THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

2014/2015 MID YEAR FINAL EXAMS

1. BIO 2701 -Basic Physiology
2. BIO 2801 – Diversity of Plants
3. BIO 3045 – Conservation Biology
4. BIO 4161 – Fresh Water Ecology
5. CHE 2015 – General Analytical and Inorganic Chemistry
6. CHE 2219 – Chemical Analysis
7. CHE 2511 - Basic Organic Chemistry
8. CHE 3111 - Cellular Biochemistry
9. CHE 3411 – Chemistry of main group elements and transition metal complexes
10. CHE 4111 – Information Storage and Biochemical Genetics
11. CHE 4811 – Inorganic Industrial Chemistry
12. CSC 2111 – Computer Architecture
13. CSC 3011 – Data Structures and Algorithms
14. CSC 4745 – Multimedia and Human interactions
15. CSC -4921 – Numerical Analysis 1
16. GES 3151 – Regional Planning and Development
17. GES 3251 – Geomorphology
18. GES 3321 – Environment and Natural Resources Economics
19. GES 4181 – Urban Geography and Planning
20. GES 4281 – Geographical Hydrology
21. P 3531 – Quantum Mechanics
22. P 4221 – Introduction to Solid Physics
23. PHY 2231– Thermodynamics and properties of Matter
24. PHY 2511 – Classical Mechanics
25. PHY 4021 – Mathematical Methods for Physics

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2014 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 2701: BASIC PHYSIOLOGY
THEORY PAPER

TIME: THREE HOURS

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

SECTION A: Plant Physiology

1. (a) Draw a table listing the mineral nutrient elements that are essential for plant development, indicating macronutrients and micronutrients separately.
   (b) For each of the nutrient elements listed state two physiological functions of the element.

2. Summarise the light reactions of photosynthesis.

3 The Calvin cycle proceeds in three phases - carboxylation, reduction and regeneration of the CO_2 acceptor:
   (a) State the compartment of the chloroplast where the carbon reactions take place.
   (b) Outline the biochemical steps involved in carboxylation and reduction phases, indicate enzymes involved and clearly distinguish between the phases.

4. (a) (i) Write the chemical structure of Indole-3-acetic acid.
   (ii) Summarise the physiological effects of auxin at cellular and organ level.
   (b) Discuss the physiological roles of Abscisic acid in seed and bud dormancy and in plant responses to water stress.

SECTION B: Animal Physiology

5. (a) Discuss CO_2 transport in mammals.
   (b) Explain the effects of increased partial pressure of CO_2 on oxygen transport.

TURN OVER

6. (a) Explain principles of feedback mechanisms.
   (b) Discuss the roles and mechanisms of action of the following hormones in osmoregulation:
      (ii) Antidiuretic hormone.
      (iii) Aldosterone.

7. Describe each of the following:
   (a) Cleavage and cleavage patterns in mammals.
   (b) Structure and function of a synapse.
   (c) Structure and the digestive processes of a monogastric stomach.

8. (a) Outline the various classes of sensory receptors with reference to the stimuli detected.
   (b) With the aid of diagrams define the following lung volume parameters:
      (i) Vital capacity.
      (ii) Tidal volume.
      (iii) Inspiratory reserve volume.
      (iv) Residual volume.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2014 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 2801: DIVERSITY OF PLANTS
THEORY PAPER

TIME: THREE HOURS

INSTRUCTIONS: ANSWER **FIVE** QUESTIONS, **TWO** QUESTIONS FROM EACH SECTION AND THE FIFTH QUESTION FROM EITHER SECTION. USE **SEPARATE ANSWER BOOKS** FOR EACH SECTION.

SECTION A: Algae and Bryophytes

1. (a) Describe the features that separate Chaetophorales from other green algae?
   (b) Describe thallus structure and reproduction in *Stigeoclonium*.

2. (a) Describe vegetative structure in *Chara*.
   (b) Describe reproduction in Chara.
   (c) Explain why this alga is considered anomalous among green algae.

3. Describe thallus structure and various forms of asexual reproduction in *Ulothrix*.

4. (a) Describe the thallus structure of *Marchantia* and its special anatomical features.
   (b) Describe vegetative and sexual reproduction in *Marchantia*.

SECTION B: Tracheophytes

5. Give an account of the general vegetative, reproductive and life cycle features characteristic of the Sphenophyta (Horsetails).

6. Describe the principle stele types of Tracheophytes, their various derivatives and vascular bundle types.

7. Describe the characteristic features, distribution and diversity of the Angiosperm family Malvaceae.

8. Compare and contrast the strobilus structure, spores and gametophytes of the genera *Lycopodium* and *Selaginella*.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

2014 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 3045: CONSERVATION BIOLOGY
THEORY PAPER

TIME: THREE HOURS

INSTRUCTIONS: ANSWER QUESTIONS **ONE** AND **TWO** AND ANY OTHER THREE QUESTIONS. ILLUSTE YOUR ANSWERS WHERE NECESSARY

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1. Summarise the following concepts used in conservation biology:
   (a) Population in source.
   (b) Edge effect.
   (c) Stepping stone corridor.

2. Discuss objectives of the following concepts applied in environmental Impact Assessments:
   (a) Decision letter.
   (b) Mitigation measures.
   (c) Environmental management plan.

3. (a) Discuss Paine's (1966) species removal experiments and their significance in understanding interactions among different species in ecosystems.

4. Summarise the major causes of biodiversity losses in terrestrial and aquatic ecosystems.

5. Explain why regulating international trade of an endangered species may be more effective for conservation than banning its trade completely.

6. Discuss the competitive advantages that introduced species may possess over indigenous species that commonly lead to their dominance.

7. Describe situations that may lead an environmental management authority to require an Environmental Project Brief (EPB) instead of an Environmental Impact Assessment (EIA) for some projects.

8. Discuss the three major components of an ecological monitoring programme.

END OF THE EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2014 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 4161: FRESHWATER ECOLOGY
THEORY PAPER

TIME: THREE HOURS

ANSWER QUESTIONS **ONE** AND **TWO** AND ANY OTHER THREE QUESTIONS.
ILLUSTRATE YOUR ANSWERS WHERE NECESSARY

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1. (a) Describe the vertical distribution of dissolved oxygen for an oligotrophic, summer stratified lake.
   (b) Give reasons for occurrence of anaerobic hypolimnion in a deep oligotrophic lake.

2. Summarise each of the following concepts in relation to classification of aquatic ecosystems:
   (a) Concentration of dissolved ions.
   (b) Minimum and maximum water temperature.
   (c) Water currents.

3. Explain how productivity of lake ecosystems is affected by each of the followin:
   (a) Mean depth.
   (b) Shoreline development.
   (c) Water turbidity.

4. (a) Describe the compensation depth in relation to productivity of aquatic ecosystems.
   (b) Justify the need for phytoplankton to maximize time spent above the compensation depth.
   (c) Describe two methods that phytoplankton employ to maximize time spent above the compensation depth.

5. Compare and contrast tectonic and glacial lakes.

6. Summarise the four cardinal points in seasonal succession of phytoplankton in warm monomictic lakes.

TURN OVER

7. (a) Describe the Light and Dark Bottle Method used for determining aquatic primary productivity and its limitations.

8. Discuss the Redfield ratio and its significance in explaining abundance of ions in aquatic ecosystems.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

2014 ACADEMIC YEAR MID – YEAR EXAMINATIONS

CHE 2015 GENERAL ANALYTICAL AND INORGANIC CHEMISTRY

TIME: THREE HOURS

INSTRUCTIONS

1 There are **five** questions in this Examination Paper.

2 Answer any **Four** questions. Questions carry equal marks.

3 Essential information and data are provided for this paper

Question 1

(a) (i) Name the fertilizer formed when Calcium cyanide, $CaCN_2$ reacts with carbon.

(ii) Give a balanced equation to show the reaction if silicon carbide, carborundum reacts with chlorine.

(b) Calculate the pH and pOH of a solution obtained by mixing equal volumes of 0.10M H_2SO_4 and 0.30M NaOH.

(c) A calibration curve for the colorimetric determination of phosphorus in urine is prepared by reacting standard solutions of phosphate with molybdenum (IV) and reducing the phosphomolybdic acid complex to produce a characteristic blue colour. The measured absorbamce A is plotted against the concentration of phosphorus. From the following data determine the linear least squares line and calculate the pjhosphorus concentration in the urine sample:

Phosphorus (ppm)	**Absorbance**
1.0	0.205
2.0	0.410
3.0	0.615
4.0	0.820
Urine sample	0.625

Question 2

(a) (i) What is meant by solubility?

(ii) The solubility product of the compound P_2X was found equal to 3.58×10^{-13} on the basis of solubility measurements and the assumption of quantitative ionisation to P^+ and X^{2-} ions. Later it was found that the compound is quantitatively ionised to P_2^{2+} ions. Calculate the real solubility product of P_2X.

(b) The complex $K_2[Ni(CN)_4]$ has a magnetic moment, $\mu_s \approx 0.01$ BM. Using CFT deduce the structure.

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

TEST METHOD (%)	REFERENCE METHOD (%)
20.10	18.89
20.50	19.20
18.65	19.00
19.40	19.70
19.99	19.40

Is there a significant difference between the two methods at 95% confidence level?

Question 3

(a) Why is 4s orbital in K atom filled earlier than 3d orbital? Explain using effective nuclear charges.

(b) The Mohr method was used to determine the concentration of sodium chloride in a 1.004g sample. The sample was dissolved in water and titrated to the end point with 32.36ml of 0.1012M silver nitrate. Calculate the percent of sodium chloride in the sample.

(c) (i) Twenty millimetres of 0.100M $AgNO_3$ were added to 100.0ml of 0.050M NaCl during titration. Calculate the chloride and silver ion concentration in the resulting solution. Ksp (AgCl) = 1.75×10^{-10}.

(ii) The ionisation constant of the weak acid, HCN, is 4.00×10^{-10}. A solution is prepared by dissolving 9.802g of NaCN in enough water to make 1.00dm^3 of solution. Calculate the pH of the solution.

Question 4

(a) (i) $Ba(OH)_2$ is a strong base and can be used as an anti-acid. Calculate the pH and pOH of a 0.14M $Ba(OH)_2$ solution.

(ii) A new method of determining calcium gave 99.35% recovery (variance 0.185). The standard method gave 99.53% recovery (variance 0.152). In each case three replicate measurements were made. Test whether the two means differ significantly at the 95% confidence level.

(b) Predict the bond order of the anion in CaC_2.

(c) Consider the (unbalanced) electrochemical reaction involving the reaction of vanadium (IV) with vanadium (II) to produce vanadium (III).

$$VO^{2+} + V^{2+} \longleftrightarrow V^{3+}$$

(i) Balance this full cell reaction. [If you wish, you can use the vanadium half-cell reactions on the last page of this test to assist you.]

(ii) Assuming the reaction proceeds spontaneously left to right as above, which species is the oxidizing agent and which is the reducing agent?

(iii) Calculate the E° for the full cell reaction. [See half-cell data on last page.]

(iv) Is the reaction spontaneous as written (assuming unit activities)? How do you conclude this?

Question 5

(a) Arrange $BaCl_2$, $MgCl_2$, $BeCl_2$, $CaCl_2$ in the increasing order of ionic character.

(b) (i) Explain the difference between absolute error and standard error.

(ii) Given the E° for the following half-reactions:

$Cu^+ + e \longrightarrow Cu \quad E^\circ_{red} = 0.52V$

$Cu^{2+} + 2e \longrightarrow Cu \quad E^\circ_{red} = 0.34V$

What is the E° for the following reaction:

$Cu^+ \longrightarrow Cu^{2+} + e$?

(c) (i) Morphine, $C_{17}H_{19}NO_3$, is a painkiller found in the milky juice that oozes from unripe poppy seed capsules. Morphine is a weak base alkaloid with a p*K*b of 6.10. As with many alkaloids, the base form of morphine is not very soluble in water. Its hydrochloride salt, $C_{17}H_{19}NO_3 \cdot HCl$, however, is soluble to the extent of 1.00 g/17.5 mL of water. What is the pH of the resulting solution?

(ii) Calculate the percent reaction, and the pH of a 0.050M solution of sodium acetate. Ka for acetic acid is 1.75×10^{-5}

END OF EXAMINATION

Useful Data

$V^{2+} + 2\ e^-$	$V(s)$	$E^o = -1.18$ V
$V^{3+} + e^-$	V^{2+}	$E^o = -0.255$
$VO^{2+} + 2\ H^+ + e^-$	$V^{3+} + H_2O$	$E^o = +0.361$
$VO^{2+} + 2\ H^+ + e^-$	$VO^{2+} + H_2O$	$E^o = +1.000$

PERIODIC TABLE OF THE ELEMENTS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
																1 **H** 1.01 Hydrogen	2 **He** 4.00 Helium
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** 27.99 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									

KEY

Atomic number
X
Atomic mass

Name of the element
X

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

Universal Statistical Tables:

1. Rejection Quotient, Q, at Different Confidence Limits.

Number of Observations	Confidence Level Q_{90}	Q_{95}	Q_{99}
3	0.941	0.970	0.004
4	0.765	0.829	0.926
5	0.642	0.710	0.821
6	0.560	0.625	0.740
7	0.507	0.568	0.680
8	0.468	0.526	0.634
9	0.437	0.493	0.598
10	0.412	0.466	0.568
15	0.338	0.384	0.475
20	0.300	0.342	0.425
25	0.277	0.317	0.393
30	0.260	0.298	0.372

2. Values of t for v Degrees of Freedom at Different Confidence Limits.

Number of Degrees of Freedom	Confidence Level 90%	95%	99%	99.5%
1	6.314	12.706	63.657	127.32
2	2.920	4.303	9.925	14.089
3	2.353	3.182	5.841	7.453
4	2.132	2.776	4.604	5.598
5	2.015	2.571	4.032	4.773
6	1.943	2.441	3.707	4.317
7	1.895	2.365	3.500	4.029
8	1.860	2.306	3.355	3.832
9	1.833	2.262	3.250	3.690
10	1.812	2.228	3.169	3.581
15	1.753	2.131	2.947	3.252
20	1.725	2.086	2.845	3.153
25	1.708	2.060	2.787	3.078
Infinite	1.645	1.960	2.576	2.807

3. Values of F at the 95% Confidence Level

v_1 =	2	3	4	5	6	7	8	9	10	15	20	30
v_2 = 2	19.0	19.2	19.2	19.3	19.3	19.4	19.4	19.42.	19.4	19.4	19.4	19.
3	9.55	9.28	9.12	9.01	8.94	8.89	8.85	8.81	8.79	8.70	8.66	8.6
4	6.94	6.59	6.39	6.26	6.16	6.09	6.04	6.00	5.96	5.86	5.80	5.7
5	5.79	5.41	5.19	5.05	4.95	4.88	4.82	4.77	4.74	4.62	4.56	4.
6	5.14	4.76	4.53	4.39	4.28	4.21	4.15	4.10	4.06	3.94	3.87	3.
7	4.74	4.35	4.12	3.97	3.87	3.79	3.73	3.68	3.64	3.51	3.44	3.
8	4.46	4.07	3.84	3.69	3.58	3.50	3.44	3.39	3.35	3.22	3.15	3.
9	4.26	3.86	3.63	3.48	3.37	3.29	3.23	3.18	3.14	3.01	2.94	2.
10	4.10	3.71	3.48	3.33	3.22	3.14	3.07	3.02	2.98	2.85	2.77	2.
15	3.68	3.29	3.06	2.90	2.79	2.71	2.64	2.59	2.54	2.40	2.33	2.
20	3.49	3.10	2.87	2.71	2.60	2.51	2.45	2.39	2.35	2.20	2.12	2.
30	3.32	2.92	2.69	2.53	2.42	2.33	2.27	2.21	2.16	2.01	1.93	1.

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

2014 ACADEMIC YEAR MID – YEAR EXAMINATIONS

CHE 2219 CHEMICAL ANALYSIS

TIME: THREE HOURS

INSTRUCTIONS

1 There are **five** questions in this Examination Paper.

2 Answer any **Four** questions. Questions carry equal marks.

3 Essential information and data are provided for this paper

Question 1

(a) ZEMA limits the amount of lead in drinking water to 0.015 mg/L. Express this concentration in Molarity, ppm, and ppb.

(b) Calculate the pH and pOH of a solution obtained by mixing equal volumes of 0.10M H_2SO_4 and 0.30M NaOH.

(c) The following data were obtained in the spectrophotometric determination of iron.

Fe (ppm)	**Absorbance**
1.0	0.240
2.0	0.460
3.0	0.662
4.0	0.876

(i) Determine the linear least squares line.

(ii) Compute the concentration of iron in a solution if its absorbance is 0.452.

Question 2

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

TEST METHOD (%)	**REFERENCE METHOD (%)**
20.10	18.89
20.50	19.20
18.65	19.00
19.40	19.70
19.99	19.40

Is there a significant difference between the two methods at 95% confidence level?

(b) The ionisation constant of the weak acid, HCN, is 4.00×10^{-10}. A solution is prepared by dissolving 9.802g of NaCN in enough water to make $1.00 dm^3$ of solution. Calculate the pH of the solution.

(c) Twenty millimetres of 0.100M $AgNO_3$ were added to 100.0ml of 0.050M NaCl during titration. Calculate the chloride and silver ion concentration in the resulting solution. Ksp (AgCl) = 1.75×10^{-10}.

Question 3

(a) A solid food sample is known to contain only NaCl and KCl. A 2.000g sample of this solid is dissolved in water and all the chloride ion is precipitated as AgCl by the addition of $50.0 cm^3$ of 0.60M $AgNO_3$ solution. What is the percent of KCl in the mixture?

(b) For the following reaction indicate: $CH_3COOH + H_2O \leftrightarrow H_3O^+ + CH_3COO^-$

(i) The acid

(ii) The base

(iii) The conjugate acid

(iv) The conjugate base

(c) (i) What is meant by solubility?

(ii) The solubility product of the compound P_2X was found equal to 3.58×10^{-13} on the basis of solubility measurements and the assumption of quantitative ionisation to P^+ and X^{2-} ions. Later it was found that the compound is quantitatively ionised to P_2^{2+} ions. Calculate the real solubility product of P_2X.

Question 4

(a) (i) Explain the difference between accuracy and precision.

(ii) A new method of determining calcium gave 99.35% recovery (variance 0.185). The standard method gave 99.53% recovery (variance 0.152). In each case three replicate measurements were made. Test whether the two means differ significantly at the 95% confidence level.

(b) $Ba(OH)_2$ is a strong base and can be used as an anti-acid. Calculate the pH and pOH of a 0.14M $Ba(OH)_2$ solution.

(c) Consider the (unbalanced) electrochemical reaction involving the reaction of vanadium (IV) with vanadium (II) to produce vanadium (III).

$$VO^{2+} + V^{2+} \longleftrightarrow V^{3+}$$

(i) Balance this full cell reaction. [If you wish, you can use the vanadium half-cell reactions on the last page of this test to assist you.]

(ii) Assuming the reaction proceeds spontaneously left to right as above, which species is the oxidizing agent and which is the reducing agent?

(iii) Calculate the E^{o} for the full cell reaction. [See half-cell data on last page.]

(iv) Is the reaction spontaneous as written (assuming unit activities)? How do you conclude this?

Question 5

(a) (i) Distinguish between an anode and a cathode.

(ii) Given the E^{o} for the following half-reactions:

$Cu^{+} + e \longrightarrow Cu \quad E^{o}_{red} = 0.52V$

$Cu^{2+} + 2e \longrightarrow Cu \quad E^{o}_{red} = 0.34V$

What is the E^{o} for the following reaction:

$Cu^{+} \longrightarrow Cu^{2+} + e$?

(b) A 2.645g sample of copper ore that contains 54.10% Cu is dissolved and diluted to 250 cm^3. A spectrophotometric method gave the following results for the solutions: 5.84 , 5.77, 5.73 and 5.71mg Cu/cm^3.

(i) Decide whether the accuracy is satisfactory or not if the maximum acceptable error is less than 3%.

(iii) Calculate the standard deviation.

(c) Calculate the percent reaction, and the pH of a 0.050M solution of sodium acetate. Ka for acetic acid is 1.75×10^{-5}

END OF EXAMINATION

Useful Data

$V^{2+} + 2\ e^-$	$V(s)$	$E^\circ = -1.18$ V
$V^{3+} + e^-$	V^{2+}	$E^\circ = -0.255$
$VO^{2+} + 2\ H^+ + e^-$	$V^{3+} + H_2O$	$E^\circ = +0.361$
$VO^{2+} + 2\ H^+ + e^-$	$VO^{2+} + H_2O$	$E^\circ = +1.000$

Universal Statistical Tables:

1. Rejection Quotient, Q, at Different Confidence Limits.

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9	0.437	0.493	0.598
10	0.412	0.466	0.568
15	0.338	0.384	0.475
20	0.300	0.342	0.425
25	0.277	0.317	0.393
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2. Values of t for v Degrees of Freedom at Different Confidence Limits.

Number of Degrees of Freedom	Confidence Level 90%	95%	99%	99.5%
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2	2.920	4.303	9.925	14.089
3	2.353	3.182	5.841	7.453
4	2.132	2.776	4.604	5.598
5	2.015	2.571	4.032	4.773
6	1.943	2.441	3.707	4.317
7	1.895	2.365	3.500	4.029
8	1.860	2.306	3.355	3.832
9	1.833	2.262	3.250	3.690
10	1.812	2.228	3.169	3.581
15	1.753	2.131	2.947	3.252
20	1.725	2.086	2.845	3.153
25	1.708	2.060	2.787	3.078
Infinite	1.645	1.960	2.576	2.807

3. Values of F at the 95% Confidence Level

v_1 =	2	3	4	5	6	7	8	9	10	15	20	30
v_2 = 2	19.0	19.2	19.2	19.3	19.3	19.4	19.4	19.42.	19.4	19.4	19.4	19.5
3	9.55	9.28	9.12	9.01	8.94	8.89	8.85	8.81	8.79	8.70	8.66	8.62
4	6.94	6.59	6.39	6.26	6.16	6.09	6.04	6.00	5.96	5.86	5.80	5.75
5	5.79	5.41	5.19	5.05	4.95	4.88	4.82	4.77	4.74	4.62	4.56	4.50
6	5.14	4.76	4.53	4.39	4.28	4.21	4.15	4.10	4.06	3.94	3.87	3.81
7	4.74	4.35	4.12	3.97	3.87	3.79	3.73	3.68	3.64	3.51	3.44	3.38
8	4.46	4.07	3.84	3.69	3.58	3.50	3.44	3.39	3.35	3.22	3.15	3.08
9	4.26	3.86	3.63	3.48	3.37	3.29	3.23	3.18	3.14	3.01	2.94	2.86
10	4.10	3.71	3.48	3.33	3.22	3.14	3.07	3.02	2.98	2.85	2.77	2.70
15	3.68	3.29	3.06	2.90	2.79	2.71	2.64	2.59	2.54	2.40	2.33	2.25
20	3.49	3.10	2.87	2.71	2.60	2.51	2.45	2.39	2.35	2.20	2.12	2.04
30	3.32	2.92	2.69	2.53	2.42	2.33	2.27	2.21	2.16	2.01	1.93	1.84

PERIODIC TABLE OF THE ELEMENTS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** 1.01 Hydrogen																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** 27.99 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									

KEY

Atomic number
X
Atomic mass
Name of the element
X

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

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2014 ACADEMIC YEAR
MID YEAR EXAMINATIONS

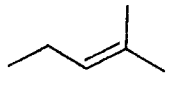
CHE 2511: BASIC ORGANIC CHEMISTRY

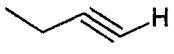
INSTRUCTIONS

1. TIME: **THREE (3)** HOURS
2. THIS PAPER CONTAINS **FIVE (5)** QUESTIONS
3. ANSWER ANY **FOUR (4)** QUESTIONS.
4. EACH QUESTION CARRIES **30 MARKS**
5. PLEASE PRESENT YOUR ANSWERS IN A **LOGICAL** MANNER
6. PLEASE BE **NEAT AND TIDY**
7. MAKE SURE YOU HAVE **SEVEN (7)** PRINTED PAGES

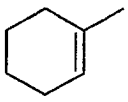
QUESTION ONE

(a) Predict the major organic products of the following reactions: ***(Mechanisms not required).***

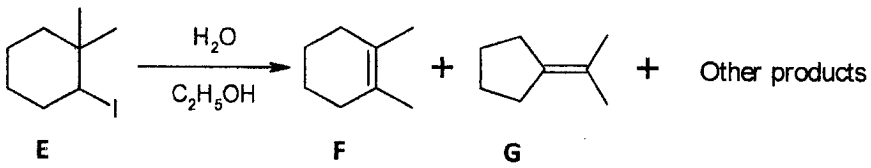
(i)  $\xrightarrow[H_2O_2]{HBr}$ **A** ***(3 marks)***

(ii)  $\xrightarrow[THF]{NaNH_2}$ **B** $\xrightarrow[DMF]{Br}$ **C**

(4 marks)

(iii)  $\xrightarrow{Br_2/H_2O}$ **D** ***3 marks***

(b) Solvolysis of the halide **E**, shown below, in aqueous ethanol (hydrolysis) gives a mixture of alcohol and alkene products. Two of the alkene products are shown below:

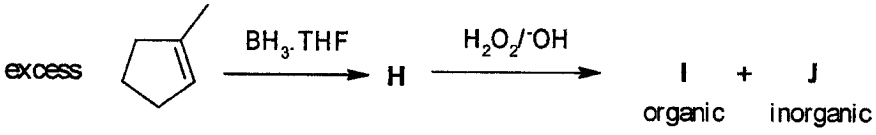


(i) Given that the solvolysis follows first order kinetics, propose a reaction mechanism to account for formation of the products **F** and **G**, shown above. Name the mechanism using symbol and provide a descriptive word for each step of your proposed mechanism.

(10 marks)

(ii) Suggest structures for two possible alcohol products. ***(4 marks)***

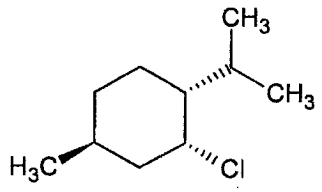
(c) Identify compounds **H–J** in the following reactions.



(6 marks)

QUESTION TWO

(a) When treated with sodium methoxide in methanol, the halide **K**, shown below gives a mixture of products, by two different types of mechanisms.



K

(i) Name the possible reaction mechanisms using symbols in this case. ***(2 marks)***

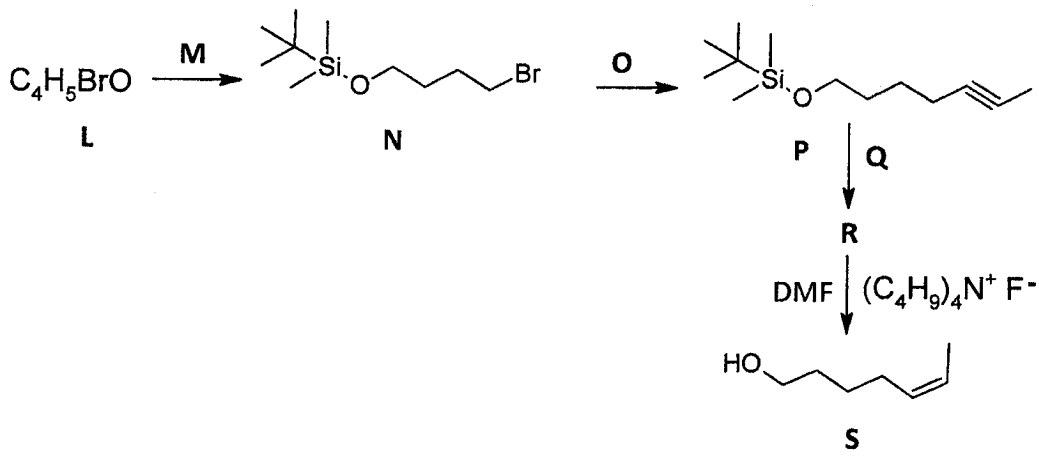
(ii) Using appropriate conformational structure and the most likely mechanism, propose stereochemical structures for possible elimination products when compound **K** is heated with sodium methoxide, (CH_3ONa), in methanol. Show the transition states. ***(8 marks)***

(b) Given that a *cis*-alkene can be converted into a *trans*-alkene containing the same number of carbon atoms in a stereospecific manner by the synthetic route shown below, propose a stereospecific synthesis of *trans*-2-pentene from *cis*-2-pentene. Show reagents, solvents, if any, conditions and the intermediates for all steps clearly.

cis-Alkene ⟶ a Vicinal dihalide ⟶ an Alkyne ⟶ *trans*-Alkene

(10 marks)

(c) Provide structures of starting materials, missing reagents, intermediates and conditions for the reactions shown below.



L **N** **S**

(10 marks)

QUESTION THREE

(a) Which reaction in the following pairs would you expect to be faster and why?

(i) The S_N2 displacement by cyanide ion on 2-bromopopane in hexane or in DMSO.

(ii) The S_N2 displacement by iodide ion on CH_3Cl or on CH_3OTs.

(3 marks each)

(b) Which reagent in the following pairs is more nucleophilic. Briefly explain in less than two sentences.

(i) $^-NH_2$ or NH_3
(ii) CH_3OH or CH_3SH

(3 marks each)

(c) Reaction **1** is faster than reaction **2**. With the aid of appropriate reaction mechanism and a labelled free energy diagram, provide a mechanistic explanation to account for this observation.

Reaction 1: $CH_3Br \xrightarrow[THF]{^-CN} CH_3CN$

Reaction 2: $CH_3CH_2Br \xrightarrow[THF]{^-CN} CH_3CH_2CN$

(7 marks)

(d) Addition of hydrobromic acid, (HBr) to 1-butene yields expected product of Markovnikov's addition. However, upon examination of the product in a laboratory, it was revealed that the product was in fact a mixture of two enantiomeric compounds.

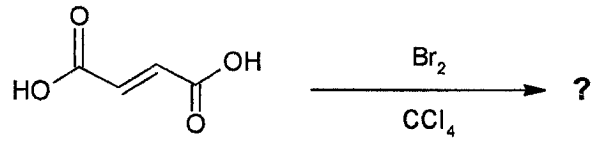
(i) Give a plausible mechanistic explanation to account for the formation of the two enantiomeric compounds.

(5 marks)

(ii) What are the configurations of the two compounds?

(2 marks)

(e) (i) Provide the Fischer projection formula of the product for the following reaction. ***(No mechanism required)***



***(2E)*-but-2-enedioic acid**
(Fumaric acid)

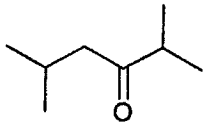
(2 marks)

(ii) State with a reason, whether the product is optically active.

(2 marks)

QUESTION FOUR

(a) Outline how you would achieve the following transformation:

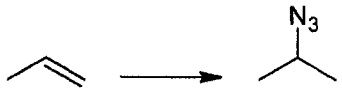


From an alcohol of no more than four carbon atoms as the organic starting material

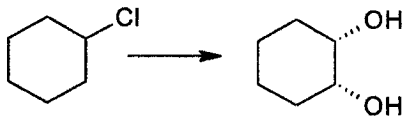
(12 marks)

(b) How would you carry out the following transformations in two steps? Show both steps clearly, including reagents, solvents (if any), conditions and pertinent stereochemistry.

(i)



(ii)

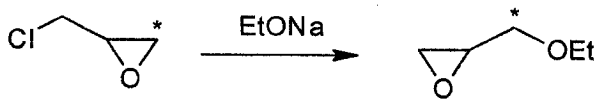


(5 marks each)

(c) Upon treatment with sulphuric acid, a mixture of ethyl and *n*-propyl alcohols yields a mixture of three ethers. Give the structures of **ANY TWO** of the three ethers. ***(No mechanism required)***

(2 marks)

(d) When sodium ethoxide reacts with 1-(chloromethyl)oxirane (also called epichlorohydrin), labelled with ^{14}C as shown by the asterisk in **I**, the major product is **II**. Provide a mechanistic explanation for this result.



1-(Chloromethyl)oxirane

(Epichlorohydrin)

I

II

(6 marks)

QUESTION FIVE

(a) Assuming the energy cost for the 1,3-diaxial interactions for Br–H to be 0.25 kcal/mol and for *tert.*-Butyl –H [$(CH_3)_3$ C–H] to be 2.7 kcal/mol:

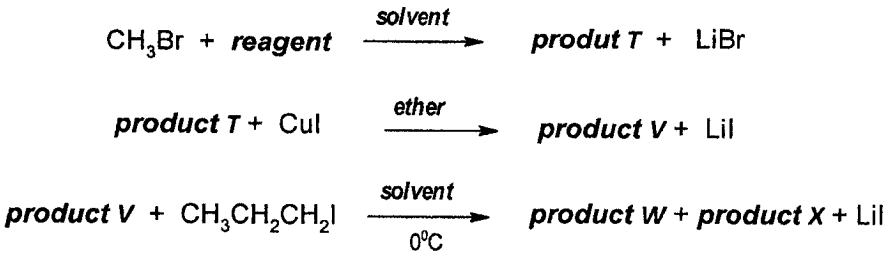
(i) Calculate the energy costs for possible conformations of *cis*-1-bromo-2-*tert.*-butylcyclohexane. ***(4 marks)***

(ii) Basing on your calculations, indicate the most stable conformation of *cis*-1-bromo-2-*tert.*-butylcyclohexane. ***(2 marks)***

(b) A mixture of (R)-2-pentanol and (S)-2-pentanol has 50% enantiomeric excess (ee) of (S)-2-pentanol. What is the percentage composition of these enantiomers?

(4 marks)

(c) The organometallic coupling reactions have been used many times for synthesis of alkanes for elongation of the carbon chain. Basing on this information provide the missing products, reagents and solvents for the following reactions. ***Reaction mechanisms are NOT required.***



(7 marks)

(d) A 0.44g sample were dissolved in 1.0 mL of solvent and placed in a 1.5 cm polarimeter tube. The D-line of sodium was used to measure the rotation of the sample. The observed rotation was found to be –9.0°. Using these data, calculate the specific rotation of the sample.

(3 marks)

(e) Below is a table of energy costs for interactions in alkane conformations:

Interaction	Type	Cause	Enegry cost (kcal/mol
H-H	eclipsed	torsional strain	1.0
H-CH_3	eclipsed	mostly torsional strain	1.4
CH_3-CH_3	eclipsed	torsional plus steric strain	2.5
CH_3-CH_3	gauche	steric strain	0.9

(i) Sketch a quantitative potential-energy diagram for rotation about C2–C3 bond in *n*-butane and assign the true energy value to each conformation.

(8 marks)

(ii) Provide descriptive names for the most stable conformation and the least stable conformation.

(2 marks)

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

2014 ACADEMIC YEAR

MID-YEAR EXAMINATIONS

CHE3111: CELLULAR BIOCHEMISTRY

INSTRUCTIONS

1. TIME: **THREE (3)** HOURS
2. ANSWER ANY **FIVE (5)** QUESTIONS
3. EACH QUESTION CARRIES **20 EQUAL MARKS**
4. PLEASE PRESENT YOUR ANSWERS IN A **LOGICAL MANNER**
5. PLEASE **BE NEAT AND TIDY**
6. MAKE SURE YOU HAVE **FOUR (4)** PRINTED PAGES

Question 1

a) Microorganisms play a major role in the nitrogen cycle. **Show** the three main chemical reactions for the conversion of atmospheric nitrogen into ammonia catalyzed by the molybdenum iron-protein subunit of the nitrogenase enzyme. **[6 marks]**

b) In animals the catabolism of organic molecules such as amino acids results in the production of urea. Using chemical structures **show** how the enzymes of the urea cycle are able to regenerate ornithine in the presence of carbamoyl phosphate and aspartate. **Indicate** all the enzymes involved. **[14 marks]**

Question 2

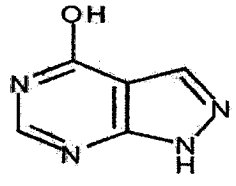
a) **Draw** the series of steps depicting the citric acid cycle showing the structures, enzymes and cofactors involved.
If malonate is introduced into the citric acid cycle, **what** would be the effect? **[11 marks]**

b) **Explain** the concepts of substrate availability, product inhibition and allosteric feedback inhibition in terms of the citric acid cycle. **[9 marks]**

Question 3

a) **Discuss** the similarities and differences between the enzymes carbamoyl phosphate synthetase I and carbamoyl phosphate synthetase II. **[8 marks]**

b) Gout is a disease condition which results due to a defect in the metabolism of purine nucleotides and can be treated by the administration of allopurinol whose structure is given below. Using chemical structures **write** the mechanism for the catabolism of adenosine 5'-monophosphate into uric acid and **explain** why allopurinol can be used in the treatment of gout. **[12 marks]**



Allopurinol

Question 4

Phosphatyldyl serine is synthesized mainly the through sn-glycerol 3-phosphate pathway.

a) **Name** one use of phosphatidyl serine in a cell. **[2 marks]**

b) **Name** two sites where phosphatidyl serine is synthesized. **[2 marks]**

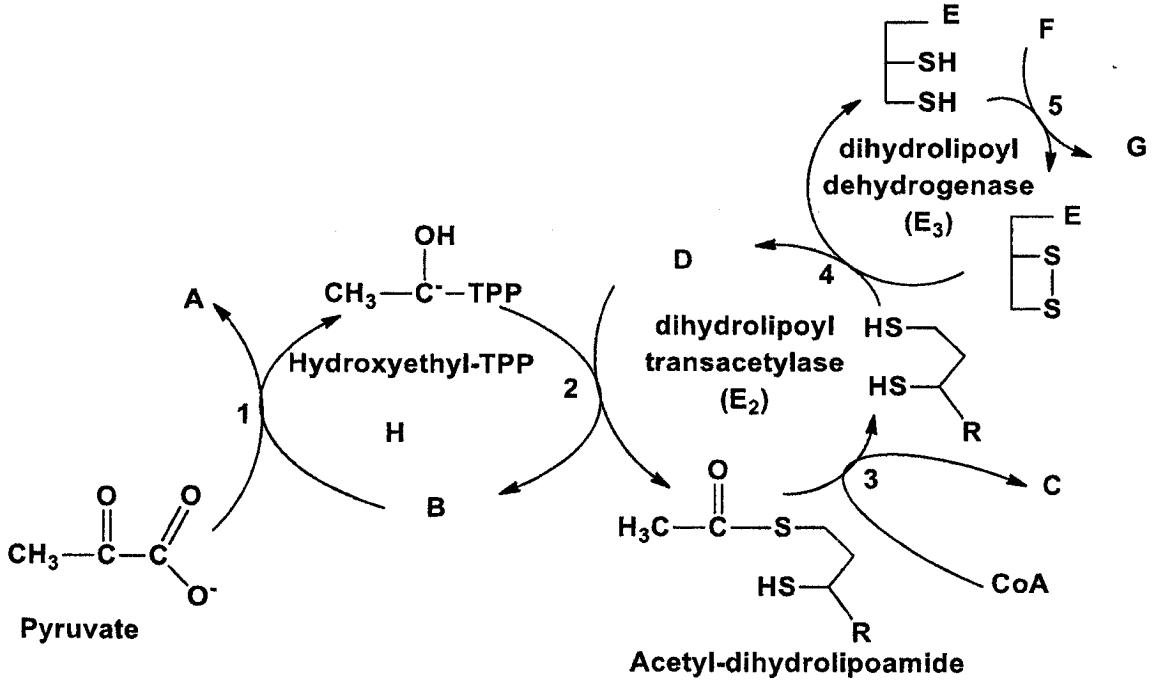
c) Clearly **outline** the synthesis of phosphatidyl serine through the sn-glycerol 3-phosphate pathway, **naming** the necessary enzymes at each step. Use R and R' to represent fatty acids in position 1 and 2 respectively. Also cytidine monophosphate, diphosphate and triphosphate may simply be shown as CMP, CDP and CTP in your structures. **[16 marks]**

Question 5

a) Using the relevant structures and enzymes **compare and contrast** glycolysis and gluconeogenesis pathways. **[8 marks]**

b) **How many** ATP molecules are produced when glucose is completely oxidized given that NADH produces 3 ATP molecules and $FADH_2$ produces 2 ATP molecules? **How many** ATP molecules are produced when pyruvate is completely oxidized? **[4 marks]**

c) **Give** the names of the missing reactants (or products) labelled A – G and the missing enzyme name for H. Note that E represents the same compound. **[8 marks]**



Question 6

a) **How** much iron is in haemoglobin of a 70 kg adult? Assume that the blood is 70 ml/kg body weight and that the haemoglobin is 16 mg/ml (Fe = 56 g/mol). **[2 marks]**

b) **Briefly** discuss the probable molecular mechanism for the sigmoidal oxygen dissociation curve of haemoglobin. **[4 marks]**

c) Suppose the β-polypeptide chain of haemoglobin binds strongly to a column packed with a strong cation-exchanger resin at pH 3.5 and that it can be washed off the column by passing a buffer of pH 10.
   i) **Give** a brief explanation for this observation.
   ii) **What** chemical entity enables such a peptide to bind to the column at pH 3.5?
   [4 marks]

d) **Rearrange** the Michaelis-Menten equation to give [S] as a function of [S]/v and **draw** sketch of a graph for this function. **[6 marks]**

e) **Give** any ONE reason that explains how acid-base catalysis enhances enzyme catalyzed reactions. **[4 marks]**

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
DEPARTMENT OF CHEMISTRY

2014 ACADEMIC YEAR
MID-YEAR EXAMINATIONS

CHE 3411: CHEMISTRY OF MAIN GROUP ELEMENTS AND TRANSITION METAL COMPLEXES

INSTRUCTIONS:

1. TIME ALLOWED: **THREE (3)** HOURS ONLY
2. ENSURE YOU HAVE **SIX (6)** PRINTED PAGES
3. THIS EXAM PAPER CONSISTS OF **TWO (2)** SECTIONS
4. EACH SECTION HAS **THREE (3)** QUESTIONS
5. ATTEMPT A **TOTAL OF FOUR (4)** QUESTIONS; **TWO (2)** FROM EACH SECTION
6. EACH QUESTION CARRIES **15 MARKS**
7. ANSWER EACH QUESTION IN A **SEPARATE** ANSWER BOOKLET
8. PLEASE PRESENT YOUR WORK IN A **TIDY AND ORDERLY MANNER**
9. PERIODIC TABLE IS ON PAGE SIX

Section A

Instructions:

1. Attempt any **two (2)** questions from this section
2. Answer each question in a **separate** answer booklet

Question One

The following passage is part of a typical answer to the question:

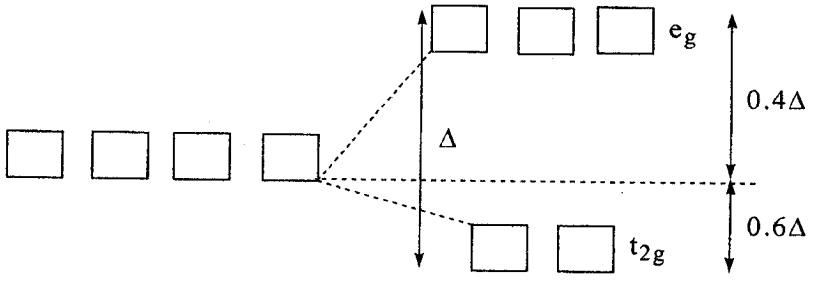
"Write an essay on the characteristic features of transition metal complexes."

However, it contains **FIFTY (50)** deliberate mistakes. List these in the order in which they appear in the passage and CORRECT them. **Marks may be deducted for wild guessing.**

A coordination complex may be defined as a compound containing a central atom or ion to which are attached atoms whose number usually equals the number corresponding to oxidation number or valence of the central atom or ion. The coordinated groups are called ions. They are always ionic. Such atoms are attached to the central atom by means of what are called ionic bonds. These atoms may be unidentate (Gk: *uni* = one, *dentate* = leg), bidentate, tridentate, or multidentate. The total number of ligands surrounding and bonded to the central atom is known as the oxidation number of the central atom.

Coordination compounds of transition metal are often highly coloured, *e.g.* $[Cr(en)_3]^{3-}$, $[Fe(CN)_6]^{2-}$, $[CoCl_4]^{2+}$, $[Co(NH_3)_6]^{+}$ and $[NiBr_4]$. The origin of this colour can be explained by considering how the energies of the ligand orbitals split on forming the complex.

On forming an octahedral complex, for example, the approach of the five ligands causes the metal *d*-orbitals to split into two sets: the t_{2g} set, which comprises the orditals $d_{x^2-y^2}$ and d_{z^2} which point between the ligands and hence are raised in energy, and the e_g set, which comprises the d_{xy}, d_{xz}, d_{y^2} orbitals which point towards the ligands and are lowered in energy. The diagram below shows the splitting.

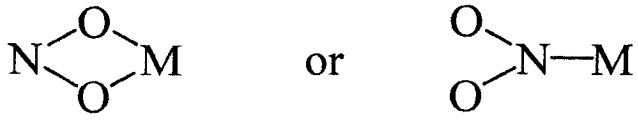


The energy gap is called Δ and can be divided as shown. An electron in the lower level may be raised to the higher level by absorbing infrared radiation so that when it falls back to the lower level it emits light, and therefore appears t have colour. The magnitude of Δ varies with the ligand so that weak ligands such F^- give large Δ's and strong field ligands such as cyanide (CNO^-) give small Δ's. The colour of the complex does not, however, change with the ligand type.

Complexes have different magnetic properties; those with unpaired electrons are ferromagnetic while those with paired electrons are diamagnetic. Some electronic configurations show both types of magnetic property; *e.g.* a d^6 configuration (Ni^{2+}) can have four unpaired electrons or no unpaired electron. These are called low-spin and high-spin, respectively.

Four-coordinate complexes (i.e. tetrahedral and square planar) have the same splitting diagram but we change the symbols from t_{2g} to t_g and e_g to e_2. Another interesting effect shown by transition metal complexes is the Born-Haber Effect, which is related to the unequal occupancy of the metal *d*-orbitals and causes octahedral to be distorted. It arises from electrons in the metal orbitals repelling the ligands so that if there are different numbers of electrons in the orbitals, then the bond angles in these directions will be different.

A final property of transition metal complexes is isomerism. There are five major types of isomerism. These are: geometric isomerism, *e.g.* $[Co(NH_3)_5Cl]^+$*cis-* and *trans-*, optical *trans-* $[Co(en)_4Cl_2]^+$ and linkage isomerism in which some ligands can be bidentate or monodentate, *e.g.* NO_2 can be



I forgot to mention that Δ_h is greater than Δ_d.

Question Two

(a) A few weeks ago, you prepared the coordination compounds $[Co(NH_3)_5NO_2]Cl_2$and $[Co(NH_3)_5ONO]Cl_2$, starting with $CoCl_2.6H_2O$. Starting with $CoCO_3$ and any other reagent that you may require, show by way of equations(s) and clearly stating the reaction conditions, how you would prepare $[Co(NH_3)_5NO_2]Cl_2$ and $[Co(NH_3)_5ONO]Cl_2$.

(b) Suggest an explanation that accounts for each of the following observations:

(i) Variation of the species' radii (pm):

$_{23}V$	$_{24}Cr^{2+}$	$_{25}Mn^{3+}$
122	84	69

(ii) Variation in the **third** ionization energies (kJ mol^{-1}):

$_{24}Cr$	$_{25}Mn$	$_{26}Fe$
3056	3251	2956

(iii) The crystal field splitting of metal *d*-orbitals in a given ligand environment increases with increasing oxidation state of a given transition metal.

(iv) The compound $CrCl_3.6H_2O$ exists in three forms. All produce a precipitate with silver nitrate solution, but in different proportions.

Question Three

(a) Draw and label **all** geometric isomers for each of the following species:

(i) $Co(NH_3)_5CO_3Cl$
(ii) $[Fe(H_2NCH_2CH_2NH_2)_3]^{3+}$
(iii) $Co(NH_3)_3Cl_3$

(b) The addition of ammonia solution to an aqueous solution of copper (II) sulfate results in the formation of pale blue precipitate, **A**, which dissolves on addition of more ammonia solution to give a deep blue solution, **B**. **A** also dissolves in dilute hydrochloric acid to give a pale blue solution, **C**, and in concentrated hydrochloric acid to give a green solution, **D**. On heating, **A** yields a black precipitate, **E**.

Deduce, giving the name and formula, the species **A** to **E**.

(c) Name the following species according to the IUPAC nomenclature:
(i) $[Ni(CN)_4]^{2-}$
(ii) $Na_2[Fe(CN)_5NO]$
(iii) $[Cr(NH_3)_2(H_2O)_3(OH)](NO_3)_2$

(d) Write down the formula for each of the following species:
(i) pentaamminenitritocobalt(III) sulfate
(ii) diamminesilver(I) hexacyanoferrate(II)
(iii) tetraamminecarbonatocobalt (III) tetrachlorocuprate (II)

Section B

Instructions:

1. Attempt any **two (2)** questions from this section
2. Answer each question in a **separate** answer booklet

Question One

(a) Mineral beryl, $Be_3Al_2Si_6O_{18}$ is a cyclic metasilicate.

(i) Write the anion present in it.
(ii) What is the net charge on the anion?
(iv) Sketch the skeletal structure of anion.

(b) Why oil paintings containing lead(II) compounds darken over many decades?

(i) Write an equation for the darkening process.
(ii) Explain why dilute solutions of H_2O_2 can be used to restore the original colour of oil painting?

(c) Nitrous acid, HNO_2 can be oxidized and reduced but HNO_3 can only be reduced. Describe on the basis of oxidation states of nitrogen.

Question Two

(a) Describe the effect of conjugation in an electronic transition.

(b) Draw the splitting pattern for F_{ax} and F_{eq} in PF_5.

(c) In N_2O molecule the vibrations are simultaneously Raman and IR active. Why? Is CS_2 molecule IR and Raman active?

Question Three

(a) What is the action of H_2SO_4 on:

(i) oxalic acid
(ii) $KMnO_4$
(iii) Peroxides

(b) Compare the strength of oxyacids of chlorine giving reasons.

(c) What are phosphazenes? Describe the bonding.

END OF EXAMINATION

PERIODIC TABLE OF THE ELEMENTS

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

KEY

Atomic number
X
Atomic mass
Name of the element X

1 **H** 1.01 Hydrogen																1 **H** 1.01 Hydrogen	2 **He** 4.00 Helium
3 **Li** 6.94 Lithium	4 **Be** 9.01 Beryllium											5 **B** 10.81 Boron	6 **C** 12.01 Carbon	7 **N** 14.01 Nitrogen	8 **O** 16.00 Oxygen	9 **F** 19.00 Fluorine	10 **Ne** 20.18 Neon
11 **Na** 23.00 Sodium	12 **Mg** 24.31 magnesium											13 **Al** 26.98 Aluminium	14 **Si** 28.09 Silicon	15 **P** 30.99 Phosphorus	16 **S** 32.07 Sulphur	17 **Cl** 35.45 Chlorine	18 **Ar** 39.95 Argon
19 **K** 39.10 Potassium	20 **Ca** 40.08 Calcium	21 **Sc** 44.96 Scandium	22 **Ti** 47.88 Titanium	23 **V** 50.94 Vanadium	24 **Cr** 52.00 Chromium	25 **Mn** 54.94 Manganese	26 **Fe** 55.85 Iron	27 **Co** 58.93 Cobalt	28 **Ni** 58.69 Nickel	29 **Cu** 63.55 Copper	30 **Zn** 65.39 Zinc	31 **Ga** 69.72 Gallium	32 **Ge** 71.61 Germanium	33 **As** 74.92 Arsenic	34 **Se** 78.96 Selenium	35 **Br** 79.90 Bromine	36 **Kr** 83.80 Krypton
37 **Rb** 85.47 Rubidium	38 **Sr** 87.62 Strontium	39 **Y** 88.91 Yttrium	40 **Zr** 91.22 Zirconium	41 **Nb** 92.91 Niobium	42 **Mo** 95.94 Molybdenum	43 **Te** 97.91 Technetium	44 **Ru** 101.07 Ruthenium	45 **Rh** 102.91 Rhodium	46 **Pd** 106.42 Palladium	47 **Ag** 107.87 Silver	48 **Cd** 112.41 Cadmium	49 **In** 114.82 Indium	50 **Sn** 118.71 Tin	51 **Sb** 121.76 Antimony	52 **Te** 127.60 Tellurium	53 **I** 126.90 Iodine	54 **Xe** 131.29 Xenon
55 **Cs** 132.91 Caesium	56 **Ba** 137.33 Barium	57 - 71	72 **Hf** 178.49 Hafnium	73 **Ta** 180.95 Tantalum	74 **W** 183.84 Tungsten	75 **Re** 186.21 Rhenium	76 **Os** 190.23 Osmium	77 **Ir** 192.22 Iridium	78 **Pt** 195.08 Platinum	79 **Au** 196.97 Gold	80 **Hg** 200.59 Mercury	81 **Tl** 204.38 Thallium	82 **Pb** 207.2 Lead	83 **Bi** 208.98 Bismuth	84 **Po** 208.98 Polonium	85 **At** 209.99 Astatine	86 **Rn** 222.02 Radon
87 **Fr** (223.02) Francium	88 **Ra** 226.03 Radium	89 - 103	104 **Unq** 261.11	105 **Unp** 262.11	106 **Unh** 263.12	107 **Uns** 262.12	108 **Uno** 265.00	109 **Une** 265									

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

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2014 ACADEMIC YEAR
MID-YEAR EXAMINATION

CHE 4111 INFORMATION STORAGE AND BIOCHEMICAL GENETICS

INSTRUCTIONS

1. TIME: **THREE (3) HOURS**
2. ANSWER ANY **FIVE (5)** QUESTIONS
3. EACH QUESTION CARRIES **20 MARKS**
4. PLEASE PRESENT YOUR ANSWERS IN A LOGICAL MANNER
5. ENSURE THAT YOU HAVE**FIVE (5)** PRINTED PAGES

Question 1

In tabular form, **compare** and **contrast** prokaryotic and eukaryotic replication.

[20 marks]

Question 2

EITHER

(a) **Describe**in detail the synthesis of DNA starting from initiation to termination.
[20 marks]

OR

(b) **Discuss** in detail **ρ (rho) dependent termination** and **ρ-independent termination.** **[20 marks]**

Question 3

Compare the Base Excision Repair and Nucleotide Excision Repair systems by identifying the type of DNA damage recognized, the bonds cleaved as well as the enzymes involved in each system. **[20 marks]**

Question 4

(a) **Calculate** the molecular weight of mRNA that codes for a protein of molecular weight 75,000 (molecular weight of an amino acid is 120 and ribonucleotide is 320) **[2 marks]**

(b) **Elucidate** the protein translation step in bacteria using diagrams. **[8 marks]**

(c) Using a well labelled diagram, **explain** the salient features of transfer RNA. **[6marks]**

(d) Use the genetic code given on page 5 to answer the following question;

(i) **Decode** the following nucleotide sequence: **[2 marks]**

UCUGAAUGCCGGGAAACAGAA

(ii) If the GAA codon is mutated to UAA **what** mutant protein forms? **[2 marks]**

Question 5

(a) **Explain** what is meant by the expression "higher order chromatin structure" in terms of chromosomes. **[10 marks]**

(b) **Copy and complete** the following table

Type of recombination	**Sequence homology**	**Proteins Involved**	**Results**
Homologous recombination			
Conservative site specific recombination			
Transposition			

[10 marks]

Question 6

(a) Give short answers for the following questions:

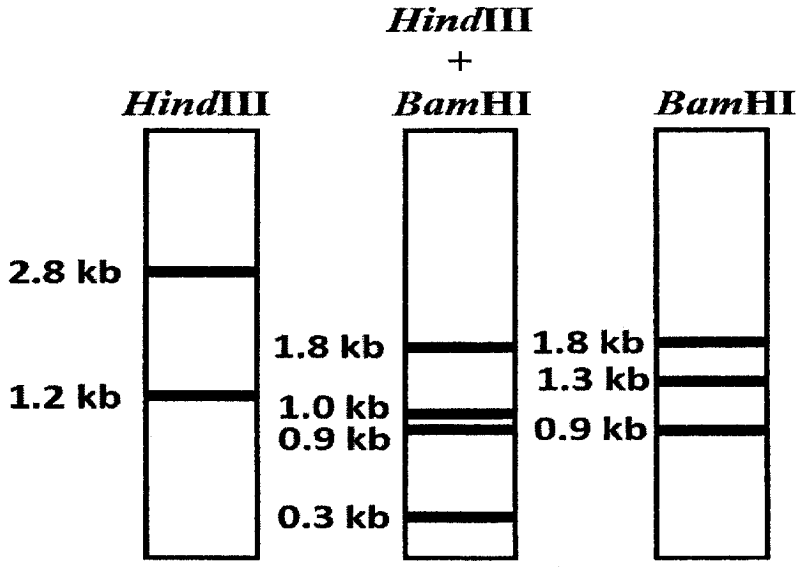
(i) **What** is meant by 'genomic library'? **[2 marks]**

(ii) **Why** do restriction endonucleases not hydrolyze DNA from the organism that produces them? **[2 marks]**

(iii) T4 DNA ligase is a very important enzyme in DNA technology. **What** exactly is it used for? **[2 marks]**

(iv) **Why** would you not use DNase I in preparation of genomic library? **[2 marks]**

(b) DNA was digested with *HindIII* and *BamHI* enzyme and then run on an agarose gel. The figure below shows the result of this experiment. **What** was the original DNA structure (show only the relative positions of the restriction sites on your piece of DNA)? **[12 marks]**

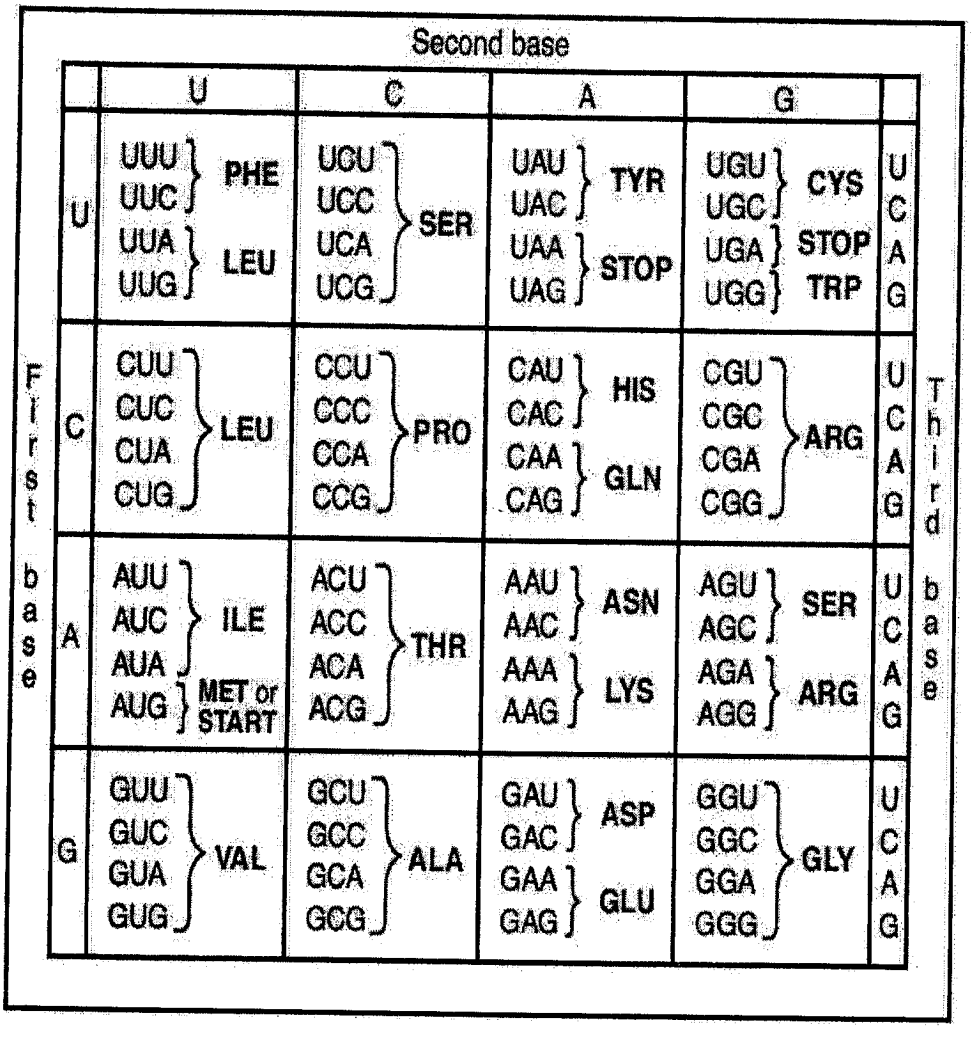


Question 7

(a) Biotechnology – friend or foe? **Discuss** in details citing experimental evidence for either answer. **[10 marks]**

(b) In biotechnology, PCR is a key technique. **What** is PCR? **How** might you use PCR to introduce a new restriction site in a genomic DNA? **[10 marks]**

Useful information



First base	Second base: U	Second base: C	Second base: A	Second base: G	Third base
U	UUU, UUC: PHE	UCU, UCC, UCA, UCG: SER	UAU, UAC: TYR	UGU, UGC: CYS	U C A G
	UUA, UUG: LEU		UAA, UAG: STOP	UGA: STOP; UGG: TRP	
C	CUU, CUC, CUA, CUG: LEU	CCU, CCC, CCA, CCG: PRO	CAU, CAC: HIS	CGU, CGC, CGA, CGG: ARG	U C A G
			CAA, CAG: GLN		
A	AUU, AUC, AUA: ILE	ACU, ACC, ACA, ACG: THR	AAU, AAC: ASN	AGU, AGC: SER	U C A G
	AUG: MET or START		AAA, AAG: LYS	AGA, AGG: ARG	
G	GUU, GUC, GUA, GUG: VAL	GCU, GCC, GCA, GCG: ALA	GAU, GAC: ASP	GGU, GGC, GGA, GGG: GLY	U C A G
			GAA, GAG: GLU		

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
DEPARTMENT OF CHEMISTRY

2014/15 ACADEMIC YEAR MID-YEAR FINAL EXAMINATIONS

CHE 4811
INORGANIC INDUSTRIAL CHEMISTRY

Duration: THREE (3) HOURS

INSTRUCTIONS TO THE CANDIDATES:

1. THIS PAPER CARRIES 100 MARKS AND HAS A TOTAL OF SIX (6) QUESTIONS.
2. EACH QUESTION CARRIES 20 MARKS.
3. QUESTION NUMBER 1 (No. 1) IS COMPULSORY.
4. ANSWER A TOTAL OF 5 QUESTIONS ONLY.
5. ANSWER EACH QUESTION IN A SEPARATE ANSWER BOOKLET PROVIDED.

QUESTION 1

a) A standard grain size analysis test was carried out in order to determine the relative proportions of different grain sizes as they are distributed among certain size ranges. The following results were obtained in the table shown below.

sieve #	Sieve size mm	% mass Retained	Cumulative % retained	% finer
4	4.75	154		
8	2.36	72		
16	1.18	72		
30	0.6	141		
40	0.425	85		
50	0.30	80		
100	0.15	149		
200	0.075	45		
Pan		24		

i. Give that the mass of sample - Wt = 824g, copy and complete the table of results provided for you. Show only one sample calculation for each column.

(4 marks)

ii. Use the data in the table above to plot a graph on the graph paper provided for you (sieve size vs. % finer).

(8 marks)

b) Calculate the total % mass loss during this sieve analysis?

(4 marks)

c) From the graph, obtain diameters Corresponding to 10%, 30% and 60% finer. Label your lines clearly in ink on your graph.

(4 marks)

QUESTION 2

a) List three grinding laws and express each of these in terms of half empirical models used for different particle size.

(6 marks)

b) Describe the mechanism of operation for the Vertical shaft impactor crusher.

(4 marks)

c) A material is crushed in a Blake jaw crusher (The work index -12.74) so that the average size of particles is reduced from 50 mm to 10 mm, with the consumption of energy of 13.0 kW. Calculate the energy needed to crush material of average size 75 mm to average size of 25 mm based on:

a) Rittinger's law. (4 marks)

b) Kick's law. (4 marks)

c) Which of the results would you regard as being more reliable? (2 marks)

QUESTION 3

a) Explain how grinding results can be evaluated in terms of Grinding degree by referring to grain size and specific surface area. (6 marks)

b) What is the power required to crush 100 ton/h of limestone if 80% of the feed pass a 5.1 cm screen and 80% of the product 0.3 cm screen? The work index for limestone is 12.74. (6 marks)

c) Sketch a Dodge type jaw and describe the mechanism of operation. (8 marks)

QUESTION 4

a) What is the difference between laminar and turbulent flow, and briefly explain the transitions that are expected when a well ordered flow of a fluid is intensified. (4 marks)

b) Consider a Laminar boundary layer over a flat plate. Sketch the velocity profile as a function of the distance from the plate surface, du/dy. Express shear strain γ in terms of the rate of shear strain. (8 marks)

c) The flow rate of a liquid is 4 M^3/s and the cylindrical pipe in which the fluid flows has a diameter of 6cm. Determine the Reynolds number for the fluid which has a density of 1268 kg/m^3 and the viscosity is 17 Pa.s, and in addition indicate the flow regime (Laminar/Turbulence). (8 marks)

QUESTION 5

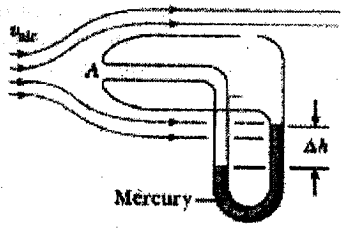
a) Briefly describe the operation principle of the sharp edged orifice.

(4 marks)

b) Account for how you would use a Pitot static tube to measure the volume flow rate in a turbulent pipe flow.

(8 marks)

c) A Pitot tube can be used to determine the velocity of air flow by measuring the difference between the total pressure and the static pressure. If the fluid in the tube is mercury, density ρ_{Hg} = 13.6 kg/m^3 and Δh = 5.0cm, find the speed of air flow. Assume that the air is stagnant at point A and take ρ_{air} = 1.25 kg/m^3.



(8 marks)

QUESTION 6

a) Briefly describe the concept of Theoretical volumetric flow rate and the Discharge Coefficient. Make reference to at least one real situation where it may have relevance.

(4 marks)

b) A Venturi Meter is a device that allows flow rates through pipes to be calculated by measuring the difference in pressure created by a contraction in a pipe. By using a sketch show how the given equation below is derived.

$$P_1 - P_2 = gh_p(\rho_m - \rho)$$

(8marks)

c) The air supply to an engine on a test bed passes down a 180 mm diameter pipe fitted with an orifice plate 90 mm diameter. The pressure drop across the orifice is 80 mm of paraffin. The coefficient of discharge of the orifice is 0.62 and the density of air and paraffin are 1.2 kg/m^3 and 830 kg/m^3 respectively. Calculate the mass flow rate of air to the engine.

(8 marks)

END OF EXAM

STUDEND ID.....

DATA TABLE FOR QUESTION 1

sieve #	Sieve size mm	% mass Retained	Cumulative % retained	% finer
Pan				

THE UNIVERSITY OF ZAMBIA

School of Natural Sciences

Department of Computer Science

CSC2111 – COMPUTER ARCHITECTURE

2014/2015 FINAL EXAM

Date:	Monday 2nd March 2015
Venue:	Upper Dining Hall
Time:	09:00 – 12:00 hrs
Duration:	3 Hours

Instructions

1. This exam has 6 questions.
2. Answer any **five (5)** questions.
3. Write your answers on a separate answer sheet.

QUESTION 1 [20 marks]

1. What, in general terms, is the distinction between computer organization and computer architecture? **[2 marks]**
2. Draw a diagram showing the components of a control unit. **[4 marks]**
3. What is a stored program computer? **[2 marks]**
4. At the integrated circuit level, give the three principal constituents of a computer system and state their function? **[6 marks]**
5. Convert the following hexadecimal numbers to their binary equivalents: **[3 marks]**
   a. D52 b. 239
6. Convert the following binary numbers to their hexadecimal equivalents: **[3 marks]**
   a. 00 1001 b. 1010 0111

QUESTION 2 [20 marks]

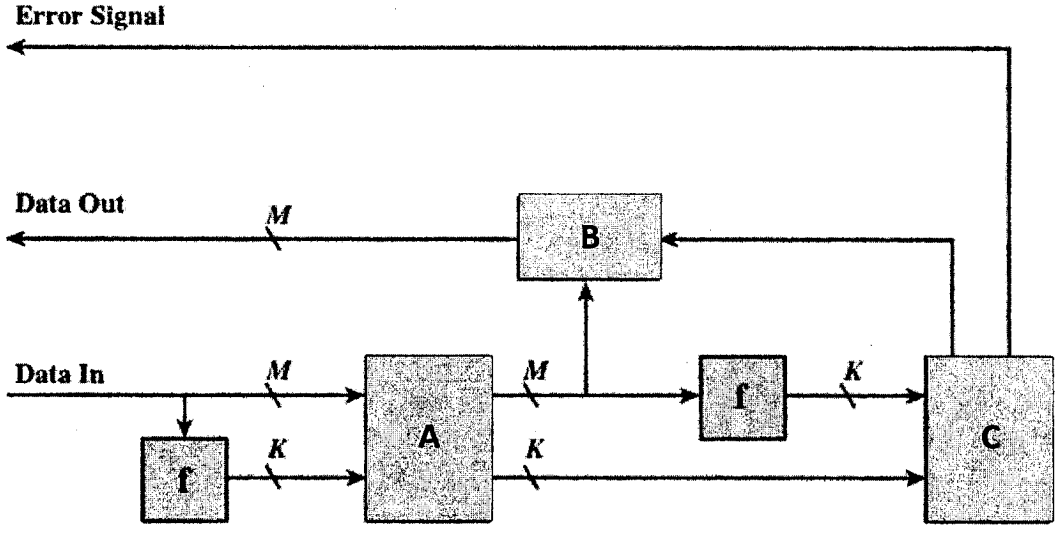
1. Give an example of embedded system and state its market. **[1 marks]**
2. What is a benchmark in computer science? Give an example. **[2 marks]**
3. State and explain the 2 classes of interrupts. **[2 marks]**
4. What is the control bus and what kind of signals can it transmit? **[4 marks]**
5. List the 3 elements of bus design that serve to classify buses and give their sub parameters **[6 marks]**
6. Consider a memory organization with a 16-bit memory addresses and word length of 4 bytes. What is the 2nd byte number of the fifth last word #? **[5 marks]**

QUESTION 3 [20 marks]

1. Define the terms sequential access, direct access, and random access? **[3 marks]**
2. What is the general relationship among access time, memory cost, and capacity? **[2 marks]**
3. Draw a diagram showing a typical cache organization in relation to the processor and the system bus. **[5 marks]**
4. Cache is a component that stores instructions/data so that future requests for either can be served faster, list and explain 2 elements considered in the design of cache. **[4 marks]**
5. What is victim cache? **[1 mark]**
6. Explain what write-through and write-back are giving the potential problems for each
7. Define unified cache and spilt cache. **[2 marks]**
8. Given the following values calculate the capacity of the disk. (Answer should be in GB) **[3 marks]**
   - 512 bytes/sector
   - 300 sectors/track (on average)
   - 20,000 tracks/surface
   - 2 surfaces/platter
   - 5 platters

QUESTION 4 [20 marks]

1. Give 2 key properties of semiconductor memory? **[2 marks]**
2. What is the difference between DRAM and SRAM in terms of (a) application and in terms of (b) characteristics such as speed, size, and cost? **[4 marks]**
3. Explain why one type of RAM is considered to be analog and the other digital. **[4 marks]**
4. Give 3 applications for ROM? **[3 marks]**
5. The diagram below shows how error correction is normally set up in computers. If f represents the error correction function, label the components A, B and C **[3 marks]**



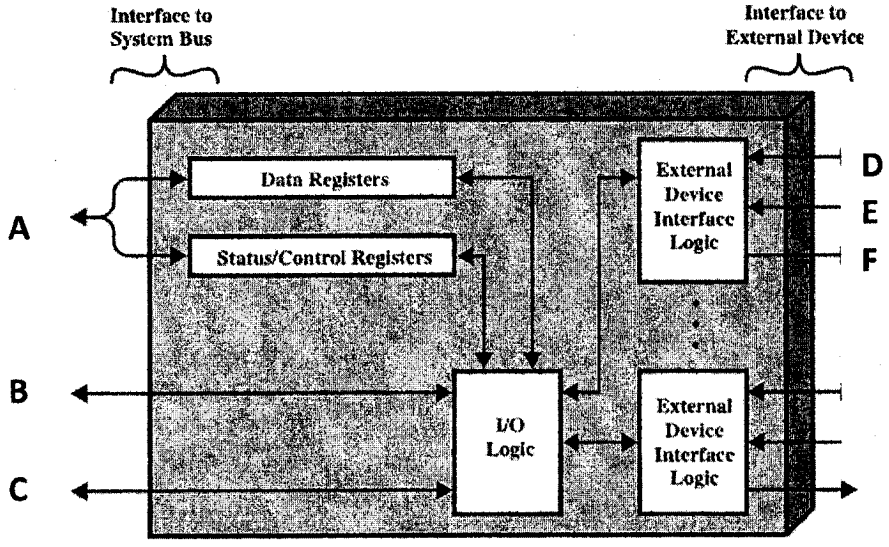
6. Given the 12-bit word 001101101111, composed of 8 data bits and 4 check bits, has an error, find in which position the error is in using a hamming code of 0111. **[4 marks]**

QUESTION 5 [20 marks]

1. Give 2 advantages of using a glass substrate for a magnetic disk? **[2 marks]**
2. What common characteristics are shared by all RAID levels? **[3 marks]**
3. What is the difference between CAV and CLV? **[3 marks]**
4. Explain the terms striped data **[2 marks]**
5. How is redundancy achieved in a RAID system? **[2 marks]**
6. In the context of RAID, what is the distinction between parallel access and independent access? **[4 marks]**
7. The access time for retrieving a piece of data is defined as Taccess = Tseek + Trotational + Ttransfer. Given the following information calculate the access time. **[4 marks]**
   - Rotational Rate = 7200 RPM
   - Average Seek Time = 9 ms
   - Average number of sectors per track = 400

QUESTION 6 [20 marks]

1. List and explain three broad classifications of external, or peripheral, devices. **[3 marks]**
2. What is the difference between memory-mapped I/O and isolated I/O? **[4 marks]**
3. Explain the three major functions of an I/O module? **[3 marks]**
4. Below is a block diagram of an I/O module, label the lines marked A - F **[6 marks]**



7. Explain the three ways a processor can use to determine which device issued the interrupt, when a device interrupt occurs? **[3 marks]**
8. Assume a memory access to main memory on a cache "miss" takes 30 ns and a memory access to the cache on a cache "hit" takes 3 ns. If 80% of the processor's memory requests result in a cache "hit", what is the average memory access time? **[1 marks]**

- END -

THE UNIVERSITY OF ZAMBIA

School of Natural Sciences

Department of Computer Studies

MID YEAR - FINAL EXAMINATION

DATA STRUCTURES AND ALGORITHMS
CSC 3011

Date:	TUESDAY, 3RD MARCH 2015
Time:	09:00hrs – 12:00hrs
Duration:	3 Hours
Venue:	SPORTS HALL

Instructions

a) *There are SEVEN (7) questions in this paper and you are required to answer ANY FIVE (5) OF THEM IN ANY ORDER.*
b) *All questions have carry the weight of 20 marks each*
c) *Each question should start on its separate page or booklet*

1. Consider the following pseudocode

```
Algorithm mystery(A, n)
    Input: Array A of integers and of size n > 1000
    X ← new array of size n
    for c ← 0 to n do
        s ← 0
        for d ← 0 to c do
            s ← s + A[d]
        X[c] ← s
End.
```

   i. What happens to the array a with the following call: mystery(a,5) where a = [12, 23, 25, 30, 20]
   ii. Give the best asymptotic (big-Oh) analysis of the following algorithm.

2. An algorithm processes 1000 items in a time 1ms.
   i. If the algorithm is of logarithmic order, show how much time does it require to process double the number of items.
   ii. How much time is required to process the same number of items if it is a linearly ordered algorithm?

3.
   i. Explain the four features of a recursive function
   ii. Define a recursive function, which given the parameter n, it will print "I Love Algorithms" n times.

4. A recursive algorithm to convert a number to its binary equivalent leads to the following recurrence relation.

$$T(1) = 1$$
$$T(n) = T(n/2) + O(1)$$

   i. Solve this recurrence relationship and determine the order of this algorithm.
   ii. Does it perform better than a quadratic ordered algorithm? Explain.

5.
   i. Describe the two methods of implementing a Hashtable
   ii. Explain the various mechanisms employed in handling collisions in Hashtables.
   iii. Insert the following elements to an initially empty Hash table of size 11 using the modulo function for hashing and quadratic probing

13, 24, 35, 46

6. Consider the array below

50	33	12	77	82	14	27	92	29	82

Representing a complete binary tree?

i. Is this a max heap?

ii. Explain.

iii. Use Heapsort to rearrange the elements in ascending order, showing the contents of the array at each stage.

7.

i. Explain what a binary search tree is

ii. Explain the following terms as related to trees

a) Depth of a node

b) Height of a tree

c) Path between nodes

d) Order of a node

iii. Add the following to an initially empty AVL-Tree

50 33 12 77 82 14 27 92 29 82

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

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

FINAL EXAMINATION

MULTIMEDIA AND HUMAN COMPUTER INTERACTION
CSC 4745

Date:	3rd MARCH, 2015
Time:	14:00hrs – 17:00hrs
Duration:	3 Hours
Venue:	UPPER DINING HALL

Instructions

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

Section A

Answer ALL Questions in this Section

Q.1

a) Define HCI. (1 Mark)

b) What are the three reasons for the growth of multimedia from a marketing standpoint? (3 marks)

c) What are the currents challenges of the search engines? (3 marks)

d) List three key characteristics of the interaction design process. (3 Marks)

e) Below are a number of proposed interactive products. What do you think are the key usability goals and user experience goals for each of them?

I. a mobile device that allows young children to communicate with each other and play collaborative games. (2 Marks)
II. a video and computer conferencing system that allows students to learn at home. (2 Marks)
III. an Internet application that allows the general public to access their medical records via interactive TV. (2 Marks)
IV. a CAD system for architects and engineers. (2 Marks)
V. an online community that provides support for people who have recently been Bereaved. (2 Marks)

Total 20 Marks

Q.2

a) Why do we study interaction design? (1 Mark)

b) Some interactive titles make decision best on user performance. What do we mean by that? (3Marks)

c) What are the three reasons for the growth of multimedia from a user Standpoint? (3 marks)

d) Define Interaction design according to Winograd. (1 Mark)

e) How does making a phone call differ when using: a public phone box and a cell phone? (2 Marks)

How have these devices been designed to take into account,

(I) the kind of users, (2 Marks)
(II) type of activity being supported, and (2 Marks)
(III) context of use? (2 Marks)

f) Create a scenario in which the problem space focuses on solving an identified problem with an existing product. (4 Marks)

Total 20 Marks

Q.3

a) List examples of questions involved in a framework for analysing the problem space. (3 Marks)

b) List the elements that determine the file size of a video. (4 marks)

c) Illustrate digitizing an analog video signal. (4 marks)

d) Define the Conceptual model. (1 Mark)

e) Why is it that Bitmap graphics are often used with photographic images? (2 marks)

f) What conceptual models are the following applications based on?

(I) a 3D video game, say a car-racing game with a steering wheel and tactile, audio, and visual feedback. (2 marks)
(II) the Windows environment. (2 marks)
(III) a web browser. (2 marks)

Total 20 Marks

Section B

Answer Any One (1) Question in this Section.

Q. 4

a) What is involved in clarifying your usability and user experience goals is a central part of working out the problem space. (5 marks)
b) Explain briefly on mental models and External cognition. (4 marks)

c) Imagine you have been asked to design an application to let people organize, store, and retrieve their email in a fast, efficient and enjoyable way. What would you do and how would you start? (4marks)

d) There are times when the multimedia title must include a great deal of text-for example, in reference titles such as encyclopedias. However, there are ways to accommodate large amounts of text without overwhelming and perhaps turning off the user. Explain the ways. (4 marks)

e) Explain in detail why we need to understand users. (5 Marks)

f) Explain briefly on design and usability principles. (5 Marks)

g) Explain briefly on Interaction design in business. (4 Marks)

h) Explain briefly on multimedia computer playback systems. (4 Marks)

i) Explain briefly the tips for reducing file size of the video. (5 Marks)

Total 40 Marks

Q. 5

a) Explain why it is not recommended to first work out how to design the physical interface. (5 Marks)

b) Which conceptual model or combination of models do you think is most suited to supporting the following user activities?

(I) downloading music off the web (3 Marks)

(II) programming (3 Marks)

c) A number of alternative interaction paradigms have been proposed by researchers intended to guide future interaction design and system development. These are ubiquitous, pervasive computing wearable computing. Explain on each in detail. (6 Marks)

d) Explain briefly on Conceptual models based on activities. (6 Marks)

e) Explain briefly on what is involved in the process of interaction design? (5 Marks)

f) Explain briefly on working together as a multidisciplinary team. (5 Marks)

h) Explain briefly on features of graphics programs. (3 Marks)

i) Explain briefly on exploring animation on the web. (4 Marks)

Total 40 Marks

END OF PAPER GOOD LUCK!!!!!

THE UNIVERSITY OF ZAMBIA

School of Natural Sciences

Department of Computer Science

MID YEAR - FINAL EXAMINATION

NUMERICAL ANALYSIS I
CSC 4921

Date:	MONDAY, 2ND MARCH 2015
Time:	09:00hrs – 12:00hrs
Duration:	3 Hours
Venue:	UPPER DINNING HALL

Instructions

a) *There are SEVEN (7) questions in this paper and you are required to answer ANY FIVE (5) OF THEM IN ANY ORDER.*

b) *All questions have carry the weight of 20 marks each*

c) *Each question should start on its separate page or booklet*

1.

i. State, without proof, the Rolle's theorem [4 Marks]

ii. State, without proof, the Intermediate theorem [4 Marks]

iii. Use the Intermediate Value Theorem and Rolle's Theorem to show that the graph of $f(x) = x^3 + 2x + k$ crosses the x-axis exactly once, regardless of the value of the constant k. [12 Marks]

2. Use the Fixed-point iteration method to approximate the positive root of the following quadratic equation to 10-3 accuracy. [20 Marks]

$$x^2 - 3x - 1 = 0$$

[Hint: identify the interval and extract an appropriate g from the expression above]

3.

i. State, without proof, the Mean-Value theorem
[8 Marks]

ii. Hence show that show that for any interval [a, b], [12 Marks]

$$|\sin(a) - \sin(b)| \leq |a - b|$$

Hint: $|\cos(x)| \leq 1 \; \forall x \in R$

4. Consider the table of values for the function $y = f(x)$

x	0	3	6	9
y	1.0000	2.1170	4.4817	9.4877

i. Use the Neville's Iterated method to approximate the value of $f(4)$ [12 Marks]

ii. Suppose f(4) is an approximation of the number e the base of the natural logarithm, what is the relative error of this approximation? [4 Marks]

iii. What is the function f? Ensure your function to give the exact values for the numbers given in the table above? [4 Marks]

5. Consider the table of values for the function $y = f(x)$

x	0	3	6	9
y	1.0000	2.1170	4.4817	9.4877

i. Use the Newton's Divided Differences method to approximate $f(2)$

6.

i. Derive the three point formula for estimating the derivative of a function. [12 Marks]

ii. Use the appropriate formula to estimate the f'(0.2) where f(x) = sin(x) and h = 0.2

[8 Marks]

7.

i. Evaluate, to six significant digits, the following integral [5 Marks]

$$\int_0^4 e^x \, dx$$

ii. Use the composite Simpson's with$h = 0.5$, to approximate the definite Integral above. [12 Marks]

iii. What is the absolute error for this approximation? [3 Marks]

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

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2014 ACADEMIC YEAR FINAL EXAMINATIONS

GES 3151: REGIONAL PLANNING AND DEVELOPMENT

TIME: **THREE HOURS**

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

---

1. With the help of illustrations, discuss the impacts of globalization on urban and regional planning in developing countries.
2. Discuss similarities and differences between the economic growth and the economic development of a country.
3. Discuss the concepts of economic base and economic multipliers in the context of regional planning.
4. Draw a diagram showing the forces in Nurske's supply-side vicious cycle of poverty and explain how these forces keep a country in a state of poverty.
5. Using examples, provide a critique on the assumptions that underlie the application of the Central Place Theory in urban and regional planning.
6. What difference can planning make in achieving sustainable human settlements?

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2014 ACADEMIC YEAR FINAL EXAMINATIONS

GES 3251: GEOMORPHOLOGY

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.

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1. Write short explanatory notes on ALL of the following:

   a) Regional and contact metamorphism
   b) Five methods of dating materials
   c) Bowen reaction series in crystallisation of igneous rocks
   d) Reynolds Number and Froude Number
   e) Relict and buried palaeosols

2. Using examples from the southern-central African region, discuss the importance of sediments in climate change studies.

3. Outline the occurrence of an earthquake and discuss the major factors that influence its size, extent of its impact, and the magnitude of damage caused.

4. With the aid of diagrams, discuss the differences between chemical weathering and physical weathering processes.

5. Outline one theory of landscape development and discuss its merits and demerits with regard to the understanding of Zambia's geomorphic legend.

6. Define a *dambo* and discuss typical characteristics of *dambos* and how their existence in tropical Africa is threatened by human activities.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2014 ACADEMIC YEAR FINAL EXAMINATIONS

GES 3321: ENVIRONMENT AND NATURAL RESOURCE ECONOMICS

TIME: Three Hours

INSTRUCTIONS: ANSWER QUESTION **ONE (1)** AND ANY OTHER THREE (3). All questions carry equal marks. Candidates are advised to make use of illustrations and examples wherever appropriate. The use of an approved calculator is allowed.

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1. Social cash transfers and farmer input support are increasingly being used among the options for the reduction of food insecurity in Zambia. In a hypothetical Twikatane project involving cash transfers, the costs associated with cash transfer are operational costs of 950 Kwacha per individual recipient per month and each individual receives 350 Kwacha per month. A village participating in the project has 250 heads of households who received cash in 2012.

   In 2013 the government claimed that they were spending too much on the cash transfers and instead decided to give the same 250 individuals inputs once (seed and fertilisers) at a cost of 500 Kwacha per individual. Individuals also paid 50 kwacha each for membership to cooperatives and 50 Kwacha for shares and 200 Kwacha towards subsidized inputs. A food security assessment at the end of 2012 showed that the hunger period had reduced by 40% and levels of malnourishment reduced by 5 percentage points among the beneficiaries. The effects of the inputs given in 2013 was assessed in 2014 and showed 40% hunger period reduction and 5 percentage points reduction in malnourishment among the beneficiaries.

   Using the information above, answer the following:

   a. Which method of cost effectiveness analysis is appropriate in this case? Explain your answer.
   b. Carry out an appropriate analysis to assess if the claim by the government is justified.
   c. Which option would you recommend? Explain your answer.

2. Write short explanatory notes on each of the following:
    a. Rivalry in consumption
    b. Stocks and flows
    c. Welfare economics
    d. Pareto improvement
    e. Resource rent

3. Using examples, explain the typology of values represented in total economic value.

4. Using any two environmental valuation methods, contrast indirect and direct valuation techniques.

5. Study figure 1 and answer the questions that follow.

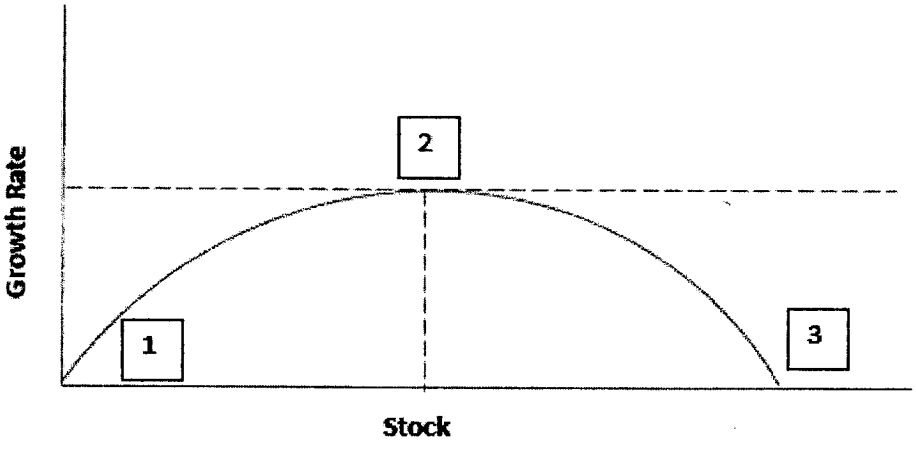

Figure 1: Sigmoid Growth Curve for Fisheries Resources

    a. Explain the sigmoid growth curve shown in figure 1 in relation to regions 1, 2 and 3.
    b. Distinguish between Maximum Sustainable Yield (MSY) and Economic Efficiency.
    c. Explain what is meant by a pedagogical instrument in the management of fisheries resources and state the advantages and disadvantages of this type of instrument.

6. Using examples, discuss whether market-based instruments are better suited for air pollution control than regulatory instruments in Zambia?

END OF EXAMINATION

UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2014 ACADEMIC YEAR FINAL EXAMINATIONS
GES 3441 REMOTE SENSING

TIME : Three (3) Hours
INSTRUCTIONS : Answer question **ONE**, and any other **THREE** questions.
ALL questions carry equal marks.

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1. Write short explanatory notes on **ALL** of the following:
   a) Radiometric enhancement
   b) Atmospheric windows
   c) Low-pass filters
   d) Normalised Difference Vegetation Index (NDVI)
   e) Spectral signature
   f) Information classes and spectral classes
   g) Image understanding
   h) Cubic convolution resampling
   i) Image compression

2. Show the relevance of remote sensing to Zambia, and identify the limitations of remote sensing methods compared to ground bases observations.

3. 'Several regions of the electromagnetic spectrum are NOT useful in remote sensing'.
   a) Explain why this is the case.
   b) What would be the best atmospheric conditions for remote sensing in the visible portion of the spectrum?

4. 'The spectral characteristics of an image pixel do not necessarily correspond to a specific land cover type'. Explain, using illustrations.

5. Outline the factors that influence the spectral reflectance characteristics of soil.

6. A Zambian millionaire wishes to invest some of his money in a remote sensing project. Being a layman in this field, he wants to fully understand it before he can invest his Ngwee in it. He has since hired you as an expert.
   a) As a starting point, explain to him what remote sensing is.
   b) Using appropriate examples, discuss with him the four basic questions that remote sensing methods try to address.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

2014 ACADEMIC YEAR FINAL EXAMINATIONS

GES 4181: URBAN GEOGRAPHY AND PLANNING

TIME: Three (3) Hours

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

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1. Write short explanatory notes on **ALL** of the following
   a) Rank-size rule
   b) Fordism
   c) False urbanisation
   d) Gravity models in urban geography
   e) The paradox of urbanisation.

2. 'The spontaneous appearance of slums in developing countries is largely attributed to the failure of urban planning'. Discuss.

3. Explain how cities are defined by the residential mosaic.

4. 'Third World urbanisation is driven not by economic and industrial forces, but primarily by demographic forces'. Discuss

5. How do Islamic cities provide examples of cultural values, economic necessities and environmental conditions as reflected in their urban form and land-use?

6. Explain the factors in the organization of human activity in geographical space which contribute to uneven development and regional inequalities.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2014 ACADEMIC YEAR FINAL EXAMINATIONS

GES 4281: GEOGRAPHICAL HYDROLOGY

TIME: **Three hours**

INSTRUCTIONS: Answer any **FOUR** questions.

All questions carry equal marks. Candidates are encouraged to make use of illustrations and examples wherever appropriate.

---

1. Write short explanatory notes on **ALL** of the following:

   a) Deterministic and stochastic hydrological processes
   b) Two baseflow separation methods
   c) Stomata response to solar irradiance
   d) Hydrological cycle
   e) Darcy's law

2. With the aid of diagrams, describe the infiltration process and factors affecting it.

3. Discuss the limiting factors in precipitation measurements in the river basins of Zambia.

4. Using examples, discuss the assertion that 'groundwater resources in Zambian cities are becoming increasingly threatened both in quantity and quality'.

5. State four climatic and three physical catchment characteristics and discuss their relevance to drainage basin studies.

6. Trace the development of evaporation modeling and outline the salient features of the Penman equation.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
PHYSICS DEPARTMENT
UNIVERSITY EXAMINATIONS
2014/15 ACADEMIC YEAR MID-YEAR EXAMINATIONS
P3531 - QUANTUM MECHANICS

TIME: 3 HOURS MAX MARKS: 100

ATTEMPT **FOUR** QUESTIONS ONLY. ALL QUESTIONS CARRY EQUAL MARKS.

You may use the following information:

Electron rest mass m_0	= 9.1×10^{-31} Kg
Boltzmann constant k	= 1.38×10^{-23} J/K
Proton rest mass M_p	= 1.67×10^{-27} Kg
Planck's constant h	= 6.6×10^{-34} J.s
Speed of light c	= 3×10^{8} m/s
$\hbar$	= 1.05×10^{-34} Js
1 e.V.	= 1.6×10^{-19}J
Stefan's constant σ	= 5.67×10^{-8} W/m^2.K^4

Laplacian in spherical polar coordinates

$$\nabla^2 = \frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial}{\partial r}\right) + \frac{1}{r^2\sin\theta}\frac{\partial}{\partial\theta}\left(\sin\theta\frac{\partial}{\partial\theta}\right) + \frac{1}{r^2\sin^2\theta}\frac{\partial^2}{\partial\phi^2}$$

The angular momentum L^2 operator in spherical coordinates

$$L^2 = -\hbar^2\left[\frac{1}{\sin\theta}\frac{\partial}{\partial\theta}\left(\sin\theta\frac{\partial}{\partial\theta}\right) + \frac{1}{\sin^2\theta}\frac{\partial^2}{\partial\phi^2}\right]$$

Q.1. (a) According to classical statistical mechanics, the average energy of an assemblage in equilibrium at a temperature T is given by

$$\bar{E} = \frac{\int_0^\infty E e^{-\frac{E}{kT}} dE}{\int_0^\infty e^{-\frac{E}{kT}} dE}$$

(i) State Planck's postulate for a black-body radiation and use it to show that the average energy of an atomic oscillator is given by

$$\bar{E} = \frac{E_0}{exp\left(\frac{E_0}{kT}\right) - 1}$$

[5]

(ii) Hence show that the energy density in a black-body radiation is given by [5]

$$\rho(\lambda, T) = \frac{8\pi hc}{\lambda^5 [\exp(hc/\lambda kT) - 1]}$$

(iii) Use the result in (ii) above to show that the total emissive power of a black-body is given by σT^4. Given

$$\int_0^\infty \frac{x^3 dx}{e^x - 1} = \frac{\pi^4}{15}$$

[5]

(a) (i) State the position-momentum uncertainty relation and use it to obtain the energy-time uncertainty relation. [5]

(ii) Using order of magnitude calculations, show that the position-momentum uncertainty relation holds in case of electron diffraction through a single slit. [5]

Q.2 (a) Without calculations, write down the values of the following commutators:

(i) $[x, p_y]$,
(ii) $[y, p_y]$
(iii) $[yz, p_y]$,
(iv) $[x, y]$,
(v) $[x, x^2]$,
(vi) $[p_x p_y, p_z]$
(vii) $[p_x p_y, x]$,
(viii) $[L_x, L_y]$,
(ix) $[L^2, L_x]$
(x) $[J^2, J_y]$. [10]

(b) (i) Using Dirac's bra and ket notation, define adjoint of an operator and hermitian operator.

(ii) Show that the eigenvalues of a hermitian operator are real. [2+3]

(c) What are compatible observables? Prove that two compatible observables commute. [6]

(d) Prove that for any two operators A and B, $(AB)^+=B^+A^+$, where the superscript + denotes adjoint of an operator. [4]

Q.3. The normalized wave-function of a particle trapped in an infinite square well potential of width *2a* is given as a linear combination of its eigenfunctions

$$\psi = C\left[\sin\left(\frac{3\pi x}{a}\right) + \frac{1}{4}\cos\left(\frac{3\pi x}{2a}\right)\right]; \quad \text{inside the well i.e. } |x| < a$$
$$= 0 \text{ outside the well, i.e. } |x| \geq a.$$

(a) Show that for a normalized wave function $C = 2/\sqrt{5}a$ [10]

(b) If a measurement of the total energy is made, what are the possible results of such a measurement? [10]

(c) Calculate the probability of measuring each of the energy values. [5]

Q.4. (a) Starting with the classical definition of the orbital angular momentum and using the basic commutation relations between the position and momentum operators,
(i) obtain the commutation relation between the orbital angular momentum operators L_x *and* L_y,
(ii) using the concept of similarity, write down the commutation relations between L_y *and* L_z, *and between* L_z *and* L_x,
(iii) give physical meaning to the commutation relations. [8+2+1]

(b) For a general angular momentum, let $J_\pm = J_x \pm iJ_y$. Using the commutation relations obtained in (a) above, show that
(i) $[J_z, J_+] = +\hbar J_+$
(ii) $[J^2, J_+] = 0$ [4+3]

(c) Let ψ_{jm} be an eigenstate of J^2 and J_z with eigenvalues $j(j+1)\hbar^2$ and $m\hbar$, respectively. Using the results in 4 (b) above, show that $J_+\psi_{jm}$ is likewise an eigenstate of J^2 and J_z. What are the eigenvalues? [7]

Q.5. Consider a particle of mass *m* confined within a rectangular box with impenetrable walls of sides L_x=*L and* L_y= L_z=2*L*.

(a) Choosing an appropriate coordinate system, write down the time-independent Schrodinger equation for the particle and the boundary conditions. [4]

(b) Using the method of separation of variables, solve the Schrodinger equation and obtain the allowed energy levels and the normalized eigenfunctions. [17]

(c) Find the energy of the lowest two energy levels and their degeneracy. [4]

Q.6. (a) Write down the time-independent Schrodinger equation for a one-dimensional linear harmonic oscillator. [3]

(b) Substituting

$$y=\left(\frac{m\omega}{h}\right)^{\frac{1}{2}}x \quad ;\alpha=\frac{2E}{h\omega}$$

show that the Schrodinger equation in (a) above becomes

$$\frac{d^2u(y)}{dy^2}+(\alpha-y^2)u(y)=0$$

[5]

(c) Using $u(y)=H(y)exp\left(-\frac{y^2}{2}\right)$ as the general solution of the equation in (b) above, show that *H(y)* satisfies

$$H''-2y'H+(\alpha-1)H=0$$

[4]

(d) Assuming a power series solution of H, show that the power series should terminate. [8]

(e) Hence show that the energy eigenvalues are given by

$$E_n=\left(n+\frac{1}{2}\right)h\omega \quad ;n=0,1,2$$

[5]

..... **END OF THE EXAMINATION** .....

THE UNIVERSITY OF ZAMBIA
DEPARTMENT OF PHYSICS
MID-YEAR EXAMINATIONS 2015
P4221: INTRODUCTION TO SOLID STATE PHYSICS

TIME: THREE HOURS
ANSWER: ANY FOUR QUESTIONS
MAXIMUM MARKS: 100

Electron mass: $m_e = 9.1 \times 10^{-31}$kg
Boltzmann's constant: $k_B = 1.38 \times 10^{-23}$ J/K
Electron charge: $e = 1.6 \times 10^{-19}$C
Planck's constant: $\hbar = 1.054 \times 10^{-34}$ Js
Permittivity of free space: $\varepsilon_0 = 8.854 \times 10^{-12}$ F/m
Bohr radius $a_0 = 5.3 \times 10^{-11}$m
Permeability of free space $\mu_0 = 4\pi \times 10^{-7}$ H/m
1 amu $= 1.67 \times 10^{-27}$ kg

$$(1+\alpha)^n \simeq 1 + n\alpha \text{ for } \alpha \ll 1$$

$$\int_0^\infty r^n e^{-\mu r} dr = \frac{n!}{\mu^{n+1}}$$

The Landé g factor is

$$g = 1 + \frac{J(J+1) + S(S+1) - L(L+!)}{2J(J+1)}$$

---

1. (**a**) The potential energy between two doubly-ionised atoms bound into a molecule is

$$U(r) = -\frac{A}{r} + \frac{B}{r^n}$$

where A and B are positive constants.

(**i**) Suggest a plausible expression for A. [2marks]

(**ii**) Prove that binding is possible only if $n > 1$. [6marks]

(**iii**) Prove that if the equilibrium distance is the same, the binding energy is greater for $n = 4$ than for $n = 3$. [6marks]

(**iv**) If the equilibrium distance is the same, determine for which case, $n = 3$ or $n = 4$, the molecule can be pulled further apart before it breaks. [5marks]

(**b**) Describe the origin of the van der Waals force and explain its importance in producing binding in solidified noble gases. [6marks]

2. (**a**) A cubic box of dimension L contains four electrons at absolute zero. The energy of a particle in such a box is

$$E_{n_1 n_2 n_3} = \frac{\hbar^2 \pi^2}{2mL^2}\left(n_x^2 + n_y^2 + n_z^2\right)$$

(**i**) Explain what is meant by the independent-electron approximation and the Pauli exclusion principle and hence determine the Fermi energy of this system. [4marks]

(**ii**) If $L = 2 \times 10^{-10}$ m, determine the Fermi temperature, the Fermi velocity and the Fermi wavelength. [9marks]

(**b**) The Drude theory for electric transport leads to Ohm's law

$$\mathbf{j} = \sigma \mathbf{E}$$

where

$$\sigma = \frac{ne^2 l}{\sqrt{3mk_B T}}$$

is the conductivity. This expression has the same structure in the Drude theory as in the more accurate theory of Sommerfeld.

(**i**) Explain why the Sommerfeld formula gives the correct value for σ while the Drude formula does not. [3marks]

(**ii**) Determine the factor by which the Drude formula over-estimates σ. [3marks]

(**iii**) A resistor made with a material whose Fermi energy is 4.5 eV has a length of 1 cm and a cross-sectional ares of 2 mm^2. It passes a current of 100 mA when the voltage across it is 9 V.

Assuming an electron concentration of $n = 3.2 \times 10^{28}$ m^{-3}, determine the mean free path for the electrons in the resistor. [6marks]

3. (**a**) The Fermi-Dirac distribution function is given by

$$f_{FD} = \frac{1}{1 + \exp\left(\frac{\varepsilon - \varepsilon_F}{k_B T}\right)}$$

(**i**) Interpret this function, explaining the meanings of ε and ε_F. [3marks]
(**ii**) Show that for $T = 0$, this distribution becomes the step function

$$f_{FD} = \begin{cases} 1, & \varepsilon < \varepsilon_F \\ 0, & \varepsilon > \varepsilon_F \end{cases}$$

[6marks]
(**iii**) Given that the density of energy states for a gas of N fermions in a volume V at $T = 0$ is

$$D(E) = \frac{V}{2\pi^2}\left(\frac{2m}{\hbar^2}\right)^{3/2} \varepsilon^{1/2}$$

show that the Fermi energy is

$$\varepsilon_F = \frac{\hbar^2}{2m}(3\pi^2 \frac{N}{V})^{2/3}$$

[4marks]
(**iv**) Show that the number n of electrons in the range from $\varepsilon_F - \varepsilon_0$ to ε_F, where $\varepsilon_F \gg \varepsilon_0$ is

$$n = \frac{3}{4}\frac{\varepsilon_0}{\varepsilon_F} N$$

[6marks]
(**b**) (**i**) Use free-electron theory to show that the classical value for the contribution of the electrons to the specific heat of a solid. is

$$C_V = \frac{3}{2} R$$

[4marks]
(**ii**) Use the result of **3(a)(iv)** to estimate the correct value of C_V. [5marks]

4. (**a**) (**i**) Show that the equation which describes lattice vibrations in one dimension is

$$m\ddot{x}_n = \beta(x_{n+1} + x_{n-1} - 2x_n)$$

[3marks]

and show that the dispersion relation for lattice vibrations in one dimension is

$$\omega = \sqrt{\frac{4\beta}{m}} \left| \sin\left(\frac{ka}{2}\right) \right|$$

[6marks]

(**iv**) Hence determine the force constant for a substance in which the maximum frequency of vibration is 2×10^{14} Hz and the mass of each atom is 27 amu. [2marks]

(**b**) The two branches of the dispersion relation for a linear diatomic lattice correspond to the equations.

$$\omega^2 = \beta\left(\frac{1}{m} + \frac{1}{M}\right) \pm \beta\left[\left(\frac{1}{m} + \frac{1}{M}\right)^2 - \frac{4\sin^2 ka}{mM}\right]^{1/2}$$

(**i**) Determine the masses m and M of the atoms if the force constant is $\beta = 820$ N/m and the minimum and maximum frequencies of vibrations for the optical branch are respectively $2.1 \times 10^{14}\text{s}^{-1}$ and $2.7 \times 10^{14}\text{s}^{-1}$... [9marks]

(**ii**) Determine the size of the forbidden gap. [5marks]

5. (**a**) Explain why diamagnetism is found in every substance and why it however apparently does not manifest itself. [4marks]

(**b**) In the Bohr atom, the single electron rotates in a circular orbit about the nucleus with the centripetal force being provided by the electrostatic attraction between the charges. The angular
momentum is quantised so that

$$L = mv\rho = n\hbar$$

(**i**) Show that the motion of the electron leads to the magnetic moment

$$\mu_0 = -\pi e f \rho^2$$

[6marks]

(**ii**) Assuming the ground state, for which $n = 1$, calculate the magnetic moment. [4marks]

(**iii**) When a magnetic induction B is applied at right angles to the plane of the orbit of the electron, a diamagnetic dipole moment

$$\Delta\mu = -\frac{e^2 B\rho^2}{4m}$$

is induced. For a hydrogen-like atom,

$$\langle r^2 \rangle = \frac{a_0^2 n^2}{2Z^2} \left(5n^2 - 3l(l+1) + 1\right)$$

Determine the magnetisation of hydrogen gas at standard temperature and pressure (STP) when a magnetic induction $B = 10$ T is applied. [4marks]

(**iv**) Calculate the susceptibility at STP.. [2marks]

Note: At STP, a mole of gas occupies 22.4 $m^3$and contains 6×10^{26}molecules. Here the molecules are diatomic. Assume that even though the atoms are bound into molecules, the electrons have the same orbital radius r as in atomic hydrogen. Assume also that the electrons are in the ground state.

(**c**) The magnetisation of paramagnetic sample of spin J is

$$M = N \frac{\sum_{m_J=-J}^{m_J=J} -m_J g \mu_B e^{-m_J g \mu B/k_B T}}{\sum_{m_J=-J}^{m_J=J} e^{-m_J g \mu B/k_B T}}$$

In a certain substance $L = 1$ and $S = 0$.

(**i**) Determine M. [6marks]

(**ii**) Determine M in the high-temperature limit. [3marks]

6. (**a**) Give two improvements of the Debye theory of heat capacity over that of Einstein. [3marks]

(**b**) (**i**) Justify the existence of a cut-off frequency in the Debye theory of heat capacity. [2marks]

(**ii**) Given that the number of vibrational modes in the frequency range from f to $f + df$ in a solid of volume V with N particles is

$$Z(f)dv = 4\pi V \left(\frac{2}{v_t^3} + \frac{1}{v_l^3}\right) f^2 df$$

show that the cut-off frequency is given by

$$f_D = \left(\frac{9N}{4\pi V}\right)^{1/3} \left(\frac{2}{v_t^3} + \frac{1}{v_l^3}\right)^{-1/3}$$

[3marks]

(**ii**) Given that the lattice molar heat capacity is

$$C_V = 3R\left(\frac{\theta_D}{T}\right)F_D$$

where

$$F_D = 3\left(\frac{T}{\theta_D}\right)^4 \int_0^{\theta_D/T} \frac{e^x x^4}{(e^x-1)^2}dx,\ x = \frac{hf}{k_BT} \text{ and } \theta_D = \frac{hf_D}{k}$$

determine its value in the the low- and the high-temperature limits. [11marks]

(**c**) In a ferromagnetic substance at ordinary temperatures and in the paramagnetic region,

$$M = Ngu_B(J+1)x/3$$

with

$$x = \frac{gJ\mu_B(B+\lambda M)}{k_BT}$$

Derive the Curie-Weiss law

$$\chi = \frac{C}{T-T_C}$$

and hence give expressions for the Curie temperature T_C and the Curie-Weiss constant C.. [6marks]

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

The University of Zambia

School of Natural Sciences
Department of Physics
2014/15 Academic Year
Mid-Year University Examinations
PHY2231: Thermodynamics & Properties of Matter

Answers QUESTION ONE (1) and <u>any other four</u> questions. All questions carry equal marks. The marks are shown in brackets.

Time: Three (3) hours. **Maximum marks = 100.**

Write clearly your computer number on the answer book. Show your working clearly. Omission of essential work will lead to loss of marks.

==========

Physical Constants

- Acceleration due to gravity $g = 9.80665\ \text{m.s}^{-2}$,
- Universal gas constant $R = 8.314\ \text{J/mole.K}$,
- Density of mercury, $\rho_{\text{mercury}} = 13600\ \text{kg/m}^3$,
- Density of water, $\rho_{\text{water}} = 1000\ \text{kg/m}^3$,
- Specific heat capacity of oil is 1450J/kg.K,
- Stefan Boltzmann constant is $\sigma = 5.672\times10^{-8}\ \text{Wm}^{-2}\text{K}^{-4}$,
- Planck's constant $h = 6.6261\times10^{-34}\ \text{J.s}$,
- Boltzmann's constant $k = 1.38066\times10^{-23}\ \text{J/K}$
- Speed of light in vacuum $c = 2.9979\times10^{8}\ \text{m/s}$.
- Specific heat capacity of water $c_w = 4184\ \text{J/kg.K}$

GEOMETRICAL MOMENT OF INERTIA

$$I_g = \begin{cases} \dfrac{\pi}{4}r^4 & \text{for a circular beam of radius } r. \\ \dfrac{bd^3}{12} & \text{for a beam of breadth } b \text{ and thickness } d. \end{cases}$$

FORMULAE THAT MAY BE USEFUL

1st Law of thermodynamics	$dq = du + Pdv = dh - vdP$
2nd Law of thermodynamics	$dq = Tds$
Combined 1st and 2nd Law of thermodynamics	$Tds = du + Pdv$
Specific work done by a gas as its volume changes from v_i to v_f.	$w = \int_{v_i}^{v_f} Pdv$
Newton's law of cooling	$\frac{dT}{dt} = k\left[T - T_a\right]$
Solution to Newton's law of cooling	$T = T_a + \left[T_0 - T_a\right]e^{kt}$
Fourier's law of thermal conductivity	$\frac{dQ_x}{dt} = \dot{Q}_x = -\kappa_x A\frac{dT}{dx}$
General heat conduction equation	$\nabla\cdot\left[\kappa\nabla T\right] + q_g = \rho c_p\left[\frac{\partial T}{\partial t}\right]$
Specific heat capacity at constant pressure	$c_p = \left[\frac{\partial q}{\partial T}\right]_p = \left[\frac{\partial h}{\partial T}\right]_p = T\left[\frac{\partial s}{\partial T}\right]_p$
Specific heat capacity at constant volume	$c_v = \left[\frac{\partial q}{\partial T}\right]_v = \left[\frac{\partial u}{\partial T}\right]_v = T\left[\frac{\partial s}{\partial T}\right]_v$
Mayer's relation for ideal gases	$c_P - c_v = R$
Specific enthalpy	$h = u + Pv$
Specific Gibbs free energy	$g = h - Ts = u + Pdv - Ts$
Specific Helmholtz free energy	$f = u - Ts$
Heat change ΔQ due to temperature difference ΔT.	$\Delta Q = mc_p\Delta T$
Ideal gas equation	$Pv = RT$
Van der Waals equation of state	$\left[P + \frac{a}{v^2}\right]\left[v - b\right] = RT$
Ideal gas equation under adiabatic conditions	$Pv^\gamma = \text{constant}$
Stefan-Boltzmann law	$I = \varepsilon\sigma T^4$
Wein's displacement law	$\lambda_m T = 2898\mu\text{m-K}$

FORMULAE THAT MAY BE USEFUL CONTINUED

Efficiency of a Carnot engine	$\eta = 1 - \frac{T_2}{T_1}$
Output temperature of a fluid from a convoluted pipe with walls at temperature T_B	$T_{f,o} = T_B - \left[T_B - T_{f,i}\right]\exp\left(-\frac{U}{\dot{m}c_p}x\right)$
Overall rate of heat transfer in a heat exchanger	$\dot{Q} = U_A \cdot A \cdot \tilde{T}_m$
Logarithmic mean temperature difference	$\tilde{T}_m = \frac{\tilde{T}_o - \tilde{T}_i}{\log_e\left(\tilde{T}_o/\tilde{T}_i\right)}$
Relation between the length L of an object and coefficient of linear expansion α .	$L = L_o\left[1+\alpha\left[T-T_0\right]\right] = L_o\left[1+\alpha\Delta T\right]$
Relation between the area A of an object and coefficient of superficial expansion β .	$A = A_o\left[1+\beta\left[T-T_0\right]\right] = A_o\left[1+\beta\Delta T\right]$
Relation between the volume V of an object and coefficient of superficial expansion γ .	$V = V_o\left[1+\gamma\left[T-T_0\right]\right] = V_o\left[1+\gamma\Delta T\right]$
Young's modulus	$Y = \frac{F/A_\perp}{\Delta L/L_o}$
Bulk modulus	$K = -\frac{dP}{dV/V_o}$
Shear modulus	$\eta = \frac{F/A_\parallel}{\theta}$
Work done in stretching a material	$W = \frac{1}{2}kx^2$
Energy stored per unit volume in a stretched material	$U_e = \frac{1}{2} \times \text{stress} \times \text{strain}$
Relation between Bulk modulus K, Young's modulus Y and Poisson's ratio σ.	$3K = \frac{Y}{1-2\sigma}$
Relation between Young's modulus Y, Shear modulus η and Poisson's ration σ.	$\eta = \frac{Y}{2\left[1+\sigma\right]}$
Poisson's ratio σ	$\sigma = \frac{\beta}{\alpha}$

FORMULAE THAT MAY BE USEFUL CONTINUED

Torsional rigidity of a hollow cylinder of inner radius r_i and outer radius r_0.	$c = \frac{\pi\eta}{2L}\left[r_o^4 - r_i^4\right]$
Mass density ρ of a material of mass m and volume V.	$\rho = \frac{m}{V}$
Bending moment τ for a material of Young's modulus Y and geometric moment of inertia I_g	$\tau = YI_g\frac{d^2y}{dx^2}$
Surface tension γ	$\gamma = dw/dA = F/2l$
Pressure difference for a curved liquid surface	$\Delta P = 2\gamma\left[\frac{1}{R_1} + \frac{1}{R_2}\right]$
Excess pressure inside a spherical liquid drop bubble	$P = \frac{2\gamma}{R}$
Excess pressure inside a spherical soap bubble	$P = \frac{4\gamma}{R}$
Surface tension by Jaeger's method	$\gamma = \frac{gR}{2}\left[\rho_i h_i - \rho h\right]$
Capillarity and surface tension relation	$\gamma = \frac{r\left[h + \frac{r}{3}\right]\rho g}{2\cos\theta}$
Planck's equation of thermal radiation	$u_\lambda = \frac{8\pi ch}{\lambda^5}\left[\frac{1}{e^{(ch/\lambda kT)} - 1}\right]$
Poiseulli's equation of viscous fluid flow	$\dot{V} = \frac{\pi P}{8\eta l}r^4$
Velocity v of sound in a medium of elastic modulus E and density ρ	$v = \sqrt{\frac{E}{\rho}}$
Bernoulli's equation	$\frac{P}{\rho} + gh + \frac{1}{2}u^2 = \text{constant}$

STATISTICAL FORMULAE

Arithmetic mean $\bar{x}$ (or expectation value $\langle x \rangle$) for a set of N data points x_i where $i = 1, 2, 3, ..., N$	$\bar{x} = \langle x \rangle = \frac{1}{N}\sum_{i=1}^{N} x_i$
Deviation X_i of the i^{th} data point from the mean $\bar{x}$	$X_i = x_i - \bar{x}$
Sum of deviations of the i^{th} data point from the mean $\bar{x}$	$\sum_{i=1}^{N} X_i = \sum_{i=1}^{N} [x_i - \bar{x}] = 0$
Sample variance σ^2	$\sigma^2 = \begin{cases} \frac{1}{N-1}\sum_{i=1}^{N} X_i^2 \\ \frac{S_{XX}}{N-1} \end{cases}$
Sample standard deviation σ	$\sigma = \begin{cases} \sqrt{\frac{1}{N-1}\sum_{i=1}^{N} X_i^2} \\ \sqrt{\frac{S_{XX}}{N-1}} \end{cases}$
Standard error ε	$\varepsilon = \pm \frac{\sigma}{\sqrt{N}}$
Pearson's correlation coefficient r	$r = \begin{cases} \frac{1}{[N-1]\sigma_x \sigma_y}\sum_{i=1}^{N} X_i Y_i \\ \frac{S_{XY}}{[N-1]\sigma_x \sigma_y} \end{cases}$
Coefficient of determination r^2	$r^2 = \left[\frac{\sum_{i=1}^{N} X_i Y_i}{[N-1]\sigma_x \sigma_y}\right]^2 = \left[\frac{S_{XY}}{[N-1]\sigma_x \sigma_y}\right]^2$
Gradient a_1 of the graph of best fit straight line	$a_1 = r\frac{\sigma_y}{\sigma_x}$
Intercept a_0 of the best fit straight line	$a_0 = \bar{y} - \bar{x}a_1$
Equation of best fit line is	$y = a_0 + a_1 x$

1 Figure 1 shows the experimental arrangement that was used to determine Young's modulus E for the material of a beam by the method of bending of a beam supported at its ends and loaded at the center. In this particular experiment, a copper beam was used.

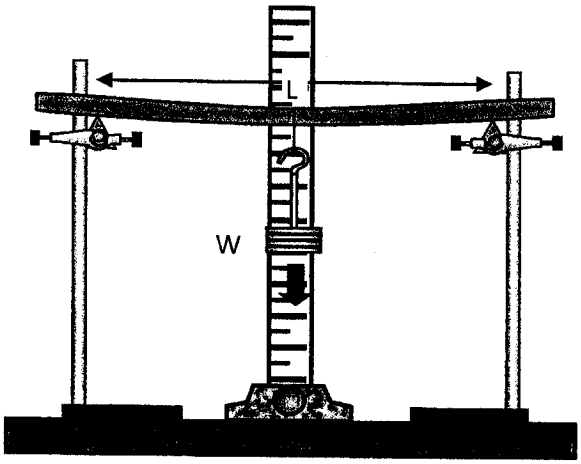


Figure 1: Experimental arrangement for determining the Young's of a material of a horizontally placed beam

The Young's modulus for a material of a beam loaded at its center is theoretically given by

$$E = \frac{MgL^3}{4bd^3y}$$

where y is the depression of the beam, b is the width of the beam, d is the thickness of the beam, L is the length of the beam between two knife edges, M is the mass loaded at the center of the beam, E is the Young's modulus while g is the acceleration due to gravity. The values of L, b and d were measured and found to be 0.677m, $24.9\times10^{-3}\text{m}$ and $3.3\times10^{-3}\text{m}$, respectively. Table 1 shows that data obtained from the experiment.

Table 1: Data Collected for load M and corresponding depression y.

Load M at the centre of the beam [Kg]	Depression y of the centre of the beam [m]
0.1	0.00126
0.2	0.00227
0.3	0.00291
0.4	0.00384

(a) Plot the graph of depression y against mass M. Indicating appropriate axes labels, units, scale and graph title. **[2]**

(b) Conduct a regression analysis and verify that the best-fit equation for the data in table 1 is given by

$$y = 0.0084M + 0.0005$$ **[12]**

(c) Use the best-fit equation in (b) to draw the best-fit line for data in 1. **[1]**

(d) Use the theoretical equation, together with the regression analysis to determine the experimental value of Young's modulus E for copper material and show that it is equal to $1.0114 \times 10^{11} \text{Pa}$, **[3]**

(e) Write a conclusion for this experiment. **[2]**

2. An isotropic and uniform steel bar of 3mm^2 cross-section and with a length of 1.2m is heated from 20.0°C to 80.3°C while fixed rigidly between two supports. At 20.0°C the physical properties of steel are that its Young's modulus is 2.0×10^{11} Pa , its coefficient of linear expansion is $12.0 \times 10^{-6}\ \text{K}^{-1}$, while its density is 7900.0kg/m^3. Show that the

(i) tensile strain within the steel bar is 723.6×10^{-6}, **[2.5]**

(ii) tensile stress within the steel bar is equal to 1.4472×10^{8} Pa, **[2.5]**

(iii) coefficients of superficial and cubical expansion are approximately $24.0 \times 10^{-6}\ \text{K}^{-1}$ and $36.0 \times 10^{-6}\ \text{K}^{-1}$, respectively, **[2]**

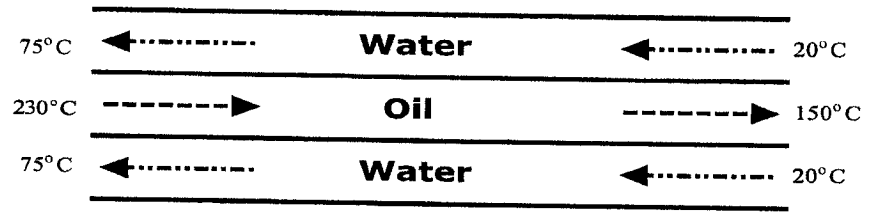
(iv) change in length of the steel bar as its temperature changes from 20.0°C to 80.3°C is $\Delta L = 0.87$ mm, **[2]**

(v) density of the steel bar at 80.3°C is $\rho = 7882.89\ \text{kg/m}^3$ **[5]**

(vi) energy stored per unit volume of the steel bar as it expands from 20.0°C to 80.3°C is $52359.7\ \text{J/m}^3$. **[2]**

(vii) fractional change in the velocity of sound waves in the steel bar as temperature changes from 20.0°C to 80.3°C is 0.00108481, **[4]**

3. (a) In a counter-flow double pipe heat exchanger, water is heated from 20°C to 75°C by an oil with a specific heat capacity of 1450J/kg.K and mass flow rate of 0.9kg/s. In the process, the oil is cooled from 230°C to 150°C.



Flow arrangement of the heat exchanger

If the overall heat transfer coefficient is 620W/m^2°C, show that the

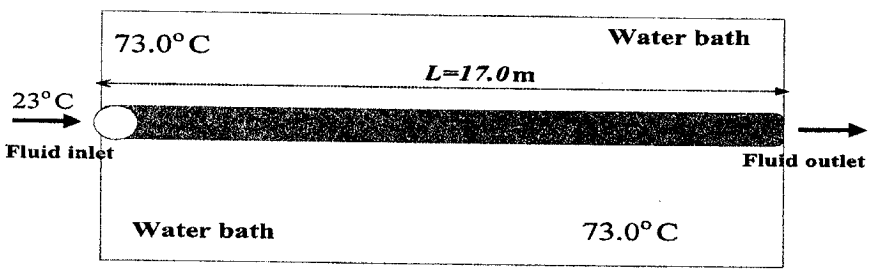
(i) rate of heat transfer $\dot{Q} = 104400$ J/s, **[2]**

(ii) mass flow rate of water is $\dot{m} = 0.454$ kg/s, **[3]**

(iii) logarithmic mean temperature difference of the heat exchanger is 142.134°C, **[2]**

(iv) surface area of the heat exchanger is $A = 1.18471$ m^2. **[3]**

(b) Water enters a 17.0 m long convoluted pipe at a temperature 23°C and at a flow rate of 0.005 kg/s.



If the walls of the pipe are maintained at 73°C by a heat bath and the average heat transfer coefficient per unit length of pipe is 6.0 W/m°C,

(i) Show that the variation of temperature along to pipe is given by

$$T(x) = 73 - 50e^{\left(-\frac{6x}{20.92}\right)},$$

where x is the distance from the inlet of the pipe. **[2]**

(ii) Find the temperature of the water when it exists. **[1]**

(iii) Show that the rate at which heat is being extracted from the water bath to the convoluted pipe is 1038.02 J/s. **[3]**

(iv) On a piece of graph paper, plot the graph of water temperature rise $T(x)$ against length of pipe x for the above process. **[4]**

4. (a) The surface tension of a soap solution is 20×10^{-3} N/m. Consider a soap bubble of radius 3×10^{-3} m. Show that the

(i) excess pressure inside the soap bubble is $\Delta P = 26.66$ N/m^2, **[2]**

(ii) surface energy of the soap bubble is 4.52×10^{-6} J. **[2]**

(b) A slab of thickness $L = 0.25$m is made of copper and has a thermal conductivity $\kappa = 387.6$W/mK. If one of the surfaces is kept at 100°C and the other surface at 0°C, show that the net heat flux (i.e. energy per unit time per unit area) across the slab is 155040 W/m^2. **[2]**

(c) A beam of circular cross section and negligible weight is supported at the ends and a load of mass 1.7 kg is applied at its middle. If the beam has a length of 1.2m, a radius of 7.0 cm and is made of a material with Young's modulus equal to 2.0×10^{10} Nm^{-2}, show that the

(i) depression of the beam at a point 15.0cm from one of its ends is equal to 58.39 nm, **[12]**

(ii) maximum depression of the beam is 1.59 μm **[2]**

5. (a) Show that the couple required per unit radian c' in case of a hollow cylinder of internal and outer radii r_i and r_o, respectively, length L and Shear modulus η is given by

$$c' = \frac{\pi\eta}{2L}\left[r_o^4 - r_i^4\right].$$ **[12]**

(b) The Sun can be considered as a black body at a surface temperature of 6000K.

(i) What is a black body? **[2]**

(ii) Show that the energy emitted by the Sun per unit area, per unit time is equal to $7.35\times10^{7}\,\text{W/m}^2$. **[3]**

(iii) Use the Wein's displacement law to show that the characteristic wavelength of the solar spectrum is $\lambda_m = 483\text{ nm}$. **[3]**

6. (a) The angular displacement of a torsional oscillating system is given by

$$\theta = \pi \sin\left(2\pi t + \frac{\pi}{4}\right).$$

(i) What is the angular amplitude of oscillation? **[1]**

(ii) What is the phase constant? **[1]**

(iii) What is the period of oscillation for the watch? **[2]**

(iv) Show that the maximum angular speed is $2\pi^2\text{ rad/s} = 19.7392\text{ rad/s}$. **[3]**

(v) Show that the angular speed of the wheel when its displacement is $\pi/6$ rad is equal to 19.4631 rad/s. **[3]**

(b) A detective arrives at a crime scene where a body has just been found. The temperature of the body is taken at 05:59 AM and found to have an average value of 23.4°C. The room where the body is found to have a digital programmable thermostat which indicates that the room has been kept at a constant temperature of 21.0°C for the past 3 days. After evidence from the crime scene is collected, exactly one hour after the first temperature measurement, the temperature of the body is taken once more and found to have an average value of 22.9°C. Assuming that the victim's body temperature was normal (i.e. $37.0\ ^\circ\text{C}$) prior to death, use Newton's law of cooling to

(i) calculate the radiation cooling constant for the body, **[8]**

(ii) show that the victim's estimated time of death is about $21:52\text{hrs}$. **[2]**

7. (a) One gram of an ideal gas at $300K$ is compressed isothermally to half its initial volume.

(i) Show that the work is done by the ideal gas is -1728.85 J. **[6]**

(ii) Hence, or otherwise, show that the increase in entropy is 5.763 J/K **[4]**

(b) A gas obeys the van der Waals equation of state.

(i) Show that the specific work under isothermal conditions by gas obeying the van der Waals equation of state and whose volume changes from v_1 to v_2 is given by

$$w = RT\log_e\left(\frac{v_2 - b}{v_1 - b}\right) + a\left[\frac{1}{v_2} - \frac{1}{v_1}\right],$$

where a and b are van der Waals constants while R is the universal gas constant. **[6]**

(iv) Hence, or otherwise, show that the change in specific entropy of the gas is

$$\Delta s = R\log_e\left(\frac{v_2 - b}{v_1 - b}\right) + \frac{a}{T}\left[\frac{1}{v_2} - \frac{1}{v_1}\right].$$ **[4]**

--------- END OF PHY2231 EXAM 2015 ---------

THE UNIVERSITY OF ZAMBIA
DEPARTMENT OF PHYSICS
SCHOOL OF NATURAL SCIENCES
2014/15 ACADEMIC YEAR

MID YEAR UNIVERSITY EXAMINATIONS

PHY-2511: CLASSICAL MECHANICS

Time allowed: **3 Hours**

Instructions

- **This examination paper contains 7 questions. Each question carries 20 marks. Attempt any 5 questions out of the 7 questions given.**
- **This paper has a total of 100 marks. All questions carry equal marks**
- **Show all your work clearly. Omission of essential work will result in loss of marks**
- **Write your computer number clearly on the answer sheet**

Where necessary, you may use the following:

In plane polar coordinates

$x = r\cos\theta, \qquad y = r\sin\theta$

$\vec{v} = \dot{r}\hat{\vec{r}} + r\dot{\theta}\hat{\vec{\theta}} \qquad \vec{a} = \left(\ddot{r} - r\dot{\theta}^2\right)\hat{\vec{r}} + \left(r\ddot{\theta} + 2\dot{r}\dot{\theta}\right)\hat{\vec{\theta}}$

In cylindrical coordinates

$x = \rho\cos\phi \qquad y = \rho\sin\phi \qquad z = z$

$\vec{v} = \dot{\rho}\hat{\vec{\rho}} + \rho\dot{\phi}\hat{\vec{\phi}} + \dot{z}\hat{\vec{z}} \qquad \vec{a} = \left(\ddot{\rho} - \rho\dot{\phi}^2\right)\hat{\vec{\rho}} + \left(\rho\ddot{\phi} + 2\dot{\rho}\dot{\phi}\right)\hat{\vec{\phi}} + \ddot{z}\hat{\vec{z}}$

In spherical coordinates

$x = \rho\cos\phi \qquad y = \rho\sin\phi \qquad z = z$

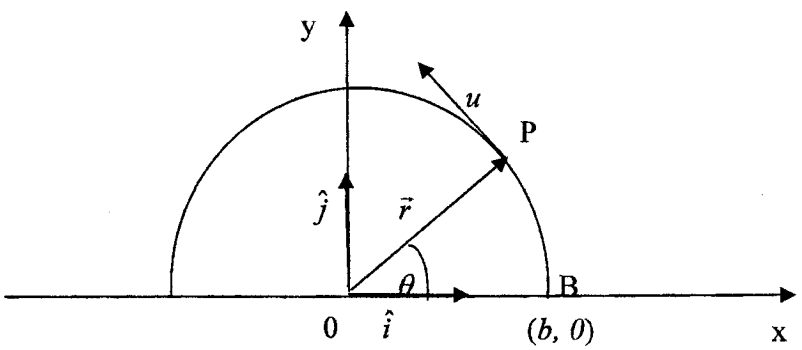
$$\vec{v} = \dot{r}\hat{\vec{r}} + r\dot{\theta}\hat{\vec{\theta}} + \left(r\dot{\phi}\sin\theta\right)\hat{\vec{\phi}}$$

$$\vec{a} = \left(\ddot{r} - r\dot{\theta}^2 - r\sin^2\theta\dot{\phi}^2\right)\hat{\vec{r}} + \left(r\ddot{\theta} + 2\dot{r}\dot{\theta} - r\sin\theta\cos\theta\dot{\phi}^2\right)\hat{\vec{\theta}} + \left(r\sin\theta\ddot{\phi} - 2\dot{r}\dot{\phi} + 2r\dot{\theta}\dot{\phi}\cos\theta\right)\hat{\vec{\phi}}$$

$$\int \cos x dx = \sin x + C$$

$$\int \sin x dx = -\cos x + C$$

Q1 A particle P is moving with constant speed u in the anti-clockwise direction around a circle centre O and radius b as shown in the figure below.



At time $t = 0$, P is at the point $B(b, 0)$,

(a) Obtain the expression for the position vector $\vec{r}$, in terms of $u, b, t, \hat{i}$ and $\hat{j}$. **[2 marks]**

(b) Show that the velocity vector is given by **[2 marks]**

$$\vec{v} = -u\sin\left(\frac{ut}{b}\right)\hat{i} + u\cos\left(\frac{ut}{b}\right)\hat{j}$$ **[5 marks]**

(c) From your expression in (b) above, verify that the speed is u. **[5 marks]**

(d) Show that the acceleration vector is

$$\vec{a} = -\frac{u^2}{b}\cos\left(\frac{ut}{b}\right)\hat{i} - \frac{u^2}{b}\sin\left(\frac{ut}{b}\right)\hat{j}$$ **[2 marks]**

(e) Show that the acceleration vector points towards the origin. **[4 marks]**

Q2(a) Is it possible for a two dimensional motion to have acceleration in one dimension?

[1 mark]

(b) If your answer to (a) above is yes, give a practical example. **[1 mark]**

(c) A particle sliding along a radial groove in a rotating turntable has polar coordinates at time t given by

$$r = ct, \qquad \theta = \Omega t$$

where c and Ω are positive constants.

(i) Find the velocity vector of the particle. **[4 marks]**

(ii) Find the acceleration vector of the particle. **[6 marks]**

(iii) Show that the speed of the particle at time t is $\sqrt{c^2+(\Omega t)^2}$ **[4 marks]**

(iv) Deduce that for $t>0$, the angle between the velocity vector and acceleration vectors is always acute. **[4 marks]**

Q3 A particle of mass m is subjected to a force $F(t)=m(\exp(-bt))$. The initial position and speed are zero.

(a) Find the expression for position as a function of time. **[12 marks]**

(b) Obtain the expression for position in the limiting case when $t\to\infty$. **[2 marks]**

(c) Find the expression for the velocity as a function of time if F has the form $F(x)=-kx$. **[6 marks]**

Q4(a) A particle of mass m starts from rest and moves under a force given by $\overline{F}=\hat{i}\cos(\omega t)+\hat{j}\sin(\omega t)$.

(i) Obtain the expression for the velocity at any time t. **[8 marks]**

(ii) Obtain the expression for the position at any time t. **[6 marks]**

(iii) In which plane is the particle moving? **[1 mark]**

(iv) Using your result or otherwise, validate the initial condition $\bar{r}(0)=0$ **[1 mark]**

(b) The position of a particle is given in metres by the position vector $\bar{r}=2\hat{i}-5\hat{j}+4\hat{k}$. What is the distance of the particle from the origin? **[4 marks]**

Q5 A particle of mass m is traveling along the x-axis such that at $t=0$, it is located at $x=0$ and has a speed v_0. The particle is acted upon by a force which opposes the motion and has a magnitude proportional to the square of the instantaneous speed. Find the

(a) speed, **[8 marks]**

(b) position and **[8 marks]**

(c) acceleration of the particle at any time $t>0$. **[3 marks]**

(d) Does the particle come to rest? **[1 marks]**

Q6(a) A system of six particles each of unit mass are located at $(1, 0,-1),(-2, 1,-3),(3,-1, 1)$, $(5, 0,-3)$, $(8, 4, 2)$ and $(4,-5,-6)$ respectively. Find the coordinates of the center of mass of the system of particles. **[8 marks]**

(b) Show that if the total momentum of a system of particles is constant, that is conserved, then the center of mass is at rest or in motion with constant velocity. **[4 marks]**

(c) Consider a thin rod of length L and linear mass density λ. Employing the Parallel Axis Theorem, find the moment of inertia about an axis perpendicular to the rod a distance $3L/4$ from one end. **[8 marks]**

Q7 A particle of mass m_1 and kinetic energy T_1 collides elastically with a particle of mass m_2 which is at rest. The particle of mass m_2 leaves the collision point at an angle θ_2 with the original direction of m_1, while m_1 continues in the forward direction at an angle θ_1 from its original path.

(a) Obtain the expression for the kinetic energy T_2 in terms of θ_2, m_2, m_1 and momentum of m_1 with which the particle of mass m_2 leaves the collision. **[15 marks]**

(b) Show that for a given value of T_1, the energy in part (a) above is maximum for a *head-on* collision. **[5 marks]**

**********END OF PHY 2511 EXAMINATION**********

UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
DEPARTMENT OF PHYSICS
MID-YEAR UNIVERSITY EXAMINATIONS
2014/2015 ACADEMIC YEAR

B.Sc. PHYSICS
PHY4021
MATHEMATICAL METHODS FOR PHYSICS

DURATION: Three hours.

INSTRUCTIONS: Answer any four questions from the six given. *Each question carries 25 marks with the marks for parts of questions indicated.*

MAXIMUM MARKS: 100

DATE: Monday, 23th February 2015.

Formulae that may be needed:

1.
$$u_x = v_y, \qquad u_y = -v_x$$

2.
$$f^{(n)}(z_0) = \frac{n!}{2\pi i}\oint_C \frac{f(z)}{(z-z_0)^{n+1}}\,dz, \qquad (n = 1, 2, \ldots)$$

3.
$$\sum_{m=0}^{\infty} q^m = 1 + q + q^2 + \ldots = \frac{1}{1-q}, \quad |q| < 1$$

4.
$$\left|\frac{z_{n+1}}{z_n}\right| \leq q < 1, \quad \text{for } n \text{ greater than some } N$$

5.
$$\lim_{n\to\infty}\left|\frac{z_{n+1}}{z_n}\right| = L.$$

6.
$$\sqrt[n]{|z_n|} \leq q < 1, \quad \text{for } n \text{ greater than some } N$$

7.

$$\lim_{n\to\infty} \sqrt[n]{|z_n|} = L$$

8.

$$\begin{aligned} R &= \frac{1}{L^*}, \quad L^* = \lim_{n\to\infty} \left|\frac{a_{n+1}}{a_n}\right| \\ R &= \frac{1}{\tilde{L}}, \quad \tilde{L} = \lim_{n\to\infty} \sqrt[n]{|a_n|} \\ R &= \frac{1}{\tilde{l}}, \quad \tilde{l} = \text{largest limit of } \lim_{n\to\infty} \sqrt[n]{|a_n|} \end{aligned}$$

9.

$$(\cosh z)' = \sinh z, \qquad (\sinh z)' = \cosh z$$

10.

$$\operatorname*{Res}_{z=z_0} f(z) = \lim_{z\to z_0} (z - z_0) f(z)$$

11.

$$\operatorname*{Res}_{z=z_0} \frac{p(z)}{q(z)} = \frac{p(z_0)}{q'(z_0)}$$

12.

$$\operatorname*{Res}_{z=z_0} f(z) = \frac{1}{(m-1)!} \lim_{z\to z_0} \left\{ \frac{d^{m-1}}{dz^{m-1}} [(z - z_0)^m f(z)] \right\}$$

13.

$$\oint_C f(z)\, dz = 2\pi i \sum_{j=1}^{k} \operatorname*{Res}_{z=z_j} f(z)$$

14. Improper integrals of rational trigonometric functions of $\sin\theta$ and $\cos\theta$ (integration taken counterclockwise)

$$\int_C f(z)\, \frac{dz}{iz} = 2\pi i \sum_{j=1}^{k} \operatorname*{Res}_{z=z_j} \left[\frac{f(z)}{iz}\right], \qquad C: \ |z| = 1$$

where $f(z)$ is obtained from $f(\cos\theta, \sin\theta)$ by the substitutions

$$\cos\theta = \frac{1}{2}\left(z + \frac{1}{z}\right), \qquad \sin\theta = \frac{1}{2i}\left(z - \frac{1}{z}\right)$$

15. Improper integrals of rational functions:

$$\int_{-\infty}^{\infty} f(x)\, dx = 2\pi i \sum \operatorname{Res} f(z)$$

16.

$$e^z = \sum_{n=0}^{n=\infty} \frac{z^n}{n!}$$

17.

$$y = \sum_{n=0}^{\infty} a_n x^n, \qquad y' = \sum_{n=0}^{\infty} n a_n x^{n-1}, \qquad y'' = \sum_{n=0}^{\infty} n(n-1) a_n x^{n-2}$$

QUESTION 1

(i) Test whether or not the function $f(z) = z(\overline{z} + z)$ is differentiable using the definition of differentiation. (15 marks)

(ii) Show that the function

$$u = x^2 - y^2$$

is harmonic. Find the conjugate harmonic function v. (10 marks)

QUESTION 2

(i) Use the method of path to integrate

$$\int_C \frac{z^2}{2-z}\, dz, \qquad C : |z+2| = 5, \text{ anticlockwise.}$$

(10 marks)

(ii) Check your answer to part (i) by using Cauchy's integral formulae. (5 marks)

(iii) Test if the following series converges:

$$\sum_{n=1}^{\infty} \frac{1}{\sqrt{n}}.$$

(5 marks)

(iv) Find the center and radius of convergence of th following series:

$$\sum_{n=0}^{\infty} \frac{(-1)^n}{n!} z^{2n}.$$

(5 marks)

QUESTION 3

(i) Find all of the Laurent series of the function

$$\frac{1}{2z^5 - 3z^6},$$

and state their region of convergence. (8 marks)

(ii) Expand the following function as a Laurent series with center $z_0 = -4$:

$$f(z) = \frac{1}{z(z+4)^2}.$$

(8 marks)

(iii) Integrate the following improper integral using an appropriate formula, and state any condition that must be satisfied for the formula to be used:

$$\int_{-\infty}^{\infty} \frac{x^2}{(x^2+1)(x^2+4)}\, dx.$$

(9 marks)

QUESTION 4

Consider the following matrix:

$$A = \begin{bmatrix} 1 & 1+i \\ 1-i & -1 \end{bmatrix}.$$

(i) Test to find whether or not the matrix A is Hermitian. (5 marks)

(ii) Find the eigenvalues and eigenvectors of the matrix A. (14 marks)

(iii) (a) Write down the transformation which diagonalises the matrix A, and use your results from part (ii) to write down the transformation matrix. DO NOT PERFORM THE DIAGONALISATION.

(3 marks)

(b) Use your results from part (ii) to write the diagonal form of the matrix A. What can you say about the diagonal elements. Do they conform to some general principle? If so, state the principle. (3 marks)

QUESTION 5

(i) State the condition for the existence of a power series solution of a second order linear differential equation. (4 marks)

(ii) Show that a power series solution of the differential equation below exists, and then find the solution by the power series method.

$$y'' - 4xy' + (4x^2 - 2)y = 0.$$

Calculate coefficients up to a_5. (21 marks)

QUESTION 6

(i) The Euler-Lagrange equation is

$$\frac{\partial F(y,\dot{y},x)}{\partial y} - \frac{d}{dx}\frac{\partial F(y,\dot{y},x)}{\partial y} = 0.$$

Derive the simplified form when F does not depend on x, i.e., when F has the form $F(y,\dot{y})$. (9 marks)

(ii) Derive the formula for the shortest distance between two points in a plane.

(13 marks)

(iii) How are the constants of integration that arise in part (ii) determined? (3 marks)

END