2) as a separate section in a pocket inside the back cover.

The C_n Groups (*continued*)

C_4	E	C_4	C_2	C_4^3		
A	1	1	1	1	z, R_z	$x^2 + y^2, z^2$
B	1	-1	1	-1		$x^2 - y^2, xy$
E	$\{1$	i	-1	$-i\}$	$(x, y)(R_x, R_y)$	(yz, xz)
	$\{1$	$-i$	-1	$i\}$		

C_5	E	C_5	C_5^2	C_5^3	C_5^4		$\varepsilon = \exp(2\pi i/5)$
A	1	1	1	1	1	z, R_z	$x^2 + y^2, z^2$
E_1	$\{1$	ε	ε^2	ε^{2*}	$\varepsilon^*\}$	$(x, y)(R_x, R_y)$	(yz, xz)
	$\{1$	ε^*	ε^{2*}	ε^2	$\varepsilon\}$		
E_2	$\{1$	ε^2	ε^*	ε	$\varepsilon^{2*}\}$		$(x^2 - y^2, xy)$
	$\{1$	ε^{2*}	ε	ε^*	$\varepsilon^2\}$		

C_6	E	C_6	C_3	C_2	C_3^2	C_6^5		$\varepsilon = \exp(2\pi i/6)$
A	1	1	1	1	1	1	z, R_z	$x^2 + y^2, z^2$
B	1	-1	1	-1	1	-1		
E_1	$\{1$	ε	$-\varepsilon^*$	-1	$-\varepsilon$	$\varepsilon^*\}$	(x, y) (R_x, R_y)	(xz, yz)
	$\{1$	ε^*	$-\varepsilon$	-1	$-\varepsilon^*$	$\varepsilon\}$		
E_2	$\{1$	$-\varepsilon^*$	$-\varepsilon$	1	$-\varepsilon^*$	$-\varepsilon\}$		$(x^2 - y^2, xy)$
	$\{1$	$-\varepsilon$	$-\varepsilon^*$	1	$-\varepsilon$	$-\varepsilon^*\}$		

C_7	E	C_7	C_7^2	C_7^3	C_7^4	C_7^5	C_7^6		$\varepsilon = \exp(2\pi i/7)$
A	1	1	1	1	1	1	1	z, R_z	$x^2 + y^2, z^2$
E_1	$\{1$	ε	ε^2	ε^3	ε^{3*}	ε^{2*}	$\varepsilon^*\}$	(x, y) (R_x, R_y)	(xz, yz)
	$\{1$	ε^*	ε^{2*}	ε^{3*}	ε^3	ε^2	$\varepsilon\}$		
E_2	$\{1$	ε^2	ε^{3*}	ε^*	ε	ε^3	$\varepsilon^{2*}\}$		$(x^2 - y^2, xy)$
	$\{1$	ε^{2*}	ε^3	ε	ε^*	ε^{3*}	$\varepsilon^2\}$		
E_3	$\{1$	ε^3	ε^*	ε^2	ε^{2*}	ε	$\varepsilon^{3*}\}$		
	$\{1$	ε^{3*}	ε	ε^{2*}	ε^2	ε^*	$\varepsilon^3\}$		

C_8	E	C_8	C_4	C_2	C_4^3	C_8^3	C_8^5	C_8^7		$\varepsilon = \exp(2\pi i/8)$
A	1	1	1	1	1	1	1	1	z, R_z	$x^2 + y^2, z^2$
B	1	-1	1	1	1	-1	-1	-1		
E_1	$\{1$	ε	i	-1	$-i$	$-\varepsilon^*$	$-\varepsilon$	$\varepsilon^*\}$	(x, y) (R_x, R_y)	(xz, yz)
	$\{1$	ε^*	$-i$	-1	i	$-\varepsilon$	$-\varepsilon^*$	$\varepsilon\}$		
E_2	$\{1$	i	-1	1	-1	$-i$	i	$-i\}$		$(x^2 - y^2, xy)$
	$\{1$	$-i$	-1	1	-1	i	$-i$	$i\}$		
E_3	$\{1$	$-\varepsilon$	i	-1	$-i$	ε^*	ε	$-\varepsilon^*\}$		
	$\{1$	$-\varepsilon^*$	$-i$	-1	i	ε	ε^*	$-\varepsilon\}$		

3. The D_n Groups

D_2	E	$C_2(z)$	$C_2(y)$	$C_2(x)$		
A	1	1	1	1		x^2, y^2, z^2
B_1	1	1	−1	−1	z, R_z	xy
B_2	1	−1	1	−1	y, R_y	xz
B_3	1	−1	−1	1	x, R_x	yz

D_3	E	$2C_3$	$3C_2$		
A_1	1	1	1		$x^2 + y^2, z^2$
A_2	1	1	−1	z, R_z	
E	2	−1	0	$(x, y)(R_x, R_y)$	$(x^2 - y^2, xy)(xz, yz)$

D_4	E	$2C_4$	$C_2(=C_4^2)$	$2C_2'$	$2C_2''$		
A_1	1	1	1	1	1		$x^2 + y^2, z^2$
A_2	1	1	1	−1	−1	z, R_z	
B_1	1	−1	1	1	−1		$x^2 - y^2$
B_2	1	−1	1	−1	1		xy
E	2	0	−2	0	0	$(x, y)(R_x, R_y)$	(xz, yz)

D_5	E	$2C_5$	$2C_5^2$	$5C_2$		
A_1	1	1	1	1		$x^2 + y^2, z^2$
A_2	1	1	1	−1	z, R_z	
E_1	2	2 cos 72°	2 cos 144°	0	$(x, y)(R_x, R_y)$	(xz, yz)
E_2	2	2 cos 144°	2 cos 72°	0		$(x^2 - y^2, xy)$

D_6	E	$2C_6$	$2C_3$	C_2	$3C_2'$	$3C_2''$		
A_1	1	1	1	1	1	1		$x^2 + y^2, z^2$
A_2	1	1	1	1	−1	−1	z, R_z	
B_1	1	−1	1	−1	1	−1		
B_2	1	−1	1	−1	−1	1		
E_1	2	1	−1	−2	0	0	$(x, y)(R_x, R_y)$	(xz, yz)
E_2	2	−1	−1	2	0	0		$(x^2 - y^2, xy)$

4. The C_{nv} Groups

C_{2v}	E	C_2	$\sigma_v(xz)$	$\sigma_v'(yz)$		
A_1	1	1	1	1	z	x^2, y^2, z^2
A_2	1	1	−1	−1	R_z	xy
B_1	1	−1	1	−1	x, R_y	xz
B_2	1	−1	−1	1	y, R_x	yz

C_{3v}	E	$2C_3$	$3\sigma_v$		
A_1	1	1	1	z	$x^2 + y^2, z^2$
A_2	1	1	−1	R_z	
E	2	−1	0	$(x, y)(R_x, R_y)$	$(x^2 - y^2, xy)(xz, yz)$

C_{4v}	E	$2C_4$	C_2	$2\sigma_v$	$2\sigma_d$		
A_1	1	1	1	1	1	z	$x^2 + y^2, z^2$
A_2	1	1	1	−1	−1	R_z	
B_1	1	−1	1	1	−1		$x^2 - y^2$
B_2	1	−1	1	−1	1		xy
E	2	0	−2	0	0	$(x, y)(R_x, R_y)$	(xz, yz)

C_{5v}	E	$2C_5$	$2C_5^2$	$5\sigma_v$		
A_1	1	1	1	1	z	$x^2 + y^2, z^2$
A_2	1	1	1	−1	R_z	
E_1	2	2 cos 72°	2 cos 144°	0	$(x, y)(R_x, R_y)$	(xz, yz)
E_2	2	2 cos 144°	2 cos 72°	0		$(x^2 - y^2, xy)$

C_{6v}	E	$2C_6$	$2C_3$	C_2	$3\sigma_v$	$3\sigma_d$		
A_1	1	1	1	1	1	1	z	$x^2 + y^2, z^2$
A_2	1	1	1	1	−1	−1	R_z	
B_1	1	−1	1	−1	1	−1		
B_2	1	−1	1	−1	−1	1		
E_1	2	1	−1	−2	0	0	$(x, y)(R_x, R_y)$	(xz, yz)
E_2	2	−1	−1	2	0	0		$(x^2 - y^2, xy)$

5. The C_{nh} Groups

C_{2h}	E	C_2	i	σ_h		
A_g	1	1	1	1	R_z	x^2, y^2, z^2, xy
B_g	1	−1	1	−1	R_x, R_y	xz, yz
A_u	1	1	−1	−1	z	
B_u	1	−1	−1	1	x, y	

C_{3h}	E	C_3	C_3^2	σ_h	S_3	S_3^5		$\varepsilon = \exp(2\pi i/3)$
A'	1	1	1	1	1	1	R_z	x^2+y^2, z^2
E'	1	ε	ε^*	1	ε	ε^*	(x, y)	(x^2-y^2, xy)
	1	ε^*	ε	1	ε^*	ε		
A''	1	1	1	−1	−1	−1	z	
E''	1	ε	ε^*	−1	$-\varepsilon$	$-\varepsilon^*$	(R_x, R_y)	(xz, yz)
	1	ε^*	ε	−1	$-\varepsilon^*$	$-\varepsilon$		

C_{4h}	E	C_4	C_2	C_4^3	i	S_4^3	σ_h	S_4		
A_g	1	1	1	1	1	1	1	1	R_z	x^2+y^2, z^2
B_g	1	−1	1	−1	1	−1	1	−1		x^2-y^2, xy
E_g	1	i	−1	$-i$	1	i	−1	$-i$	(R_x, R_y)	(xz, yz)
	1	$-i$	−1	i	1	$-i$	−1	i		
A_u	1	1	1	1	−1	−1	−1	−1	z	
B_u	1	−1	1	−1	−1	1	−1	1		
E_u	1	i	−1	$-i$	−1	$-i$	1	i	(x, y)	
	1	$-i$	−1	i	−1	i	1	$-i$		

C_{5h}	E	C_5	C_5^2	C_5^3	C_5^4	σ_h	S_5	S_5^7	S_5^3	S_5^9		$\varepsilon = \exp(2\pi i/5)$
A'	1	1	1	1	1	1	1	1	1	1	R_z	x^2+y^2, z^2
E_1'	1	ε	ε^2	ε^{2*}	ε^*	1	ε	ε^2	ε^{2*}	ε^*	(x, y)	
	1	ε^*	ε^{2*}	ε^2	ε	1	ε^*	ε^{2*}	ε^2	ε		
E_2'	1	ε^2	ε^*	ε	ε^{2*}	1	ε^2	ε^*	ε	ε^{2*}		(x^2-y^2, xy)
	1	ε^{2*}	ε	ε^*	ε^2	1	ε^{2*}	ε	ε^*	ε^2		
A''	1	1	1	1	1	−1	−1	−1	−1	−1	z	
E_1''	1	ε	ε^2	ε^{2*}	ε^*	−1	$-\varepsilon$	$-\varepsilon^2$	$-\varepsilon^{2*}$	$-\varepsilon^*$	(R_x, R_y)	(xz, yz)
	1	ε^*	ε^{2*}	ε^2	ε	−1	$-\varepsilon^*$	$-\varepsilon^{2*}$	$-\varepsilon^2$	$-\varepsilon$		
E_2''	1	ε^2	ε^*	ε	ε^{2*}	−1	$-\varepsilon^2$	$-\varepsilon^*$	$-\varepsilon$	$-\varepsilon^{2*}$		
	1	ε^{2*}	ε	ε^*	ε^2	−1	$-\varepsilon^{2*}$	$-\varepsilon$	$-\varepsilon^*$	$-\varepsilon^2$		

C_{6h}	E	C_6	C_3	C_2	C_3^2	C_6^5	i	S_3^5	S_6^5	σ_h	S_6	S_3		$\varepsilon = \exp(2\pi i/6)$
A_g	1	1	1	1	1	1	1	1	1	1	1	1	R_z	x^2+y^2, z^2
B_g	1	−1	1	−1	1	−1	1	−1	1	−1	1	−1		
E_{1g}	1	ε	$-\varepsilon^*$	−1	$-\varepsilon$	ε^*	1	ε	$-\varepsilon^*$	−1	$-\varepsilon$	ε^*	(R_x, R_y)	(xz, yz)
	1	ε^*	$-\varepsilon$	−1	$-\varepsilon^*$	ε	1	ε^*	$-\varepsilon$	−1	$-\varepsilon^*$	ε		
E_{2g}	1	$-\varepsilon^*$	$-\varepsilon$	1	$-\varepsilon^*$	$-\varepsilon$	1	$-\varepsilon^*$	$-\varepsilon$	1	$-\varepsilon^*$	$-\varepsilon$		(x^2-y^2, xy)
	1	$-\varepsilon$	$-\varepsilon^*$	1	$-\varepsilon$	$-\varepsilon^*$	1	$-\varepsilon$	$-\varepsilon^*$	1	$-\varepsilon$	$-\varepsilon^*$		
A_u	1	1	1	1	1	1	−1	−1	−1	−1	−1	−1	z	
B_u	1	−1	1	−1	1	−1	−1	1	−1	1	−1	1		
E_{1u}	1	ε	$-\varepsilon^*$	−1	$-\varepsilon$	ε^*	−1	$-\varepsilon$	ε^*	1	ε	$-\varepsilon^*$	(x, y)	
	1	ε^*	$-\varepsilon$	−1	$-\varepsilon^*$	ε	−1	$-\varepsilon^*$	ε	1	ε^*	$-\varepsilon$		
E_{2u}	1	$-\varepsilon^*$	$-\varepsilon$	1	$-\varepsilon^*$	$-\varepsilon$	−1	ε^*	ε	−1	ε^*	ε		
	1	$-\varepsilon$	$-\varepsilon^*$	1	$-\varepsilon$	$-\varepsilon^*$	−1	ε	ε^*	−1	ε	ε^*		

6. The D_{nh} Groups

D_{2h}	E	$C_2(z)$	$C_2(y)$	$C_2(x)$	i	$\sigma(xy)$	$\sigma(xz)$	$\sigma(yz)$		
A_g	1	1	1	1	1	1	1	1		x^2, y^2, z^2
B_{1g}	1	1	−1	−1	1	1	−1	−1	R_z	xy
B_{2g}	1	−1	1	−1	1	−1	1	−1	R_y	xz
B_{3g}	1	−1	−1	1	1	−1	−1	1	R_x	yz
A_u	1	1	1	1	−1	−1	−1	−1		
B_{1u}	1	1	−1	−1	−1	−1	1	1	z	
B_{2u}	1	−1	1	−1	−1	1	−1	1	y	
B_{3u}	1	−1	−1	1	−1	1	1	−1	x	

D_{3h}	E	$2C_3$	$3C_2$	σ_h	$2S_3$	$3\sigma_v$		
A_1'	1	1	1	1	1	1		x^2+y^2, z^2
A_2'	1	1	−1	1	1	−1	R_z	
E'	2	−1	0	2	−1	0	(x, y)	(x^2-y^2, xy)
A_1''	1	1	1	−1	−1	−1		
A_2''	1	1	−1	−1	−1	1	z	
E''	2	−1	0	−2	1	0	(R_x, R_y)	(xz, yz)

D_{4h}	E	$2C_4$	C_2	$2C_2'$	$2C_2''$	i	$2S_4$	σ_h	$2\sigma_v$	$2\sigma_d$		
A_{1g}	1	1	1	1	1	1	1	1	1	1		x^2+y^2, z^2
A_{2g}	1	1	1	−1	−1	1	1	1	−1	−1	R_z	
B_{1g}	1	−1	1	1	−1	1	−1	1	1	−1		x^2-y^2
B_{2g}	1	−1	1	−1	1	1	−1	1	−1	1		xy
E_g	2	0	−2	0	0	2	0	−2	0	0	(R_x, R_y)	(xz, yz)
A_{1u}	1	1	1	1	1	−1	−1	−1	−1	−1		
A_{2u}	1	1	1	−1	−1	−1	−1	−1	1	1	z	
B_{1u}	1	−1	1	1	−1	−1	1	−1	−1	1		
B_{2u}	1	−1	1	−1	1	−1	1	−1	1	−1		
E_u	2	0	−2	0	0	−2	0	2	0	0	(x, y)	

D_{5h}	E	$2C_5$	$2C_5^2$	$5C_2$	σ_h	$2S_5$	$2S_5^3$	$5\sigma_v$		
A_1'	1	1	1	1	1	1	1	1		x^2+y^2, z^2
A_2'	1	1	1	−1	1	1	1	−1	R_z	
E_1'	2	2 cos 72°	2 cos 144°	0	2	2 cos 72°	2 cos 144°	0	(x, y)	
E_2'	2	2 cos 144°	2 cos 72°	0	2	2 cos 144°	2 cos 72°	0		(x^2-y^2, xy)
A_1''	1	1	1	1	−1	−1	−1	−1		
A_2''	1	1	1	−1	−1	−1	−1	1	z	
E_1''	2	2 cos 72°	2 cos 144°	0	−2	−2 cos 72°	−2 cos 144°	0	(R_x, R_y)	(xz, yz)
E_2''	2	2 cos 144°	2 cos 72°	0	−2	−2 cos 144°	−2 cos 72°	0		

D_{6h}	E	$2C_6$	$2C_3$	C_2	$3C_2'$	$3C_2''$	i	$2S_3$	$2S_6$	σ_h	$3\sigma_d$	$3\sigma_v$		
A_{1g}	1	1	1	1	1	1	1	1	1	1	1	1		x^2+y^2, z^2
A_{2g}	1	1	1	1	−1	−1	1	1	1	1	−1	−1	R_z	
B_{1g}	1	−1	1	−1	1	−1	1	−1	1	−1	1	−1		
B_{2g}	1	−1	1	−1	−1	1	1	−1	1	−1	−1	1		
E_{1g}	2	1	−1	−2	0	0	2	1	−1	−2	0	0	(R_x, R_y)	(xz, yz)
E_{2g}	2	−1	−1	2	0	0	2	−1	−1	2	0	0		(x^2-y^2, xy)
A_{1u}	1	1	1	1	1	1	−1	−1	−1	−1	−1	−1		
A_{2u}	1	1	1	1	−1	−1	−1	−1	−1	−1	1	1	z	
B_{1u}	1	−1	1	−1	1	−1	−1	1	−1	1	−1	1		
B_{2u}	1	−1	1	−1	−1	1	−1	1	−1	1	1	−1		
E_{1u}	2	1	−1	−2	0	0	−2	−1	1	2	0	0	(x, y)	
E_{2u}	2	−1	−1	2	0	0	−2	1	1	−2	0	0		

D_{8h}	E	$2C_8$	$2C_8^3$	$2C_4$	C_2	$4C_2'$	$4C_2''$	i	$2S_8$	$2S_8^3$	$2S_4$	σ_h	$4\sigma_d$	$4\sigma_v$		
A_{1g}	1	1	1	1	1	1	1	1	1	1	1	1	1	1		x^2+y^2, z^2
A_{2g}	1	1	1	1	1	−1	−1	1	1	1	1	1	−1	−1	R_z	
B_{1g}	1	−1	−1	1	1	1	−1	1	−1	−1	1	1	1	−1		
B_{2g}	1	−1	−1	1	1	−1	1	1	−1	−1	1	1	−1	1		
E_{1g}	2	$\sqrt{2}$	$-\sqrt{2}$	0	−2	0	0	2	$\sqrt{2}$	$-\sqrt{2}$	0	−2	0	0	(R_x, R_y)	(xz, yz)
E_{2g}	2	0	0	−2	2	0	0	2	0	0	−2	2	0	0		(x^2-y^2, xy)
E_{3g}	2	$-\sqrt{2}$	$\sqrt{2}$	0	−2	0	0	2	$-\sqrt{2}$	$\sqrt{2}$	0	−2	0	0		
A_{1u}	1	1	1	1	1	1	1	−1	−1	−1	−1	−1	−1	−1		
A_{2u}	1	1	1	1	1	−1	−1	−1	−1	−1	−1	−1	1	1	z	
B_{1u}	1	−1	−1	1	1	1	−1	−1	1	1	−1	−1	−1	1		
B_{2u}	1	−1	−1	1	1	−1	1	−1	1	1	−1	−1	1	−1		
E_{1u}	2	$\sqrt{2}$	$-\sqrt{2}$	0	−2	0	0	−2	$-\sqrt{2}$	$\sqrt{2}$	0	2	0	0	(x, y)	
E_{2u}	2	0	0	−2	2	0	0	−2	0	0	2	−2	0	0		
E_{3u}	2	$-\sqrt{2}$	$\sqrt{2}$	0	−2	0	0	−2	$\sqrt{2}$	$-\sqrt{2}$	0	2	0	0		

7. The D_{nd} Groups

D_{2d}	E	$2S_4$	C_2	$2C_2'$	$2\sigma_d$		
A_1	1	1	1	1	1		x^2+y^2, z^2
A_2	1	1	1	−1	−1	R_z	
B_1	1	−1	1	1	−1		x^2-y^2
B_2	1	−1	1	−1	1	z	xy
E	2	0	−2	0	0	(x, y); (R_x, R_y)	(xz, yz)

D_{3d}	E	$2C_3$	$3C_2$	i	$2S_6$	$3\sigma_d$		
A_{1g}	1	1	1	1	1	1		x^2+y^2, z^2
A_{2g}	1	1	−1	1	1	−1	R_z	
E_g	2	−1	0	2	−1	0	(R_x, R_y)	(x^2-y^2, xy), (xz, yz)
A_{1u}	1	1	1	−1	−1	−1		
A_{2u}	1	1	−1	−1	−1	1	z	
E_u	2	−1	0	−2	1	0	(x, y)	

D_{4d}	E	$2S_8$	$2C_4$	$2S_8^3$	C_2	$4C_2'$	$4\sigma_d$		
A_1	1	1	1	1	1	1	1		x^2+y^2, z^2
A_2	1	1	1	1	1	−1	−1	R_z	
B_1	1	−1	1	−1	1	1	−1		
B_2	1	−1	1	−1	1	−1	1	z	
E_1	2	$\sqrt{2}$	0	$-\sqrt{2}$	−2	0	0	(x, y)	
E_2	2	0	−2	0	2	0	0		(x^2-y^2, xy)
E_3	2	$-\sqrt{2}$	0	$\sqrt{2}$	−2	0	0	(R_x, R_y)	(xz, yz)

D_{5d}	E	$2C_5$	$2C_5^2$	$5C_2$	i	$2S_{10}^3$	$2S_{10}$	$5\sigma_d$		
A_{1g}	1	1	1	1	1	1	1	1		x^2+y^2, z^2
A_{2g}	1	1	1	−1	1	1	1	−1	R_z	
E_{1g}	2	2 cos 72°	2 cos 144°	0	2	2 cos 72°	2 cos 144°	0	(R_x, R_y)	(xz, yz)
E_{2g}	2	2 cos 144°	2 cos 72°	0	2	2 cos 144°	2 cos 72°	0		(x^2-y^2, xy)
A_{1u}	1	1	1	1	−1	−1	−1	−1		
A_{2u}	1	1	1	−1	−1	−1	−1	1	z	
E_{1u}	2	2 cos 72°	2 cos 144°	0	−2	−2 cos 72°	−2 cos 144°	0	(x, y)	
E_{2u}	2	2 cos 144°	2 cos 72°	0	−2	−2 cos 144°	−2 cos 72°	0		

7. The D_{nd} Groups (Continued).

D_{6d}	E	$2S_{12}$	$2C_6$	$2S_4$	$2C_3$	$2S_{12}^5$	C_2	$6C_2'$	$6\sigma_d$		
A_1	1	1	1	1	1	1	1	1	1		x^2+y^2, z^2
A_2	1	1	1	1	1	1	1	−1	−1	R_z	
B_1	1	−1	1	−1	1	−1	1	1	−1		
B_2	1	−1	1	−1	1	−1	1	−1	1	z	
E_1	2	$\sqrt{3}$	1	0	−1	$-\sqrt{3}$	−2	0	0	(x, y)	
E_2	2	1	−1	−2	−1	1	2	0	0		(x^2-y^2, xy)
E_3	2	0	−2	0	2	0	−2	0	0		
E_4	2	−1	−1	2	−1	−1	2	0	0		
E_5	2	$-\sqrt{3}$	1	0	−1	$\sqrt{3}$	−2	0	0	(R_x, R_y)	(xz, yz)

8. The S_n Groups

S_4	E	S_4	C_2	S_4^3		
A	1	1	1	1	R_z	x^2+y^2, z^2
B	1	−1	1	−1	z	x^2-y^2, xy
E	1	i	−1	$-i$	(x, y); (R_x, R_y)	(xz, yz)
	1	$-i$	−1	i		

S_6	E	C_3	C_3^2	i	S_6^5	S_6		$\varepsilon = \exp(2\pi i/3)$
A_g	1	1	1	1	1	1	R_z	x^2+y^2, z^2
E_g	1	ε	ε^*	1	ε	ε^*	(R_x, R_y)	(x^2-y^2, xy); (xz, yz)
	1	ε^*	ε	1	ε^*	ε		
A_u	1	1	1	−1	−1	−1	z	
E_u	1	ε	ε^*	−1	$-\varepsilon$	$-\varepsilon^*$	(x, y)	
	1	ε^*	ε	−1	$-\varepsilon^*$	$-\varepsilon$		

S_8	E	S_8	C_4	S_8^3	C_2	S_8^5	C_4^3	S_8^7		$\varepsilon = \exp(2\pi i/8)$
A	1	1	1	1	1	1	1	1	R_z	x^2+y^2, z^2
B	1	−1	1	−1	1	−1	1	−1	z	
E_1	1	ε	i	$-\varepsilon^*$	−1	$-\varepsilon$	$-i$	ε^*	(x, y); (R_x, R_y)	
	1	ε^*	$-i$	$-\varepsilon$	−1	$-\varepsilon^*$	i	ε		
E_2	1	i	−1	$-i$	1	i	−1	$-i$		(x^2-y^2, xy)
	1	$-i$	−1	i	1	$-i$	−1	i		
E_3	1	$-\varepsilon^*$	$-i$	ε	−1	ε^*	i	$-\varepsilon$		(xz, yz)
	1	$-\varepsilon$	i	ε^*	−1	ε	$-i$	$-\varepsilon^*$		

9. The Cubic Groups

T	E	$4C_3$	$4C_3^2$	$3C_2$		$\varepsilon = \exp(2\pi i/3)$
A	1	1	1	1		$x^2+y^2+z^2$
E	1	ε	ε^*	1		$(2z^2-x^2-y^2,$
	1	ε^*	ε	1		$x^2-y^2)$
T	3	0	0	−1	(R_x, R_y, R_z); (x, y, z)	(xy, xz, yz)

The Cubic Groups (Continued).

T_h	E	$4C_3$	$4C_3^2$	$3C_2$	i	$4S_6$	$4S_6^5$	$3\sigma_h$		$\varepsilon = \exp(2\pi i/3)$
A_g	1	1	1	1	1	1	1	1		$x^2+y^2+z^2$
A_u	1	1	1	1	−1	−1	−1	−1		
E_g	1	ε	ε^*	1	1	ε	ε^*	1		$(2z^2-x^2-y^2,$
	1	ε^*	ε	1	1	ε^*	ε	1		$x^2-y^2)$
E_u	1	ε	ε^*	1	−1	$-\varepsilon$	$-\varepsilon^*$	−1		
	1	ε^*	ε	1	−1	$-\varepsilon^*$	$-\varepsilon$	−1		
T_g	3	0	0	−1	−3	0	0	−1	(R_x, R_y, R_z)	(xz, yz, xy)
T_u	3	0	0	−1	−3	0	0	1	(x, y, z)	

T_d	E	$8C_3$	$3C_2$	$6S_4$	$6\sigma_d$		
A_1	1	1	1	1	1		$x^2+y^2+z^2$
A_2	1	1	1	−1	−1		
E	2	−1	2	0	0		$(2z^2-x^2-y^2,$ $x^2-y^2)$
T_1	3	0	−1	1	−1	(R_x, R_y, R_z)	
T_2	3	0	−1	−1	1	(x, y, z)	(xy, xz, yz)

O	E	$6C_4$	$3C_2(=C_4^2)$	$8C_3$	$6C_2$		
A_1	1	1	1	1	1		$x^2+y^2+z^2$
A_2	1	−1	1	1	−1		
E	2	0	2	−1	0		$(2z^2-x^2-y^2,$ $x^2-y^2)$
T_1	3	1	−1	0	−1	$(R_x, R_y, R_z); (x, y, z)$	
T_2	3	−1	−1	0	1		(xy, xz, yz)

O_h	E	$8C_3$	$6C_2$	$6C_4$	$3C_2(=C_4^2)$	i	$6S_4$	$8S_6$	$3\sigma_h$	$6\sigma_d$		
A_{1g}	1	1	1	1	1	1	1	1	1	1		$x^2+y^2+z^2$
A_{2g}	1	1	−1	−1	1	1	−1	1	1	−1		
E_g	2	−1	0	0	2	2	0	−1	2	0		$(2z^2-x^2-y^2,$ $x^2-y^2)$
T_{1g}	3	0	−1	1	−1	3	1	0	−1	−1	(R_x, R_y, R_z)	
T_{2g}	3	0	1	−1	−1	3	−1	0	−1	1		(xz, yz, xy)
A_{1u}	1	1	1	1	1	−1	−1	−1	−1	−1		
A_{2u}	1	1	−1	−1	1	−1	1	−1	−1	1		
E_u	2	−1	0	0	2	−2	0	1	−2	0		
T_{1u}	3	0	−1	1	−1	−3	−1	0	1	1	(x, y, z)	
T_{2u}	3	0	−1	−1	−1	−3	1	0	1	−1		

10. The Groups $C_{\infty v}$ and $D_{\infty h}$ for Linear Molecules

$C_{\infty v}$	E	$2C_\infty^\Phi$	…	$\infty\sigma_v$		
$A_1 \equiv \Sigma^+$	1	1	…	1	z	x^2+y^2, z^2
$A_2 \equiv \Sigma^-$	1	1	…	−1	R_z	
$E_1 \equiv \Pi$	2	$2\cos\Phi$	…	0	$(x, y); (R_x, R_y)$	(xz, yz)
$E_2 \equiv \Delta$	2	$2\cos 2\Phi$	…	0		(x^2-y^2, xy)
$E_3 \equiv \Phi$	2	$2\cos 3\Phi$	…	0		
…	…	…	…	…		

$D_{\infty h}$	E	$2C_\infty^\Phi$	…	$\infty\sigma_v$	i	$2S_\infty^\Phi$	…	∞C_2		
Σ_g^+	1	1	…	1	1	1	…	1		x^2+y^2, z^2
Σ_g^-	1	1	…	−1	1	1	…	−1	R_z	
Π_g	2	$2\cos\Phi$	…	0	2	$-2\cos\Phi$	…	0	(R_x, R_y)	(xz, yz)
Δ_g	2	$2\cos 2\Phi$	…	0	2	$2\cos 2\Phi$	…	0		(x^2-y^2, xy)
…	…	…	…	…	…	…	…	…		
Σ_u^+	1	1	…	1	−1	−1	…	−1	z	
Σ_u^-	1	1	…	−1	−1	−1	…	1		
Π_u	2	$2\cos\Phi$	…	0	−2	$2\cos\Phi$	…	0	(x, y)	
Δ_u	2	$2\cos 2\Phi$	…	0	−2	$-2\cos 2\Phi$	…	0		
…	…	…	…	…	…	…	…	…		

11. The Icosahedral Groups*

I_h	E	$12C_5$	$12C_5^2$	$20C_3$	$15C_2$	i	$12S_{10}$	$12S_{10}^3$	$20S_6$	15σ		
A_g	1	1	1	1	1	1	1	1	1	1		$x^2+y^2+z^2$
T_{1g}	3	$\frac{1}{2}(1+\sqrt{5})$	$\frac{1}{2}(1-\sqrt{5})$	0	−1	3	$\frac{1}{2}(1-\sqrt{5})$	$\frac{1}{2}(1+\sqrt{5})$	0	−1	(R_x, R_y, R_z)	
T_{2g}	3	$\frac{1}{2}(1-\sqrt{5})$	$\frac{1}{2}(1+\sqrt{5})$	0	−1	3	$\frac{1}{2}(1+\sqrt{5})$	$\frac{1}{2}(1-\sqrt{5})$	0	−1		
G_g	4	−1	−1	1	0	4	−1	−1	1	0		
H_g	5	0	0	−1	1	5	0	0	−1	1		$(2z^2-x^2-y^2,$ $x^2-y^2,$ $xy, yz, zx)$
A_u	1	1	1	1	1	−1	−1	−1	−1	−1		
T_{1u}	3	$\frac{1}{2}(1+\sqrt{5})$	$\frac{1}{2}(1-\sqrt{5})$	0	−1	−3	$-\frac{1}{2}(1-\sqrt{5})$	$-\frac{1}{2}(1+\sqrt{5})$	0	1	(x, y, z)	
T_{2u}	3	$\frac{1}{2}(1-\sqrt{5})$	$\frac{1}{2}(1+\sqrt{5})$	0	−1	−3	$-\frac{1}{2}(1+\sqrt{5})$	$-\frac{1}{2}(1-\sqrt{5})$	0	1		
G_u	4	−1	−1	1	0	−4	1	1	−1	0		
H_u	5	0	0	−1	1	−5	0	0	1	−1		

* For the pure rotation group I, the outlined section in the upper left is the character table; the g subscripts should, of course, be dropped and (x, y, z) assigned to the T_1 representation.

Appendix IV

A Caveat Concerning the Resonance Integral

On pages 137–139 we described a seemingly straightforward and obvious method for evaluating the integral β. This involved equating the so-called experimental or empirical resonance energy of benzene, defined as the energy difference between "real" benzene and Kekulé benzene, to a multiple of β. This procedure is widely used and is of at least empirical validity, as shown by the fact that it gives essentially the same value to β in various molecules. Some results illustrative of this point are given in the following table.

Table of Experimental Resonance Energies and the Derived Value of β

COMPOUND	OBSERVED RESONANCE ENERGY, KCAL/MOLE	THEORETICAL RESONANCE ENERGY, HÜCKEL APPROX.	$-\beta$
Benzene	36	2β	18
Diphenyl	70–80	4.38β	~17
Naphthalene	75–80	3.68β	~21
Anthracene	105–116	5.32β	~20
Phenanthrene	110–125	5.45β	~21

Vertical Resonance Energy

In the process just described we are actually considering not only the energy of delocalization but also the energy required to stretch and compress the C-C bonds in Kekulé benzene from the lengths 1.54 and 1.34 Å to the common length 1.39 Å found in real benzene. Thus the experimental resonance

B: Correlation Table for Group O_h

This table shows how the representations of group O_h are changed or decomposed into those of its subgroups when the symmetry is altered or lowered. This table covers only representations of use in dealing with the more common symmetries of complexes. A rather complete collection of correlation tables will be found as Table X-14 in *Molecular Vibrations* by E. B. Wilson, Jr., J. C. Decius, and P. C. Cross, McGraw-Hill, New York, 1955.

O_h	O	T_d	D_{4h}	D_{2d}	C_{4v}	C_{2v}	D_{3d}	D_3	C_{2h}
A_{1g}	A_1	A_1	A_{1g}	A_1	A_1	A_1	A_{1g}	A_1	A_g
A_{2g}	A_2	A_2	B_{1g}	B_1	B_1	A_2	A_{2g}	A_2	B_g
E_g	E	E	$A_{1g}+B_{1g}$	A_1+B_1	A_1+B_1	A_1+A_2	E_g	E	A_g+B_g
T_{1g}	T_1	T_1	$A_{2g}+E_g$	A_2+E	A_2+E	$A_2+B_1+B_2$	$A_{2g}+E_g$	A_2+E	A_g+2B_g
T_{2g}	T_2	T_2	$B_{2g}+E_g$	B_2+E	B_2+E	$A_1+B_1+B_2$	$A_{1g}+E_g$	A_1+E	$2A_g+B_g$
A_{1u}	A_1	A_2	A_{1u}	B_1	A_2	A_2	A_{1u}	A_1	A_u
A_{2u}	A_2	A_1	B_{1u}	A_1	B_2	A_1	A_{2u}	A_2	B_u
E_u	E	E	$A_{1u}+B_{1u}$	A_1+B_1	A_2+B_2	A_1+A_2	E_u	E	A_u+B_u
T_{1u}	T_1	T_2	$A_{2u}+E_u$	B_2+E	A_1+E	$A_1+B_1+B_2$	$A_{2u}+E_u$	A_2+E	A_u+2B_u
T_{2u}	T_2	T_1	$B_{2u}+E_u$	A_2+E	B_1+E	$A_2+B_1+B_2$	$A_{1u}+E_u$	A_1+E	$2A_u+B_u$

DATA SHEET
The Periodic Table of the Elements

I	II											III	IV	V	VI	VII	0
						1 **H** Hydrogen 1											4 **He** Helium 2
7 **Li** Lithium 3	9 **Be** Beryllium 4											11 **B** Boron 5	12 **C** Carbon 6	14 **N** Nitrogen 7	16 **O** Oxygen 8	19 **F** Fluorine 9	20 **Ne** Neon 10
23 **Na** Sodium 11	24 **Mg** Magnesium 12											27 **Al** Aluminium 13	28 **Si** Silicon 14	31 **P** Phosphorus 15	32 **S** Sulphur 16	35.5 **Cl** Chlorine 17	40 **Ar** Argon 18
39 **K** Potassium 19	40 **Ca** Calcium 20	45 **Sc** Scandium 21	48 **Ti** Titanium 22	51 **V** Vanadium 23	52 **Cr** Chromium 24	55 **Mn** Manganese 25	56 **Fe** Iron 26	59 **Co** Cobalt 27	59 **Ni** Nickel 28	64 **Cu** Copper 29	65 **Zn** Zinc 30	70 **Ga** Gallium 31	73 **Ge** Germanium 32	75 **As** Arsenic 33	79 **Se** Selenium 34	80 **Br** Bromine 35	84 **Kr** Krypton 36
85 **Rb** Rubidium 37	88 **Sr** Strontium 38	89 **Y** Yttrium 39	91 **Zr** Zirconium 40	93 **Nb** Niobium 41	96 **Mo** Molybdenum 42	**Tc** Technetium 43	101 **Ru** Ruthenium 44	103 **Rh** Rhodium 45	106 **Pd** Palladium 46	108 **Ag** Silver 47	112 **Cd** Cadmium 48	115 **In** Indium 49	119 **Sn** Tin 50	122 **Sb** Antimony 51	128 **Te** Tellurium 52	127 **I** Iodine 53	131 **Xe** Xenon 54
133 **Cs** Caesium 55	137 **Ba** Barium 56	139 **La** Lanthanum 57 *	178 **Hf** Hafnium 72	181 **Ta** Tantalum 73	184 **W** Tungsten 74	186 **Re** Rhenium 75	190 **Os** Osmium 76	192 **Ir** Iridium 77	195 **Pt** Platinum 78	197 **Au** Gold 79	201 **Hg** Mercury 80	204 **Tl** Thallium 81	207 **Pb** Lead 82	209 **Bi** Bismuth 83	**Po** Polonium 84	**At** Astatine 85	**Rn** Radon 86
Fr Francium 87	226 **Ra** Radium 88	227 **Ac** Actinium 89 †															

*58-71 Lanthanoid series
†90-103 Actinoid series

140 **Ce** Cerium 58	141 **Pr** Praseodymium 59	144 **Nd** Neodymium 60	**Pm** Promethium 61	150 **Sm** Samarium 62	152 **Eu** Europium 63	157 **Gd** Gadolinium 64	159 **Tb** Terbium 65	162 **Dy** Dysprosium 66	165 **Ho** Holmium 67	167 **Er** Erbium 68	169 **Tm** Thulium 69	173 **Yb** Ytterbium 70	175 **Lu** Lutetium 71
232 **Th** Thorium 90	**Pa** Protactinium 91	238 **U** Uranium 92	**Np** Neptunium 93	**Pu** Plutonium 94	**Am** Americium 95	**Cm** Curium 96	**Bk** Berkelium 97	**Cf** Californium 98	**Es** Einsteinium 99	**Fm** Fermium 100	**Md** Mendelevium 101	**No** Nobelium 102	**Lr** Lawrencium 103

Key

a
X
b

a = relative atomic mass
X = atomic symbol
b = proton (atomic) number

The volume of one mole of any gas is 24 dm^3 at room temperature and pressure (r.t.p.)

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2008 ACADEMIC YEAR FIRST SEMESTER
FINAL EXAMINATIONS

C451: ADVANCED ORGANIC CHEMISTRY

TIME: THREE HOURS

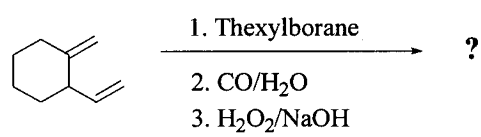
INSTRUCTIONS:

1. **Answer any four questions.**
2. **Marks allocation for questions is shown [x]**

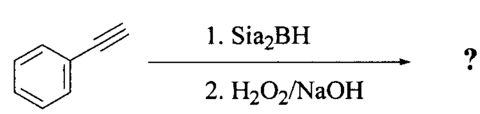
Question 1

(a) Predict the major products and give the mechanisms of the following reactions:

(i)

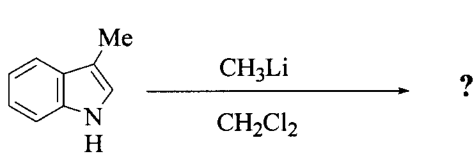


(ii)



[20]

(b) A substituted carbene usually reacts as a singlet. Making use of this information, write the structure of the major organic product of the following reaction. Show clearly the generation of the carbene and all intermediates involved in this reaction.



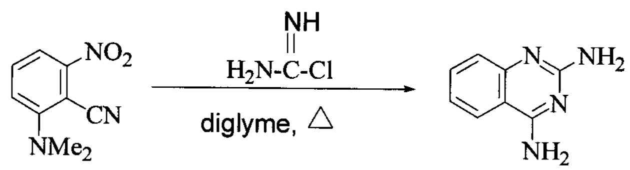
[10]

(c) Discuss the structure activity relationships in 4-aminoquinoline anti-malarial agents.

[8]

Question 2

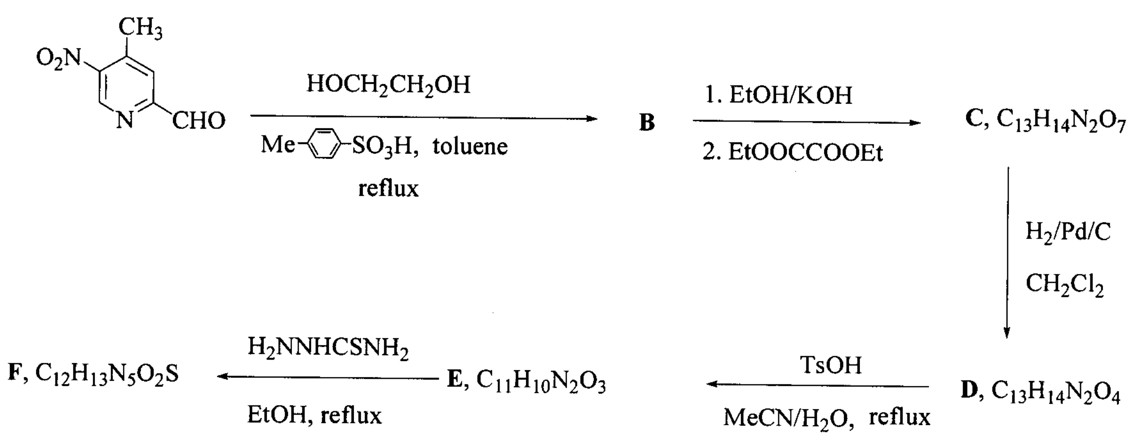
(a) Suggest the mechanisms of the reactions involved in the following synthesis of the anti-malarial drug **A**, structure shown below:



antimalarial drug A

[8]

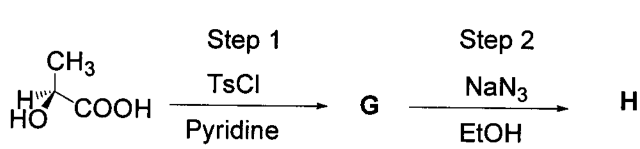
(b) A synthesis of an antiparasitic agent **F**, claimed to be effective in the treatment of trypanosomiasis is shown below:



(i) Identify all intermediates in the above synthesis.
(ii) Suggest the mechanisms of the reactions involved in the formation of **D** from **C**.

[14]

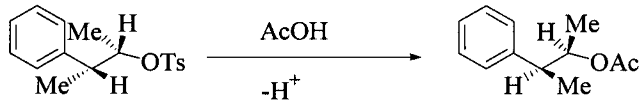
(c) Give the structures of compounds **G** and **H** and provide mechanisms for steps 1 and 2 in the following reaction sequence.



[8]

Question 3

(a) Upon solvolysis in acetic acid at room temperature, the tosylate **I,** structure shown below, gave a 48:48:4 mixture of compounds **J**, **K** and (**L** + **M**).



K + **L** + **M**

Tosylate I — 48% — 48% — 4%

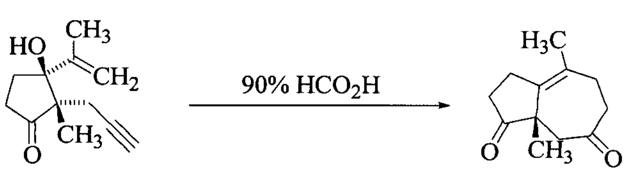
(i) Give the structures of **K**, **L** and **M**.

(ii) Provide a reaction mechanism for the formation of **K** and **L**.

[14]

(b) (i) Give reasons as to why anchimeric assistance by triple bonds is not as effective as that from the double bonds.

(ii) Provide the mechanism for the following reaction:



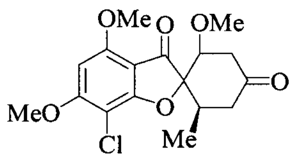
[10]

(c) Acetolysis of H_3C-O-$(CH_2)_5$-OTs proceeds at about 31 times as fast as that of H_3C-S-$(CH_2)_5$-OTs. Account for this observation.

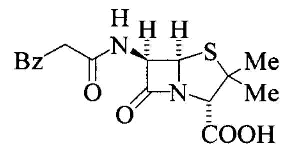
[6]

Question 4

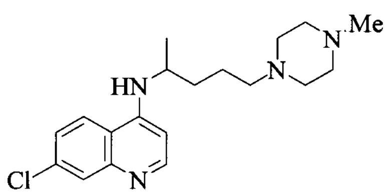
(a) (i) State the principal medicinal uses of the drugs, **N**, **O**, **P** and **Q**, structures shown below:



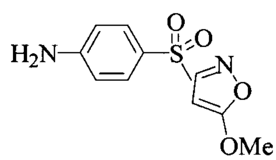
N



O



P



Q

(ii) Give the mode of pharmacological action of the drug **N**.

(iii) Identify the pharmacophore in the drug **O**.

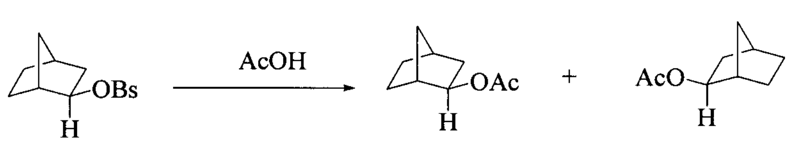
[14]

(b) Propose a synthesis of the drug **P**, structure shown in Q4(a) (i), from non-heterocyclic starting materials.

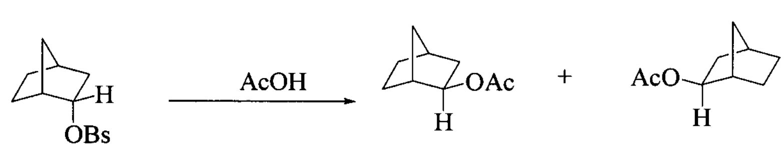
[10]

(c) The most studied system in which σ – participation is envisaged to occur is the 2-norbornyl system. Winstein found that solvolysis of optically pure norbornyl *2- exo*-brosylate in acetic acid gave a racemic *exo*-acetate as the sole product with no *endo*-material as shown in equation 1 below. Furthermore, this solvolysis occurred 350 times faster than that of the optically pure *2-endo*-isomer, which also gave solely *exo*-material as shown in equation 2.

Eq. 1:



Eq 2:



Provide a reaction mechanism to explain this result.

[6]

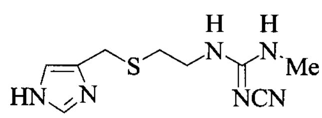
Question 5

(a) Alkenes react readily with borane to form the corresponding alkylboranes. On the basis of this information, how you would synthesise the compound **S** from compound **R**. Show the mechanisms of the reactions involved in your proposed synthesis.

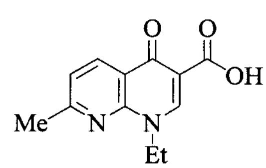
compound R **compound S**

[12]

(b) Propose a synthesis of the biologically active compounds **T** and **U**, structures shown below from readily available non-heterocyclic starting materials. State the reagents, including solvents, and special reaction conditions, if any, for each step of your proposed synthesis.



compound T



compound U

[18]

END OF THE EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2008 ACADEMIC YEAR FIRST SEMESTER
FINAL EXAMINATIONS

C491: ORGANIC INDUSTRIAL CHEMISTRY I
TIME: THREE (3) HOURS

INSTRUCTIONS: Answer any three (3) questions.

QUESTION 1

The initial process in the refining of crude petroleum takes place in the atmospheric distillation unit.

(a) Draw a flow chart with accompanying notes showing the refining process in this section of the refinery plant.
(b) What is the role of the cracking process in petroleum refining? Give brief notes on hydro-catalytic cracking.
(c) The efficiency of the distillation column (n) is determined by the number of theoretical plates. Derive an expression that gives n.
(d) Biodiesel derived from Jatropha has been identified as one alternative substitute for fossil based diesel.
    (i) What are the reasons for switching to biodiesel?
    (ii) Although biodiesel may be used straight after extraction, it is desirable to carry out an etherification reaction to obtain the final product. Show the chemical equation involved and indicate the purpose of carrying out this chemical transformation?

QUESTION 2

Paper manufacturing involves separation of fibres from wood or suitable vegetable matter to form a *'mat'* consisting a network of fibres.

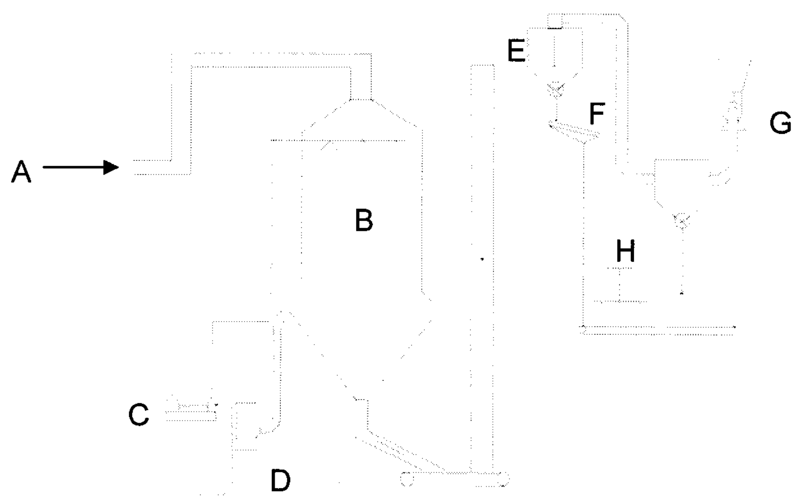
(a) What is the composition of wood? Give rough estimates of the percentages of the various components.
(b) Draw a flow diagram of the chemical recovery process in the pulping. Outline in note form the process, conditions and relevant chemical equations.
(c) What components identified in (a) above are likely to affect the quality of paper if pulping is not properly done?
(d) The following are used as fillers in the manufacture of paper: titanium oxide, aluminium sulphate, starch and plastic. What is the purpose/use of these additives to paper?

QUESTION 3

(a) Surfactants are surface-active substances found in both soaps and detergents. What is the role of these substances?

(b) How does water hardness affect the effectiveness of washing soap? Indicate how this problem is alleviated in detergent or soap formulation.

(c) Given below is a flow chart showing part of the detergent manufacturing processing.



Identify the units/elements A-H shown in the flow chart and indicate their purpose or function.

QUESTION 4

(a) Insecticides can be classified as stomach poisons, contact insecticides and fumigants. For each class indicate the nature of the interaction and give at least one example in each class.

(b) Elemental sulphur is a typical example of a fungicide.

   (i) Describe in brief its preparation for use as a fungicide.

   (ii) Outline problems associated with sulphur produced in the colloidal form. What measures are used to mitigate these problems

(c) Benzene is used as a high-octane fuel as well as a solvent. Describe the process for the production of benzene clearly indicating the process conditions.

END OF EXAMINATION

The University of Zambia

School of Natural Science

Department of Computer Studies

FINAL EXAM SEMESTER I - December 2008

Computer Networks and Data Communication Systems (CS3061)

Instructions

1. There are **two sections** and a total of **six questions** in this question paper.
2. Each question carries **20 marks** only
3. You are required to **answer a total of five questions**
4. **Section A** has **two** questions while **section B** has **four questions**
5. **Answer all** questions in **section A** and any **three** questions in **section B**

Date: Thursday 4th December 2008

Time: 09:00hrs – 12:00hrs

Venue: New Dinning Hall

NOTE: Do not open this paper until you are told to do so

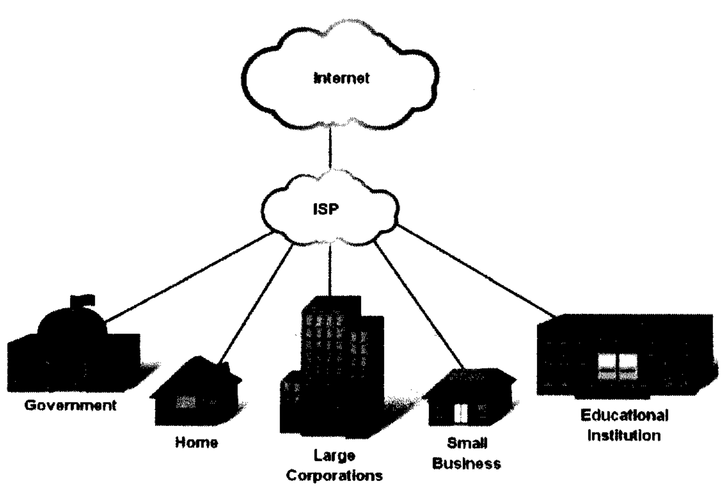
<u>SECTION A</u> – Answer all the questions in this section

1) Question One

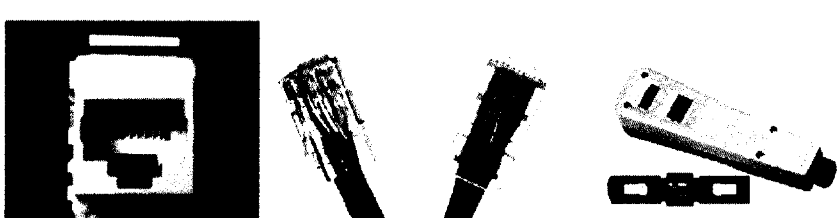
a) Define the following terms [5]
   i) Computer Network
   ii) Satellite
   iii) Multiplexing
   iv) Broadcasting
   v) Authentication

b) **Draw** a well labeled diagram of the **OSI model** and the **TCP/IP model** [5]
   i) For the OSI model show at least **one networking device** found at each layer
   ii) For the TCP/IP model show at least **one protocol** found at each layer

   The diagram below shows the role of an ISP in the Internet connectivity and how we connect to the Internet. Name any four ISPs in Zambia. [2]

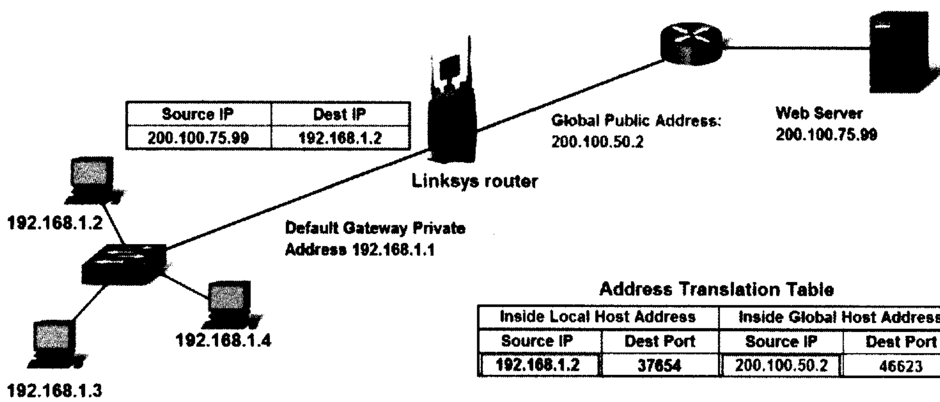


c) The diagrams below show the equipment and the components used in computer networks. Identify and name each one of them. [3]



(a) (b) (c)

d) The diagram below shows how Network Address Translation (NAT) works when using private addresses to connect to the Internet. Using the diagram below explain how NAT works [5]

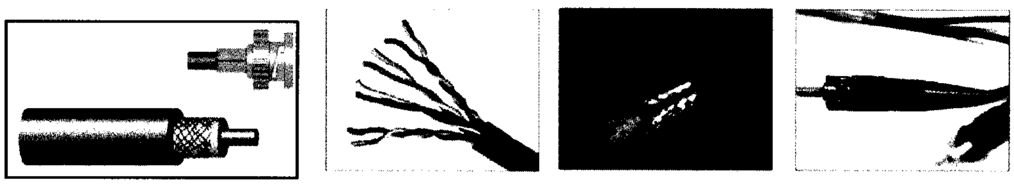


Address Translation Table

Inside Local Host Address		Inside Global Host Address	
Source IP	Dest Port	Source IP	Dest Port
192.168.1.2	37654	200.100.50.2	46623

2)Question Two

a) The diagram below shows the types of networking media that can be used in implementing a computer network. Identify and name each of them. [2]



(a) (b) (c) (d)

b) Convert the following numbers [2]
   i) 128_{ten} to **base two**
   ii) 1011111000010100_{two} to **base sixteen**

c) Identify the group where the following IP addresses belong and give the default subnet masks of each one of them. [2]
   i) 121.87.134.90
   ii) 203.176.64.9

d) Given the IP network address as **143.201.0.0** [14]
   i) In order to create twelve (12) subnets,
      (1) How many bits can you borrow from the host portion?
      (2) How many usable IP addresses will be in each created subnet
   ii) Draw a table with four columns having the Subnet, Network Address, Usable IP Range and broadcast address of each subnet for **all the possible subnets** as shown below

Subnet	Network Address	Usable IP Range	Broadcast Address
0	143.201.0.0		
1			
⋮			
n			143.201.255.255

Section B – Answer any three questions in this section

3) Question Three

a) Define the following terms [3]
   i) Network Collision
   ii) Vampire Taps
   iii) Segment

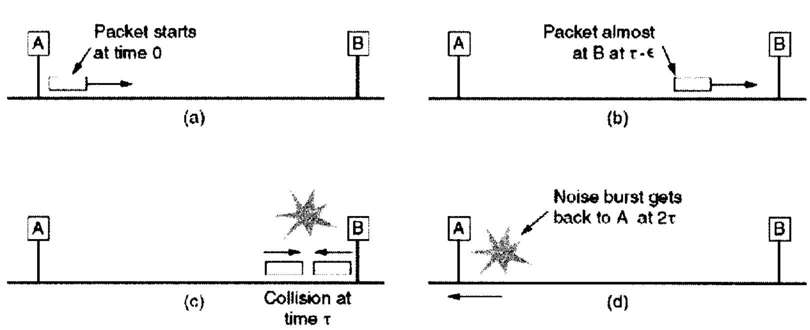
b) "Ethernet" refers to the cable (the ether). Today Ethernet Technology has been used to implement more than 95% of the Local Area Networks (LAN). The table below shows the Ethernet cabling. Complete the table by filing in the blanks[4]

#	Name	Cable	Max Segment	Maximum Bandwidth
1	10Base5			10Mbps
4	100Base-TX			100Mbps
5	100Base-FX			100Mbps
7	1000Base-LX			1000Mbps

c) Draw a well labeled diagram showing the **DIX Ethernet Frame** [3]

d) Mobile phones have gone through three distinct generations, with different technologies. Name the generations and their respective technologies. [3]

e) The diagram below shows a collision on the Local Area Network between communicating devices A and B. **Give** a brief description of the scenario shown below. [3]



f) **The 802.11 standard** states that each **conformant wireless LAN** must provide nine services which are divided into two categories namely *distribution services* and *station services*. The distribution services relate to managing cell membership and interacting with stations outside the cell. In contrast, the station services relate to activity within a single cell. **List** any ***eight*** **(8) services** that each 802.11 Standard Wireless LAN is supposed to provide [4]

4) Question Four

a) What is the difference between ***flow control*** and ***congestion control***? [2]

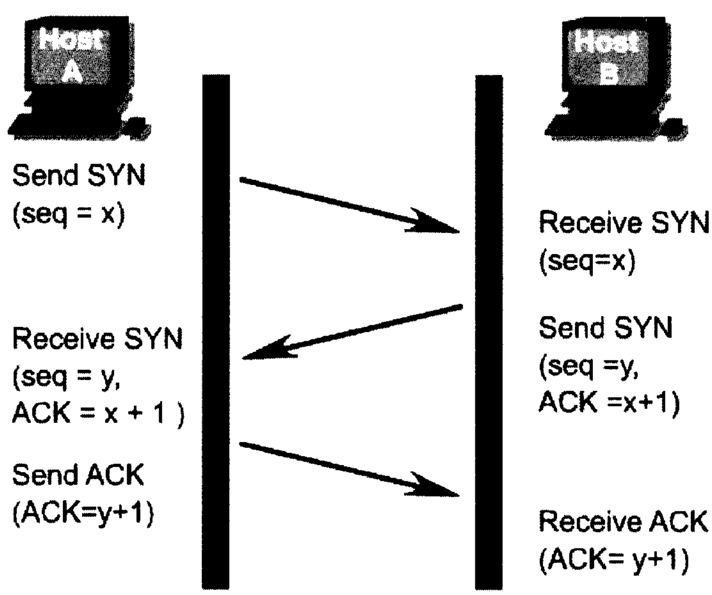
b) There are four primary parameters that together determine the Quality of Service (QoS) of a given network. **Name** and **List** the four parameters [2]

c) Compare the operation of the *Connectionless Service* and the *Connection-Oriented Service* at the network layer[6]

d) Routing algorithms can be grouped into two major grouping namely ***non-adaptive*** and ***adaptive routing algorithm***. **Explain** how each works[4]

e) Three other IP addresses that are supposed to be given to the computer wanting to connect to the network (Internet) are the Subnet Mask, the DNS and the Default Gateway. Give the function each of these addresses [3]

f) Identify the diagram below and give a brief description of what is happening. [3]



5)Question Five

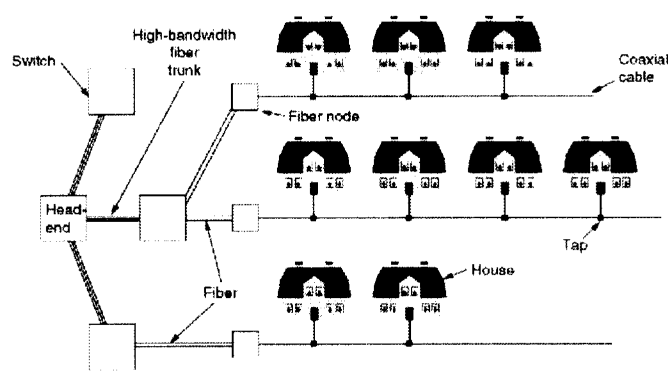
a) The two primary duties of the transport layer are to provide flow control and reliability by defining end-to-end connectivity between host applications. **List** any four basic transport services provided by the transport layer [2]

b) **Draw** a well labeled diagram showing the communication satellites and some of their properties, including altitude above the earth, round-trip delay time and number of satellites needed for global coverage. [4]

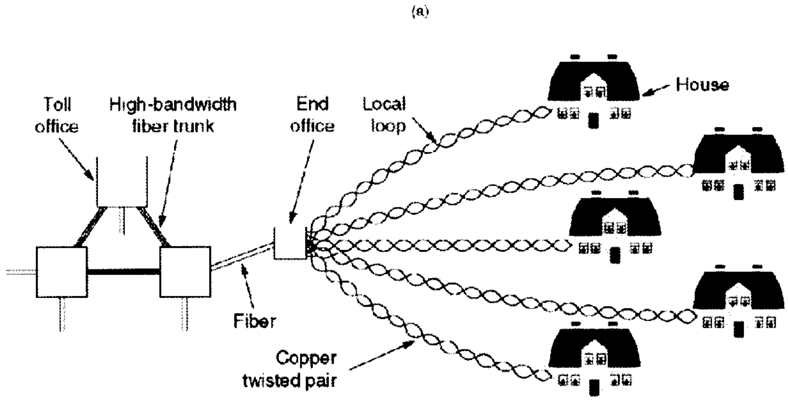
c) Give a brief description how each of the following works [6]
   i) Frequency Division Multiplexing
   ii) Wavelength Division Multiplexing
   iii) Time Division Multiplexing

d) The primary duties of the transport layer are to transport and regulate the flow of information from a source to a destination, reliably and accurately. **Briefly explain** how <u>flow control</u> and <u>reliability</u> are achieved through sliding windows, sequencing numbers, and acknowledgments. [6]

e) Identify the following diagrams [2]



(a)



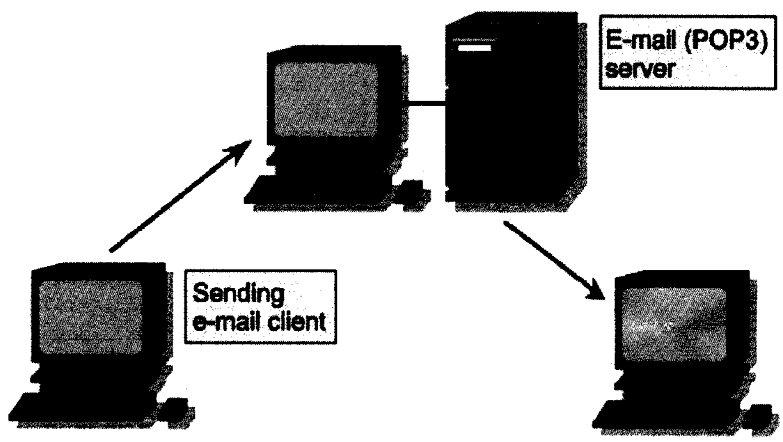
(b)

6) Question Six

a) **Give** a brief ***description*** of each of the following [4]
   i) Firewall
   ii) Virtual Private Networks (VPN)

b) **List** any **four** application layer protocols. [2]

c) With the help of the diagram shown below, **explain** how the email system works mentioning the role of the three protocols SMTP, IMAP4 and POP3. [5]



d) Write a sample HTML code that would be used to display your name in a web browser. [2]

e) The network topologies are classified as ***physical*** or ***logical topologies***. With the help of a diagram, **name** and **give two** examples of the **physical topologies** [4]

f) IPv4 addresses are slowly running out and to help avoid the problem of limited IP addresses, some IP addresses were set aside for private usage. These addresses allow hosts to communicate locally without each device needing a public IP address. However they can not be routed on the Internet. **List all** the groups of the *Reserved IP Addresses* [3]

End of the Examination Paper

THE UNIVERSITY OF ZAMBIA

DEPARTMENT OF COMPUTER STUDIES
FIRST SEMESTER EXAMINATION 2008

CS4241: ELECTRONICS FOR COMPUTING III

TIME:	3 HOURS
INSTRUCTIONS:	FOLLOW INSTRUCTIONS FOR EACH SECTION
	TOTAL MARKS 100

Section I Multiple choice
(1 mark each, wrong answers carry a negative 0.25 marks)
Use answer sheet.

1. Which of the following is **not** true about operating in real mode?
   a. Executes one program at a time
   b. Is not available in modern processors
   c. Is only available in DOS applications
   d. Only addresses 1 MB of memory
2. Which of the following is true about operating in real mode?
   a. Uses 16 bit access to memory
   b. PC hardware can be interrupted by bad code
   c. Allows the system to use virtual memory
   d. Is only available in DOS applications
3. Which of the following is **not** true about operating in virtual real mode?
   a. Allows a real-mode application to run within a protected-mode operating system
   b. Creates virtual machines for each program that runs in real mode
   c. In the event of a program error, only the virtual machine is affected
   d. Does not allow the system to use virtual memory
4. Which of the following is not a common hardware upgrade?
   a. RAM capacity
   b. Chipset upgrade
   c. Hard drive size
   d. Processor speed
5. In the device manager how is an improper installation of a device driver indicated?
   a. Yellow exclamation points
   b. Yellow question points
   c. Bold lettering of the device
   d. None of the above
6. Which program is used to clone computer OS on a network?
   a. MSCONFIG
   b. SysPrep
   c. SysLog
   d. IPCONFIG

14. The motherboard is **not** also known as the
    a. system board,
    b. the backplane,
    c. main board.
    d. form factor
15. The GPU on the motherboard is an acronym for
    a. General Purpose Unit
    b. Graphics Partition Unit
    c. Graphics Processing Unit
    d. General Processing Unit
16. How many pins does a DDR DIMM have?
    a. 168
    b. 184
    c. 240
    d. 64
17. What type of memory is often used for cache?
    a. SRAM
    b. SDRAM
    c. DDR
    d. DDR2
18. Which of these is **not** a common drive interface
    a. USB
    b. EIDE
    c. SCSI
    d. SATA

19. A serial cable has a maximum length of
    a. 50 feet
    b. 50 meters
    c. 80 meters
    d. 2 meters
20. How many FireWire devices can be connected to a USB port?
    a. 256
    b. 127
    c. 63
    d. 128

21. Which standard define the parallel port?
    a. IEEE 1284
    b. ISO 1284
    c. IEEE 802.3
    d. IEEE 1918
22. Standard Ethernet transmits data at
    a. 10 Mbps
    b. 100 Mbps
    c. 1000 Mbps
    d. 56 baud
23. A digital projector can be considered to use which technology?
    a. CRT
    b. LCD
    c. DLP
    d. LED
24. Latency with regard to Hard disks refers to
    a. access time
    b. the time it takes for needed bytes to pass under a R/W head
    c. seek time
    d. time it takes to clear the landing zone
25. How many bytes occupy the address field of a frame on the Hard Disk?
    a. 6
    b. 512
    c. 3
    d. 588
26. The address information of a hard disk are stored in the
    a. BIOS
    b. CMOS
    c. RAM
    d. Cache
27. What is **not** necessary to have a bootable CDROM?
    a. A bootable CD-ROM drive mechanism
    b. A BIOS that supports the bootable CD-ROM
    c. A CD with boot code and an operating system on it.
    d. A CMOS that supports the bootable CD-ROM
28. What is the wavelength of a DVD laser?
    a. 405 nm
    b. 650 nm
    c. 200 μm
    d. 900 nm

29. The transmission register of UART has an address offset of
    a. 00H
    b. 01H
    c. 02H
    d. 04H
30. What should be done before upgrading windows 2000 to windows XP?
    a. Update all the device drivers
    b. Download a legitimate authentication key
    c. Backup all data files
    d. Upgrade the CPU
31. PCI devices do not have jumper settings or dip switches. How are they configured?
    a. CMOS setup
    b. through DOS
    c. Windows setup
    d. they are always self-configuring
32. A switching power supply steps down voltage by means of:
    a. transformers
    b. a network of resistor conduits
    c. turning off and back on in rapid cycles
    d. a network of capacitors
33. What is the first CPU to include an internal math coprocessor?
    a. 386DX
    b. 486DX
    c. Pentium
    d. Pentium Pro
34. You have a serial scanner connected to your computer configured to use com3. It is turned on. Your modem is using com1, and you can't dial out. What is the most likely problem?
    a. you have an i/o conflict
    b. you have a conflict with IRQ 4
    c. you have a loose connection
    d. you have a conflict with IRQ 3
35. What is the i/o address for com1?
    a. 3e8
    b. 3bc
    c. 5f8
    d. 3f8
36. A COM port is a _______ port.
    a. parallel
    b. serial
    c. multi
    d. scsi

37. Modems use _______________ transmission.
    a. synchronous
    b. asynchronous
    c. timed interval
    d. sata
38. A parity error usually indicates a problem with:
    a. memory
    b. hard drive
    c. hard drive controller
    d. power supply
39. Your IDE hard drive is not spinning up when you turn on the PC What is the most likely problem.
    a. bad data cable
    b. incorrect jumper setting on drive
    c. loose molex connector
    d. bad system board
40. Before a serial port transmits, it send a ...
    a. Rx
    b. RTS
    c. Tx
    d. RQS

Section II
Short answer (2 marks each, Answer all)

1. What are the four main roles of an operating system?
2. What is the difference between multitasking and multithreading?
3. What is meant by an Hardware Compatability List?
4. What two characteristics common to all RAM.
5. What does EFM stand for and why is it important with regards to CD operations?
6. Which key sequence will allow windows XP start in safe mode?
7. What are the two major functions of an OS?
8. List the stages of the boot process.
9. How do multimedia extension improve graphics performance?
10. What are the two major areas of CD-ROM electronics.

Section III
Write a short essay on <u>two</u> of these topics. (20 marks) (1 to 2 pages)

1. Write a short essay on the differences between a desktop operating system and a network operating system.
2. Outline the sequence of events that NTLDR performs during the boot process.
3. Draw the block diagram of the UART circuit and explain how it functions

END OF EXAMINATION

CS4251 Answer sheet

1	A	B	C	D
2	A	B	C	D
3	A	B	C	D
4	A	B	C	D
5	A	B	C	D
6	A	B	C	D
7	A	B	C	D
8	A	B	C	D
9	A	B	C	D
10	A	B	C	D
11	A	B	C	D
12	A	B	C	D
13	A	B	C	D
14	A	B	C	D
15	A	B	C	D
16	A	B	C	D
17	A	B	C	D
18	A	B	C	D
19	A	B	C	D
20	A	B	C	D
21	A	B	C	D
22	A	B	C	D
23	A	B	C	D
24	A	B	C	D
25	A	B	C	D
26	A	B	C	D
27	A	B	C	D
28	A	B	C	D
29	A	B	C	D
30	A	B	C	D
31	A	B	C	D
32	A	B	C	D
33	A	B	C	D
34	A	B	C	D
35	A	B	C	D
36	A	B	C	D
37	A	B	C	D
38	A	B	C	D
39	A	B	C	D
40	A	B	C	D

THE UNIVERSITY OF ZAMBIA
DEPARTMENT OF COMPUTER STUDIES
CST3011 – ALGORITHMS AND DATA STRUCTURES

UNIVERSITY EXAMINATIONS SEMESTER I 2008

Monday, December 01, 2008

INSTRUCTIONS: **There are SIX (6) questions in this examination and you are required to answer ONLY FIVE (5) of them in any order. All questions have the same weight. Question ONE (1) is COMPULSORY**

DURATION: **3 Hours**

1.

a. Explain why is it necessary to perform algorithm analysis?

b. Explain the meaning of the following

   i. F(N) is O(N)

c. Prove the following statement

   i. $\sum_{i=1}^{N} i$ is $O(N^2)$ [Hint: evaluate the summation]

d. State L'Hopital's law

e. Hence or otherwise prove the following

   i. For any constant k $\log^k N = o(N)$

f. An algorithm takes 0.5ms for input size of 100. How long will it take for input size of 500 if the running time is the following:

   i. Logarithmic

   ii. Quadratic.

2.

a. Describe how each of the following sort mechanisms operate
   i. SelectionSort
   ii. ShellSort

b. For each of the sorting algorithms above show using tables, the passes as the following array is sorted. Each pass should indicate the comparisons and swaps involved. For ShellSort use the {5,3,1} sequence
   A = {10,5,6,4,12,11,7,8,2,1,3,9}

3.

a. Consider the following algorithm (known as the Horner's rule) to evaluate the polynomial $f(x) = \sum_{i=0}^{N} a_i x^i$

```
poly = 0;
    for(i = n; i>=0; i--)
        poly = x * poly + a_i
```

   where a_is are coefficients in the polynomial.
   i. Show how the steps are performed by this algorithm fo x = 3; $f(x) = 4x^4 + 8x^3 + x + 2$
   ii. What is the running time of this algorithm? [Calculate the number of operations involved in the evaluation]

b. Determine, for the typical algorithms that you use to perform calculations by hand, the running time to do the following
   i. Add two N-digit integers

4.

a. What are the four basic rules of recursion?

b. Write a recursive method that returns the number of 1's in the binary representation of a non-negative integer N. Use the fact that this is equal to the number of 1's in the representation of N/2 plus 1, if N is an odd number [Consider repeated division by 2]

c. Write a recursive method which takes in two positive integers M and N and returns the product of M and N. The Algorithm evaluates the product by repeated addition of M, N times ie M + M + .. + M (N times)

5.

a. Describe the following data structures
   i. Queue
   ii. Stack

b. Give two applications of each data structure above

c. Given a data structure called a Deque consisting of a list of items, on which the following operations are possible:

- Push(x): Insert item x on the front end of the Deque
- Pop(): Remove the front item of the Deque and return it.
- Inject(x): Insert item x on the rear end of the Deque
- Eject(): Remove the rear item from the Deque and return it

Give a linked list implementation this data structure using java in which all the routines described above take a constant order (O(1)) time of execution. Assume the structure holds integer types.

6.

a. Show the result of inserting 3, 1, 4, 6, 9, 2, 5, 7, into an initially empty binary search tree
b. Show the order in which the nodes are visited using
   i. Pre-order traversal
   ii. In-order traversal
c. Given the following expression a*b*(a + d) – e. Draw an expression tree
d. Hence give the prefix representation of the expression above.
e. Show how the prefix expression is evaluated using the stack.

*************************END OF EXAMINATION************************
HAPPY FESTIVE SEASON

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

Department of Computer Studies

EXAM:	**2008 - SEMESTER ONE FINAL**
COURSE:	**CST3031 – INTRODUCTION TO SOFTWARE ENGINEERING**
DURATION:	**3 HOURS**
DATE:	**27^{TH} NOVEMBER, 2008**

INSTRUCTIONS

- ***Attempt any five(5) questions***
- *All questions carry equal marks(**20 marks each**)*
- ***Clearly number** your answers*
- ***Use the marks** as a guide to the **detail required** in your answers while keeping your answers **concise and relevant**.*

GOOD LUCK!!

QUESTION ONE

(a) Consider a system for administering the lending of books at a university library. A person must be a member of the university's community and must be in good standing– that is, not have any outstanding fines or overdue books – to borrow books. A book may be borrowed for up to two weeks at a time. A book loan may be renewed if the book is returned before the loan's due date and if no other library member has expressed an interest in borrowing the book. If a book is returned after the loan's due date, the borrower will be charged a fine of K5000 for each late day. Fines are paid to the library staff at the circulation desk, where books are returned. Heavily-used books may be put on reserve, meaning that members can read them only in the library and cannot borrow them. The library has terminals that members use to search for books, to determine the loan status of a book, or to express interest in borrowing a book that is currently out on loan. Members also use the terminals to check out books from the library and to renew book loans. The terminals have scanners for scanning the member's library card and for scanning the barcodes on books. The terminals will authenticate the member and check his or her standing before processing book loans or renewals.

i. Provide a context diagram for the library lending system. **[6 marks]**

ii. Provide a use-case diagram that depicts only those use cases that are initiated by library members. **[6 marks]**

iii. Draw a data-flow diagram modeling the data processing involved when a member first steps up to the terminal and ends when the terminal issues a receipt (a slip of paper with the loan's due date) for the book loan. Assume that the use case applies to the loan of a single book. **[8 marks]**

QUESTION TWO

(a) Explain requirements elicitation and analysis in the software engineering process, particularly in the context of a contract for bespoke (custom) software under the following headings;

i. Its role and who does it?
ii. What the inputs are and who provides them?
iii. Differentiate between user requirements, system requirements and system specification, in terms of content and language.
iv. List at least five possible users of a requirements document and state how they use it. **[12 marks]**

(b) You are eliciting requirements for a new release of an existing product. For each of the elicitation problems described below, list a distinct elicitation technique that would best address that problem. **[8 marks]**

i. You want to understand how users really use the existing system, as opposed to how they tell you they use the system.

ii. You want to invent new requirements or features to be added to the new release.

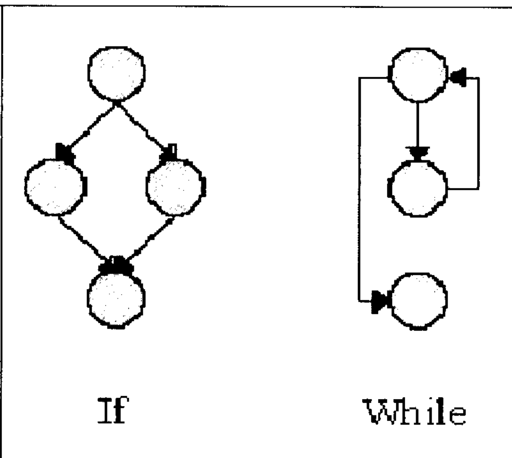
iii. You want to understand the original requirements of the existing system.

iv. You want to get a quick sense of the most popular features of the existing system.

QUESTION THREE

(a) Given the following code fragment and notation for representing control flow,

```
1:      WHILE NOT EOF LOOP
2:           Read Record;
2:           IF field1 equals 0 THEN
3:               Add field1 to Total
3:               Increment Counter
4:           ELSEIF field2 equals 0 THEN
5:                     Print Total, Counter
5:                     Reset Counter
6:                ELSE
6:                     Subtract field2 from Total
7:                END IF
8:           END IF
8:           Print "End Record"
9:        END LOOP
9:        Print Counter
```



i. Define path testing. **[2 marks]**

ii. Using the code, draw the corresponding flow graph. **[6 marks]**

iii. Determine the cyclomatic complexity of the flow graph. **[4 marks]**

iv. Determine a basis set of independent paths. **[4 marks]**

v. Prepare test cases that will force execution of each path in the basis set. **[4 marks]**

QUESTION FOUR

(a) Discuss the client-server model in the architectural design process under the Following headings;

i. The role it plays
ii. Schematic representation (draw a diagram) of your choice to depict a sample model
iii. Mention two advantages and two disadvantages the model presents.

[8 marks]

(b) Control Models

i. What is a control model concerned with?
ii. What is centralized based control?
iii. Describe the *nature of control* and *applicability* of the call-return and manager models.

[12 marks]

QUESTION FIVE

(a) Compare and contrast *black box* and *white box* testing. **[10 marks]**

(b)

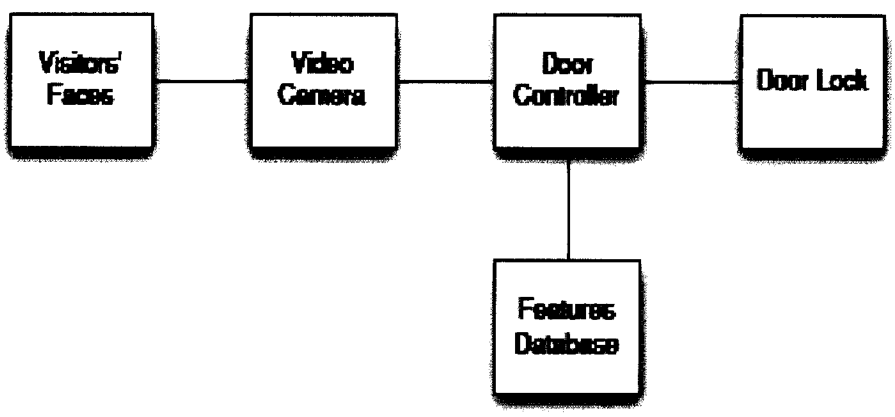
i. Why is it important to be able to partition the test space into *equivalence classes*?
ii. For the following code fragment, describe 3 different test cases, and for each, describe the class of test cases it represents.

[10 marks]

```
char * triangle (int x, y, z) {
/*
    requires: The parameters are in ascending order (i.e. x <= y <= z)
    effects: If x, y and z are the lengths of the sides of a triangle,
    this function classifies the triangle using one of the three
    strings, "scalene", "isosceles" or "equilateral". If x, y, and z
    do not form a triangle, the empty string is returned.
*/
    char *r;
    r="scalene";
    if (x==y || y==z)
    r="equilateral";
    if (x==z)
    r="isosceles";
    if (x <= 0 || (x+y) <= z)
    r="";
    return (r); }
```

QUESTION SIX

(a) Consider the following problem. A door to a secure area is to be controlled by a computer that recognizes facial features. The face of each person desiring admission is captured in a video stream, and the features are compared with entries in a database of the features of people who have been cleared for entry. A modeller has attempted to capture the above problem in the following context diagram:



i. Should Visitors' Faces be a domain (box) in the context diagram? Defend your answer. **[3 marks]**

ii. Should Video Camera be a domain in the context diagram? Defend your answer. **[3 marks]**

(b) A lift (elevator) in a building responds to users pressing the call button on different floor levels. Further, the lift will go to a particular floor either once it is called there from rest, or if a user enters the lift and presses a particular floor button. Once the door has been opened, it will wait 10 seconds before closing unless a call or floor button is pressed. If the lift has not been called for 5 minutes it returns to its rest position at the top of the building.

Draw a state machine to show the possible states the lift can be in and the actions that move it from state to state. **[10 marks]**

(c) Draw a UML class diagram for software to represent the following associations. A Partnership has a husband who is a Male, a wife who is a Female and any number of children who are Persons. A Male is a Person. A Female is a Person. A Marriage is a type of Partnership. There is no need to show attributes and methods for the classes but do show aggregation, inheritance and roles. **[4 marks]**

QUESTION SEVEN

(a) Consider a requirements specification for a simple scientific calculator application, intended to run on a palmtop Personal Digital Assistant (PDA). Give, in appropriate language, a plausible example of each of the following, first as a user requirement, (1 mark each) and then as it might be refined into a system requirement (1 mark each). **[10 marks]**

i. A functional requirement
ii. A usability requirement
iii. A domain requirement
iv. A performance requirement
v. An interoperability requirement

(b) Describe the four basic activities which are represented in all software process models. **[4 marks]**

(c) For each of the following systems, indicate, giving reasons, what would be the most appropriate type of process model to follow;

i. A software system to control a medical X-ray machine **[2 marks]**

ii. A web based tool to allow software developers on different sites to collaborate in debugging their software **[2 marks]**

iii. An implementation of a new data compression algorithm intended to replace an existing program **[2 marks]**

THE END

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

DEPARTMENT OF COMPUTER STUDIES

CST3141 Object Oriented Analysis and Design

Semester One Exam 2008/2009

Tuesday, November 25th, 2008

Instructions:

Answer All Questions in Section A and B.

Answer any Two Question in Section C

Duration: 3hrs

Make sure that you type your Name and the Computer Number on your answer sheet.

Section A.
Answer all Questions.

1. Which of the following best describes composition?
   A) A package of model elements.
   B) A set of realizations for a single use case.
   X) A relationship between a whole and its parts.
2. Which of the following best describes how composition differs from aggregation?
   A) A part cannot be removed from a composition, whereas a part can be removed from an aggregation.
   B) A part can belong to only one composition, whereas a part can belong to more than one aggregation.
   C) A part that belongs to a composition cannot have associations with any other classes, whereas a part that belongs to an aggregation can have associations with other classes.
3. How does generalization increase the opportunities for software reuse?
   A) A generalization hierarchy can be extended to include new subclasses with minimal effort.
   B) Generalization aids the encapsulation of software components.
   X) Generalization allows a group of software components to be treated as a single whole.
4. Information used to develop use case diagrams comes from:
   A) Class Diagrams
   B) Sequence Diagrams
   C) Customer Requirements
   D) Designers best guess
5. Which statement best describes actors in a use case diagram:
   A) Actors are limited to humans that interact with the system being designed.
   B) Actors are limited to systems that interact with the system being designed.
   C) Actors are any entity outside the system being designed that interact with it.

6. If you want to plan project activities such as developing new functionalities or test cases, which of the following OOAD artifacts is the most useful?
   A) Sequence diagrams
   B) Use cases
   C) Domain model
   D) Package diagrams

7. If you need to show the physical relationship between software components and the hardware in the delivered system, which diagram can you use?
   A) Component diagram
   B) Deployment diagram
   C) Class diagram
   D) Network diagram

8. Which technique do most Object Oriented methods propose to describe the **functionality and scope** of a system?
   A) Use cases
   B) a statechart diagram
   C) flow charts
   D) Entity Relationship Diagrams

9. Which list of characteristics describes best an **Object Oriented** system?
   A) Layered architecture, modularity, reusability
   B) Encapsulation, abstraction, inheritance, polymorphism
   C) Data modelling, modularity and subtypes
   D) Inheritance, classes, concurrency, reusability

10. What is true about **UML**?
   A) UML is a standardised approach for use case modelling.
   B) UML supplies a set of notations used in the design of applications.
   C) UML is a methodology for designing and maintaining computer systems.
   D) UML stands for Unified Method Language.

11. What does **High Cohesion** mean?
   A) It means that all the classes work very closely together, which is a good principle.
   B) It means that all the classes work very closely together, which should be avoided.
   C) It means that each class does one thing well, which is a good principle.
   D) It means that each class does one thing well, which should be avoided.

12. The scenario portion of a use case description lists:
   A) All steps for every possible thing that might happen in the use case
   B) The most commonly-occurring steps during the use case (normal or Typical path)
   C) Answer B above plus the main exception path
   D) A discussion of what the developer thinks might happen during the use case

13. (6 Points) Match the appropriate descriptions to the diagram. There may be more than one correct choice that matches.

_____________Use Case Diagram

_____________Class Diagram

_____________Sequence Diagram

A. Dynamic View of Design
B. Static View of Design
C. User View of Design
D. Language of User
E. First Diagram Developed

Section B
Answer all Questions

1. **Question 1**

1.1. What is an Actor and what is a use-case? Describe, in detail, the importance of Actor and a use-case in use-case based modeling of software systems. [5 marks]

1.2. Your boss has been reading about UML and calls you into his office. He says, "I see that use cases can be derived from other use cases via inheritance and I understand that from basic OO. What I'm confused about is <<extend>>. Supposedly this handles variation in use cases, but I thought that's what inheritance is for? What's the difference between these two?" i.e. Inheritance and extension. [5 Marks]

1.3. Mention at least three visual notations (UML Diagrams) that can be used when modeling behavior. [3 pts]

1.4. What is a UML Use Case Diagram, and when should I use it? [2 Marks].

1.5. What does coupling and Cohesion refer to in OOAD.[3 Marks]

1.6. What are the guiding principles in system decomposition regarding Coupling and Cohesion. [2 Marks]

1.7. The registrar wants to add to their on-line capability by allowing those professors and students with personal digital assistants (PDAs), such as Palm handheld devices or appropriately equipped mobile phones, access to the registrar.s system. Specifically we want students to be able to view the on-line course catalog and register or un-register for courses, just as they do from their computers. Professors will be able to post grades and obtain class listings. The course catalogs and listings should be able to be downloaded to the PDA so that they can be accessed off-line. Students and professors will have to apply for separate and different access to the system. The system must be available at all times and totally secure.

1.7.1. Identify 5 Functional requirements.[5]

1.7.2. Identify at least two Non Functional Requirements[2]

1.7.3. Identify 4 use cases by providing the actors, use case names, and brief descriptions (2 or 3 Sentences) of both the use-cases and participating actor.[3]

Section C

Answer any two Questions.

1. **Question 1**

The University admissions Department keeps records on all students and staff members within the university. The information stored about each person includes their name, address, affiliated department and course in terms of students. All people within the system are assigned a unique ID number. Both undergraduate and post graduate students attend the university. Undergraduate students must take subjects worth a total of 10 points. Each semester, but must not take more than 5 subjects in any semester one semester. Each Subject is worth between 1 and 5 points and subjects are taught by one or more staff members. Postgraduate students may take subjects, or have all points requirements fulfilled by performing research. All research postgraduate students are assigned a staff member as their thesis supervisor.

The System should allow students to register for subjects or to drop them. Staff members should be allowed to sign up to teach a subject, add a new subject and delete a subject from the system.

1.1. Identify the Actors and use-cases in the University Admission system (Just List them).[4 Marks]

1.2. Construct a class Diagram, Illustrating the relevant classes (attributes and Operation), and their relationship based on the facts about a university admission department.[12 Marks]

1.3. OOAD promotes the following design goal divided into five categories: performance, dependability, cost, maintenance, and end user. Assign one or more categories to each of the following goes: [4 Marks]

1.3.1. ______________________________Users must be given feedback within one second after they issue any command.

1.3.2. ______________________________The Ticket Distributor must be able to issue train tickets, even in the event of a network failure

1.3.3. ______________________________The housing of the ticket Distributor must allow for new buttons to be installed in case the number of faces increase

1.3.4. ______________________________The Automated Teller Machine must withstand dictionary attacks (i.e., users to discover a identification number by systematic trial).

2. **Question 2**

   2.1. For the five requirement statements below, indicate what type of requirement it is, Functional (F), Usability (U), Reliability (R), Performance (P), or Scalability / Supportability (S).[10]

   2.1.1. _____ Someone who has taken a basic UML course shall be able to create a class diagram without referencing the on-line help or other help documentation.

   2.1.2. _____ The system shall encrypt all transaction data and sign it with the user.s private digital signature.

   2.1.3. _____ The system shall handle a maximum load of 20 million transactions in a 24-hour period.

   2.1.4. _____ The system shall be able to accommodate an unlimited number of users by adding additional processing nodes to the corporate network.

   2.1.5. _____ All users of the system will be able to create an account and select their own passwords. The only restriction is that the user name and password combination must be unique.

A. Prepare a Use-case Diagram for a simple credit card validation system based on the following Text.[6 Marks]

   A simple system is to be developed to support the management of credit card transactions. Customers will use their credit card when buying an item or a service from a retailer. During the processing of the customers bill the customer credit card must be checked with the card company. The system will allow the customer to check their account status and pay outstanding debt. The credit card company should also be able to manage the account including issuing bills, changing credit limits and canceling cards.

B. Produce a description and flow of events for one of the use-cases in your diagram. Devise two scenarios, one main and one alternative/exceptional for this use-case. Note that three descriptions are expected, one for the use-case and two scenarios. [8 Marks]

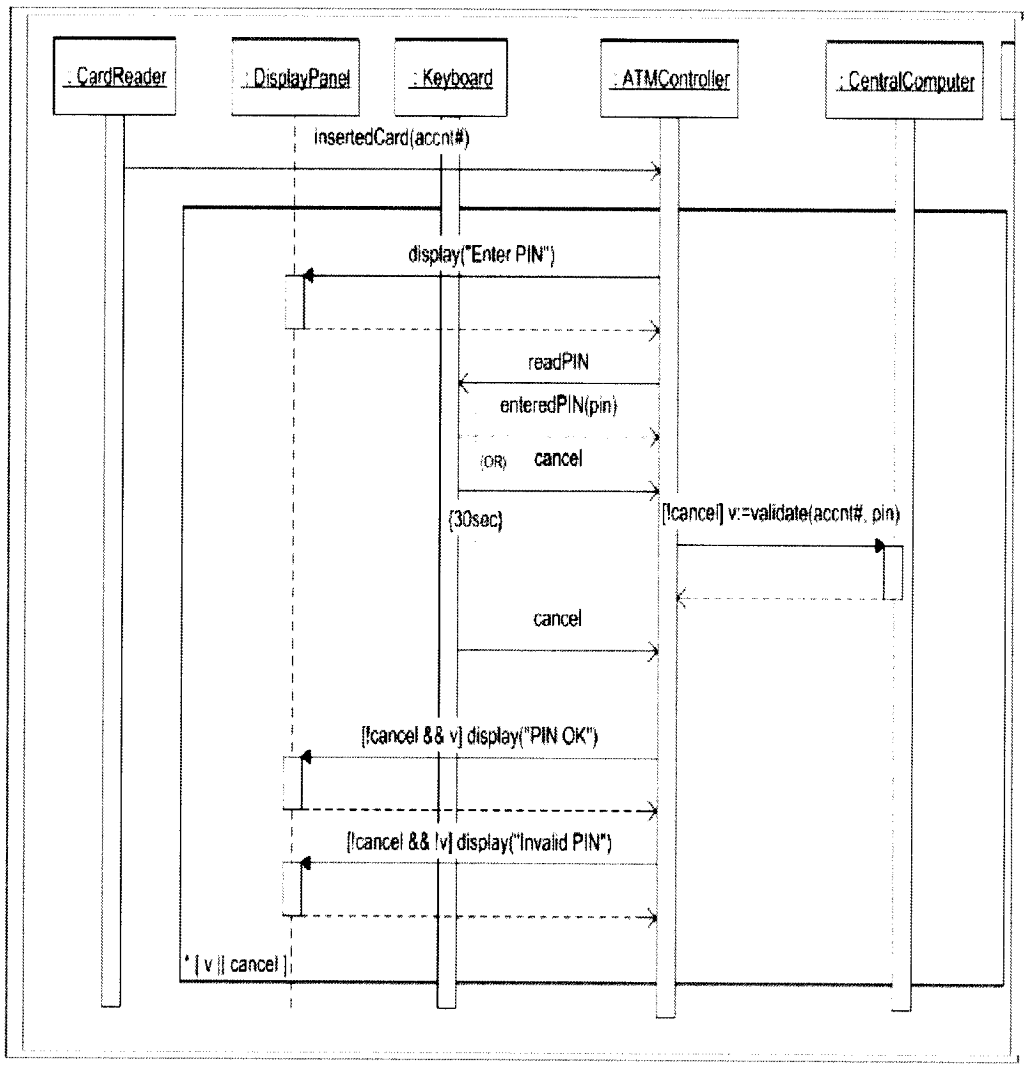
3. **Question 3**

   3.1. Construct a **Class Diagram** for the order processing system described below.[14 Marks]

   - Each order consists of one or more order lines.
   - Each order line corresponds to a particular product. Each order line has a product description, price, quantity and a field that indicates the status of this order line.
   - A product can appear on many orders.
   - A customer can place many orders, but each order belongs to only one customer.
   - Each order has an order number, date and customer number.
   - Customers can be either businesses or individuals.
   - All customers have a name and address. Business customers also have a contact name, credit rating and available credit.
   - Individual customers may have a credit card number on file.

Remember to include as much detail as possible, such as attributes, operations, associations, constraints (Multiplicities), etc...

3.2. Based on the following Sequence Diagram, Draw a UML Class Diagram identifying all the operations, properties and relationships that are in the classes involved. [6 Marks]



4. **Question 4**

Case Study
ACMA Company is in need of a warehouse management system to control movement and storage of materials within its warehouses.

This company offers the services of its warehouses and container yards to customers all over the country. It offers transport services to transport customers' goods. The operations include order redistribution within warehouses, Freight forwarding between origin and destination warehouses and handling transport services. All kinds of items can be stored in warehouses. Each item can be classified in to various categories according to the storage type. The warehouse is divided into cubicles based on the storage requirements. It is important that the location of certain items should be separated from others. e.g. chemicals and food items.

The following people will be connected with the warehouse system:
Foreman, Warehouse worker, Container yard Supervisor, Truck driver and assistant, Office personnel and Customers. Office personnel receive and accept orders from customers. The foreman in the warehouse is responsible for accepting the distribution order. Customers own their items in the warehouses and give instructions on where and when they want them to be transported. All items should be entered into a database before they are taken in to the warehouse. Container yard Supervisor handles the operations inside a container yard, such as security of the trucks parked within the yard where the Driver and the assistant break journey.

Order Distribution Scenario
A customer approaches the office of the Company with a list of items to be dispatched to various destinations in the country. The office personnel check the list, note the destinations and identify the storage type corresponding to each item by referring to an item type classification book.

Before a transit, all the items are expected to be at a specific location belonging to the customer. Thus, the original location of all the items for a specific transit is the same. The items in the order, which should be transported to the same destination, should arrive on the same date.

For a particular transit from the origin, a pre-defined route is obtained from a reference book. A route is a set of intermediate container yards between the origin and destination warehouses. The expected period that is allowed to be spent at each intermediate container yard is also specified. Another duration specifying the period to be spent on the road between successive container yards or container yards and warehouse as the case may be is also given.

After deciding the route, the office personnel phone the origin and destination warehouses to inquire about the space availability to store the items. The foremen at such warehouses check their logs for the availability of space for those items and determine whether there is sufficient space. If space is available, he makes a reservation of the space for the expected period at that time. If any of the two warehouses faces a difficulty of handling the storage, the reservations in respect of the customer order is not done and the order is not accepted.

However, if space can be reserved in both warehouses, the order is accepted and the customer is given an order number. Thereafter, the customer is free to arrange for his own transport of the consignment to the warehouse at the origin. In the alternative, the company is prepared to undertake the assignment. Order form contains order number and details of each item including item_ number, item_name, quantity, unit of measure (Weight, volume, etc.), original location, destination of the item and expected date of final arrival. The form also contains a provision for the customer to indicate any special requirements under remarks.

Freight forwarding scenario
A freight is the movement of items between any 2 warehouses. All items in a given freight go to the same warehouse. When freight is forwarded, a Freight forwarding form is filled at the origin warehouse. Each Freight forwarding form consists of the name of the foreman, freight no, current location of freight, destination of freight, intermediate container yards, and also for each item its order number, item number, name, quantity, weight, container id, truck registration number, expected date and the Remarks of the customer.

A freight is created at the origin warehouse on the route. After selecting the items for dispatching, they are stored in containers. The number of containers used depends on the requirements and whether items can be stored together or not. A single truck can carry only one container. The number of trucks is then assigned accordingly to the number of containers. The location of the freight in transit should also be tracked. Even though there is a pool of trucks available at each warehouse, there may be some trucks under repair at anytime and others may be in transit. Once dispatched, the space allocated in a specific warehouse becomes available.

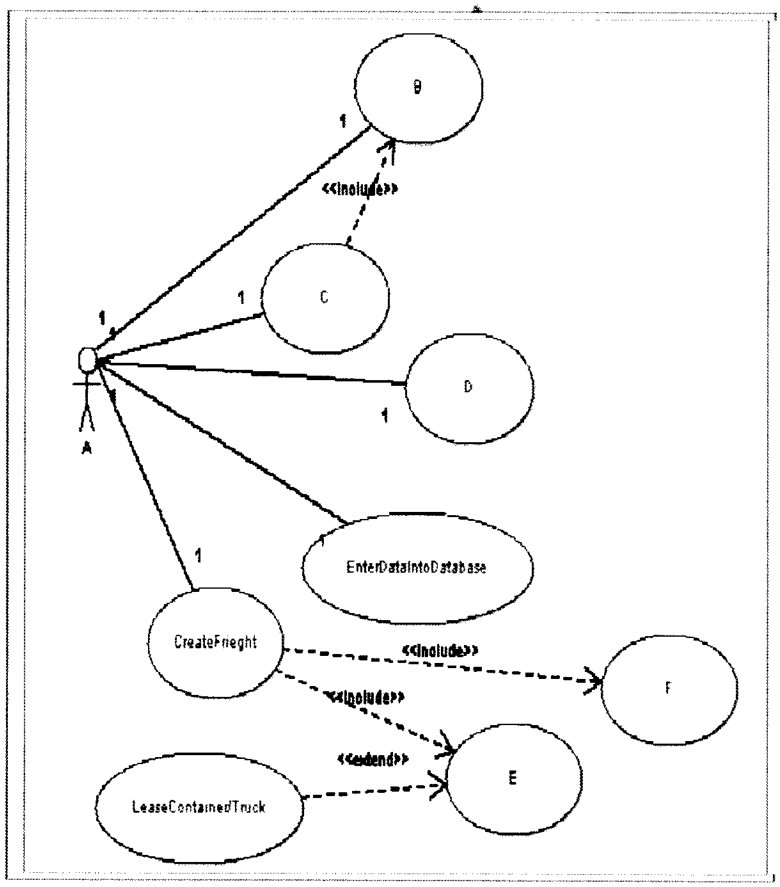
4.1. For the above case study, Office Personnel can be identified as an *Actor*. Identify the Use cases which are responsible for the business actor 'Office Personnel' (Or Use-cases used by the actor 'Office Personnel'). [4 Marks]

4.2. In addition to the actor Office Personnel, name other *Actors* one should identify for the system at the design stage. [4 Marks]

4.3. Identify SIX (06) potential classes for the above system. [6 Marks]

4.4. Following is a Use case diagram for the given system. Identify the Actors / Use cases for labels A-F from the given list.[6 Marks]

Customer, WarehouseWorker, Foreman, CheckSpaceAvailability, CancelReservedSpace, ReserveSpace, CheckTruckAvailability, AssignContainers, RejectOrder, AcceptOrder.



<u>GOOD LUCKY.</u>

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THE UNIVERSITY OF ZAMBIA
DEPARTMENT OF COMPUTER STUDIES
CST4021 – NUMERICAL ANALYSIS

UNIVERSITY EXAMINATION

Monday, November 24, 2008

INSTRUCTIONS: **There are SIX (6) questions in this examination and you are required to answer ONLY FIVE (5) of them in any order. All questions have the same weight. Question ONE (1) is COMPULSORY**

DURATION: **3 Hours**

1.

a. Define the following
   i. Limit of a function f at a point x_0.
   ii. Continuity of a function at a point x_0.
   iii. Differentiability of a function at a point x_0

b. Show that the function

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

is continuous at $x_0 = 1$

c.
   i. What number is represented by the following machine number

   1|1 0 0 0 0 1 0 | 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 1 0

   ii. What are the next smallest and largest machine numbers of the number above

d. Given a number p = 999999, what is the range of numbers which approximate the p to 5 significant digits?

2.

a. State, without proof, the fixed point theorem

b. Let $f(x) = x^2 - 2$, find a function g(x) from f, such that g has a unique fixed point in [1,2]. [Show, precisely, how your g has a unique fixed point in the interval]

c. Using the sequence from b above, find $x_5$the approximation of the fixed point of g in the given interval

3. .

a. Show that the Secant method can be rewritten as follows

$$x_{n+1} = \frac{x_{n-1}f(x_n) - x_n f(x_{n-1})}{x_n - x_{n-1}}$$

b. Show why this formula is still inferior to the original one in terms of implementing a computer program that approximates the roots using the Secant method.

c. Using the Secant method, compute x_6 the approximation of the root of the following function $f(x) = x^3-10$.[Hint: first find the interval in which the root exists and pick x_0 and x_1 the initial approximations from the interval]

4.

a. Suppose $x_j = j \; for \; j = 0, 1, 2, 3$ and it is known that $P_{0,1} = 2x + 1, P_{0,2}(x) = x + 1, P_{1,2,3}(x) = 3$. Find $P_{0,1,2,3}(2.5)$

b. Approximate f(0.5) using the following data and the Newton forward divided-difference formula.

x	0.0	0.2	0.4	0.6	0.8
f(x)	1.00000	1.22140	1.49182	1.82212	2.22554

5.

a. Suppose the following data has been experimentally collected

x	1.00	0.01	1.02
f(x)	1.27	1.32	1.38

Approximate $f'(1.005)$ Using the centered difference formula.

b. Use the Trapezoidal and Simpsons rule to approximate the following definite integrals.

$$\int_0^{0.1} x^{1/3}dx$$

c. Compare the approximations to the actual value and find the error bound in each case.

6.

a. Show that the system of equations below is solvable.

$$2x_1 + 4x_2 - x_3 = -5$$
$$x_1 + x_2 - 3x_3 = -9$$
$$4x_1 + x_2 + 2x_3 = 9$$

b. Solve the system of equations using the Gaussian Elimination Method with backward substitution

c. Show that the following matrix is invertible

$$\begin{matrix} 4 & 0 & 1 \\ 2 & 1 & 0 \\ 2 & 2 & 3 \end{matrix}$$

d. Compute the inverse of the matrix

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

♣♣♣♣♣HAPPY FESTIVE SEASON♣♣♣♣♣

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2008 ACADEMIC YEAR FIRST SEMESTER
FINAL EXAMINATIONS

GEO 111: INTRODUCTION TO HUMAN GEOGRAPHY I

TIME : Three hours

INSTRUCTIONS : Answer question 1 (40%) and any three others (60%). Candidates are encouraged to use illustrations wherever appropriate.

---

1. Study the information given in Table 1 showing the distribution of water taps in selected townships in the City of Lusaka and then answer questions that follow.

Table1: Number of taps in selected townships.

Township	**Number of residents**	**Number of taps**
A	36,000	1, 300
B	21,000	2, 000
C	60,000	2, 700
D	25,000	1, 500
E	69,000	3, 000
F	65,000	2, 800

Source: Hypothetical

a. Calculate the ratio of advantage for each of the six townships
b. Draw the Lorenz curve for the distribution of taps in the six townships and show the line of perfect equality and inequality gap
c. Explain the curve that emerges

2. Write short explanatory notes on all of the following:
   a) Settlement sites
   b) Functional complexity
   c) The Central Place Theory
   d) The urbanization curve
   e) The origins of first cities

3. Using the diffusion of the mobile phone technology in Zambia as an example, explain the four stages in the diffusion of an innovation through a region.

4. Discuss the extent to which the distribution of functional areas within a typical city is influenced by urban land values.

5. With the aid of examples, explain the factors which contributed to the emergence of major Early World Cultural Hearths.

6. 'Living organisms could not have emerged from non-living sources'. Discuss this statement with reference to the origin of man.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2008 ACADEMIC YEAR FIRST SEMESTER FINAL EXAMINATIONS

GEO 111: INTRODUCTION TO HUMAN GEOGRAPHY I

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THE UNIVERSITY OF ZAMBIA
DIRECTORATE OF DISTANCE EDUCATION
2008 ACADEMIC YEAR DISTANCE EDUCATION FINAL EXAMINATIONS

GEO 111
INTRODUCTION TO HUMAN GEOGRAPHY I

TIME: THREE (3) HOURS

INSTRUCTIONS: ANSWER QUESTION ONE (40%) AND ANY OTHER THREE QUESTIONS. ILLUSTRATE YOUR ANSWERS WHEREVER POSSIBLE. USE OF A CALCULATOR AND AN APPROVED ATLAS IS ALLOWED.

---

1. Study the information in Table 1 below comparing the number of people employed in the manufacturing of soft drinks with the total number of people employed in manufacturing industry in Lusaka Province, Copperbelt Province and Zambia.

Table 1: *Total number of people employed in manufacturing industry and number of people employed in soft drinks manufacturing industry in Lusaka Province, Copperbelt Province and Zambia, 2009*

	Number of people employed in soft drinks manufacturing industry	**Total number of people employed in manufacturing industry**
Copperbelt Province	45,000	630,000
Lusaka Province	76,000	810,000
Zambia	106,000	1,900,000

Using the formula **LQ** $= \dfrac{e_i/e}{E_i/E}$

(a) Calculate location quotients for the Copperbelt and Lusaka Provinces for the number of employees in the manufacturing of soft drinks by comparing the provincial figures to the figures for the entire Zambia.

(b) Interpret your location quotients.

2. Discuss one of the three models of urban growth and show how it approximates to urban growth in Zambia.

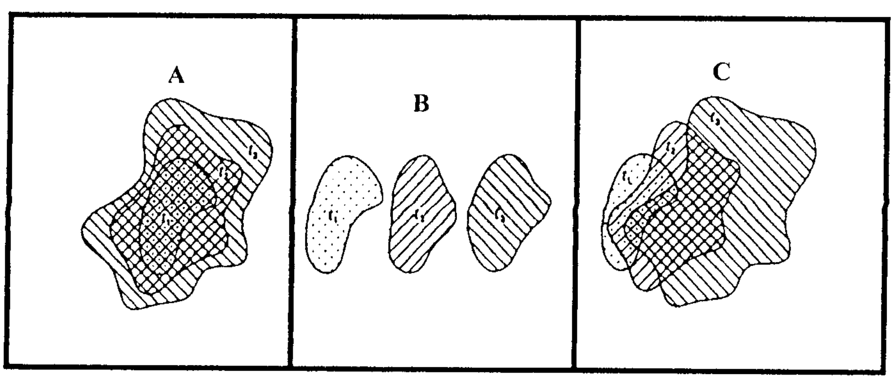
3. Write explanatory notes on each of the following:
   (a) Julian Huxley's three components of culture.
   (b) Settlement patterns.
   (c) Weber's Location Theory.
   (d) The factors encouraging growth of primate cities.

4. Explain the main assumptions of von Thunen's model of land use. How do these assumptions compare with agricultural activities around the city of Lusaka?

5. With respect to the development of human geography, explain the following dichotomous relationships:

   (a) Nomothetic versus idiographic studies.
   (b) Determinism versus possibilism.
   (c) Biblical explanation of creation versus evolution theory.
   (d) Interdisciplinarity versus Compartmentalised approach.

6. Using examples, explain the three types of spatial diffusion shown in the following diagram:



END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2008 ACADEMIC YEAR FIRST SEMESTER UNIVERSITY FINAL EXAMINATIONS

GEO 155: INTRODUCTION TO PHYSICAL GEOGRAPHY

TIME: Three hours

INSTRUCTIONS: Answer any **FOUR** questions.
All questions carry equal marks. Candidates are advised to make use of illustrations and examples wherever appropriate.

---

1. Write short explanatory notes on ALL of the following:
   a) Specific humidity
   b) Fluvial terrace
   c) Ventifact
   d) Clay humus complex
   e) Taxonomical scale of organisms

2. Identify and discuss the ocean currents and the air masses that influence the climate of Zambia.

3. 'Each major pedogenic regime produces a highly distinctive soil type that reflects latitudinal variations in energy budgets'. Discuss this assertion with reference to four (4) major pedogenic regimes.

4. Discuss the various processes of folding and faulting in landform development.

5. Explain the effects of continental drift on the distribution patterns of flora and fauna on earth.

6. Using a specific example, discuss the meteorological effects of the interactions between oceans and the atmosphere.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
DIRECTORATE OF DISTANCE EDUCATION

2008 ACADEMIC YEAR DISTANCE EDUCATION FINAL EXAMINATIONS

GEO 175: INTRODUCTION TO MAPPING TECHNIQUES IN GEOGRAPHY
PAPER I: PRACTICAL
MAP READING, ANALYSIS AND INTERPRETATION

IMPORTANT
AMMENDMENTS AND CHANGES TO EXAMINATION QUESTION PAPER

Please note that two different versions of Map sheet 1131 C4 were purchased not by design but rather by mistake and unintentionally and this has prompted to make some changes to the already prepared examination.

The changes are as follows:

Question 4 (a) The question should read as follows:

When was Map Sheet 1131 published and by whom?

Question 4 (j) should read as:

Determine the direction of the road junction in Grid Square3187 from Grid Reference Point260920 as a compass direction and also as a bearing from True North. [2 marks]

Question 4 (m) should read as:

What landscape feature is associated with the Power Line south of northing 90 on Map Sheet 1131 C4?

Question number 5 (i) should read as:

The Lwitikila and it main unnamed tributary.

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2008 ACADEMIC YEAR FIRST SEMESTER FINAL EXAMINATIONS

GEO 271: QUANTITATIVE TECHNIQUES IN GEOGRAPHY

TIME: Three hours

INSTRUCTIONS: Answer any **four** questions. All questions carry **equal marks**. Use of a Philips' University Atlas is allowed. Candidates are encouraged to make use illustrations wherever appropriate.

---

1. Using George Brown's (1978) three main types of explanation, describe the nature of explanation in geography.

2. Outline and explain the main elements of a research proposal.

3. Mr. Mpoku is to undertake a study to evaluate the impact of agro-forestry technology on crop yields in Munyinyika Village. What would be the essence of literature review in the study?

4. Outline the characteristics of scientific research, and show the steps used in carrying out scientific research.

5. With the aid of diagrams, list and describe three types of experimental research designs.

6. GEO 271 students were asked to formulate research problems, and one that came up was 'to establish the levels of mother's affection to children.' What are the flaws in this research problem?

7. A large organization has a sports and leisure complex (the facilities include tennis and squash courts, football, rugby and hockey pitches, gymnasium, sports hall and a swimming pool) which is available for the use of members of staff, administrative, clerical and production, and their families, at a very low subscription.

   The organization has most of its administrative and clerical staff located in the city centre; the production staff are located in three factories on the outskirts of the city. The sports and leisure complex is close to one of the factories but some distance from the other two factories. The management of the organization are concerned by the high costs of this complex and also that the facilities are very much under-used. The management are considering two alternatives: (i) selling the complex; (ii) retaining the complex but trying to encourage use by existing staff and/or making the facilities available to people other than staff and their families. Such people would have to pay an economic subscription.

The management has asked you to conduct two surveys: (i) to find out whether employees currently use the complex and are likely to use the complex in the future; and (ii) to find out whether people other than staff and their families living in the area would wish to use the complex.

Briefly explain how you would select samples for the two surveys.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2008 ACADEMIC YEAR FIRST SEMESTER FINAL EXAMINATION

GEO 381: ENVIRONMENT AND DEVELOPMENT I

TIME: Three hours

INSTRUCTIONS: Answer question **one (1)** and three other questions.
All questions carry equal marks.

---

1. Explain the concept of tradeoffs between environment and development.

2. Discuss the main pillars of sustainable development and their significance to achieving the millennium development goals

3. The integration of African economies in the global realm has accelerated physical pressure on the environment. Use Zambia as an example.

4. What is the significance of Environmental Impact Assessment (EIA) to planning and development in Zambia? State two barriers to its implementation in Zambia.

5. 'In any environmental management process information of the environment is important and can be achieved through the construction of an inventory'. Discuss.

6. The discourse on environment has a political dimension. Explain using examples conditions that may give rise to conflict.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

2008 ACADEMIC YEAR FIRST SEMESTER FINAL EXAMINATIONS

GEO 481: ENVIRONMENT AND DEVELOPMENT II

TIME: Three hours

INSTRUCTIONS: Answer any **four** questions. All questions carry equal marks. use of a Philip's University Atlas is allowed.

---

1. Define bioenergy and outline the major constraints to increased bioenergy use.

2. Discuss Zambia's status with regard to the definition of physical and economic water scarcity.

3. Outline the factors responsible for forest fragmentation and discuss the effects of tropical forest fragmentation on greenhouse gas sequestering.

4. An urban area is an opportunity as well as a threat. Discuss

5. Describe the adverse of livestock production on the environment and possible mitigation measures

6. Write short explanatory notes on the importance of each of the following with regard to water management:
   (a) Abstraction and user rights.
   (b) Waste water discharge licensing.
   (c) Controlling well construction activities.
   (d) Land surface zoning for ground water conservation and protection.
   (e) Catchment level water resources management.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
2008 ACADEMIC YEAR FIRST SEMESTER FINAL EXAMINATIONS

GEO 911: POPULATION GEOGRAPHY

TIME: **Three hours**
INSTRUCTIONS: **Answer any FOUR questions.**
All questions carry equal marks
Use of a Philip's University Atlas is and a certified calculator is allowed.

---

1. Selected demographic indicators for the Republic of South Africa are presented in Table 1.

Table 1: Selected demographic indicators for the Republic of South Africa (2005)

Indicators	**Values, Period and rates**
P_i	46, 904, 567
Period	2005 to 2010
Birth Rate	23/1000
Death Rate	16/1000

a) Use formulae (i), (ii) and (iii) to project what the population of the Republic of South Africa will be in 2010.

(i) $P_2 = P_1 \times (1 + r)$

(ii) $P_2 = P_1 \times e^{rt}$

(iii) $P_2 = P_1 (1 + r)^t$

(b) Explain the strengths and weaknesses of the formulae presented in (i), (ii) and (iii) in relation to the demographic indicators presented in Table 1.

2 Examine the factors that contribute to differences between countries which are in the early expanding and late expanding stages of the Demographic Transition (DT).

3 'Countries might have different population policies but their policies tend to have common elements.' Discuss.

4 Ascertain the contribution of enhancing the status of women in the regulation of both fertility and mortality rates in any country in the world.

5 Distinguish between non-economic values and disvalues of children as propounded by Huffman and Huffman (1977).

6 Discuss the merits of pre-, within-, inter- and post- censal surveys.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2008 ACADEMIC YEAR FIRST SEMESTER FINAL EXAMINATIONS

GEO 915: MEDICAL GEOGRAPHY

TIME: Three hours

INSTRUCTIONS: Answer any **four** questions. All questions carry equal marks. Use of a Philips' Atlas is allowed. Candidates are encouraged to use illustrations wherever appropriate.

---

1. Using SWOT analysis, compare and contrast traditional and conventional healthcare delivery systems.
2. Discuss the assertion that 'HIV/AIDS infection is as a result of sexual behaviour'.
3. 'Social and economic environments play important roles in the diffusion of communicable diseases'. Explain.
4. Evaluate any four components of the Health Reforms in Zambia.
5. 'You are what you eat'. Discuss this assertion in relation to nutrition and disease.
6. Explain how medical geography is linked to other disciplines.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2008 ACADEMIC YEAR FIRST SEMESTER
FINAL EXAMINATIONS

GEO 921: ECONOMIC GEOGRAPHY

TIME : Three hours

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

---

1. 'Economic Geography results from economic behaviour as it appears in the landscape around us' (Hurst, 1972). Discuss.

2. With the aid of examples, explain the major causes of industrial plant closures.

3. 'Decision-making activities including location decisions are behavioural processes' (Dicken, 1971). Discuss this statement with reference to the classical industrial location theory.

4. Show how distance can have a major influence on global trade for a developing country such as Zambia. Give examples.

5. Outline and discuss the challenges of domestic tourism in Zambia.

6. With the aid of examples, explain the role of clusters in the growth of industries in developing countries.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2008 ACADEMIC YEAR FIRST SEMESTER FINAL EXAMINATIONS

GEO 971: AERIAL PHOTOGRAPHY AND AIR PHOTO INTERPRETATION

PAPER I

TIME: Three Hours

INSTRUCTIONS: Answer question one and any other three questions. All questions carry equal marks. Use of a Philip's University Atlas is allowed

---

1. Write short explanatory notes on **ALL** of the following:

(a) *Camera obscura*
(b) Atmospheric path radiance
(c) Interpupillary distance
(d) Absolute and differential parallax
(e) Photographic overlap.

2. Describe the process involved in object detection, identification, and classification, and show how they aid in photo interpretation.

3. Define stereoscopy, and illustrate how it enhances air photo interpretation.

4. Explain various innovations that have contributed to the present status of aerial photography.

5. Elucidate the assertion that photo interpretation is premised on experience and imagination.

6. Outline, at least five (5), problems that you would encounter in acquiring and interpreting small-scale aerial photographs for crop condition assessment in Zambia.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2008 ACADEMIC YEAR FIRST SEMESTER FINAL EXAMINATIONS
GEO 971: AERIAL PHOTOGRAPHY AND AIR PHOTO INTERPRETATION

PAPER II

TIME: Three Hours

INSTRUCTIONS: Answer question <u>one</u> and any other <u>two</u> questions. All questions carry equal marks. Use of a Philip's University Atlas is allowed. Use of an approved calculator is allowed

MATERIALS: Aerial photographs Lusaka run 39:58 and 59; tracing paper; graph paper

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1. Figure 1.0 below is an illustration of derivations of height using parallax in a stereo-pair of aerial photographs.

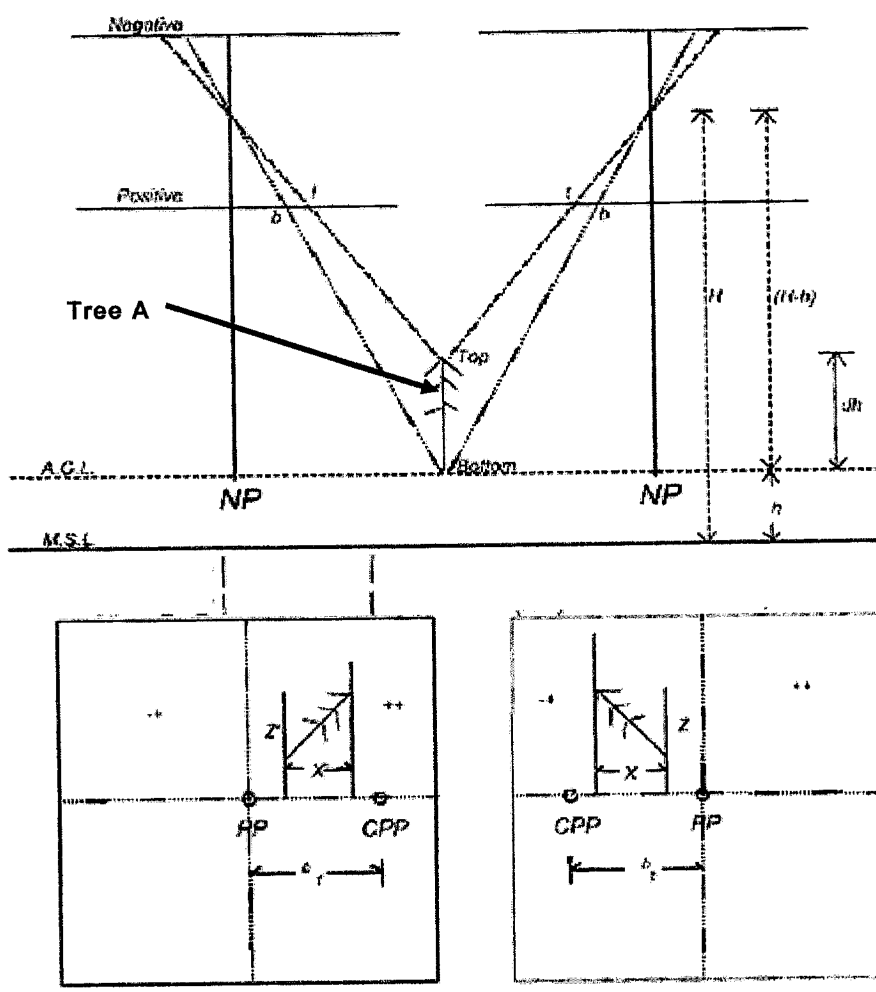

Figure 1.0 Graphic Representation of Parallax

Using the diagram above and providing notations derive the mathematical relationships showing the equivalences of the following:

(a) Absolute parallax (aP)
(b) Differential parallax (dP)
(c) The height of tree A (ΔH)

2. Assume that an aircraft was flying at an altitude of 1500m above the datum taking vertical photographs with a 305 mm focal length camera. Two image points a and b (of A and B on the ground) were depicted on a photograph and their photo coordinates were measured to be xa = 65.3 mm, ya = 71.5 mm, xb = -29.5 mm, and yb = -52.3 mm. If point A is 163 m and point B is 198 m below the datum, what is the horizontal distance on the ground between A and B?

3. A photo survey is carried out at a height of 4560m above the mean altitude of the area. The camera used has a focal length of 152.00mm.

(a) What is the mean scale of the photo?
(b) What is the scale at a hilltop situated approximately 380m above the mean altitude of the terrain?
(c) What is the scale at a valley floor approximately 228m below the mean altitude of the terrain?

4. Table 1.0, below shows three (3) cover types reflecting electromagnetic radiation in varying frequencies.

Table 1.0 Cover Types and EM in Varying Frequencies

Cover Type	Frequency (Cycles/sec)	Absolute Temperature (k)
A	7.5×10^{13}	400
B	3.3×10^{13}	300
C	6.0×10^{12}	200

Note: Planck's constant = 6.626×10^{-34} Sec
Stefan-Boltzman constant = 5.6×10^{-8} w.m^2 (^{o}K)$^{-4}$

(a) Establish the radiation type being reflected by each cover type.

(b) Comment on whether the land cover types above would be recognisable on an aerial photograph taken using black and white infrared film and a yellow filter.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
Department of Mathematics & Statistics

2008 ACADEMIC YEAR
FIRST SEMISTER FINAL EXAMINATIONS

M 111 : MATHEMATICAL METHODS I

TIME ALLOWED: Three (3) Hours

INSTRUCTIONS:
(a) Answer any **Five (5)** questions.
(b) Write down **your COMPUTER** No. and **TG. No.** on **ALL** your answer booklet.
(c) Use of Calculators is not **allowed** in this examination.

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1. (a) Let $X=[1,10]$ be the Universal set and $A=[1,4]$, $B=(2,8)$ and $C=[3,6)$ be the subsets of X. Find each of the following sets and display them on the real line.

   (i) B' (ii) $A\cap(B-C)$ (iii) $A\cap B$

   (b) (i) Solve the equation

   $$\cos x\cos 30^o - \sin x \sin 30^o = \frac{1}{2}, \qquad -180^o \le x \le 180^o$$

   (ii) If α and β are roots of the equation $x^2-4x+2=0$, Without solving the equation, find the value of :

   $$\frac{\alpha}{\beta^2}+\frac{\beta}{\alpha^2}$$

   (iii) Let $f(x)=\begin{cases} 2x+1 & if\ x\le -1 \\ x^2-2 & if\ x>-1 \end{cases}$

   Show that $f(x)$ is continuous at $x=-1$

   (c) Solve the inequality $\left|\frac{x}{x-3}\right|\le 2$ for real values of x.

2. (a) Let $f(x) = 3\cos(2x - \pi)$, $\quad 0 \le x \le 2\pi$.

(i) Find the amplitude of f(x)

(ii) Find the phase displacement of f(x)

(iii) Find the period of f(x)

(iv) Sketch the graph of f(x)

(v) Find the values of x for which $f(x) = \dfrac{3}{2}$

(b) Find the derivative of the function $f(x) = \dfrac{1}{x-1}$, from the first principles.

(c) (i) Express $1.51\bar{4}$ in the form $\dfrac{r}{q}$ where $r, q \in Z$, $q \neq 0$.

(ii) Given that $z = \dfrac{\sqrt{3}+1}{1-i}$, find $z^2 - \dfrac{1}{z^2}$, giving the answer in the form a + ib, where a and b are real numbers.

3. (a) Solve the following equations

(i) $\sqrt{3-x} - \sqrt{7+x} = 0$ $\qquad$ (ii) $2x^3 - 3x^2 - 3x + 2 = 0$

(b) Let $f(x) = -2x^2 + 11x - 15$, find the maximum or minimum point and value of $f(x)$. Hence, sketch the graph of $f(x)$.

(c) Find $\dfrac{dy}{dx}$ of the following functions,

(i) $y = 12\sqrt{x} - x^{\frac{3}{2}}$

(ii) $y = x^2 \sin(3x^2 - 1)$

(iii) $y = (x - \dfrac{1}{x})^3$

(iv) $y = \dfrac{\sin x}{1 + \cos x}$

4. (a) Let $f(x)=4+2\cos(x+k)^{o}$, $0 \le x \le 360^{o}$, where k is a constant value, $0 < k < 360^{o}$. The curve with equation $y = f(x)$ passes through the point $(30^{o},5)$.

(i) find the value(s) of k

(ii) Solve the equation $f(x)=2$.

(iii) Find the greatest and least values of f(x).

(iv) Sketch the graph of f(x)

(v) Write the coordinates of the points where the curve meets the y-axis.

(b) Let the two functions f and g be defined by:

$$f(x)=\frac{25}{3x-2}, \quad 1 < x \le 9$$

$$g(x)=x^2, \quad 1 < x \le 3.$$

(i) Show that f is a one to one function.

(ii) Find the domain of f^{-1}.

(iii) Find the composite function fog.

(iv) Hence, solve the equation $(fog)(x) = \frac{2}{x-1}$.

(v) Find $(fog)(-1)$.

(c) Express $\frac{\sqrt{2}+1}{\sqrt{2}-1}$ in the form $a+b\sqrt{2}$, where a and b are real numbers.

5. (a) Given the function $f(x) = -\sqrt{2-x}$,

(i) State the domain of f(x)

(ii) State the range of f(x)

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

(iv) Find the solution set of the inequality $f(x) \ge 0$

(b) (i) Given that $y = \sec x + \tan x$,

Prove that $\frac{dy}{dx} - y\tan x = 1$.

(ii) Evaluate $\lim_{x\to 3} \frac{x^3-27}{x^2-9}$

(c) Let $f(x) = \frac{2x+1}{x-1}$.

(i) Find the domain of f(x).

(ii) Find the range of f(x).

(iii) Find the vertical and horizontal asymptotes (if any).

6. (a) Let $f(x) = -|3x+1| + 2$.

(i) Sketch the graph of the function f(x).

(ii) Find the points at which the graph cuts the x-axis.

(iv) Find the range of values of x for which $|3x+1| - 2 \leq 0$.

(b) The complex numbers z_1 *and* z_2 are given by:

$z_1 = 24 + 7i$, $z_2 = 4 - 3i$

(i) Given that $z_1 + \alpha z_2$ is real, where α is real , find the value of α .

(ii) Given that $z_1 + (p+iq)z_2 = 0$, where p and q are real numbers find p and q.

(c) Let $(x-2)$ be a factor of $f(x)$ where $f(x) = x^3 - x^2 + Ax + B$.

(i) Find an equation satisfied by the constants A and B

(ii) Given further that when f(x) is divided by x-3 the remainder is 10, find a second equation satisfied by A and B.

(iii) find the values of A and B

(iv) Using your values of A and B solve the equation $f(x) = 0$.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

UNIVERSITY SEMESETER I EXAMINATIONS- 2009

M114 – MATHEMATICAL METHODS II -B

INSTRUCTIONS:
1. Answer any **four (4)** questions.
2. All questions carry equal marks.
3. Show all the necessary work to earn full marks.
4. Write down the questions attempted in one of the columns on the front page of the main booklet.
5. Use of calculators is **not** allowed.

TIME ALLOWED: Three (3) hours.

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1. **(a)** By using the substitution $t = \tan\frac{1}{2}x$, prove that

(i) $\cos ec x = \frac{1+t^2}{2}$ and $\cot x = \frac{1-t^2}{2t}$

(ii) Use the result that $\cos ec x - \cot x = \tan\frac{1}{2}x$, show that $\tan 15^0 = 2 - \sqrt{k}$, and state the value of k,

(b) The function f is defined for all real x by $f(x) = \cos x^0 - \sqrt{3}\sin x^0$

(i) Express $f(x)$ in the form $R\cos(x+\theta)^0$, where $R > 0$ and $0^0 < \theta < 90^0$

(ii) Solve the equation $|f(x)| = 1$ giving your answers in the interval $0^0 \le x \le 360^0$

(c) Find the equation of the tangent line to the curve $x^3 + y^3 = 2xy$ at the point $P(1, 1)$

(d) Find the value of k such that $4x^2 - 15xy + ky^2 = 0$ represents a pair of straight lines.

2 (a) Given the equation of the circles

$$x^2 + y^2 - 6x + 7 = 0 \text{ and } x^2 + y^2 + 2x - 8y - 1 = 0$$

(i) Show that the circles touch externally.
(ii) Find the coordinates of their point of contact.
(iii) Find the equation of their common tangent.

(b) $\underset{\sim}{a} = 3i - 2j - k$, $\underset{\sim}{b} = 3i - 5j + 2k$ and $\underset{\sim}{c} = i + pj + qk$,

(i) Find the angle between $\underset{\sim}{a}$ and $\underset{\sim}{b}$
(ii) Find the constants p and q given that $\underset{\sim}{c}$ is perpendicular to $\underset{\sim}{a}$ and $\underset{\sim}{c}$ is perpendicular to $\underset{\sim}{b}$
(iii) Using values of p and q found in (ii), find a unit vector perpendicular to both $\underset{\sim}{a}$ and $\underset{\sim}{c}$

(c) Given the equation of the curve $f(x) = \frac{1}{3}x^3 - 2x^2 + 3x$

(i) Find the x and y intercepts
(ii) Find the stationary points.
(iii) Test the nature of the stationary points
(iv) Find if any the point(s) of inflection.
(v) Sketch the graph of the curve labeling all the necessary features.

(d) Evaluate $\int_{\ln 2}^{\ln 3} e^{3x}\, dx$

3 (a) A square cardboard ABCD is of side 8 meters. A square of x meters is removed from each of corners and the remainder is folded to form an open tray of depth x meters and volume V metres^3

(i) Show that $V = 64x - 32x^2 + 4x^3$

(ii) Find the value of x for which $\frac{dV}{dx} = 0$

(iii) Show that the value of x gives the maximum value of V

(iv) Find this maximum value of V.

(b) Find the area A of the region in the XY plane bounded by the graphs of $2y = 16 - x^2$ and $x + 2y = 4$

(c)

(i) Find $r > 0$ and θ given that $rcis\theta = (-\sqrt{3} - i)^8$.

(ii) Show that $\sinh^{-1} x = \ln(x + \sqrt{x^2 + 1})$

(d)

(i) Find $\int e^{3x} \sqrt{1 + e^{3x}}\, dx$

(ii) Show that $\frac{d}{dx}\left[\sin^{-1}(\cos x)\right] = -1$

4 (a) Discuss and sketch the graph of the equation labeling the direct ices, center and focus (foci)

$$9x^2 + y^2 - 36x + 8y + 43 = 0$$

(b) Find the inverse of the matrix

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

and hence solve using the **inverse method** the system of equations

$$\begin{aligned} x + z &= 3 \\ -2x + 2y + z &= 2 \\ x + y + 2z &= 4 \end{aligned}$$

(c) A spherical balloon is blown up so that its radius increases at a constant rate of $0.01\,\text{cm s}^{-1}$. Find the rate of increase in the volume when the radius is 5cm.

5 (a) Prove by mathematical induction that for all positive integers $n \geq 1$

$$5^{2n} - 1 \text{ is divisible by } 24$$

(b) In the binomial expansion of $\left(1 + \frac{x}{n}\right)^n$ in ascending powers of x , the coefficient of x^2 is $\frac{7}{16}$. Given that n is a positive integer,

(i) Find the value of n.

(ii) Evaluate the coefficient of x^3 the expansion.

(c) Solve for x the equation
$4\cosh x + 8\sinh x = 1$
for all real values of x giving the root as a natural logarithm.

(d)

(i) Evaluate $\int_0^1 \frac{x^2 - 1}{(x^3 - 3x + 1)^6}\,dx$

(ii) Find $\int x e^x \, dx$

END OF EXAMINATION

2 (a) (i) Find the values of x which satisfy the following inequality:

$$x^3 - 3x^2 \leq 10x$$

(ii) Find the integer value of:

$${}^6C_0 \ + \ {}^6C_2 \ + \ {}^6C_6$$

(b) (i) Given that $x^3 - 4x^2 - 3x + 10 = (x-1)(x+2)(x-c) + px + q$, find the value of p, of q and of c.

(ii) Write in the form $A + B\sqrt{C}$, where A, B and C are integers:

$$\left(2\sqrt{5}+1\right)\left(3\sqrt{5}-2\right)$$

(c) (i) Express as a single term in its lowest terms:

$$\frac{2}{2x-1} - \frac{1}{2x+1} - \frac{2}{4x^2-1}$$

(ii) Express in terms of $\log_a x$, $\log_a y$ and $\log_a z$:

$$\log_a\left(\frac{x^3 y}{z^6}\right)$$

3 (a) (i) Given the function $f(x) = \dfrac{3x+1}{x-3}$ $\quad x \neq 3$,

find $(f \circ f)^{-1}$ (2)

(ii) How many different four – digit numbers can made from the digits

3 , 4 , 5 , 6, 7, 8

if no digit may be repeated?

(b) (i) Let the universal set E, be the set of letters in the English alphabet such that

$$A = \{ b, r, e, a, k, f, s, t \}$$
$$B = \{ l, u, n, c, h \}$$
$$C = \{ s, u, p, e, r \}$$

Find $(A \cap C) \cap (B' \cap C)$

3 (b) (ii) Find the value of p if the equation

$$x^2 + (p-2)x + 10 - p = 0$$

has equal roots.

(c) Solve for x such that:

(i) $\sqrt{x+5} - 2 = \sqrt{x-7}$

(ii) $4^{2x-1} = \left(\frac{1}{16}\right)^{1+x}$

4 (a) Given $f(x) = x^3 + x^2 - 3x + 1$,

(i) Express $f(x)$ as a product of a linear function and a quadratic function

Hence,

(ii) Resolve into partial fractions $\dfrac{3x+1}{x^3+x^2-3x+1}$.

(b) Find the positive integer n such that

(i) $\left(2+\sqrt{2}\right)^3 + \left(2-\sqrt{2}\right)^3 = n$

(ii) $\binom{n}{2} = 15$

(c) (i) Express in the form $\frac{a}{b}$ where a, b are integers and $b \neq 0$:

1. 3222222222.........

(ii) If α and β are roots of the quadratic equation $x^2 + 3x - 2 = 0$,
find the value of $\dfrac{1}{\alpha^2} + \dfrac{1}{\beta^2}$

5 (a) The polynomial $P(x) = 2x^3 + ax^2 + bx + 6$ is a exactly divisible by $x-2$ and on division by $x+1$ leaves a remainder -12.

(i) Calculate the values of a and b.

(ii) Using the values found in (i), solve $f(x) = 0$

(b) (i) Find the real values of x and y when :

$$\frac{x}{1-i} + \frac{y}{1+3i} = 2$$

(ii) Solve the simultaneous equations

$$x - y = 21$$
$$\log x + \log y = 2$$

(c) (i) Evaluate :

$$\frac{1}{\log_2 36} + \frac{1}{\log_3 36}$$

(ii) Solve the inequality:

$$\frac{3x}{x-1} > x$$

END OF EXAMINATION

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

2008 ACADEMIC YEAR
FIRST SEMESTER FINAL EXAMINATIONS

M 211 - MATHEMATICAL METHODS III

<u>**INSTRUCTIONS**</u>:
1. Answer any **Five (5)** of the seven Questions only.
2. Show all essential working to obtain full marks.
3. Indicate the question number for each question attempted on the cover main answer booklet.
4. All questions carry equal marks.

TIME ALLOWED: Three (3) hours

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1. The equation of the conic section is given by

$$x^2 + xy + y^2 = 6.$$

(a) Transform the equation in standard form, and hence, identify the curve.

(b) Find its vertex (or vertices), focus (or foci) and the directrix (or directrices).

Hence,

(c) sketch the curve.

2. (a) Identify the conic section

$$r = \frac{6}{3 - 4\cos\theta},$$

and give its eccentricity and distance of the directrix from the origin. Hence, sketch the conic, indicating the position one of the foci, the x and y - intercepts and the directrix.

(b) The position of a planet in elliptical orbit around the sun is given by the polar equation

$$r = \frac{k}{1 + e\cos\theta},$$

for some value of the eccentricity e. Find
(i) the distance when the planet is closest to a sun;
(ii) the distance when the planet is furthest from the sun;
(iii) hence, show that

$$r = \frac{a(1-e^2)}{1 + e\cos\theta},$$

where a, is the length of the semi-major axis of the elliptic path.

(c) A satellite elliptically orbits around the earth (radius $\approx$ 6360 km) so that the maximum distance from the satellite is 20,000 km and minimum distance is 10,000 km. Find the eccentricity of the orbit and give a polar formula for this position.

3. (a) Evaluate the limit if it exists:

(i) $\lim\limits_{x \to 2} \dfrac{x^3 - 8}{x - 2}$

(ii) $\lim\limits_{x \to \infty} \dfrac{\ln(1 + e^{3x})}{x}$

(iii) $\lim\limits_{x \to \infty} (1 + x^2)^{5/x^2}$.

(b) Find the curvature and the radius of curvature of the curve

$$2xy + x + y = 4,$$

at the point (1,1).

(c) Given that the arc length is measured from the point $(0, \frac{1}{4})$, find the intrinsic equation of the curve with Cartesian equation $4y = \cosh 4x$.

4. (a) (i) Define the continuity of a function $f(x)$ at a point $x = a$.

(ii) State Rolle's theorem.

(iii) State the Mean Value theorem.

(b) (i) Find the value of c prescribed in the Rolle's theorem for the function

$$f(x) = x^3 - 12x$$

on the interval $0 \le x \le 2\sqrt{3}$.

(ii) Use the Mean value theorem to approximate $\sqrt[6]{65}$

(c) Use the linearization method to approximate the value of $\dfrac{1.05}{0.95}$.

5. Evaluate the integrals:

(a) $\displaystyle\int \frac{(x+3)}{(x^2+6x)^{1/3}}\,dx$

(b) $\displaystyle\int \frac{1}{1+\sin x - \cos x}\,dx$

(c) Find the volume generated by revolving the plane within the curve $4x^2 + 9y^2 = 36$ about the x – axis.

6. (a) At every point of a certain curve, $y'' = x^2 - 1$. Find the equation of the curve if it passes through the point $(1,1)$ and is tangent to the line $x + 12y = 13$ at the point.

(b) Evaluate $\displaystyle\int_{\theta=0}^{\theta=2\pi} y\,dx$, given that $x = \theta - \sin\theta$, $y = 1 - \cos\theta$.

(c) Find the area of the surface of revolution generated by revolving about the x – axis the arc of the parabola $y^2 = 12x$, from $x = 0$ to $x = 3$.

7. Evaluate

(a) $\int \ln(1+x^2)\,dx$

(b) $\int_3^5 \frac{dx}{\sqrt{x^2+16}}$.

(c) Find the length of the arc of the curve $x=t^2$, $y=t^3$ from $t=0$ to $t=4$.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
DEPARTMENT OF MATHEMATICS AND STATISTICS

SEMESETER I EXAMINATIONS - 2008
DISTANCE EDUCATION
M211 – MATHEMATICAL METHODS III

INSTRUCTIONS:
1. Answer any **four (4)** questions.
2. All questions carry equal marks.
3. Show all the necessary work to earn full marks.
4. Write down the questions attempted on the front page of the main booklet.
5. Use of calculators is **not** allowed.

TIME ALLOWED: Three **(3)** hours.

1. (a) Given the function $f(x) = \ln x - \frac{1}{8}x^2$, find a and b given that

$$\sqrt{1+\left[f'(x)\right]^2} = \frac{a}{x} + \frac{x}{b}$$

(b) Show that the polar equation of the hyperbola

$$\frac{x^2}{a^2} - \frac{y^2}{b^2} = 1 \quad \text{is} \quad r^2 = \frac{-b^2}{1-e^2\cos^2\theta}$$

(c) Consider the polar equation of the conic given by,

$$r = \frac{6}{3+2\cos\theta},$$

(i) Identify the conic
(ii) Discuss the conic stating its focus, vertex and directrix
(iii) Sketch the curve stating clearly the points of intercepts.

2. (a) Given the equation

$$xy = 1$$

(i) Identify the conic given by this equation.
(ii) Use a suitable rotation of axes to find an equation for the graph in an $X'Y'$ plane.
(iii) Sketch the graph labeling vertices.

(b) Let $f(x) = \begin{cases} x+1, & x < -1 \\ (x+1)^2, & x \geq -1 \end{cases}$

(i) Determine whether f is continuous at $x = -1$
(ii) Sketch the graph of f

2 (c) Find $\lim_{x\to+\infty} \dfrac{x^2+1}{x\sqrt{3x^2+1}}$

3 (a) Evaluate $\lim_{x\to 0+} \left(\dfrac{1}{x} - \dfrac{1}{\tan^{-1} x}\right)$

(b) If $f(x) = x^3 - 8x - 5$

(i) Show that f satisfies the hypothesis of the mean value theorem on the interval $[1, 4]$.

(ii) Hence find the number c in the open interval $(1, 4)$ that satisfies the conclusion of the theorem.

(c) Find two pints on the graph of the equation

$$x^2 - xy + y^2 = 4$$

at which the slope of the tangent line is 1.

4 (a) Let $f(x) = \ln(1+x)$

(i) Find a formula for the $4th$ Taylor polynomial of f about 0.

(ii) Hence calculate $p_4(1)$.

(b) (i) Find $\displaystyle\int \frac{1}{x^2\sqrt{x^2+1}}\,dx$

(ii) Given that $f(x) = \sqrt{a^2 - x^2}$ where $-\pi \le x \le \pi$, find the volume of generated by the function when rotated about the x-axis.

5 (a) Evaluate the integral:

(i) $\displaystyle\int (2x + 9x^3)\sqrt{1 + 4x^2 + 9x^4}\,dx$

(ii) $\displaystyle\int \tan x \sin^2 x \cos^5 x\,dx$

(b) Find the curvature of the function $y = \sin x$ at the point $T\left(\dfrac{\pi}{2}, 1\right)$

(c) Given the graphs of the curves

$y = e^x$ and $y = \sqrt{x}$ for $x \ge 0$,

(i) sketch on the same diagram, the graphs of the curves.

(ii) shade the area A, the area bounded by the two curves and the lines $x = 0$ and $x = 1$.

(iii) Hence, find the area A

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

Department of Mathematics and Statistics

2008 ACADEMIC YEAR

FIRST SEMESTER FINAL EXAMINATIONS

M221: LINEAR ALGEBRA I

Time allowed: Three (3) hours

Instructions: (i) Answer any **Five** (5) Questions
(ii) Show all Essential Working

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1. (a) Let A and B be m by n matrices. What is meant by the following terms;

(i) A is an echelon matrix
(ii) A and B are row equivalent

(b) Find the reduced row-echelon matrix of the matrix

$$\begin{pmatrix} \frac{2}{\sqrt{3}} & 0 & \sqrt{12} \\ 1 & 1 & -2 \\ -3 & 1 & 2 \end{pmatrix}.$$

(c) (i) Find the value(s) of λ for which a system of linear equations with coefficient matrix

$$\begin{pmatrix} 1 & 0 & 1 \\ 4 & \lambda & 4 \\ 3 & 1 & \lambda \end{pmatrix}$$

is solvable by Cramer's rule.

(ii) If (α_1, α_2) and (β_1, β_2) are solutions of a system of linear equations, show that $((1-t)\alpha_1 + t\beta_1, (1-t)\alpha_2 + t\beta_2)$ is also a solution of the system.

2. (a) Define the following terms;

(i) A symmetric matrix M.
(ii) The normal form of an m by n matrix A.

(b) (i) Express the matrix $\begin{pmatrix} 1 & \pi & 2 \\ -1 & \pi & 0 \\ \frac{1}{2} & 4 & -5 \end{pmatrix}$ as a sum of a symmetric and a skew-symmetric matrix.

(ii) Let A be an n by n matrix. Show that A is invertible if and only if the homogenous system $Ax = 0$ of n linear equations in n variables $x_1, x_2, \cdots, x_n$ has no non-trivial solution.

(c) (i) Find the adjoint of the matrix $\begin{pmatrix} 2 & 1 & 3 \\ 4 & 1 & 4 \\ 3 & 1 & 2 \end{pmatrix}$.

(ii) Hence solve the system of linear equations

$$\begin{aligned} 2x + y + 3z &= 4 \\ 4x + y + 4z &= 1 \\ 3x + y + 2z &= 0 \end{aligned}$$

3. (a) Define the following;

(i) An orthogonal matrix
(ii) A skew-symmetric matrix

(b) If A and B are non-singular matrices, and if $(AB)^{-1} = C$ show that $C = B^{-1}A^{-1}$.

(c) (i) Evaluate the determinant $\begin{vmatrix} a & b \\ c & 1 \end{vmatrix}$. Hence find the values of the determinant if a, b and c are the cube roots of unity.

(ii) If A and B are orthogonal matrices, $AB = BA$ and $BA^t + AB^t = -I$, show that $A + B$ is also orthogonal.

4. (a) Define the following

(i) A consistent system of linear equations
(ii) An upper triangular matrix

(b) (i) If a matrix A satisfies the equation $3A^2 - A = 5I$, show that A is invertible and $A^{-1} = \frac{1}{5}(3A - I)$.

(ii) Prove that the inverse of a matrix is unique.

(c) (i) Solve the following system of linear equations over the field $\mathbb{R}$ using elementary row operations.

$$\begin{aligned} 2x + y + 3z &= 4 \\ 4x + y + 4z &= 1 \\ 3x + y + 2z &= 0 \end{aligned}$$

(ii) Find a matrix A such that $X^tAX = 3I_2$, for $X = \begin{pmatrix} 1 & 0 \\ -1 & 1 \end{pmatrix}$.

5. (a) Define each of the following terms

(i) a subspace U of a vector space V
(ii) a basis of a subspace U of a vector space V

(b) Show that a subset U of $V_4(\mathbb{R})$ which is given by

$$U = \{(a, b, c) : a + b + c = 0\}$$

is a subspace of $V_4(\mathbb{R})$.

(c) Find an $\mathbb{R}$-basis for a subspace U of $V_4(\mathbb{R})$ which is generated by the vectors

$$v_1 = (1, 1, 1, 1),\ v_2 = (0, 1, 1, 1),\ v_3 = (0, 0, 1, 1),\ v_4 = (0, 0, 0, 1).$$

6. (a) Define each of the following terms

(i) the kernel $ker\ T$ of a linear transformation T
(ii) the image $Im\ T$ of a linear transformation T

(b) Prove that if $T : U \to V$ is a linear transformation, then the kernel $ker\ T$ and the image $Im\ T$ are subspaces of U and V respectively

(c) Given that $T : V_4(\mathbb{R}) \to V_3(\mathbb{R})$ is a linear transformation defined by

$$T(r, s, t, u) = (r - s + t + u, r + 2t - u, r + s + 3t - 3u),$$

find a basis and dimension of the image of T and of the kernel of T

7. (a) Define the following terms,

(i) the rank of a linear transformation $T : U \to V$
(ii) a non-singular linear transformation

(b) Show that a linear transformation T given by

$$T(x, y, z) = (2x, 4x - y, 2x + 3y - z)$$

is non-singular. Hence determine $rank\ T$

(c) If $T : V_3(\mathbb{R}) \to V_3(\mathbb{R})$ is defined as in question 7(b) above, find the formula for T^{-1}.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

UNIVERSITY FIRST SEMESTER EXAMINATIONS

28th NOVEMBER 2008

M231 - REAL ANALYSIS I

INSTRUCTIONS

1. Answer any **five(5)** questions.
2. All questions carry equal marks.

TIME ALLOWED: Three (3) hours

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1. (a) i. Using quantifiers, state the following sentence: " for every x there exists y such that $|x - y| < 2$"
   ii. Negate the sentence in 1(a)i above.

   (b) Let P and Q be truth-functional forms. Write down the truth-tables for the following:
   i. $\neg(P \text{ or } Q)$
   ii. $P \Rightarrow Q$

   (c) i. Let A and B be truth functional forms. When is A logically equivalent to B ?
   ii. Using the definition in (c) (i) above, show that $p \Leftrightarrow q$ is logically equivalent to $(p \;\&\; q)$ or $(\neg p \;\&\; \neg q)$.

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2. (a) i. Define a set.
   ii. Let A be a set. Define a sequence in A.

   (b) Let A , B and C be sets. Suppose $A \subset B$ and $B \subset C$. Prove that $A \subset C$.

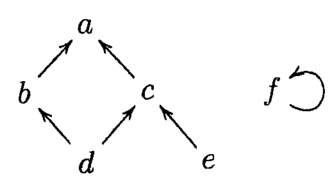
   (c) Let A and B be non-empty sets and $f \subset A \times B$ be a function. Prove that f^{-1} is a function if and only if f is a bijection.

---

3. (a) Define the following:
   i. the smallest element b in a subset S of a partially ordered set P.
   ii. a segment $S(a)$ determined by an element a in a partially ordered set P.

   (b) i. Let P be a partially ordered set and $S \subset P$. Prove that the smallest element a of S is unique.
   ii. Let P be a partially ordered set, show that both the empty set $\emptyset$ and the singleton set $\{x\}$ where $x \in P$ are totally ordered.

   (c) Let $X = \{a, b, c, d, e, f\}$ with elements related as follows:



   where for each $x_1, x_2 \in X$, $x_1 \to x_2$ implies $x_1 \leq x_2$.
   i. Find all the minimal elements of X.
   ii. Find all the maximal elements of X.

---

4. (a) Define the following:
   i. an order preserving function.
   ii. a well ordered set.

   (b) i. Prove that every subset of a well ordered set is well ordered.
   ii. Let P_1, P_2, P_3 be partially ordered sets, $f : P_1 \to P_2$ and $g : P_2 \to P_3$ be order preserving functions. Prove that the composite $g \circ f : P_1 \to P_3$ is order preserving.
   iii. Prove that if W is a well ordered set, then it is totally ordered.

   (c) Show that the function $f : \mathbb{R} \to \mathbb{R}$ defined by $f(x) = \pi x + 10$ is order preserving.

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5. (a) Define the following:
   i. a countable set.
   ii. an infinite set.

   (b) i. Let A and B be sets. Prove that if A is finite, then $A \cap B$ is finite.
   ii. Prove that the set $\mathbb{N}$ of natural numbers is infinite.

   (c) i. Let 4 and 7 be ordinal numbers. Prove that 4 is less than or equal 7.
   ii. Let $a, b, c, d \in \mathbb{R}$, with $0 < a < b$ and $0 < c < d$. show that the open intervals (a, b) and (c, d) are equivalent.

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6. (a) Define the following:
    i. a mathematical structure called field.
    ii. a totally ordered field.

   (b) Given that the set of real numbers $\mathbb{R}$, is a totally ordered field. Prove that if $a \in \mathbb{R}$ then $a^2 = 0 \Rightarrow a = 0$.

   (c) Let $(\mathbb{F}, +, \cdot, P)$ be a totally ordered field. Prove that if $x \in P$ then $x^{-1} \in P$ and deduce that $1 \in P$.

---

7. (a) i. Let $(\mathbb{F}, +, \cdot, P)$ be a totally ordered field. What does $x < y$ mean and what does $x \leq y$ mean?
    ii. Assume that the set of real numbers $\mathbb{R}$ is a totally ordered field. If $a \in \mathbb{R}$, define the absolute value, $|a|$, of a.

   (b) Prove the following:
    i. If $a \in \mathbb{R}, |a| = 0 \Leftrightarrow a = 0$
    ii. $\forall\ a \in \mathbb{R}, |-a| = |a|$
    iii. $a, b \in \mathbb{R}, |a \cdot b| = |a| \cdot |b|$
    iv. $a, c \in \mathbb{R}, c \geq 0, |a| \leq c \Leftrightarrow -c \leq a \leq c$

■ END OF EXAM ■

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2008 ACADEMIC YEAR
FIRST SEMESTER EXAMINATIONS

M261 INTRODUCTION TO STATISTICS

Time Allowed: Three (3) Hours

Instructions:
1. Answer any Five (5) Questions
2. Show All Essential Working
3. Statistical Tables will be provided
4. Calculators are Allowed

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1. (a) Define the following:
   (i) a statistic
   (ii) inferential statistics

   (b) A psychologist observed reaction times to a stimulus and recorded the following 40 reaction times, in seconds:

2.7	3.1	4.0	3.3	3.6	2.1	1.3	2.2	3.7	3.7
3.7	3.4	3.4	3.3	2.9	2.3	3.3	4.5	3.1	3.5
2.6	3.0	3.3	2.4	0.9	1.5	2.7	2.7	2.6	2.3
1.3	1.7	2.2	3.2	2.8	3.1	3.4	2.6	1.7	2.5

   (i) Construct a grouped frequency distribution table for the reaction times using the classes 0.5 – 0.9, 1.0 – 1.4,...
   (ii) Using the same classes in (i) above, construct a histogram and a frequency polygon on the same graph.
   (iii) Describe the distribution of the reaction times.

   (c) At a city high school, past records indicate that maths scores have a normal distribution with a mean of 51 and a standard deviation of 9. If 100 pupils in the high school are to take the test, find the probability that the
   (i) score of one randomly selected pupil exceeds 72.
   (ii) mean score of the pupils is between 49 and 52.

2. (a) Define the following:
   (i) a stratified sample
   (ii) a sampling distribution

(b) The following data represent weights (in kg) of 30 passengers on a bus.

45	32	19	51	37	55	40	23	48	9
60	35	44	58	37	15	53	78	47	40
65	50	25	75	53	45	61	34	63	46

   (i) Represent the data on an ordered stem and leaf plot.
   (ii) Construct a boxplot for the data. Which of these data values are outliers, if any?

(c) Light bulbs made by an electrical firm have a length of life that is normally distributed with a standard deviation of 30 hours. A sample of 25 bulbs has an average life of 600 hours.
   (i) Construct a 99% confidence interval for the mean life of all light bulbs produced by the firm.
   (ii) Explain the meaning of the confidence interval in (i).
   (iii) How large a sample is needed if we wish to be 95% confident that our sample mean will be within 5 hours of the true mean?

3. (a) Define the following:
   (i) a type II error
   (ii) a random sample

(b) A plant manager claims that the mean number of calories per 10g can of tomato paste is 150. A random sample of 100 cans gave a standard deviation of 20 calories. A weight watchers group thought that the mean was larger than 150 and decides that the claim be rejected if the sample mean is greater than 155.
   (i) Find the probability of committing a type I error if the claim is true.
   (ii) Find the probability of committing a type II error if the true mean number of calories is 159.
   (iii) Explain the meaning of committing a type II error in this context.

(c) An astronaut believes that the mean launch temperature of successful space shuttle flights exceeds that of unsuccessful shuttle flights by $5^0 C$. The following results were obtained based on 23 shuttle flights:

	sample size	mean launch temperature	standard deviation
Unsuccessful flights	7	63.71	8.16
Successful flights	16	72.13	4.84

Assuming that the launch temperatures are normally distributed with equal variances test the astronaut's belief. Use a 10% level of significance.

4. (a) The Speedy oil change company advertised a 15-minute wait for an oil change. A sample of 23 oil changes showed a mean time of 16.5 minutes and a standard deviation of 4.3 minutes. Assume the population is approximately normal.

   (i) At the 5% level of significance, is there sufficient evidence that the mean time for an oil change is different from 15 minutes?

   (ii) Calculate a 95% confidence interval for the standard deviation of oil change times.

(b) An experiment was conducted to compare yields of 4 varieties of maize using 12 equal plots on 3 farms. The following results were obtained:

		Farm			Total
		1	2	3	
Variety	A	45	43	51	139
	B	47	46	52	145
	C	48	50	55	153
	D	42	37	49	128
Total		182	176	207	565

(Hint: You may use $\sum_{i=1}^{4}\sum_{j=1}^{3} y_{ij}^2 = 26867$)

(i) What design is used in the experiment?

(ii) Write down a model for the above design. Explain all the terms in your model. State all the assumptions.

(iii) Are the maize varieties significantly different? Test at the 0.01 level of significance.

5. (a) A committee was formed to study traffic conditions in an industrial complex. The committee wanted to see whether the modes of transportation used to get to work changed over a period of 5 years. Five years before, 70% of the workers used public transportation, 20% used company transportation, 8% used personal vehicles and the rest used other modes. The committee obtained the following information from a sample of 500 workers.

Transportation mode	Number of people
Public transport	320
Company transport	130
Personal vehicle	35
Other means	15

Is there sufficient evidence to indicate that the modes of transportation used to get to work have changed? Use $\alpha = 0.05$.

(b) The following table shows how many weeks a sample of six persons have worked at a car inspection station and the number of cars one inspected between noon and 2pm on a given day.

Number of weeks employed (x)	2	7	9	1	5	12
Number of cars inspected (y)	13	21	23	14	15	21

(Hint: You may use the following summary statistics:
$\sum_{i=1}^{6} x_i = 36$, $\sum_{i=1}^{6} x_i^2 = 304$, $\sum_{i=1}^{6} y_i = 107$, $\sum_{i=1}^{6} y_i^2 = 2001$, $\sum_{i=1}^{6} x_i y_i = 721$)

(i) Find the simple linear regression equation.
(ii) Interpret the estimated parameter(s) in (i) above.
(iii) Copy and complete the following ANOVA table.

Source of variation	Sum of squares (SS)	Degrees of freedom (df)	Mean square (MS)	F*
Regression Error			 5.4782	
Total				

(iv) Is there a significant linear relationship between the number of weeks employed and the number of cars inspected?

6. (a) (i) Define and state three causes of response bias.
(ii) Define a cluster sample.

(b) A physician claims that a new exercise programme reduces a person's waist size by 2cm on the average over a 5-day period. The waist size of 6 men who participated in this exercise programme are recorded before and after the 5-day period and the following results are obtained:

Waist size before	90.4	95.5	98.7	115.9	104.0	85.6
Waist size after	91.7	93.9	97.4	112.8	101.3	84.0

(i) Construct a 99% confidence interval for the mean waist size difference. Is the claim valid?
(ii) State the assumption(s) required for your answer in (i) to be valid.

(c) To determine whether there really is a relationship between an employee's performance in a company's training programme and his or her ultimate success in the job, a sample of 400 cases was taken and the following results were obtained:

		Performance in training programme			Total
		Below average	Average	Above average	
Success in job	Poor	37	100	59	196
	Good	23	88	93	204
Total		60	188	152	400

Are performance in the training programme and success in the job independent? Use a 0.01 level of significance.

END OF EXAMINATION

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

2008 ACADEMIN YEAR
FISRT SEMESTER FINAL EXAMINATIONS

M331 - REAL ANALYSIS III

INSTRUCTIONS: Answer any **five** questions.

TIME ALLOWED: Three (**3**) hours.

Q1. (a) Let $A \subset \mathbf{R}$. What is meant by each of the following:

(i) Neighbourhood of a point $x \in A$;
(ii) Interior point of A;.
(iii) Open set.

(b) Prove each of the following:

(i) Let $A \subset \mathbf{R}$. Prove that the interior of A is open.
(ii) Every open set G is a union of open intervals.
(iii) A set G is open if and only if $G^o = G$.

(c) Find interior of each of the following sets:

(i) $\{x \in \mathbf{R} : -2 \leq x \leq 2\}$
(ii) $\{x \in \mathbf{R} : |x| < 3\}$
(iii) $(-1,4) \cup [5,7)$

Q2. (a) Define each of the following:

(i) Limit point of a set.
(ii) Closed set
(iii) Closure of a set

(b) Prove each of the following:
(i) The closure of a set $X \subset \mathbf{R}$ is closed.
(ii) If $G \subseteq \mathbf{R}$ is open and $F \subseteq \mathbf{R}$ is closed, then $G - F$ is open and $F - G$ is closed.

(c) Prove that G is open if and only if $x \in G \Rightarrow x \notin \overline{G^c}$.

Q3. (a) What is meant by the each of the following:

(i) Open cover of a set $E \subset \mathbf{R}$;
(ii) A set $K \subset \mathbf{R}$ is compact;
(iii) Two sets A and B are separated.

(b) Prove each of the following:

(i) Every subset of a compact set is compact.
(ii) If the sets A and B are separated and $A \cup B$ is closed, then A and B are closed.

(c) (i) Prove that if $\{I_n\}_{n=1}^{\infty}$ is a sequence of closed intervals, $I_n = [a_n, b_n], \forall n \in \mathbf{N}$, such that $I_{n+1} \subset I_n$, then $\bigcap_{n \in \mathbf{N}} I_n \neq \phi$, and
(ii) if in addition $\lim_{n \to \infty}(b_n - a_n) = 0$ then $\exists x \in \mathbf{R} \ni \{x\} = \bigcap_{n \in \mathbf{N}} I_n$.

Q4. (a) Define each of the following:

(i) Continuity of a function at a point.
(ii) Uniform continuity of a function on $I \subset \mathbf{R}$.

(b) Prove that if f is a continuous mapping and E is a compact set, then $f(E)$ is compact.

(c) Determine whether the function $f(x) = x^2 \sin \frac{1}{x^2}$, $x \neq 0$ and $f(x) = 0$, $x = 0$

is (i) continuous on (-1,1),
(ii) uniformly continuous on (-1,1).

Q5. (a) Define each of the following:

(i) pointwise convergence of a sequence of real valued functions;
(ii) uniform convergence of a sequence of real valued functions.

(b) Let $\{f_n\}_{n=1}^{\infty}$ be a sequence of functions such that for all $x \in I \subset \mathbf{R}$ $\lim_{n \to \infty} f_n(x) = f(x)$ and if $M_n = \operatorname{lub}_{x \in I} |f_n(x) - f(x)|$. Prove that $\{f_n\}_{n=1}^{\infty}$ converges uniformly to f if and only if $\lim_{n \to \infty} M_n = 0$.

(c) If $f_n(x) = \frac{x^n}{n}$ in $0 < x < 1$, prove that (f_n) converges uniformly in [0,1].

Q6. (a) Define each of the following:

(i) pointwise convergence of series of real valued functions;
(ii) uniform convergence of series of real valued functions.

(b) Prove

(i) If $\{f_n\}_{n=1}^{\infty}$ is a sequence of real valued functions and $|f_k(x)| \le M_k$ for all $x \in I \subset \mathbf{R}$ for $k = 1,2,3,\ldots$ and if the series of non-negative constants $\sum_{k=1}^{\infty} M_k$ converges, then $\sum_{k=1}^{n} f_k(x)$ converges uniformly on I.

(ii) If $\{f_n\}_{n=1}^{\infty}$ is a sequence of functions on the interval $I \subset \mathbf{R}$ which converges uniformly to f on I, then f is continuous on I.

(c) Show that $\sum_{k=1}^{\infty} \frac{x^n}{n!}$ converges to a continuous function on $I \subset \mathbf{R}$ for $[-1,1]$.

Q7. (a) When is a function said to be

(i) strictly monotonically increasing on an interval $I \subset \mathbf{R}$
(ii) monotonically decreasing on an interval $I \subset \mathbf{R}$
(iii) of bounded variation on $[a, b]$?

(b) Prove each of the following:

(i) If a function f is continuous and strictly monotonic with domain $[a, b]$ and has an inverse function g, then g is continuous.

(ii) A function f of bounded variation over $[a, b]$ is necessarily bounded.

(c) Let f be a function of bounded variation over [a, b]. Show that the variation function $V(x) = V_f(a,x)$ is monotonically increasing on $[a, b]$.

END OF EXAMINATION

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

2008 ACADEMIC YEAR
FIRST SEMESTER FINAL EXAMINATIONS

M335 - TOPOLOGY

TIME ALLOWED: Three (3) hours.

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

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1. (a) Define the following:

   (i) An indexed family of sets.
   (ii) Image of a set under a function.
   (iii) A countable set.

   (b) Prove the following:

   (i) If $(X, \pounds_1)$ and $(X, \pounds_2)$ are topological spaces, and $f: X \to Y$ is a continuous function, then $f^{-1}(B)$ is closed in $\pounds_1$ wherever B is closed in $\pounds_2$.

   (ii) If M and N are neighbourhoods of a point x_0 in a topological space $(X, \pounds)$ then $M \cap N$ is also a neighbourhood of x_0.

   (iii) Every metric space is a Hausdorff space.

   (c) Let $X = \{a, b, c, d, e\}$, $A = \{a, b, c\}$, and
   $\pounds = \{\, \phi, \{a\}, \{a, b\}, \{a, c, d\}, \{a, b, c, d\}, \{a, b, e\}, X \,\}$

   Find the following:
   (i) Interior of A.
   (ii) Exterior points of A.
   (iii) The closure of A.

2. (a) Define the following:

   (i) A topology on a non-empty set X.
   (ii) Interior of a set in a topological space.
   (iii) A compact topological space.

(b) Prove the following:

(i) The intersection of any finite number of open sets in a metric space is open.

(ii) If (A, d) is a metric space then a subset E of A is open if and only if E is a union of open-spheres.

(iii) An open sphere in a metric space is an open set.

(c) (i) Let $X = \{1, 2\}$, show that X under the power set topology is locally connected.

(ii) Let (X, £) be a topological space where $X = \{a, b\}$ and $£ = \{ \phi, \{a\}, X \}$. Find some other topology $£^*$ on X, with $£^* \neq £$ such that the identity map $i : (X, £^*) \rightarrow (X, £\}$ is continuous.

3. (a) Define the following:
(i) Metric space.
(ii) An open sphere or open ball.
(iii) An open set in a metric space.

(b) Prove the following:

(i) If (X, £) is a topological space with A and B subsets of X, then $\text{int}(A \cap B) = \text{int}(A) \cap \text{int}(B)$.

(ii) If $£_1$ and $£_2$ are two topologies on a non-empty set X, then $£_1 \cap £_2$ is also a topology on X.

(iii) If X is connected, then the only subsets of X which are both open and closed are ϕ and X.

(c) Define $f : \mathbf{R} \rightarrow \mathbf{R}$ by $f(x) = \dfrac{1}{x+2}$

(i) What is the domain of f ?
(ii) What is the range of f ?
(iii) Find f(A), where $A = [-3, -1)$.
(iv) Find $f^{-1}(B)$, where $B = (-2, 1]$

4. (a) Define the following:

(i) A continuous function from one topological space to another.
(ii) A neighbourhood of a point in a topological space.
(iii) A connected topological space.

(b) Prove the following:

(i) The intersection of any collection of closed sets in a metric space is closed.

(ii) If (A, d) is a metric space, and x_0 is a limit point of E a subset of A, then every neighbourhood of x_0 contains infinitely many points of E.

(iii) A necessary and sufficient condition that two metric spaces (A, d) and (B, d^*) be metrically equivalent is that $\exists$ a function $f : A \to B$ such that f is bijective and for each pair $x, y \in A$. $d^*(f(x), f(y)) = d(x, y)$.

(c) (i) Let (A, d_1) and (A, d_2) be two metric spaces. Define $d(X,Y) = d_1(x_1, y_1) + d_2(x_2, y_2)$ for any pair $X, Y \in A^2$. Is (A^2, d) a metric space? Justify your answer.

(ii) Let $X = \{a, b, c, d, e\}$ and $£ = \{\phi, \{a\}, \{c, d\}, \{a, c, d\}, \{b, c, d, e\}, X\}$. Determine whether or not the subset $Z = \{b, d, e\}$ is connected.

5. (a) Define the following:

(i) Limit point of a set in a metric space.
(ii) A component of a topological space.
(iii) A Hausdorff space.

(b) Prove the following:

(i) Let $f : (X, £_x) \to (Y, £_y)$ be a continuous function, if A is a connected subset of X, then f(A) is a connected subset of Y.

(ii) Let $g : X \to Y$ be a continuous function and B be a compact subset of X, then g(B) is a compact subset of Y.

(iii) If $(Z, £_z)$ is a subspace (relative topological space) of a topological space $(X, £_x)$ then a subset D of Z is closed in the subspace if and only if $D = Z \cap F$, where F is a closed set in $(X, £_x)$.

(c) (i) Let $(\mathbf{R}^2, d)$ be a metric space where for any $P = (x, y)$ and $Q = (a, b)$ in $\mathbf{R}^2$, $d(P, Q) = |x - a| + |y - b|$. Let $P_0 = (-2, 1)$ and $r = 1$. Construct and display the open sphere $S_r(P_0)$.

(ii) State (without proof) the Heine-Borel theorem.

(iii) Let A be any finite subset of a topological space. Show that A is compact.

END OF EXAMINATION.

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

2008 ACADEMIC YEAR
FIRST SEMESTER FINAL EXAMINATIONS

M361 - MATHEMATICAL STATISTICS

TIME ALLOWED: Three (3) hours.

INSTRUCTIONS:
1. Answer any **four (4)** questions.
2. Full credit will only be given when the necessary working is shown.

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1. (a) Define the following terms:

   (i) Characteristic function of a random variable X.

   (ii) j^{th} order statistics.

   (iii) Jacobian of the transformation $(U, V) \to (X, Y)$ where $X = g_1(U, V)$ and $Y = g_2(U, V)$.

   (b) Prove the following:

   (i) If X and Y are independent random variables such that $X \sim g(\alpha, \lambda)$ and $Y \sim g(\beta, \lambda)$ then $X + Y \sim g(\alpha + \beta, \lambda)$.

   Note: If $Z \sim g(\theta, \lambda)$, then $f_Z(z, \theta, \lambda) = \dfrac{\lambda^{\theta} z^{\theta-1} e^{-\lambda z}}{\Gamma(\theta)}, \quad \begin{matrix} z > 0 \\ \theta > 0 \\ \lambda > 0 \end{matrix}$

   (ii) If the random variables $Y_1, Y_2, \ldots, Y_k$ are independent normally distributed with means μ_j's and variances σ^2_j's i.e. $Y_j \sim N(\mu_j, \sigma^2_j)$, then $Z = \sum_{j=1}^{k} \left(\dfrac{Y_j - \mu_j}{\sigma_j} \right)^2$ has chi-square distribution with k-degrees of freedom.

(c) Let $X_1, X_2, \dots, X_n$ be a random sample from Geometric distribution with pdf $f_X(x, \theta) = \theta(1-\theta)^{x-1}$, $x = 1, 2, 3, \dots$; $\theta \in (0, 1)$

(i) Construct the most powerful test of size α for testing $H_0: \theta = \theta_0$ vs $H_a: \theta = \theta_1$, where $\theta_0 > \theta_1$.

(ii) Does the geometric distribution posses a monotone likelihood ratio? Justify your answer.

2. (a) Define the following terms:

(i) Parameter space.
(ii) The estimate of $\tau(\theta)$.
(iii) Likelihood function.

(b) (i) Define the t-distribution (no density expression).

(ii) Define the f-distribution (no density expression).

(iii) Given that $X_1, X_2, \dots, X_n$ is a random sample from $N(\mu, \sigma^2)$. Derive the distribution of $\overline{X}$, the sample mean.

(c) Consider a random sample $X_1, X_2, \dots, X_n$ from the exponential distribution with probability density function

$$f_X(x, \theta) = \frac{1}{\theta} e^{-\frac{x}{\theta}}, \quad x > 0, \ \theta > 0$$

Let $\hat{\theta}_1 = \overline{X}$ and $\hat{\theta}_2 = \dfrac{n\overline{X}}{n+1}$

(i) Find the expectations of $\hat{\theta}_1$ and $\hat{\theta}_2$
(ii) Find the variances of $\hat{\theta}_1$ and $\hat{\theta}_2$
(iii) Find the efficiency of $\hat{\theta}_1$ relative to $\hat{\theta}_2$

3. (a) Explain what is meant by the following:

(i) Maximum likelihood estimator (MLE) of θ.
(ii) An estimator $\hat{\theta}$ is unbiased.
(iii) An estimator $\hat{\theta}$ is UMVUE.

(b) Let $X_1, X_2, \ldots, X_n$ be a random sample from $f_X(x, \theta) = \theta(1-x)^{\theta-1}$, $x \in (0, 1)$ and $\theta > 0$.

(i) Show that the probability density function posses a monotone likelihood ratio.

(ii) Find the uniformly most powerful test of size α for testing $H_0 : \theta = \theta_0$ vs $H_a : \theta > \theta_0$.

(iii) If $n = 2$, and for testing $H_0 : \theta = 1$ vs $H_a : \theta < 1$, the decision is to reject H_0 if $X_1 + X_2 < \dfrac{1}{4}$. Find the size of the test.

(c) (i) State the generalized likelihood ratio test.

(ii) Let $X_1, X_2, \ldots, X_n$ be a random sample from

$$f_X(x,\theta) = \frac{x\, e^{-\frac{x}{\theta}}}{\theta^2}, \quad x > 0, \quad \theta > 0$$

Construct the generalized likelihood ratio test for testing $H_0 : \theta = 5$ vs $H_a : \theta \neq 5$.

4. (a) Define the following terms:

(i) Most powerful test.
(ii) Generalized likelihood ratio.
(iii) Uniformly most powerful test.

(b) Let X_1 and X_2 be a random sample of size 2 from $f_X(x) = \dfrac{1}{x^2}$, $x \geq 1$.

Let $Z = X_1 X_2$ and $Y = X_2$

(i) Find the joint density function of Z and Y.
(ii) Find the marginal density function of Z.

(c) (i) State without proof the theorem concerning the theoretical lower bound for the variance of unbiased estimator $\hat{\theta}$ based on a random sample of size n.

(ii) Let $X_1, X_2, \ldots, X_n$ be a random sample of size n from a uniform distribution over the interval $(0, \theta)$.
Is the estimator $\hat{\theta}$ = maximum $\{X_1, X_2, \ldots, X_n\}$ consistent estimator of the parameter θ? Justify your answer.

5. (a) Define the following terms:

(i) Critical region of a test.
(ii) Power function of a test.
(iii) Size of the test.

(b) Let $X_1, X_2, \ldots, X_n$ be a random sample of size n from a probability function $f_X(x,\theta) = \frac{2x}{\theta} e^{-\frac{x^2}{\theta}}$, $\theta > 0$, $x > 0$

(i) Show that $\hat{\theta} = \frac{\sum_{i=1}^{n} x_i^2}{n}$ is unbiased estimator of θ.

(ii) Obtain an expression for the variance of $\hat{\theta}$.
Use the fact that $\mathrm{Var}(\hat{\theta}) \simeq \left[-n\, E\left\{ \frac{\partial^2}{\partial \theta^2} \, ln\left(f_X(x,\theta) \right) \right\} \right]^{-1}$

(c) Let $X_1, X_2, \ldots, X_n$ be a random sample of size n from density function

$$f_X(x, \theta) = 3\theta x^2 e^{-\theta x^3} \quad , \theta > 0 , \; x > 0.$$

(i) Show that $f_X(x, \theta)$ belongs to the family of exponential family.

(ii) Find the sufficient statistics for θ.

(iii) Derive the maximum likelihood estimator for θ.

(iv) Derive the uniformly most powerful test of size α for testing $H_0 : \theta = \theta_0$ vs $H_a : \theta > \theta_0$.

END OF EXAMINATION.

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2008 ACADEMIC YEAR
FIRST SEMESTER FINAL EXAMINATIONS

M411: THEORY OF FUNCTIONS OF A COMPLEX VARIABLE I

TIME ALLOWED: Three (3) Hours

INSTRUCTIONS : Answer any **Five** (5) questions from this paper

Omission of essential working may result in loss of marks

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1. (a) (i) Find the maximum of $|z^3 + 1|$ if $|z| \leq 2$

(ii) Find the real and the imaginary parts of

$\frac{z+1}{2z}$ where $z = x + iy$

(b) (i) Find the center and the radius of the circle

$|z+i| = \frac{1}{3}|z-1|$

(ii) If $u(x, y) = y^3 - 3x^2y$, show that u is a harmonic function and hence find its harmonic conjugate.

2. (a) (i) Find the principal value of $(1+i)^{1-i}$

(ii) Determine the imaginary part of sin (2 + 3i)

(b) Let $f(z) = \log(z+1)$

(i) Show that $f(z)$ is differentiable on a domain on which it is single valued

(ii) Hence find the derivative of $f(z)$

3. (a) Find the radius of convergence of the series

(i) $\sum_{n=0}^{\infty} \frac{z^{3n}}{e^n}$

(ii) $\sum_{n=0}^{\infty} 5^{(-1)^n} z^n$

(b) Let $f(z) = \frac{z}{z^2 - 1}$

(i) Express $f(z)$ in partial fractions

(ii) Hence find the power series of $f(z)$ about the origin and state then region where your series is valid

(iii) Evaluate $\int_\gamma f(z)dz$ where γ is the circle $|z + 1| = 1$

4. (a) Let $\gamma(t) = 2e^{it}$, $0 \le t \le \frac{\pi}{2}$ be a curve in the complex plane.

(i) Estimate the value of $\left| \int_\gamma \frac{dz}{z^2 + 1} \right|$

(ii) Evaluate $\int_\gamma \left(z^2 - 3|z| + \operatorname{Im} z\right) dz$

(b) Let f be analytic on a domain D and let z_0 be a point in D. Given that $f(z)$ has a zero of order m at z_0

(i) Express $f(z)$ in the form $f(z) = \sum_{n=0}^{\infty} a_n (z - z_0)^n$

(ii) Let $g(z) = \frac{f(z)}{(z - z_0)^m}$. Show that $g(z)$ is analytic on D

5. (a) Let $f(z) = \sin z$. Show that

(i) the image of the line $x = \alpha$ is a hyperbola

(ii) the image of the line $y = \beta$ is an ellipse

(b) Let γ be a circle $|z| = 2$. Find the value of

(i) $\int_\gamma \frac{dz}{z^2 - 2z - 3}$

(ii) $\int_\gamma \frac{e^{2z}}{(z-1)^2(z^2+10)} dz$

6. (a) Let $T(z) = \dfrac{1-z}{1+z}$.

Set $T_1(z) = T(z) = \dfrac{1-z}{1+z}$, $T_2(z) = T_1(T_1(z))$ and in general

$T_n(z) = T_{n-1}(T_1(z))$

(i) Show that $T(z)$ is a one-to-one function

(ii) Find the fixed points of $T(z)$

(iii) Find an expression for $T_n(z)$

(b) Find a linear fractional transformation T such that T maps the real axis onto itself and the imaginary axis onto the circle $\left|w - \dfrac{1}{2}\right| = \dfrac{1}{2}$

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

2008 ACADEMIC YEAR
FIRST SEMESTER FINAL EXAMINATIONS

M 421 : STRUCTURE AND REPRESENTATIONS OF GROUPS

TIME ALLOWED: Three (3) Hours

INSTRUCTIONS: Answer **Five (5)** questions in all with at least two (2) questions from each section.

SECTION A : STRUCTURE OF GROUPS

(Answer at least two (2) questions from this section)

1. (a) Define each of the following terms:

   (i) a normal series of s finite group G.

   (ii) a commutator (derived) subgroup G' of a group G.

   (b) Prove that

   (i) If a group G has a normal series

   $$G = G_0 \geq G, \ldots \geq G_r = \{ e \}$$

   Then every subgroup N of G possesses a normal series.

   (ii) If G has a normal subgroup N such that the factor group G / N is abelian, then N contains the commutator (derived) subgroup G' of G.

   (c) Show that if N is a normal subgroup of a group G such that $N \cap G' = \{e\}$, then N contains the centre $Z(G)$ of G.

2. (a) What is meant by the statements;

   (i) G is a direct product of its normal subgroups.

   (ii) N is a sylow $p-$subgroup of G.

(b) Given that $H_1, H_2, \ldots, H_n$ are normal subgroups of a group G such that

(i) $H_1 \cdot H_2 \cdot \ldots \cdot H_n = G$

and (ii) $H_1 \cdot H_2 \cdot \ldots \cdot H_{i-1} \cap H_i = \{ e \}$

then show that each element g of G has a unique expression of the form

$g = h_1 \cdot h_2 \cdot \ldots \cdot h_n$ where $h_i \in H_i$.

(c) Show that if G is a group of order P_1P_2, where P_i are primes such that P_2 is greater than P_1 and P_1 does not divide $P_2 - 1$, then G is a direct product of its sylow subgroups. Hence deduce that a group of order 35 is a direct product of its sylow subgroups.

3. (a) Let G be a finite permutation group on the set Ω, then give the meaning of each of the following terms:

(i) the stabilizer G_α of $\alpha \in \Omega$ in G.

(ii) G is a regular permutation group.

(b) Show that in a transitive group, all the stabilizers are conjugate to each other.

(c) Show that if G is a regular primitive group on Ω then it is of prime order.

SECTION B: REPRESENTATIONS OF GROUPS

(Answer at least two (2) questions from this section)

4. (a) Give the meaning of each of the following terms:

(i) a reducible representation of a group G.

(ii) a group character χ of a group G.

(b) (i) State (without proof) Schur's lemma.

(ii) Prove that a group character is a class function on G.

(c) Given that a matrix representation T of a group G over the field of rational numbers is such that for a certain element x in the centre $Z(G)$ of G,

$$T(x) = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix},$$

Then

(i) Show that the matrix A given by $A = I_2 + T(x)$ satisfies the condition $T(g) A = A T(g)$ for all $g \in G$.

(ii) Deduce that T is a reducible representation of G over Q.

5. (a) What is the meaning of the terms

(i) a <u>left regular</u> representation of a group G?
(ii) the <u>character of</u> a representation of G?

(b) Let $\theta : G \to S_n$ be a mapping from a finite group G to the symmetric group S_n of the degree n given by $\theta(g) = \begin{pmatrix} x_1 & x_2 & \cdots & x_n \\ \theta(x_1) & \theta(x_2) & \theta(x_n) \end{pmatrix}$ where $x_i \in G$ and $\theta \in S_n$, then prove that θ is a representation of G.

(c) Give the left regular representation of the group $D_3 = \langle a, b: 3 = b^2 = e, ba = a^2b \rangle$. Hence obtain all the characters of the representation θ.

6. (a) What is the meaning of each of the following:

(i) a <u>completely reducible</u> representation of a group G.
(ii) a <u>character table</u> of a group G.

(b) State and prove the Mashke's Theorem.

(c) Let $T : G \to GL(2, \mathbf{R})$ be a mapping such that $T(a) = \begin{pmatrix} 0 & 1 \\ -1 & -1 \end{pmatrix}$.

Show that T is an irreducible representation of G.

7. (a) Give the meaning of each of the following terms:

(i) the <u>character of a representation</u> of a group G.
(ii) the <u>first orthogonality relations</u> for the group characters of G.

(b) Let $h_1, h_2, \ldots, h_n$ be the conjugacy classes of G of order di (i = 1, 2, ... n), $\chi^{(j)}$ (j = 1, ..., n) and let be the irreducible characters of G. Then by using the first orthogonality relations for the characters of G, show that

$$\frac{1}{|G|} \sum di \, \chi_i^{(u)} \, \chi_{j*}^{(k)} = \begin{cases} 1 & \text{if } i = j \\ 0 & \text{if } i \neq j \end{cases}$$

where $\chi_i^{(k)} = \chi_{(g_i)}^{(k)}$ for each $g_i \in h_i$

and $\chi_{j*}^{(k)} = \chi^{(k)}(g_k^{-1})$ for each $g_j^{-1} \in h_{j*}$

(c) Deduce from your result in (b) above that the squares of the degrees of the characters of G equals the order of G.

END OF EXAMINATION.

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

2008 ACADEMIC YEAR
FIRST SEMESTER FINAL EXAMINATIONS

M431 - REAL ANALYSIS V

INSTRUCTIONS: Answer any **five (5)** questions.

TIME ALLOWED: Three (3) hours.

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1. (a) (i) Let X be a set and $d : X \times X \to \mathbf{R}$ be a function. When is d called a metric?

   (ii) Let X be a set and d a metric on X. Give the definition of the following:
   an open ball in X;
   an open set in X.

   (b) (i) Let X be a metric space, $x \in X$ and $r > 0$. Show that the open ball of radius r and centre x as an open set in X.

   (ii) Give an example of an open set O in $\mathbf{R}$, $O \neq \mathbf{R}$, $O \neq \Phi$, and prove that it is an open set in $\mathbf{R}$ with usual metric.

2. (a) Let X be a metric space and $A \subset X$. Define

   (i) The closure, $\overline{A}$ of A
   (ii) A point of closure of A.

   (b) (i) Let X be a metric space and $A \subset X$. Prove that

   $$B = \{x \in X : x \text{ is a point of closure of A}\}$$

   is a closed set in X.

   (ii) Let $1 \leq p < \infty$. $\forall N \in \mathbf{N}$ let $E_N = \{\{x_n\}_{n=1}^{\infty} \in l^p : x_n = 0 \ for \ n > N\}$. Prove that E_N is closed in l^p and contains no open balls.

3. (a) Define the following:

   (i) For $1 \leq p < \infty$, l^p; and $\|x\|_p$ for $x \in l^p$;

   (ii) l^∞; and $\|x\|_\infty$ for $x \in l^\infty$.

   (b) (i) If $1 \leq p < q < \infty$, show that $l^p \subset l^q$ and $l^p \subset l^\infty$.

   (ii) Let $X = \{a_1, a_2, \ldots, a_N, 0, 0, \ldots\}$, that is $a_n = 0$ for $n > N$ show that $\|x\|_\infty = \lim_{p \to \infty} \|x\|_p$.

4. (a) Define (i) a compact metric space
   (ii) a sequentially compact metric space

   (b) Prove a metric space is sequentially compact if and only if every infinite subset has a point of accumulation.

5. (a) Give the definition of

   (i) a totally bounded metric space
   (ii) a complete metric space

   (b) Prove that a sequentially metric space is totally bounded and complete.

6. (a) Define (i) continuity of a mapping from a metric space (X, d_X) into a metric space (X, d_Y) at a point $x_0 \in X$
   (ii) uniform continuity of a mapping on a metric space.

   (b) Prove that if $f : X \to Y$ is a continuous mapping of a compact metric space X into a metric space Y, then it is uniformly continuous.

7. (a) Define (i) upper semi continuity of a function at a point x_0 of a metric space X.
   (ii) uniform convergence of a sequence of functions (f_n) on a metric space.

   (b) (i) Let (X, d) be a metric space. Prove that a function $f : X \to \mathbf{R}$ is upper semi continuous on X if and only if $\forall\, \alpha \in \mathbf{R}$, $\{x \in X : f(x) < \alpha\}$ is open in X.

   (ii) Let (X, d_X) and (X, d_Y) be metric spaces. Prove that if $\forall\, n \in \mathbf{N}$, $f_n : X \to Y$ is uniformly continuous on X and if $(f_n)_{n=1}^{\infty}$ converges uniformly to a function $f : X \to \mathbf{R}$, then f is uniformly continuous.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2008 ACADEMIC YEAR
FIRST SEMESTER FINAL EXAMINATIONS

M911: MATHEMATICAL METHODS V

TIME ALLOWED: Three (3) Hours

INSTRUCTIONS : Answer any **Five** (5) questions from this paper

Omission of essential working may result in loss of marks

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1. (a) (i) Define functional dependence of two functions $u(x, y)$ *and* $v(x, y)$

(ii) Show that the functions $u(x,y) = \dfrac{x-y}{x+3}$ and $v(x,y) = \dfrac{x+3}{y+3}$ are functionally dependent and find their functional relation

(b) Let $F(x,y) = \left(\dfrac{y}{x} + 3y^3\right)i + \left(\ln x + 9xy^2\right)j$ be a vector field.

(i) Show that F(x, y) is a gradient of some function $f(x, y)$

(ii) Hence find the potential function $f(x, y)$

2. (a) Let $z = x^y$, where $x = f(u, v)$, $y = g(u, v)$, define z as a function of u and v. Given that when $u = 1$ and $v = 2$ we have $f(1, 2) = 2$, $g(1, 2) = -2$, $\dfrac{\partial x}{\partial u} = -1$, $\dfrac{\partial x}{\partial v} = 3$, $\dfrac{\partial y}{\partial u} = 5$ and $\dfrac{\partial y}{\partial v} = 0$, calculate using the chain rule the value of $\dfrac{\partial z}{\partial u}$ at the point $(u, v) = (1, 2)$

(b) Let $F : \mathbf{R}^4 \rightarrow \mathbf{R}^2$ be given by $F(x, y, z, w) = (z^3x + w^2y^3 + 2xy,\ xyzw-1) = (0, 0)$ and let $\mathbf{x} = (x, y)$ and $\mathbf{y} = (z, w)$.

(i) Show that F determines $\mathbf{y} \in \mathbf{R}^2$ as a function $f(x, y)$ of $\mathbf{x} \in \mathbf{R}^2$ near the point (-1, -1, 1, 1) in $\mathbf{R}^4$.

(ii) Hence find the Jacobian matrix of $f(x, y)$ at (-1, -1)

3. (a) Let $f : \mathbf{R}^2 \to \mathbf{R}^2$ be defined by $f(x, y) = (x^4y + x, x + y^3)$

(i) Show that f is invertible in the neighborhood of the point (1, 1)
(ii) Hence find the Jacobian of the inverse function of f in the neighborhood of (1, 1). i.e $J_{f^{-1}}(f(1,1))$

(b) Determine the maximum and the minimum of the function $F(x, y, z) = x + y + z$ on the intersection of the two surfaces $x^2 + y^2 = 1$ and $z = 2$

4. (a) A corporation manufactures a product at two locations. The cost of producing x units at location 1 is $C_1 = 0.02x^2 + 4x + 500$, and the cost of producing y units at location 2 is $C_2 = 0.05y^2 + 4y + 275$. The product sells for \$15 per unit. Find the quantity that should be produced at each location to maximize the profit .

(b) Let $f(x, y) = x^2 + 2bxy + y^2$.

(i) Locate and identify all relative maxima, minima and saddle points (if such exist) of the function f.
(ii) Find the first degree polynomial which approximates f near the point (-1, 2)

5. (a) Find the directional derivative at the point (1, 2, 1) of the function $f(x, y, z) = x^3 + y^2 + z$ in the direction of the perpendicular to the surface $g(x, y, z) = -x + z^2(y - z)$ at the point (1, 2, 1)

(b) Let $\mathbf{r} = x\mathbf{i} + y\mathbf{j} + z\mathbf{k}$ be a position vector in space and let $r = \|\mathbf{r}\| = \sqrt{x^2 + y^2 + z^2}$

(i) Find $div\ r^n\mathbf{r}$
(ii) Show that $curl\ r^n\mathbf{r} = 0$

6. (a) Let a transformation from the xy – plane to the uv – plane be given by $u = x, \quad v = y(1 + 2x)$

(i) Find the image of the line $y = 3$ under the transformation

(ii) If R_{xy} is the rectangular region $R_{xy} = \{(x, y) : 0 \le x \le 3, \text{ and } 1 \le y \le 3\}$, sketch the image region R_{uv} of R_{xy}.

(iii) Find by reducing the integrals to the integrals over R_{xy} of

$$\iint_{R_{uv}} du\,dv \quad \text{and} \quad \iint_{R_{uv}} v\,dv\,du$$

(b) Let S be the surface defined parametrically by $x = u\cos v \quad y = u\sin v \quad z = v$ where $0 \le u \le 4$ and $0 \le v \le 2\pi$ Find the equation of the tangent plane to the surface at the point where $u = 2$ and $v = \dfrac{\pi}{2}$

7. (a) Describe fully the surface given by the equation

(i) $x^2 - 2y^2 + z^2 + 8x + 8y = 0$

(ii) $x^2 + y^2 + z^2 = 2(x + y + z)$

(b) Find the value of the integral $\displaystyle\iint_{R_{uv}} \frac{du\,dv}{\sqrt{(u-v)^2 + 2(u+v) + 1}}$ by substituting $u = x(1 + y)$ and $v = y(1 + x)$ where R_{uv} is the triangle bounded by the lines $v = 0$ $u = 2$ and $v = u$

The University of Zambia
School of Natural Sciences
Department of Physics
2008 Academic Year First Semester
Final Examinations
P-191:Introductory Physics - I

All questions carry equal marks. The marks are shown in brackets. Question 1 is compulsory. Attempt four more questions. Clearly indicate on the answer script cover page which questions you have attempted.

Time: Three hours. **Maximum marks = 100.**

Do not forget to write your computer number clearly on the answer book as well as on the answer sheet for Question 1. Tie them together!!

==

Wherever necessary use:

$g = 9.8 \text{m/s}^2$

$P_A = 1.01 \times 10^5 \text{ N/m}^2$

1 cal. = 4.18 J

$\rho_{\text{water}} = 1000 \text{kg/m}^3$

1 hp = 746W

1 Pascal =1 N/m^2

$G = 6.67 \times 10^{-11} \text{ Nm}^2/\text{kg}^2$

1 metric ton = 1000 kg

The University of Zambia
Physics Department
University Examinations 2008
P-191 : Introductory Physics - I

Answer sheet for Question 1

Computer Number ....

Q1. Put a cross (×) or tick mark (√) in the appropriate box. If it is on the dividing line, it will not be counted.

	a	b	c	d
A				
B				
C				
D				
E				
F				
G				
H				
I				
J				

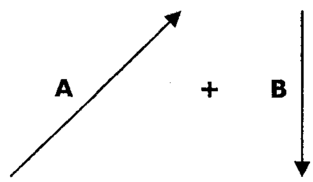
Do NOT write here.
For official use only:

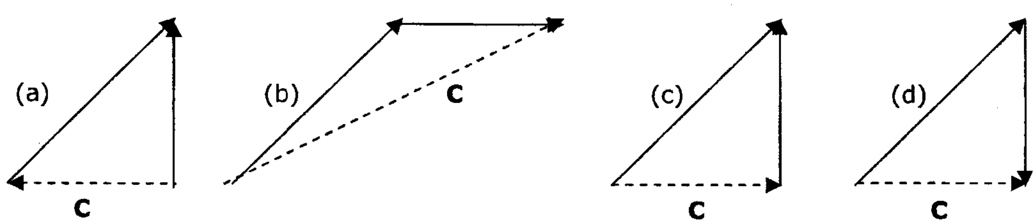
	Number of parts N	Factor f	Marks f × N
Correct		2	
Wrong		−(0.67)	
	Net Marks :		

Attach this sheet firmly with the main answer book. If you lose this sheet, you will lose the marks for Question 1 !!

Question 1: Sample answers: F (a), G (d).... etc. **DO NOT guess** the answer. For each correct answer, **2 marks** are given. For each wrong answer, **0.67** will be deducted. For no answer, zero mark. The minimum total mark for Question 1 is zero. [$10 \times 2 = 20$]

(A) The vector sum of **A** + **B** is given correctly by vector **C** in diagram:





(B) The type of mass found in Newton's second law of motion is known as:

(a) Rest mass
(b) Inertial mass
(c) Weight
(d) Gravitational mass

(C) The concept of force may be best described as:

(a) A push or pull
(b) Energy in motion
(c) A quantity tending to change the shape or state of motion of a body
(d) Transmission of power from one body to another

(D) Suppose a projectile is fired horizontally from a cliff that is 100 m high with a muzzle velocity of 80 m/s. It experiences a horizontal acceleration equal to:

(a) 0 m/s^2 (b) 9.8 m/s^2 (c) 10.2 m/s^2 (d) 980 m/s^2

(E) A 5 kg rifle fires a 20 g bullet at 1000 m/s. What is the approximate recoil velocity of the rifle?

(a) 400 m/s (b) 4 m/s (c) 40 m/s (d) 4000 m/s

(F) The product of torque and the angular displacement through which the torque acts is called:

(a) Rotational inertia
(b) Moment of inertia
(c) Radius of gyration
(d) Work

(G) A 5 kg mass is held 4 m above the floor for 10 seconds. The work done is:

(a) 200 J
(b) 0 J
(c) 20 J
(d) 200 W

(H) A planet whose mass is twice that of the earth and radius also twice that of the earth will have acceleration due to gravity equal to:

(a) 4.9 m/s^2 (b) 19.6 m/s^2 (c) 9.8 m/s^2 (d) 39.2 m/s^2

(I) A ballet dancer spins faster when she folds her arms. This is due to:

(a) Increase in energy and increase in angular momentum
(b) Constant angular momentum and increase in kinetic energy
(c) Decrease in friction
(d) Increase in energy and decrease in angular momentum

(J) A boat having length 3 m and width of 2 m is floating on a lake. The boat sinks by 1 cm when a man gets on it. The mass of the man is

(a) 42 kg
(b) 128 kg
(c) 60 kg
(d) 62 kg

ATTEMPT ANY FOUR QUESTIONS FROM BELOW:

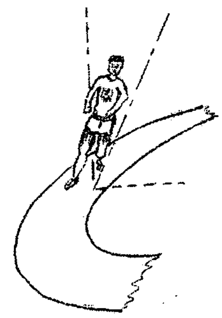
Q.2 (a) A man pushing a mop on the floor causes the mop to undergo two displacements. The first has a magnitude of 150 cm and makes an angle of 120° with the positive $x-$axis. The resultant displacement has a magnitude of 140 cm and is directed at angle of 35° to the positive $x-$ axis. Find the magnitude and direction of the second displacement. **[10]**

(b) A tennis player standing 12.6 m from the net hits a ball at 3° above the horizontal. To clear the net, the ball must rise at least 0.33 m. If the ball just clears the net at the apex of its path, how fast was the ball moving when it left the racket? **[10]**

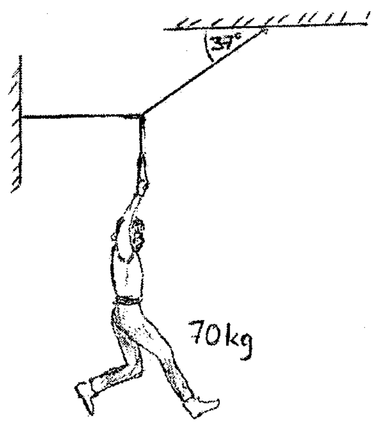
Q.3 (a) A 12 g bullet is fired horizontally into a 100 g wooden block that is initially at rest on a frictionless surface and connected to a light spring having a spring constant of 150 N/m. The bullet becomes embedded in the block. If the bullet-block system compresses the spring by a maximum of 80 cm, what was the speed of the bullet at impact with the block. **[10]**

(b) A car travels 1 km between two stops. It starts from rest and accelerates at 2.5 m/s^2 until it attains a velocity of 12.5 m/s. The car continues at this velocity for sometime and decelerates at 3 m/s^2 until it stops. Find the total time of the journey. **[10]**

Q.4 (a) A 400 m race runner on a 15 m radius circular track is running at a speed of 6.0 m/s, as shown in the figure below. At what angle should the runner lean into the curve in order to maintain proper balance? **[8]**

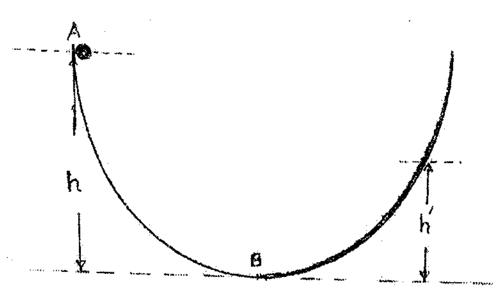


(b) Find the tension in each cable supporting the 70 kg cat burglar in the figure shown below. **[8]**

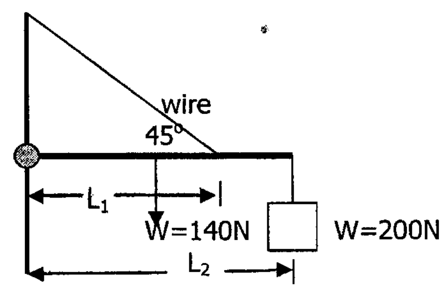


(c) A piece of wood floats in sea-water with 1/5 (one fifth) of its volume exposed. Calculate the density of the wood. (given sea-water density = 1000kg/m^3) **[4]**

Q.5 (a) A spherical glass bead of mass *m* and radius *r* is released from rest at a height of *h* = 10 cm inside a big glass bowl in which the left half is non-slip and the right side is frictionless starting from point *B* as shown. To what height does the ball rise on the right? **[10]**



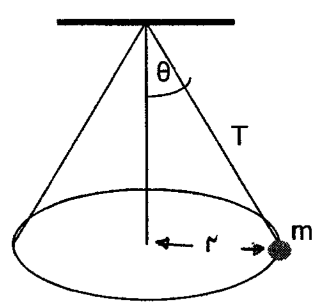
(b) A block of weight W = 200 N is supported by a uniform beam of weighing 140 N as shown in the figure below, with L_1 = 1.10 m and L_2 = 1.40 m. Find the tension in the wire and the horizontal and vertical forces exerted by the hinge on the beam.



[10]

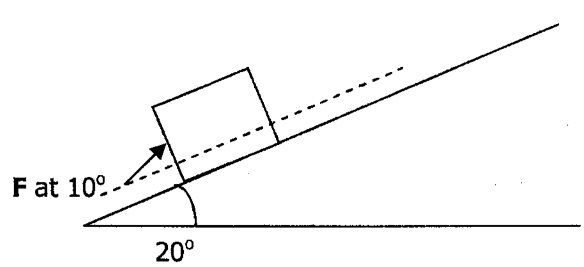
Q.6 (a) What force is necessary to keep a mass of 0.9 kg revolving in a horizontal circle of 0.8 m radius with a period of 0.6 s?

i) What is the direction of this force?
ii) Calculate also the tension in the string. **[10]**



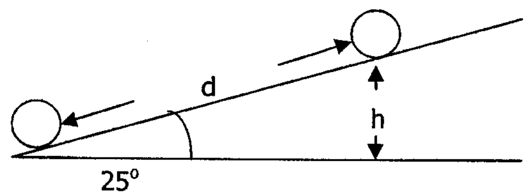
(b) A block weighing 15 N is pushed up an inclined plane making an angle of 20° with respect to the horizontal by a constant force of 10 N that makes an angle of 10° with respect to the surface of the plane as shown below. The block starts from rest and is pushed up for a distance of 2.5 m. The coefficient of friction between the block and the plane is 1.5.

Determine:
i) the work done on the block by the force
ii) the increase in potential energy of the block
iii) the increase in kinetic energy of the block **[10]**



Q.7. (a) Define a non-conservative force. **[2]**

(b) A disk is made to roll without slipping up an incline making an angle of 25° with the horizontal. If the speed at the bottom of the incline was 2.5 m/s, how high up the incline will the disk travel before rolling back down again? Neglect rolling friction. "Use the energy method". Given moment of inertia of a disk $I = \frac{1}{2}MR^2$. **[8]**



(c) A marble moving at 5.00 m/s east strikes a stationary marble of the same mass. After the collision the first marble moves at 4.33 m/s at an angle of 30° with respect to the original direction of motion. Find the velocity and show that the direction of the second marble after the collision is 60°. **[10]**

Q.8 (a) A balloon is rising vertically from rest with an acceleration of 4.9 m/s^2. At the end of 4 s, a stone is released from the balloon. How high will the stone rise above ground level? **[12]**

(b) A piece of wood of volume 0.6 m^3 floats in water. Find the volume exposed. What force is required to immerse it completely under water? (Density of wood = 600 kg/m^3, water = 1000 kg/m^3) **[8]**

END OF EXAMINATION

Some equations you may find useful:

$v_f = v_o + at$: $v_f^2 = v_o^2 + 2ax$: $x = v_o t+(1/2)at^2$: $W = mg$: $x = v_{avg.}t$: $p = mv$

$f = \mu F_N$: $Ft = m(v_f - v_o)$: $work = Fs \cos\theta$: $kinetic\ energy = (1/2)mv^2$: $Ft = \Delta p$

$g.\ p.energy = mgh$: $v_{avg.} = (1/2)(v_o + v_f)$: $power = work/time$: $t = 2u \sin\theta/g$

$\Delta PE + \Delta KE + \Delta TE = 0$: $F = ma$: $P = Fv$: $R = (2u^2 \sin\theta \cos\theta)/g$: $a_T = \alpha r$: $L = I\omega$

$v_T = \omega r$: $\omega_f = \omega_0 + \alpha t$: $\omega_f^2 = \omega_0^2 + 2\alpha\theta$: $\theta = \omega_0 t+(1/2)\alpha t^2$: $p = mv$: $F_C = mv^2/r$

$kin.\ energy_{rotation} = (1/2)I\omega^2$: $I = \Sigma mr^2$: $\tau = I\alpha = Fr$: $B = -\Delta P/(\Delta V/V_0)$

$F = (Gm_1 m_2)/r^2$: $Y = (F/A)/(\Delta L/L_0)$: $Q/\Delta t = (kA\Delta T)/\Delta L$

$W_{app.} = mg - B.F.$: $P = \rho gh$: $EPE = (1/2)kx^2$: $F = -kx$: $f = 1/\tau$: $\omega = 2\pi f$

$[(1/2)mv^2]_{avg.} = (3/2)kT$: $\Delta Q = mc\Delta T = nC\Delta T$: $\Delta L = \alpha L\Delta T$: $\Delta V = \gamma V\Delta T$: $\Delta W = P.\Delta V$

$P_1V_1^\gamma = P_2V_2^\gamma$: $Q = \Delta U + W$: $\Delta W = nRT.\ln(V_f/V_i)$: $PV = nRT$: $f = (1/2\pi)\sqrt{(k/m)}$

$I_1\omega_1 = I_2\omega_2$: $\Delta T.E. = f.s$: $area\ of\ a\ right\ cylinder = 2\pi rL$: $v = \pm\sqrt{[(k/m)(x_0^2 - x^2)]}$

$a_{max} = kx_0/m$: $a_c = \omega^2 x_0$: $P.E. = (1/2)kx^2$: $(1/2)kx^2 + (1/2)mv^2 = (1/2)kx_0^2$

$a = -kx/m$: $\omega = \sqrt{(k/m)}$: $v = \sqrt{(Y/\rho)}$: $v = \sqrt{(T/(m/L))}$: $1\ rev = 360^0 = 2\pi\ rads$

$v = \sqrt{(B/\rho)}$: $f = (1/2\pi)\sqrt{(g/L)}$: $v = \sqrt{(\gamma RT/M)}$: $0\ K = 273^0C$: $q = CV$: $\mathbf{F} = qvB_\perp$

$x = x_0 \cos(\omega t)$: $\rho = (RA)/L$: $E = (1/2)qV$: $P = IV = I^2R$

$volume\ of\ a\ sphere = (4/3)\pi r^3$: $\sin^2\theta + \cos^2\theta = 1$: $y = (\tan\theta)x - \left(\frac{g}{2v_o\cos^2\theta}\right)x^2$

$area\ of\ a\ sphere = 4\pi r^2$: $EPE = (1/2)kx^2$

The University of Zambia

Department of Physics

First Semester University Examinations - 2008

General Properties of Matter and Thermal Physics – P231

Duration: Three (3) Hours **Date: 8th December 2008**

Marks: 100 **Time: 09:00 – 12:00hrs**

Instructions

- This paper contains seven (7) questions, five (5) printed pages.
- This paper has a total of 100 marks. All questions carry equal marks.
- Attempt any five (5) questions of your choice.
- Show all your work clearly. Omission of essential work will result in a loss of marks.
- Marks allocated for each question are indicated in square brackets [ ].
- Unless otherwise stated, take the acceleration due to gravity to be $g = 9.8\,\text{m.s}^{-2}$ and the gas constant as $R = 8.314\ \text{J}\cdot\text{mol}^{-1}.\text{K}^{-1}$.

FORMULAE THAT MAY BE USEFUL

$c_v = \left(\frac{dq}{dT}\right)_v$	$c_P = \left(\frac{dq}{dT}\right)_P = \left(\frac{\partial h}{\partial T}\right)_p$	$\kappa = -v\frac{\partial P}{\partial v}$	$Tds = du + Pdv$	$\dot{V} = \frac{\pi P}{8\eta l}r^4$
$3K = \frac{1}{\alpha(1-2\sigma)}$	$\left(P + \frac{a}{v^2}\right)(v-b) = RT$	$dq = du + Pdv$	$h = u + Pv$	$c = \frac{\pi n}{2l}r^4$
$\left(\frac{\partial s}{\partial v}\right)_T = \left(\frac{\partial P}{\partial T}\right)_v$	$n = 4\frac{\pi MR^2 l}{T^2 r^4}$	$T_c = \frac{8a}{27Rb}$	$g = h - Ts$	$Pv = RT$
$T = 2\pi\sqrt{\frac{I}{c}}$	$\tau = \frac{Y}{R}I_g$	$F = -\eta A\frac{du}{dz}$	$f = u - Ts$	$R = Nk$
$n = \frac{1}{2(\alpha+\beta)}$	$I = \frac{2}{3}mr^2$	$I_g = \frac{bd^3}{12}$	$\left(\frac{\partial T}{\partial P}\right)_s = \left(\frac{\partial v}{\partial s}\right)_P$	$c_P - c_v = R$

1. (a) A uniform rod of length $l = 1\,\text{m}$, diameter $D = 0.02\,\text{m}$, and Young's modulus $2 \times 10^{11}\,\text{Nm}^{-2}$ is clamped horizontally at one end. A load of $M = 100\,\text{g}$ is attached at the free end.

(i) Neglecting the mass of the rod, show that the depression, y, of the rod at the midpoint of the rod is given by

$$y = \frac{40Mgl^3}{6\pi YD^4},$$

where g is the acceleration due to gravity. **[9]**

(ii) Hence, or otherwise, calculate the depression of the midpoint of the rod. **[1]**

(b) Starting with the first law of thermodynamics and the definitions of c_P and c_v, show that for an ideal gas

$$c_P - c_v = R,$$

where c_P and c_v are molar specific heat capacities at constant pressure and constant volume respectively. **[10]**

2. (a) (i) Write down Poiseuille's equation for the volume rate of flow of a liquid through a capillary. **[2]**

(ii) Using Poiseuille's equation, show that if two capillaries of radii r_1 and r_2 having lengths l_1 and l_2 respectively are connected in series, the rate of flow $\dot{V}$ of a liquid is given by

$$\dot{V} = \frac{\pi P}{8\eta}\left(\frac{l_1}{r_1^4} + \frac{l_2}{r_2^4}\right)^{-1}$$ **[8]**

(b) Given that the mean kinetic energy of molecules of hydrogen at 0°C is $5.64 \times 10^{-21}\,\text{J}$, calculate the Avogadro's number. **[4]**

(c) One gram of a gas expands isothermally to five times its volume. Calculate the change in its entropy in terms of the gas constant. **[6]**

3. (a) A number of little droplets of water, all of the same radius r, coalesce to form a single drop of radius R. If θ is the rise in temperature of water, show that

$$\theta = \frac{3\gamma}{c\rho}\left(\frac{1}{r} - \frac{1}{R}\right),$$

where c is the specific heat capacity of water, ρ is the density of water and γ is the surface tension of water. **[10]**

(b) Show that the bulk modulus of a gas under an adiabatic process is equal to γP, where P is the pressure of the gas and $\gamma = c_P/c_v$ is the ratio of the specific heat capacities of the gas at constant pressure and constant volume, respectively. **[5]**

(c) Van der Waals constants of a gas are $a = 0.245$ litre^2 atms mole^{-2}, $b = 2.67 \times 10^{-10}$ litre mole^{-1}. Calculate the critical temperature. **[5]**

4. (a) Using the principle of equipartition of energy, show that for a gas possessing f degrees of freedom, γ is given by

$$\gamma = 1 + \frac{2}{f},$$

Where $\gamma = c_P/c_v$ is the ratio of the specific heat capacities of the gas at constant pressure and constant volume, respectively. **[10]**

(b) A brass bar of negligible weight and 1 cm square in cross section is supported on two knife edges 100 cm apart. A load of 1 kg at the centre of the bar depresses by 2.51 mm.

(i) Show that the depression, y_m, of the bar at the midpoint is generally given by the expression

$$y_m = \frac{Wl^3}{48YI_g}$$

where Y is the Young's modulus of the material of the bar, l is the length of the bar, W is the weight placed at the midpoint of the bar and I_g is the geometric moment of inertia of the bar. **[8]**

(ii) Hence, calculate Young's modulus for brass. **[2]**

5. (a) Consider two cylinders of equal length, density and mass where one is hollow and the other one is solid. If the radius of the solid cylinder is r, while the internal and external radii of the hollow cylinder are r_1 and r_2 respectively, and n is the modulus of rigidity of the material;

(i) Show that the torsional rigidity, c, of the solid cylinder is given by

$$c = \frac{\pi n}{2l} r^4 \ .$$ **[7]**

(ii) Given that the torsional rigidity of the hollow cylinder is $c' = \frac{\pi n}{2l}\left(r_2^4 - r_1^4\right)$, show that

$$\frac{c}{c'} = \frac{1}{2(r_2/r)^2 - 1}; \ r_2 > r .$$ **[3]**

(b) Show that the radial rate of flow of heat under steady state conditions between two coaxial cylinders of length l with internal and external radii r_1 and r_2 respectively, is given by

$$\dot{Q} = \frac{2\pi l \kappa (T_1 - T_2)}{\log_e (r_2/r_1)};$$

where T_1 and T_2 are the temperatures of the internal and external cylinders respectively, κ is the thermal conductivity and $\log_e (r_2/r_1)$ and $T_1 > T_2$ and $r_2 > r_1$. **[10]**

6. (a) (i) Show that the moment of inertia, I, for a solid sphere about its diameter is given by

$$I = \frac{2}{5} MR^2 \ ,$$

where M and R are the mass and radius of the sphere, respectively. **[6]**

(ii) A sphere of mass 0.8 Kg and radius 0.03 m is suspended from a wire of length 1 m and radius 5 x 10^{-4} m. If the period of torsional oscillation of this system is 1.23 s, calculate the modulus of rigidity of the wire. **[4]**

(b) A large soap bubble of radius x contains inside it a smaller soap bubble of radius y. The smaller bubble bursts isothermally with no leakage of air from the system as a whole, and a new bubble of radius z is formed. If P is the atmospheric pressure and γ is the surface tension, show that

$$P\left(z^3 - x^3\right) + 4\gamma\left(z^2 - x^2 - y^2\right) = 0$$ **[10]**

7. (a) Show that, for an ideal gas, the work done W during an adiabatic process is given as

$$W = \frac{R}{\gamma - 1}\left(T_1 - T_2\right),$$

where R is the universal gas constant, where $\gamma = c_P / c_v$ is the ratio of the specific heat capacities of the gas at constant pressure and constant volume, respectively, while T_1 and T_2 are the initial and final temperatures respectively. **[10]**

(b) Starting with the combined first and second laws of thermodynamics, and setting $s = s(T, P)$ and $h = h(T, P)$, show that the second Tds equation is given by

$$Tds = c_p dT - T\left(\frac{\partial v}{\partial T}\right)_P dP,$$

where s is the specific entropy, v is the specific volume, h is the specific enthalpy, T is temperature, P is pressure and c_P is the specific heat capacity at constant pressure. **[10]**

<u>END OF EXAMINATION</u>

THE UNIVERSITY OF ZAMBIA
PHYSICS DEPARTMENT
University Examinations
First Semester
P251-INTRODUCTION TO CLASSICAL MECHANICS I

Date: 12 December 2008
Duration: Three Hours
Total Marks: 100
Answer any five questions

USEFUL DATA
Universal gravitational constant: $G = 6.67 \times 10^{-11} \mathrm{m^3 kg^{-1} s^{-2}}$
Radius of the Earth : $R = 6.4 \times 10^6$m
Acceleration due to gravity: g= $9.8\mathrm{ms^{-2}}$

$$e^x = 1 + x + \frac{x^2}{2} + \frac{x^3}{2 \cdot 3} + \cdots$$

$$\ln(1+x) = x - \frac{x^2}{2} + \frac{x^3}{3} - \frac{x^4}{4} + \cdots$$

$$\hat{r} = \hat{\imath}\cos\theta + \hat{\jmath}\sin\theta$$

$$\hat{\theta} = -\hat{\imath}\sin\theta + \hat{\jmath}\cos\theta$$

1\. (a) Even though the total force on a system of particles is zero, the net torque may not be zero. Show that the net torque has the same value in any coordinate system.[Hint: determine the net torques about two different origins, O and O'] [8 marks]

16 ~~18~~ + 17 + 17 + 17. + 15

(b) A ball of mass m is thrown with velocity v_0 on a horizontal surface where the retarding force is proportional to the square of the instantaneous velocity.

i. Express the velocity and the position of the ball as a function of time. [8 marks]

ii. Discuss any limits. [4 marks]

2\. (a) Can there be two dimensional motion with acceleration only in one direction? Explain. If so, give an example. [3 marks]

(b) A particle of mass m moves in a straight line under the influence of the position-dependent conservative force $F(x)$.

i. Show that the equation of motion of the particle leads to the equation of conservation of energy:

$$\frac{1}{2}mv^2 + V(x) = E$$

[4 marks]

4 + 2 + 3 +

ii. From the result in (i) above, show that the connection between the position of the particle and the time is

$$t = \int \frac{dx}{\sqrt{\frac{2}{m}(E - V(x))}} + t_0$$

[2 marks]

iii. The points at which the potential energy equals the total energy, i.e. $V(x) = E$, are called turning points. Show that the time the particle takes to move from one point $x(E)$ to the other point $x^{'}(E)$ and back, i.e., the period of the oscillatory motion, is

$$T = \sqrt{2m} \int_{x(E)}^{x'(E)} \frac{dx}{\sqrt{E - V(x)}}$$

[3 marks]

T =

(c) An object of mass m falls vertically downwards under a constant gravitational acceleration g from the top of a building. The resistive force acting on the object is mkv, where v is the velocity at any time t and $k = 0.10\text{s}^{-1}$.

i. Calculate the terminal velocity [1 mark]

ii. Derive an expression for the v at any time t in terms of g and k. [3 marks]

iii. Find an expression for the distance y travelled by the object in any time t. [2 marks]

iv. If the object hits the ground after two seconds, calculate the velocity of the object as it strikes the ground and the height of the building above the ground. [2 marks]

1 + 3 + 2 + 1

3. (a) The kinetic energy T of a particle is plotted against the displacement x. Give a physical interpretation of the slope of the curve. [2 marks]

2 + 3 + 2 + 1 + 10

(b) The speed of a particle of mass m varies with distance x as $v(x) = \alpha x^{-n}$. Assume $v(x=0) = 0$ at $t = 0$.

i. Find the force $F(x)$ responsible [3 marks]

ii. Determine $x(t)$ [4 marks]

iii. $F(t)$ [1 mark]

(c) Two blocks of unequal masses are connected by a string over a smooth pulley as shown in **Figure** 1(last page). If the coefficient of kinetic friction is μ_k, what angles of θ of the incline allow the masses to move at a contant speed? Which value is physical? Comment! [10 marks]

4. (a) i. State Newton's law of universal gravitation. [descriptive and mathematical statements are required]. [2 marks]

1 + 5 +

ii. The moon travels around the earth once every 27.3 days in an almost circular orbit of radius 3.84×10^8 m. Estimate the mass of the earth. [5 marks]

$\frac{Mv^2}{r} = \frac{GM}{R^2}$

$\sqrt{v}$.

v^2.

(b) A particle is projected vertically upward in a constant gravitational field with an initial velocity v_0 and resisted by a force that is proportional to the square of the instantaneous speed,

$6+3+5+1$

i. Write down the equation of motion and derive an expression for the maximum height reached during ascent. [8 marks]

ii. Write down the equation of motion and derive an expression for the distance travelled for the downward motion when velocity is v. [3 marks]

iii. Show that the speed of the particle when it returns to the initial position is

$$\frac{v_0 v_t}{\sqrt{v_0^2 + v_t^2}}$$

[4 marks]

5. (a) A particle moves in a palne elliptical orbit described by the position vector:

$$\vec{r}(t) = 2b \sin \omega t \,\hat{i} + b \cos \omega t \,\hat{j}$$

i. Find $\vec{v}$, $\vec{a}$ and the particle speed. [4 marks]

ii. What is the angle between $\vec{v}$ and $\vec{a}$ at time $t = \pi/2\omega$. [2 marks]

(b) An object of mass m_1 on a frictionless horizontal table is connected to an object of mass m_2 through a very light pulley P_1 and light fixed pulley P_2 as shown in **Figure 2.**

i. If a_1 and a_2 are the accelerations of m_1 and m_2 respectively, using the coordinates shown, what is the relationship between these accelerations?
[**Hint**: Let the radius of pulley P_1 be R and the length of the string through P_1 is constant and then write the length in terms of the coordinates given] [2 marks]

ii. Express the tensions in the strings and accelerations a_1 and a_2 in terms of m_1 and m_2 and g. [9 marks]

6. (a) Show that the following force is conservative and find its corresponding potential energy.

$$F_x = ayz + bx + c, \; F_y = axz + bz, \; F_z = axy + by$$

where a,b and c are constants. [6 marks]

(b) On a horizontal turntable that is rotating at constant angular speed, an insect is crawling on a radial line such that its distance from the centre increases quadratically with time according to the relationships:

$$\theta = \omega t$$

$$r = bt^2$$

where a and b are constants.

i. the velocity of the bug. [3 marks]

ii. the acceleration of the bug. [1 mark]

iii. An expression for the speed as a function of t. [2 marks]

(c) A physical or compound pendulum is a rigid body that oscillates due to its own weight about a horizontal axis that does not pass though the centre of mass of the body. For small oscillations,

i. Derive an expression for potential energy [2 marks].

ii. Show that the equation of motion is

$$\ddot{\theta} + \frac{mgl}{I}\theta = 0$$

where m is the mass of the pendulum, I is the moment of inertia and l is the length from the axis to the centre of mass. [2 marks]

iii. Hence determine $\theta(t)$. [2 marks]

iv. If the moment of inertia is $I = mk^2$ where k is the radius of gyration, derive an expression for the frequency(ω) and period(T) of the oscillations. [2 marks]

7. (a) A particle of mass m moves acording to the equations

$$x = x_0 + at^2$$

$$y = bt^3$$

$$z = ct$$

3 +4

+10

i. Find the angular momentum **L** at any time t. [4 marks]

I = mv.

ii. Find force **F** and from it the torque **N** acting on the particle and verify that that the angular momentum conservation theorem is satisfied.

[6 marks]

(b) The centre of gravity of a system of particles is the point about which external gravitational forces exert no net torque. Letting

$\vec{r_i}$=position vector of the i^{th} particle,
m_i=mass of the i^{th} particle,
$M = \sum m_i$=total mass,
g=acceleration due to gravity,

Show that for a uniform gravitational force the centre of gravity $\vec{r_0}$ is identical to the centre of mass $\mathbf{r}_{CM}$, i.e.,

$$\vec{r_0} = \frac{1}{M}\sum m_i \vec{r_i} = \vec{r}_{CM}$$

(Hint: Determine the torque about $\mathbf{r}_0$) [10marks]

END OF EXAM

Typeset with LaTeX.

Figure Captions

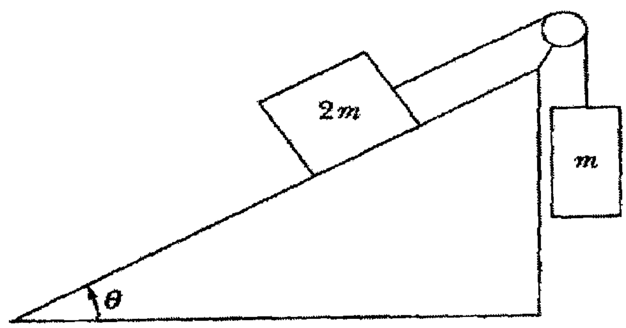


Figure 1: Question 3c

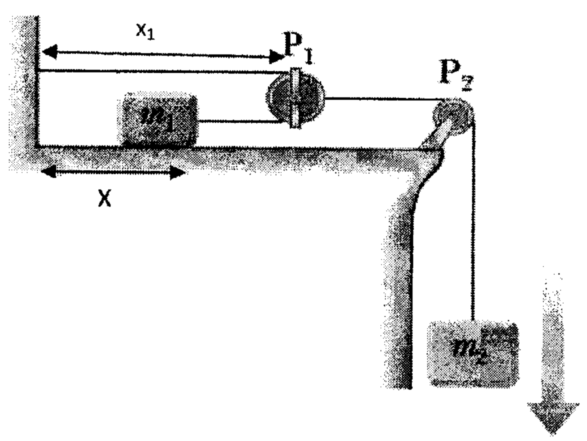


Figure 2: Question 5b

The University of Zambia
School of Natural Sciences
Department of Physics
2008 Academic Year First Semester
Final Examinations
P-261: Electricity & Magnetism

Attempt any five questions. All questions carry equal marks. The marks are shown in brackets.

Time: Three hours. **Maximum marks = 100.**

Write clearly your computer number on the answer book.

==

Wherever necessary use:

g = 9.8m/s^2	$N_{Av.}$=6.02 × 10^{23} per mole
e = 1.6 × 10^{-19}C	1 eV = 1.6 × 10^{-19}J
$\mu_0 = 4\pi\times10^{-7}$ Wb/A-m	$\varepsilon_0 = 8.85\times10^{-12}$ C^2/N.m^2
m_e =9.1 × 10^{-31} kg	c = 3 x 10^8 m/s
$\int_{CS}\vec{E}.\vec{dS}=\frac{\int dq}{\varepsilon_0}$, $\vec{B}=\mu_0\frac{i\,\vec{dl}\sin\theta}{4\pi r^2}$	$k=\frac{1}{4\pi\varepsilon_0}=9\times10^9$ N.m^2/C^2
$\int\vec{E}.\vec{dl}=0$, $\nabla.\vec{E}=\frac{\rho}{\varepsilon_0}$, $\oint\vec{B}.\vec{dl}=\mu_o i$	$\vec{F}=\mu_0\frac{I_1I_2l}{2\pi r}$, $I=I_0(1-e^{-t/\tau})$
$E_r=-\frac{\partial V}{\partial r}$, $E_\theta=-\frac{1}{r}\frac{\partial V}{\partial\theta}$, $E_\phi=\frac{1}{r\sin\theta}\frac{\partial V}{\partial\phi}$	$V=\int\vec{E}.\vec{dr}$, $\vec{D}=\varepsilon\vec{E}$
$\varepsilon=\oint E.dl=-\frac{d\phi}{dt}$, $i=\frac{V}{R}\left[1-\exp\left(-\frac{R}{L}\right)t\right]$	$V=L\frac{di}{dt}+ri$, $R=\rho\frac{L}{A}$
$B=\mu_0\frac{i}{2\pi d}$	$q=q_0e^{-t/RC}$, $i=i_0e^{-tR/L}$

Q1(a). Write an expression for the integral form of Gauss' flux theorem for a continuous distribution of charge, and explain the meaning of the symbols. [2+2]

(b) A positive charge is distributed uniformly throughout a spherical volume of radius R, the charge per unit volume being ρ.

Derive an expression for the electric field inside the sphere at a distance r ($r < R$) from the centre of the sphere.

Find the force of repulsion that a positive charge q will be subjected to when placed at a distance r from the centre of the sphere where $r < R$. [5+2]

(c) By using Gauss' flux theorem show that the electric field around a long cylinder of radius a, having a uniform surface density of charge σ is given by

$$E = \frac{\mu}{2\pi\varepsilon_0 r}$$

where μ is the charge per unit length of the cylinder. [9]

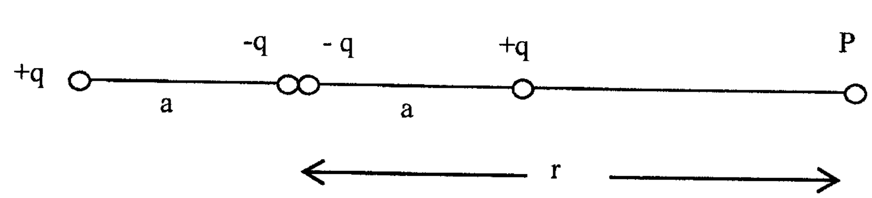
Q2(a). The electric potential of a dipole in a plane is given by

$$V = \frac{1}{4\pi\varepsilon_0}\frac{p\cos\theta}{r^2}$$

where $p = qa$, the electric dipole moment of the charge distribution and a is the charge separation. If r and θ are the polar coordinates, evaluate the resultant electric field in the plane and show that it reduces to

$$\mathbf{E} = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^3}\left(3\cos^2\theta + 1\right)^{1/2}$$ [3+3+4]

(b) One type of electric quadrupole consists of two dipoles whose effects at external points do not quite cancel each other. The arrangement is shown in the figure.



(i) Find an expression for the electric potential at the point P on the axis of this quadrupole. [4]

(ii) Show that for $r >> a$, the potential becomes

$$V = \frac{Q}{4\pi\varepsilon_0 r^3}$$

where $Q = 2qa^2$ is the electric quadrupole moment of the charge assembly. [3]

(iii) Hence or otherwise, show that the electric field of a quadrupole falls off as $\frac{1}{r^4}$. [3]

Q3(a). Calculate the potential and the field due to a dipole of dipole moment 4.5×10^{-10} coulomb/meter at a distance of 1 meter from it:

(i) On its axis,
(ii) On its perpendicular bisector. [8]

(b) A metal sphere has a radius R and is isolated from all other bodies.

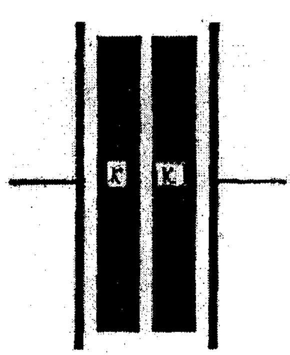
(i) Express the potential of the surface of the sphere as a function of the charge placed on it. [4]

(ii) Integrate the expression in (i) above to determine the work necessary to charge the sphere up to a potential V. [4]

(c) A rod of length L has a uniform positive charge per unit length λ and a total charge Q. Calculate the electric field at a point P along the axis of the rod, at a distance d from one end. [4]

Q4(a) (i). Obtain an expression for the capacitance of a parallel-plate capacitor in vacuum. Assume that the plate separation is d. [4]

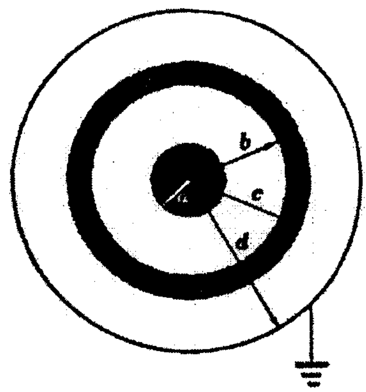
(ii) Repeat problem (i) for the case where the space between the plates of the capacitor are filled with two different dielectrics of thicknesses a and b, so that $d = a + b$. The two dielectrics have different dielectric constants K_a and K_b respectively. [4]



(b) Figure shows a metal sphere of radius a, surrounded by a spherical thick metal shell of inner and outer radii b and c. This shell is isolated electrically, with no net charge, and is surrounded by a grounded spherical shell of radius d.

(i) Find the potential of the inner sphere when a charge Q is placed on it. [4]

(ii) What is the capacitance of the sphere? [4]

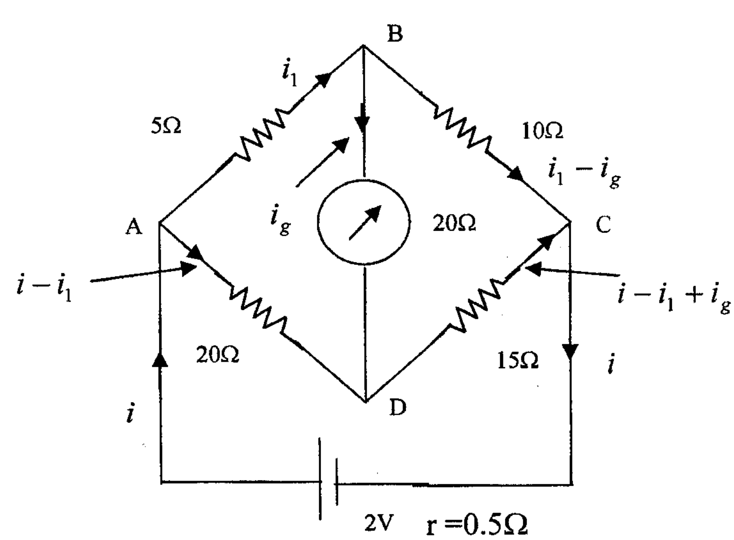


(c) A capacitor of capacitance 1 μF is discharged through a high resistance. The time taken for half the charge on the capacitor to leak was found to be 10 seconds. Find the value of the resistance. [4]

Q5(a). State and explain Kirchhoff's rules for circuits. [4]

(b) The four arms of a Wheatstone bridge are as given: *AB* has a resistance of 5Ω, *BC* has a resistance of 10Ω, *CD* has a resistance of 15Ω, and *DA* has a resistance of 20Ω. A battery with an e.m.f. of 2 volts and internal resistance 0.5Ω is connected across *A* and *C* and a galvanometer having a resistance of 20Ω is connected across *B* and *D*.

Find the current flowing in the galvanometer. [16]



Q6. A coil of inductance L is connected in series with a resistance R and a battery of constant emf V through a key. The key is closed at time $t = 0$.

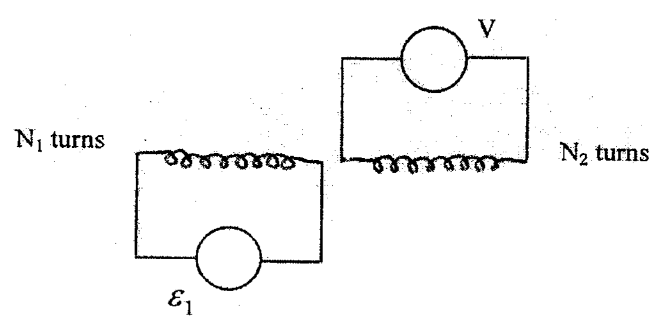
(i) Derive an expression for the growth of the current in the circuit. [8]

(ii) How long it would take for the current to reach 99% of its steady-state value? [4]

(iii) What would be the steady-state value? [2]

(iv) At what time would the potential difference across R be the same as that across L? [6]

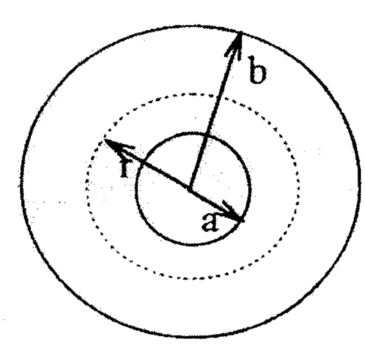
Q7. (a) For the coils shown, half the flux from one coil passes through the other. For an emf ε_1 applied to coil 1, find the voltage indicated on the a.c. voltmeter of coil 2. [5]



(b). (i) State Ampere's circuital law and explain what it means. [2]

(ii) Hence derive the usual expression for the magnitude of the magnetic field induction at a distance a from a long straight wire carrying a current i. [4]

(iii) Figure shows a hollow cylindrical conductor of radii a and b which carries a current i uniformly spread over its cross section. Show that the magnetic field **B** for points inside the body of the conductor ($a < r < b$) is given by



$$\vec{B} = \frac{\mu_0 i}{2\pi(b^2 - a^2)} \frac{r^2 - a^2}{r}$$ [9]

==End of P-261 Examination==

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
DEPARTMENT OF PHYSICS

2008 ACADEMIC YEAR FIRST SEMESTER FINAL EXAMINATIONS

P341: ANALOG ELECTRONICS I

TIME: THREE HOURS **MAXIMUM MARKS - 100**

Attempt any four questions.
All questions carry equal marks.
The marks are shown in brackets.

Q1. **(a)** Draw a single phase half-wave rectifier basic circuit with a resistive load and describe its working. Draw the input and output waveforms. [7]

(b) Use Thevenin's theorem to find V_o in the network below. [11]

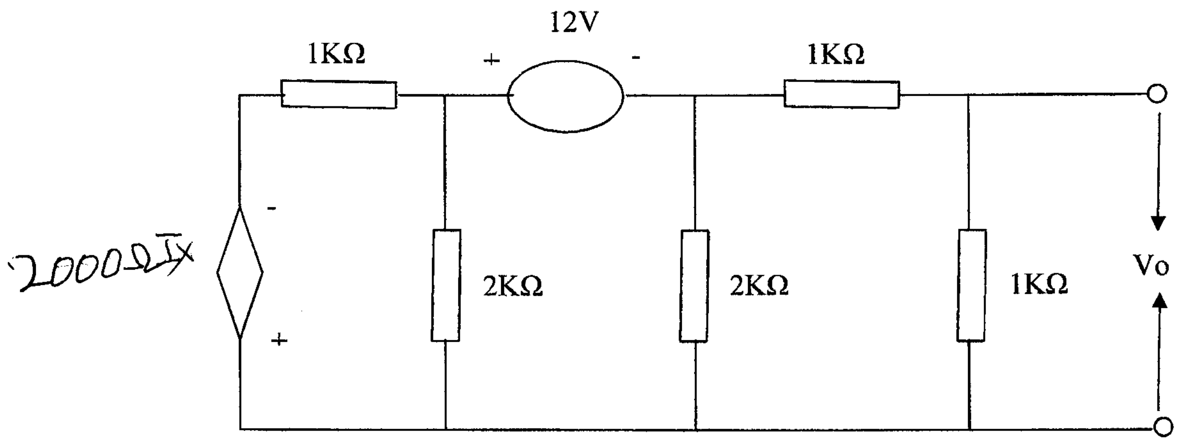


Figure 1

(c) (i) A germanium transistor is to be operated at I_C=1mA. If the collector supply V_{CC}=12V, what is the value of R_B in the base resistor method. Take $\beta = 100$. [4]

(ii) If another transistor of the same batch with $\beta = 50$ is used, what will be the new value of I_C for the same R_B? [3]

Q2. **(a)** Briefly describe the operation of an n-channel Field Effect Transistor with relevant diagrams. [11]

(b) An amplifier has a bandwidth of 500 kHz and voltage gain of 100. What should be the amount of negative feedback if the bandwidth is extended to 5 MHz? What will be the new gain after negative feedback is introduced? [4]

(c) Using the theorem of superposition show that the current in the load resistance R_L, in the circuit shown in figure 2 is

$$I_L = \frac{(V_S + I_S R_1) R_2}{R_1 R_2 + R_L (R_1 + R_2)}$$ [10]

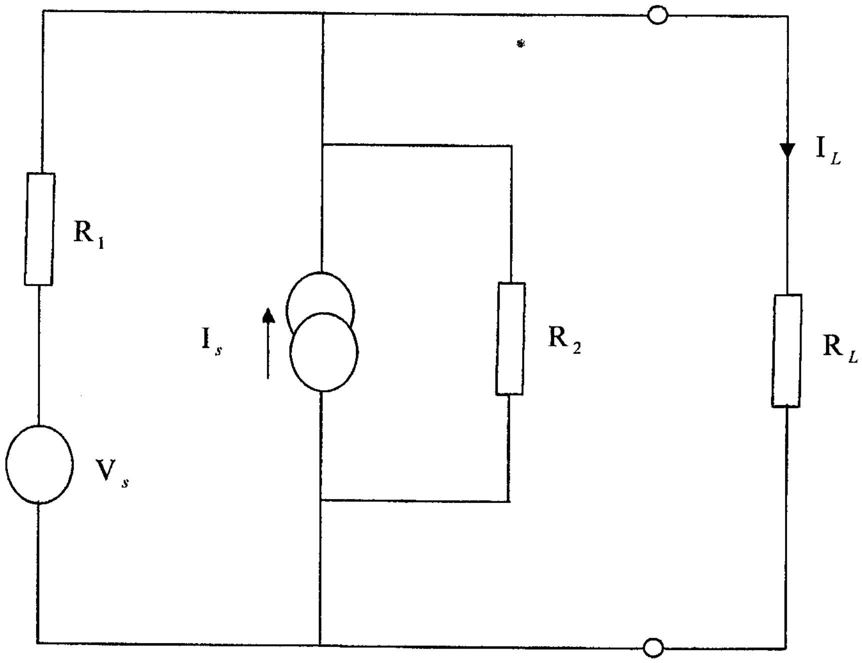


Figure 2

Q3. **(a)** Discuss mechanisms of avalanche breakdown and Zener breakdown in semiconductors. [10]

(b) A carrier wave having a frequency of 1MHz and amplitude of 1000V is modulated to a depth of 50 percent by a sine wave of 5 kHz. Find the frequencies and amplitudes of the upper and lower side of bands. [5]

(c) (i) The gain of an amplifier at lower cut off frequency 25Hz is 400. Find the maximum gain. If the bandwidth is 18.5 kHz, find the upper cut off frequency. [5]

(ii) A single stage CE transistor amplifier has current gain 200. Input resistance is 750Ω and the output resistance is 4.5 kΩ. Calculate the overall gain when two such stages are coupled by RC network. [5]

Q4. **(a)** Show that in intrinsic semiconductors, the Fermi energy level, E_F, lies in the middle of the energy gap that is midway between the conduction and valence bands. [10]

(b) An a.c of 180V and 100Hz is fed to a circuit containing a resistance R and capacitance C connected in series. Calculate the values of R and C when the maximum current is 5A and active power is 300W. [7]

(c) Design a zener voltage regulator circuit that will maintain an output voltage of 20V across 1kΩ load when the input voltage is 30 to 50V. Assume the zener knee current to be negligible compared to load current. Indicate the maximum power of the diode. [8]

Q5. (a) What is modulation? Why is modulation necessary in radio communication systems? [9]

(b) Explain the operation of a series inductor filter. [8]

(c) When 5% negative feedback is given to an amplifier, the total harmonic distortion falls from 12% to 3%. Find the voltage gain without and with negative feedback. [8]

Q6. (a) In a series circuit containing pure resistance and a pure inductance, the current and the voltage are expressed as [7]

$$i(t) = 5\sin\left(314t + \frac{2\pi}{3}\right) \quad \text{and} \quad v(t) = 15\sin\left(314t + \frac{5\pi}{6}\right)$$

(i) What is the impedance of the circuit?
(ii) What is the value of the resistance?
(iii) What is the inductance in Henrys?
(iv) What is the average power drawn by the circuit?

(b) The potential divider circuit shown below has the values as follows.

I_E=2mA, I_B=50μA, V_{BE}=0.2V, R_E=1kΩ, R_2=10kΩ and V_{CC}=10V.

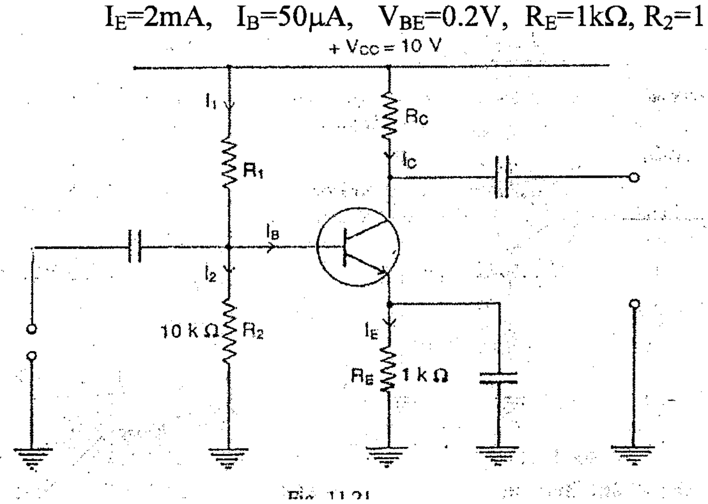


Figure 4

Find the value of R_1. [6]

(c) Write short notes on [12]

(i) Voltage regulation

(ii) Drift mobility

(iii) Modulation factor

(iv) Thermal runaway

END OF P341 EXAMINATION

UNIVERSITY OF ZAMBIA
PHYSICS DEPARTMENT
UNIVERSITY EXAMINATIONS
FIRST SEMESTER 2008
P351
INTRODUCTION TO QUANTUM MECHANICS

Time: Three Hours
Answer any four questions
All questions carry equal marks
Total marks: 100

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1. **(a)** **(i)** Interpret the wave function $\Psi(x,t)$. [2 marks]
Hence explain the following of its properties::
(ii) $\Psi(x,t)$ is single-valued [2 marks]
(iii) $\Psi(x,t)$ is continuous [2 marks]
(iv) $\Psi(x,t) \to 0$ as $x \to \pm\infty$. [2 marks]

(b) **(i)** Show that if the potential energy acting on a particle is independent of time, the time-dependent Schroedinger equation

$$-\frac{\hbar^2}{2m}\nabla^2\Psi(\mathbf{r},t) + V(\mathbf{r})\Psi(\mathbf{r},t) = i\hbar\frac{\partial}{\partial t}\Psi(\mathbf{r},t)$$

separates into two equations. [8 marks]

(ii) Show that in such a case the wave function has the form

$$\Psi(\mathbf{r},t) = \psi(\mathbf{r})e^{-i\omega t}$$

[3 marks]

(c) The force acting on a particle is given by $F(x) = -kx^{-2}$, where k is a constant.
(i) Write down the Schroedinger equation for the particle. [4 marks]
(ii) Show that the probability current density of the particle is not a function of the time. [2 marks]

2. **(a)** A particle is trapped in an infinite potential well with walls at $x = 0$ and $x = L$.
(i) Prove that the eigenfunctions of the particle are given by

$$\phi_n = \sqrt{\frac{2}{L}}\sin\frac{n\pi x}{L}, \quad n = 1, 2, 3, \ldots$$

[11 marks]

(ii) Show that the wave functions of the particle at time t are

$$\Psi_n(x,t) = \sqrt{\frac{2}{L}}\sin\frac{n\pi x}{L}\exp\left(-\frac{in^2\pi^2\hbar}{2mL^2}t\right)$$

[2 marks]

(b) The two-dimensional harmonic oscillator has the Hamiltonian

$$H(x,y) = -\frac{\hbar^2}{2m}\left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}\right) + \frac{1}{2}m\omega_1^2x^2 + \frac{1}{2}m\omega_2^2y^2$$

(i) Given that the energy levels of a one-dimensional harmonic oscillator are given by

$$E_n = (n + \frac{1}{2})\hbar\omega, \quad n = 0, 1, 2, 3, ...$$

show that the energy levels of the two-dimensional osçillator are given by

$$E_{n_1 n_2} = (n_1 + \frac{1}{2})\hbar\omega_1 + (n_2 + \frac{1}{2})\hbar\omega_2, \qquad n_1, n_2 = 0, 1, 2, 3, ...$$

[7 marks]

(ii) Explain why when $\omega_1 = \omega_2$ the energy levels are in general degenerate. [2 marks]

(iii) Obtain the degrees of degeneracy of the ground state and the first excited state. [3 marks]

3. A particle of energy E approaches a potential step from the left. The potential step is

$$V(x) = \begin{cases} 0 & \text{for} \quad x < 0 \\ -V_0 & \text{for} \quad x \geq 0 \end{cases}, \quad V_0 > 0$$

(i) Show that the solution of the time-independent Schroedinger equation in the region $x < 0$ is

$$\psi_I(x) = Ae^{ikx} + Be^{-ikx}$$

where

$$k = \left(\frac{2mE}{\hbar^2}\right)^{1/2}$$

[6 marks]

(ii) Show that the acceptable solution in the region $x \geq 0$ is

$$\psi_{II}(x) = Ce^{iqx}$$

where

$$q = \left(\frac{2m\,(E + V_0)}{\hbar^2}\right)^{1/2}$$

[5 marks]

(iii) Hence show that the reflection coefficient is

$$R = \left(\frac{k - q}{k + q}\right)^2$$

while the transmission coefficient is

$$T = \frac{4kq}{(k + q)^2}$$

[11 marks]

(iv) Prove that the two coefficients add up to unity and explain the meaning of this. [3 marks]
Note that

$$j = \frac{\hbar}{2mi}(\psi^* \frac{\partial}{\partial x}\psi - \psi\frac{\partial}{\partial x}\psi^*)$$

4. (a) Given that the definition of a Hermitian operator A is

$$\int \psi^* A\phi d\tau = \int (A\psi)^* \phi d\tau$$

(i) Show that the eigenvalues of a Hermitian operator are necessarily real and explain the importance of this. [6 marks]

(ii) Prove that the Hamiltonian operator

$$H = -\frac{\hbar^2}{2m}\frac{d^2}{dx^2} + \frac{1}{2}kx^2$$

for the linear harmonic oscillator is Hermitian. Assume that the functions on which the operator acts vanish at $x = \pm\infty$. [7 marks]

(b) (i) Show that the commutator of x and p_x is non-vanishing and explain the meaning of this. [3 marks]

(ii) Show that if eigenfunctions of a Hermitian operator belong to different eigenvalues, they are orthogonal. [5 marks]

(iii) Show that the ground-state and first-excited-state eigenfunctions

$$\psi_0(x) = \left(\frac{\alpha}{\sqrt{\pi}}\right)^{1/2} e^{-\alpha^2x^2/2} \quad \text{and} \quad \psi_1(x) = \left(\frac{\alpha}{2\sqrt{\pi}}\right)^{1/2} 2\alpha x e^{-\alpha^2x^2/2}$$

where $\alpha = \sqrt{\frac{m\omega}{\hbar}}$, of the harmonic oscillator are orthogonal. [4 marks]

5. (a) (i) Using the classical expression $\mathbf{L} = \mathbf{r} \times \mathbf{p}$, obtain the operators for the three Cartesian components of the orbital angular momentum. [2 marks]

(ii) Using the basic commutation relations $[x, p_x] = [y, p_y] = [z, p_z] = i\hbar$ for the position and momentum operators, pick a pair of components of $\mathbf{L}$ and compute their commutator. [4 marks]

(iii) By picking one component to illustrate the result, show that $\mathbf{L}^2$ commutes with any one component of $\mathbf{L}$. You may need the result $[L_i, L_j] = i\hbar L_k$,where i,j and k are taken in cyclic order. [5 marks]

(iv) Explain the importance of the results in (ii) and (iii). [2 marks]

(vi) If a system is in an eigenstate of L_z, what can you say about the values of L_x and L_y? [2 marks]

(b) In spherical polar coordinates, the operator fo the z component of $\mathbf{L}$ is

$$L_z = -i\hbar\frac{\partial}{\partial\phi}$$

(i) Given the eigenfunction

$$Y(\theta, \phi) = A\sin^3\theta e^{3i\phi}$$

where A is a normalisation constant, prove that it corresponds to $L_z = 3\hbar$. [3 marks]

(ii) If this value of L_z corresponds to the maximum z component of $\mathbf{L}$, obtain the magntiude of the angular momentum. [2 marks]

(iii) Obtain the angles which the z components of $\mathbf{L}$ make with the z axis. [5 marks]

6. (a) The normalised wave function for the ground state of a hydrogen-like atom (neutral hydrogen, He^+, Li^{2+}, etc.) with nuclear charge Ze has the form $u = Ae^{-\beta r}$ where A is a normalisation constant, $\beta = \frac{m_e Ze^2}{4\pi\epsilon_0\hbar^2}$, and r is the distance between the electron and the nucleus. Show the following:

(i) The normalisation constant is

$$A = \sqrt{\frac{\beta^3}{\pi}}$$

[4 marks]

(ii) The energy is

$$E = -\frac{m_e Z^2}{2\hbar^2}\left(\frac{e^2}{4\pi\epsilon_0}\right)^2$$

[6 marks]

(iii) The expectation values of the potential and kinetic energies are $2E$ and $-E$ respectively. [3+1 marks]

Recall that for a function that depends only on r,

$$\nabla^2 = \frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial}{\partial r}\right)$$

Also

$$dV = r^2 \sin\theta dr d\theta d\phi$$

(**b**) Consider a hydrogen atom whose wave function $\Psi(\mathbf{r}, t)$ at $t = 0$ is the following superposition of energy eigenfunctions $\psi_{nlm}(\mathbf{r}) = R_{nl}(r)Y_{lm}(\theta, \phi)$:

$$\Psi(\mathbf{r}, t=0) = A\left[3\psi_{100}(\mathbf{r}) - \psi_{210}(\mathbf{r}) + \psi_{32,-2}(\mathbf{r})\right].$$

(**i**)What is the probability at $t = 0$ of finding the system in the ground state (100), in the state (210), in the state $(32, -2)$, and in any other state? [5 marks]

(**ii**) What are the expectation values of the energy, the operator $\mathbf{L}^2$ and the operator L_z? [6 marks]

Note that hydrogen-atom energies are given by $E_n = -13.6/n^2$ eV.

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

THE UNIVERSITY OF ZAMBIA
PHYSICS DEPARTMENT
UNIVERSITY EXAMINATIONS
FIRST SEMESTER – 2008
P361 - ELECTROMAGNETISM

TIME: 3 HOURS MAX MARKS: 100

ATTEMPT ANY FOUR QUESTIONS. ALL QUESTIONS CARRY EQUAL MARKS.

You may use the following information:

$$\varepsilon_0 = 8.85 \times 10^{-12} \text{ farad/meter}$$
$$\mu_0 = 4\pi \times 10^{-7} \text{ N/A}^2$$
$$N_a = 6.0 \times 10^{23} \text{ mol}^{-1}$$

$$\int \sec\theta \, d\theta = \ln(\sec\theta + \tan\theta)$$

The vector identities

$$\vec{\nabla} \times (\vec{\nabla} \times \vec{A}) = -\vec{\nabla}^2 A + \vec{\nabla}(\vec{\nabla} \cdot \vec{A})$$
$$\vec{\nabla} \cdot (f\vec{A}) = f\vec{\nabla} \cdot \vec{A} + \vec{A} \cdot \vec{\nabla} f$$
$$\vec{\nabla} \times (f\vec{A}) = \vec{\nabla} f \times \vec{A} + f(\vec{\nabla} \times \vec{A})$$
$$\vec{\nabla}(V\vec{\nabla} V) = (\vec{\nabla} V)^2 + V\vec{\nabla}^2 V$$

The vector $\vec{r}$ 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

$$\vec{\nabla}\left(\frac{1}{r}\right) = -\frac{\hat{r}}{r^2}$$

If P is fixed and P' is allowed to move, then the gradient is

$$\vec{\nabla}'\left(\frac{1}{r}\right) = \frac{\hat{r}}{r^2}$$

In spherical coordinates (r, θ, ϕ)

$$\vec{\nabla} f = \frac{\partial f}{\partial r}\hat{r} + \frac{1}{r}\frac{\partial f}{\partial \theta}\hat{\theta} + \frac{1}{r\sin\theta}\frac{\partial f}{\partial \phi}\hat{\phi}$$

$$\vec{\nabla}^2 \equiv \frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial}{\partial r}\right) + \frac{1}{r^2\sin\theta}\frac{\partial}{\partial \theta}\left(\sin\theta\frac{\partial}{\partial \theta}\right) + \frac{1}{r^2\sin^2\theta}\frac{\partial^2}{\partial \phi^2}$$

$$\vec{\nabla}.\vec{A} \equiv \frac{2}{r}A_r + \frac{\partial A_r}{\partial r} + \frac{A_\theta}{r}\cot\theta + \frac{1}{r}\frac{\partial A_\theta}{\partial \theta} + \frac{1}{r\sin\theta}\frac{\partial A_\phi}{\partial \phi}$$

$$\vec{\nabla}\times\vec{A} = \frac{\hat{r}}{r\sin\theta}\left[\frac{\partial}{\partial\theta}\left(\sin\theta\, A_\phi\right) - \frac{\partial A_\theta}{\partial\phi}\right] + \frac{\hat{\theta}}{r}\left[\frac{1}{\sin\theta}\frac{\partial A_r}{\partial\phi} - \frac{\partial}{\partial r}\left(rA_\phi\right)\right] + \frac{\hat{\phi}}{r}\left[\frac{\partial}{\partial r}\left(rA_\phi\right) - \frac{\partial A_r}{\partial\theta}\right]$$

In cylindrical coordinates (ρ, ϕ, z)

$$\vec{\nabla} f = \hat{\rho}\frac{\partial f}{\partial \rho} + \hat{\phi}\frac{1}{\rho}\frac{\partial f}{\partial \phi} + \hat{z}\frac{\partial f}{\partial z}$$

$$\vec{\nabla}\vec{A} = \frac{1}{\rho}\frac{\partial}{\partial\rho}\left(\rho A_\rho\right) + \frac{1}{\rho}\frac{\partial A_\phi}{\partial\phi} + \frac{\partial A_z}{\partial z}$$

$$\vec{\nabla}\times\vec{A} = \hat{\rho}\left(\frac{1}{\rho}\frac{\partial A_z}{\partial\phi} - \frac{\partial A_\phi}{\partial z}\right) + \hat{\phi}\left(\frac{\partial A_\rho}{\partial z} - \frac{\partial A_z}{\partial\rho}\right) + \hat{z}\left[\frac{1}{\rho}\frac{\partial}{\partial\rho}\left(\rho A_\phi\right) - \frac{1}{\rho}\frac{\partial A_\rho}{\partial\phi}\right]$$

$$\nabla^2 f = \frac{1}{\rho}\frac{\partial}{\partial\rho}\left(\rho\frac{\partial f}{\partial\rho}\right) + \frac{1}{\rho^2}\frac{\partial^2 f}{\partial\phi^2} + \frac{\partial^2 f}{\partial z^2}$$

For any arbitrary vector $\vec{A}$ and a surface S bounding a volume τ

$$\int_\tau \left(\vec{\nabla}\times\vec{A}\right)d\tau = -\int_s \vec{A}\times d\vec{s}$$

Poisson's Equation $\qquad \vec{\nabla}^2 V = -\frac{\rho}{\varepsilon_0}$

For a long solenoid of length L, the magnetic induction is given by

$$B = \frac{\mu_0 NI}{L} \quad \text{inside}$$
$$= 0 \quad \text{outside}$$

The vector potential at a point due to a current carrying conductor

$$\vec{A} = \frac{\mu_0 I}{4\pi} \oint \frac{d\vec{l}}{r}$$

The magnetic induction

$$\vec{B} = \frac{\mu_0 I}{4\pi} \oint \frac{d\vec{l} \times \hat{r}}{r^2}$$

$$\vec{B} = \vec{\nabla} \times \vec{A}$$

Vector potential due to a magnetic dipole

$$\vec{A} = \frac{\mu_0}{4\pi} \frac{\vec{m} \times \hat{r}}{r^2}$$

The magnetic induction at a point on the axis of a circular current carrying loop is

$$B = \frac{\mu_0 I a^2}{2\left(a^2 + z^2\right)^{3/2}}$$

Force on an element of wire carrying a current

$$d\vec{F} = I\, d\vec{l}\, x\, \vec{B}$$

The Maxwell's Equations are

$$\vec{\nabla} \bullet \vec{D} = \rho_f$$
$$\vec{\nabla} \bullet \vec{B} = 0$$
$$\vec{\nabla} \times \vec{E} + \frac{\partial \vec{B}}{\partial t} = 0$$
$$\vec{\nabla} \times \vec{H} = \vec{J}_f + \frac{\partial \vec{D}}{\partial t}$$

Q.1 A charge is distributed in the form of a long cylinder with charge distribution given by:

$$\rho_{ch} = \rho_0\left(1 - \frac{\rho}{a}\right) \qquad (\rho < a)$$

$$\rho_{ch} = 0 \qquad (\rho > a)$$

where ρ_{ch} is the charge density and ρ is the cylindrical coordinate.

(a) Calculate the total charge Q. [7 marks]

(b) Use the Gauss' Law to calculate the electric field intensity at a point (i) inside, and (ii) outside the charge distribution. [3+3 marks]

(c) Use Poisson's equation to calculate the electric field intensity at a point (i) inside and (ii) outside the charge distribution. [5+5 marks]

(d) Match the results in (b) and (c) above to evaluate the value of the constant which appears in the result of (c). [2 marks]

Q.2 Consider a Class A dielectric sphere of radius R with a point charge Q placed in a small cavity of radius δ at its centre. Calculate

(a) $\vec{D}, \vec{E}$ and $\vec{P}$ at a point (i) inside and (ii) outside the sphere. [7+5 marks]

(b) Use the expression for $\vec{P}$ to obtain

(i) volume density of bound charges, [5 marks]

(ii) surface density of charges on the outer surface of the sphere as well as the surface of the cavity. [5 marks]

(c) Show explicitly that the total bound charge on the sphere is zero. [3 marks]

Q.3. (a) State the uniqueness theorem in electrostatics and explain its significance. [4 marks]

(b) An infinite grounded metallic plate has a point charge Q placed at a distance D from it.

(i) Explain and use the method of images to obtain an expression for the electric potential V at a point due to this configuration. [6 marks]

(ii) Use the expression for V in b (i) above to obtain the components E_r and E_θ of the electric field intensity. [4 marks]

(iii) Obtain an expression for the electric field intensity at a point on the plate and show that $\vec{E}$ is perpendicular to the plate. [5 marks]

(iv) Use the result in (iii) above to obtain an expression for the induced electric charge density on the plate. [2 marks]

(v) Show that the total charge induced on the plate is $-Q$. [4 marks]

Q.4.

(a) State Stoke's theorem to convert a line integral in to a surface integral and Green's (divergence) theorem to convert a surface integral in to a volume integral. Briefly but clearly describe the meaning of the line, the surface and the volume integrals involved in these theorems. Giving reasons explain if the two theorems can be successively applied to convert a line integral in to a volume integral. [6 marks]

(b) Show that the net force on a closed circuit carrying a current I in a uniform magnetic field is zero. [2 marks]

(c) A current I flows through a wire in the form of an ellipse with a and b as the semi major and semi minor axis, respectively. Find the magnetic dipole moment. [2 marks]

(d) A wire bent in the form of a rectangle of width w and height h is placed so that its height is parallel to a long wire and the near side is at a distance D from the wire, the two being in the same plane. Find the mutual inductance. [6 marks]

(e) A current I flows through a long cylindrical wire of radius R. Use Ampere's circuital law to find B at a point inside the wire. [5 marks]

(f) A cylinder is uniformly magnetized with magnetisation M. Find the volume and the surface current densities. [4 marks]

Q.5 A long wire of radius a carries a current I and is surrounded by a long 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) Find the flux of B through a section of the cylinder L meters long. [7 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. [7 marks]

(c) Find the equivalent current density inside the iron. [5 marks]

(d) Find B at distances $r > c$ from the wire. How would this value be affected if the iron cylinder were removed? [6 marks]

Q.6 (a) Show that the Maxwell's equations of electromagnetic fields in vacuum lead to wave equations. Calculate the speed of these waves. What implication did this discovery have on the nature of light? [8 marks]

(b) Assuming plane waves, show that electromagnetic waves are transverse in nature. [5 marks]

(c) Show that the $\vec{E}$ and $\vec{H}$ vectors in an electromagnetic wave are mutually perpendicular. [6 marks]

(d) Show that the vector $\vec{E} \times \vec{H}$ represents the rate of energy flow per unit normal area. [6 marks]

.... **END OF THE EXAMINATION** ....

THE UNIVERSITY OF ZAMBIA

DEPARTMENT OF PHYSICS
FIRST SEMESTER EXAMINATION 2008

P401: COMPUTATIONAL PHYSICS II

TIME:	3 HOURS
INSTRUCTIONS:	ANSWER ANY **FOUR** QUESTIONS
	TOTAL MARKS 100
	ALL QUESTIONS CARRY EQUAL MARKS

Q.1. (a) Define a preprocessor directive in C++ and give any three examples of preprocessor directives stating their purposes. [4]

(b) Explain the different kinds of looping structures in C++ with examples. [6]

(c) Explain the hierarchy of arithmetic operators available in C++ and evaluate the following expression:

2*(i % 5)*(4 + (j-3)/(k+2)) where i = 8, j = 15 and k =14. [6]

(d) Find the outputs of the following segments of code:

(i)

```
int y = 10;
if ((y++>9)&&(y++!=10)) && (y++>10)
    cout<<"a ="<<y<<"\n";
else
    cout<<"b ="<<y<<"\n";
```

[2]

(ii)

```
int i = 0, x = 0;
while ( i < 20) {
    if (i % 5 = = 0) {
        x + = i;
        cout<<"x ="<<x<<"\n";
    }
    ++i;
}
```

[3]

(b) (i) Assume a quadratic drag force ($F_d = kv^2$) on an object falling straight to the ground. Derive an appropriate expression for the acceleration. [3]

(ii) Using the result in (i), write a **function** called **EulerRichardson** that can be called by some main function to simulate this motion. Do not write the whole program, only a function which uses the Euler-Richardson method. [10]

Q.3. (a) Explain how you would seed a random number generator in C++. [3]

(b) Most methods of generating random numbers on a computer depend on a chaotic sequence. The commonest is the *multiplicative congruential method* which relies on prime numbers. Consider the sequence

$$x_{n+1} = (a * x_n)\%b$$

where $x\%y$ refers to the remainder on dividing x by y and a and b are integers which have no common factors (often both are prime numbers). This process generates all integers less than b in an apparently random order. After all b integers have been generated the series will repeat itself. Show that the sequence above has the property that it generates **all** the integers from 1 to 10 in an apparently random order if $a = 7$ and $b = 11$ and that the sequence repeats itself thereafter. Choose an appropriate seed to begin your sequence. [7]

(c) What does the term *Monte–Carlo* refer to with regard to physical or mathematical problems? [3]

(d) Write a program to evaluate the integral $\int_{0.1}^{0.6} \frac{1}{\sqrt{2\pi}} e^{-x^2/2} dx$ by Monte Carlo integration. By considering the range of values that the function being integrated can take, choose an appropriate field in which to integrate and use 500 pixels along each boundary of the field of integration. The number of trials should be entered by the user. [12]

Q.4. (a) Consider the rectangular wave function of period T given by:

$$f(t) = -1 \quad \text{for} \quad -\frac{T}{2} < t < -\frac{T}{4} \text{ and } \frac{T}{4} < t < \frac{T}{2};$$

$$f(t) = 1 \quad \text{for} \quad -\frac{T}{4} < t < \frac{T}{4}.$$

(i) Express the function $f(x)$ as an infinite Fourier series. [6]

(ii) By considering the first three terms show how the superposition of sinusoidal functions in this series converge to a rectangular wave. [3]

(iii) Distinguish between the **frequency** and **time** domains in Fourier analysis with reference to the rectangular wave form above and hence explain why a single bolt of lightening affects electronic receiver signals of several frequencies. [5]

(b) Give a quantitative description of the discrete Fourier transform (DFT) and show how two *for* loops can be used to carry it out in C++ (you are only required to write the relevant segment of code and not a whole program). [7]

(c) Explain how fast Fourier transforms (FFTs) are designed and explain how they are an improvement on the ordinary DFTs (you are **not required** to derive any FFT algorithm). [4]

Q.5. The curvature of a slender column subject to an axial load P can be modelled by

$$\frac{d^2y}{dx^2} = \frac{M}{EI}$$

where M is the bending moment, E is the modulus of elasticity and I is the moment of inertia of the cross section about its neutral axis. The system is subjected to the boundary conditions $y(0) = 0$ and $y(L) = 0$, where L is the total length of the column.

(a) Use the polynomial method to approximate the first three eigenvalues of the system described above for the case of three interior points (i.e. $h = L/4$) and $L = 3$m. [10]

(b) Use the Fadeev-Leverrier method to generate the characteristic polynomial associated with the eigenvalues of the system described above. [12]

(c) Prove that the eigenvalues found in (a) are solutions of the characteristic polynomial in (b). [3]

Q.6. (a) Give a definition of chaos. [2]

(b) Distinguish between random data and chaotic data. [2]

(c) Explain why computational physics is particularly well suited for the analysis of chaotic systems. [2]

(d) Give **short notes** to explain the following terms with regard to the modelling of population growth through various generations:

(i) Transients; [2]
(ii) Asymptotes; [2]
(iii) Extinction; [2]
(iv) Stable states; [2]
(v) Period doubling; [2]

(vi) Intermittency; [2]
(vii) Chaos. [2]

(e) Give a quantitative description of fixed points and period doubling. [5]

END OF P401 EXAMINATION

THE UNIVERSITY OF ZAMBIA

DEPARTMENT OF PHYSICS
FIRST SEMESTER EXAMINATION 2008

P421: SOLID STATE PHYSICS I

TIME:	3 HOURS
INSTRUCTIONS:	ANSWER ANY **FOUR** QUESTIONS
	TOTAL MARKS 100
	ALL QUESTIONS CARRY EQUAL MARKS

Electron rest mass $m_e = 9.11 \times 10^{-31}$ kg

Proton rest mass $m_p = 1.67 \times 10^{-27}$ kg

Planck's constant $h = 6.626 \times 10^{-34}$ Js^{-1}

Boltzmann constant $k_B = 1.38 \times 10^{-23}$ JK^{-1}

Avogadro's number $N = 6.022 \times 10^{23}$ per g mole

Permittivity of free space $\varepsilon_0 = 8.854 \times 10^{-12}$ F/m

$(\boldsymbol{c} \times \boldsymbol{a}) \times (\boldsymbol{a} \times \boldsymbol{b}) = (\boldsymbol{c} \bullet \boldsymbol{a} \times \boldsymbol{b})\boldsymbol{a}$

$$\int_0^{\theta_D/T} \frac{x^4 e^x}{(e^x - 1)^2} = \frac{4\pi^4}{15} \quad \text{at low temperature}$$

$$= \frac{1}{3}\left(\frac{\theta_D}{T}\right)^3 \quad \text{at high temperature}$$

Q.1. (a) How does the knowledge of the Brillouin zone assist in determining the allowed wave vectors which can be diffracted by a crystal? [4]

(b) Show that for a cubic lattice, the lattice constant a is given by

$$a = \left[\frac{nM_A}{N_A\rho}\right]^{1/3}$$

where n is the number of atoms per unit cell, M_A is the atomic mass, N_A is Avogadro's number and ρ is the density of the crystal material. [12]

(c) Show that the volume of the first Brillouin zone is $(2\pi)^3/V_c$, where V_c is the volume of a crystal primitive cell. Hint: The volume of a Brillouin zone is equal to the volume of the primitive parallelepiped in Fourier space. [9]

Q.2. (a) Show that the reciprocal lattice of a simple cubic structure is also S.C. [8]

(b) What is the angle between the reciprocal lattice vectors $\boldsymbol{G}_{100}$ and $\boldsymbol{G}_{111}$ in the simple cubic structure? [6]

(c) The repulsive term Br^{-n} in the lattice energy expression

$$U(r) = -N(Aq^2r^{-1}-Br^{-n})$$

is often replaced by the term $C\exp(-r/L)$, where A, B and L are constants, and r is the nearest neighbour separation. At what **equilibrium** nearest neighbour distance R_0 do the two repulsive potentials energies give rise to the same lattice energy? [11]

Q.3. (a) What is an ionic bond? State the various interactions involved and their contributions to the overall bond strength. [5]

(b) The net potential energy U_0 between adjacent atoms may sometimes be represented as a function of the interatomic distance r according to the relation

$$U(r) = -\frac{a}{r^m} + \frac{b}{r^n}$$

in which a, b, and n are all constants whose values depend on the specific material. Calculate the bonding energy U_0 at the equilibrium atomic spacing r_0 in terms of a, b, m and n. [10]

(c) In a van der Waals bonded solid where the equilibrium atomic spacing is $r_0 = 4.50$ Å, the binding energy is given by

$$U = -Ar^{-6} + B\exp\left(\frac{-r}{\rho}\right)$$

where A, B and ρ are constants. If the attractive van der Waals energy has a magnitude ten times larger than the repulsive overlap energy at the equilibrium spacing r_0, find the value of the characteristic length ρ. [10]

Q.4. (a) Describe the following:

(i) covalent bonding; [2]

(ii) metallic bonding; [2]

(ii) hydrogen bonding. [2]

(b) Consider the propagation of longitudinal waves through a linear monatomic lattice. The mass of each atom is m, the equilibrium atomic spacing is a and the stiffness constant with respect to the j^{th} nearest neighbour is C_j.

(i) Show that when more remote neighbors cannot be ignored, the dispersion relation

$$\omega^2 = 4\frac{C}{m}\sin^2\left(\frac{Ka}{2}\right)$$

is replaced by

$$\omega^2 = \frac{2}{m}\sum_{j=1}^{\infty} C_j\left[1 - \cos(jKa)\right]$$ [11]

(ii) We suppose that the interplanar force constant C_j between planes s and $s+j$ is of the form

$$C_j = A\frac{\sin jk_0 a}{ja}$$

where A and k_0 are constants and j runs over all intergers. Find an expression for $\partial\omega^2/\partial K$ and prove that it is infinite when $K = k_0$. [8]

Q.5. (a) Define:

(i) Ionization energy; [2]

(ii) Electron affinity; [2]

(iii) Cohesive energy. [2]

(b) Consider the normal modes of a linear chain in which the force constants between nearest-neighbor atoms are alternately $2C$ and $4C$. Let the masses be equal, and let the nearest-neighbor separation be $a/4$.

(i) Find $\omega(K)$ at $K=0$ and $K=\pi/a$. [14]

(ii) Sketch the shape of the dispersion relation. [5]

Q.6. (a) Explain the differences between the Debye and Einstein models of heat capacity and note the consequences of these differences. [6]

(b) In the Debye approximation, the density of states for each polarization is given by

$$D(\omega) = \frac{V\omega^2}{2\pi^2 v^3}$$

in the usual notation.

(i) Using this, obtain an expression for the heat capacity of solids. [9]

(ii) Show that the heat capacity at low temperature is proportional to T^3. [5]

(iii) Show that at high temperatures the Debye theory gives the Dulong-Petit value. [5]

END OF P421 EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2008 ACADEMIC YEAR FIRST SEMESTER FINAL EXAMINATIONS

P441 : Analog Electronics II

Time : Three hours. **Maximum marks = 100.**

Attempt any four questions.
All questions carry equal marks.
The marks are shown in brackets.

Wherever necessary use:

Electrical parameters of 714C operational amplifier

$A = 400,000$
$R_i = 33\ M\Omega$
$R_o = 60\Omega$
Supply voltages = $\pm$ 15V
Maximum output voltage swing = $\pm$13V
UGB = 0.6 MHz

LM307 operational amplifier

$V_{io} = 10$ mV dc
$I_B = 300$nA
$I_{io} = 70$ nA

Q1. (a) Explain Miller's theorem and discuss how this theorem is useful in finding the input resistance of a closed loop inverting amplifier. [10]

(b) Draw the circuit of a differential instrumentation amplifier using a transducer bridge. [6]

(c) Derive an equation for the output voltage for the above instrumentation amplifier. [9]

Q2. (a) Explain the difference between slew rate and transient response. [5]

(b) Draw the circuit of an inverting, non-inverting and differential amplifier with external offset voltage compensating network. [7]

(c) **(i)** Design a differentiator to differentiate an input signal that varies in frequency from 30Hz to about 1.5kHz. [4]

(ii) Draw the complete circuit with the component values. [4]

(iii) If a sine wave of 1V peak at 1000Hz is applied to the differentiator of part c(i), find the output voltage. [5]

Q3. (a) Define input offset voltage and explain why it exists in all operational amplifiers. [5]

(b) The 714C is configured as a non-inverting amplifier with the following specifications.

$R_1=100\Omega$ and $R_F=4.7k\Omega$

Compute the following closed loop parameters; [9]

(i) Voltage gain
(ii) Input resistance
(iii) Output resistance
(iv) Bandwidth
(v) Total output offset voltage
(vi) Output voltage if V_{in}=100mV peak-to-peak sine wave at 1kHz. Sketch the input and output waveform.

Assume that the operational amplifier is initially nulled.

(c) With figure, briefly describe the operation of a quadrature oscillator. Write the equation for the frequency of oscillation and explain conditions for maintaining oscillations. [11]

Q4. The non compensated operational amplifier MC1539 has a dc gain A=120,000 and the following break frequencies. f_{01}=5kHz, f_{02}=320kHz, f_{03}=1MHz and f_{04}=2MHz.

(a) Write the open loop gain equation for the operational amplifier as a function of break frequencies and dc gain A. [2]

(b) Find the value of open loop gain for the following frequencies. [14]

0Hz 500Hz 5kHz 50kHz 320kHz 1MHz 2MHz

(c) (i) Find the phase shift between input and output signals at 50kHz and 1.5 MHz. [5]

(ii) Define break frequency and UGB. [4]

Q5 (a) Define a filter. List the most commonly used active filters and show their frequency response curves. Indicate the ideal and practical frequency response curves separately using solid and dashed lines. Clearly show the position of stop band and pass band. [8]

(b) Design a first order high pass Butterworth filter at a cut off frequency of 1 kHz and pass band gain of 2. [5]

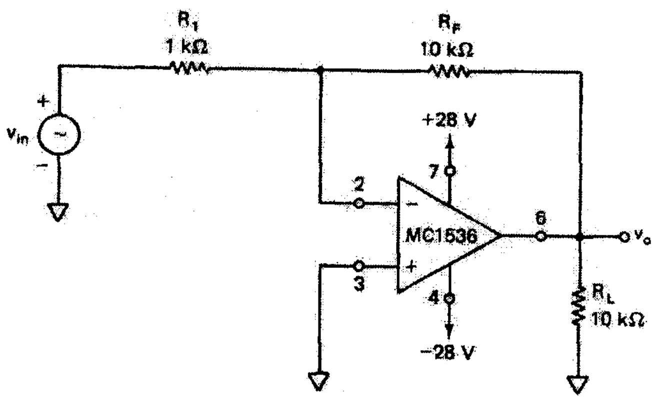
(c) Briefly explain the working of a Hartley oscillator. [12]

Q6. (a) (i) What is a comparator? [1]

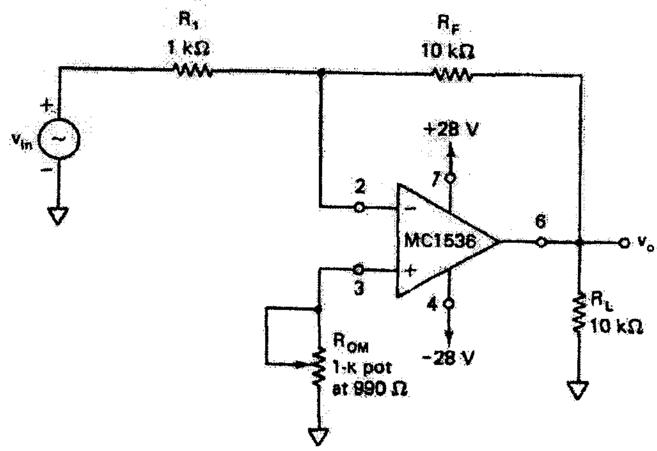
(ii) Draw the circuit of a non-inverting comparator and briefly explain its characteristics. [5]

(iii) Draw the input and output voltage waveforms when the reference voltage is V_{ref}= -2V. [4]

(b) Compute the maximum possible total output offset voltage V_{ooT} in the amplifier circuits shown in the figure below if the operational amplifier is an LM307 with supply voltages ±15V. [5]



(a)



(c) Write short notes on [10]

(i) Circuit stability
(ii) Offset minimizing resistor
(iii) Thermal current drift
(iv) Zero crossing detector

END OF P441 EXAMINATION