SCHOOL OF NATURAL SCIENCES 2013/2014 ACADEMIC YEAR MID YEAR HALF COURSE

1	BIO2701	BASIC PHYSIOLOGY
2	BIO 3045	CONSERVATION BIOLOGY
3	CHE 2015	GENERAL ANALYTICAL AND INORGANIC CHEMISTRY
4	CHE 2219	CHEMICAL ANALYSIS
5	CHE 2511	BASIC ORGANIC CHEMISTRY
6	CHE 3111	CELLULAR BIOCHEMISTRY
7	CHE 3511	SPECTROSCOPIC IDENTIFICATION OF ORGANIC COMPOUNDS AND AROMATIC CHEMISTRY
8	CHE 4811	INORGANIC INDUSTRIAL CHEMISTRY
9	CSC 3011	ALGORITHMS AND COMPLEXITY
10	GES 3151	REGIONAL PLANNING AND DEVELOPENT
11	GES 4181	URBAN GEOGRAPHY AND PLANNING
12	MAT 3401	TOPOLGY
13	MET 3429	COMPUTER TECHNIQUES
14	P 3531	QUANTUM MECHANICS
15	PHY 2231	THERMODYNAMICS AND PROPERTIES OF MATTER
16	PHY 2511	CLASSICAL MECHANICAL I
17	PHY 4021	MATHEMATICAL METHODS FOR PHYSICS
18	PHY 4031	COMPUTATIONAL PHYSICS

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2013 ACADEMIC YEAR
FINAL EXAMINATIONS

BIO 2701: BASIC PHYSIOLOGY
THEORY PAPER

TIME: THREE HOURS

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

SECTION A

1. Outline the ten chemical steps involved in the oxidation of glucose to pyruvate in glycolysis and indicate the name of the enzyme catalyzing each chemical step. Use structural formulae for the substances involved in the reactions (except ADP^+/ATP, NAD^+/NADH and orthophosphate)
2. (a) State the photosynthetic pigment composition of antenna complexes and reaction center complexes.
   (b) Describe the light reactions of photosynthesis.

3. (a) Explain the terms "climacteric" and "non-climacteric" as applied to fruits, and give four examples of each.
   (b) Discuss three physiological effects of ethylene on plant growth and development, other than in fruit ripening.
   (c) State two commercial applications of ethylene in agriculture.

4. Discuss the factors that determine the following:
   (a) Water uptake by a root cell in a mesophytic plant.
   (b) Rate of water flow through the stem of a plant.
   (c) Rate of water loss at the leaves of a land plant.

SECTION B

5. (a) State five factors that may affect oxygen transport in the blood.
   (b) Explain how changes in the factors mentioned in (a) above may affect the position of the oxygen-haemoglobin dissociation curve.

TURN OVER

6. Summarise each of the following:
   (a) Sensory reception.
   (b) Spermatogenesis.
   (c) Bile secretion and composition.
   (d) Blood leucocytes.

7. Discuss the roles of each of the following endocrine glands in the normal physiology of a mammal.
   (a) Adrenal.
   (b) Pituitary.
   (c) Thyroid.
   (d) Parathyroid.

8. (a) Explain the difference between glomerular filtration rate and creatinine clearance.
   (b) Describe the nephron concentrating mechanism that leads to the formation of hypertonic urine in desert mammals.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2013 ACADEMIC YEAR:
FINAL EXAMINATIONS

BIO 3045: CONSERVATION BIOLOGY
THEORY PAPER

TIME: THREE HOURS

INSTRUCTIONS: ANSWER **FIVE** QUESTIONS, QUESTIONS **ONE** AND **TWO** ARE **COMPULSORY**. ANSWER ANY **THREE** OTHER QUESTIONS. ILLUSTATE YOUR ANSWERS WHERE NECESSARY.

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1. Summarise the following as commonly used in conservation biology:
   (a) Initial exclusion.
   (b) Edge effect.
   (c) Stepping stone corridor.

2. Discuss the following as commonly used in environmental Impact Assessment:
   (a) Environmental Impact Statement (EIS).
   (b) Mitigation measures.
   (c) Environmental Project Brief (EPB).

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

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

5. Describe the relationships between adaptive management and ecological monitoring.

6. Discuss the competitive advantages that introduced species may have in comparison to indigenous ones that lead to their dominance.

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

8. Discuss the three main categories of an ecological monitoring programme.

END OF THE EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2013 HALF-YEAR EXAMINATIONS

CHE2015: GENERAL ANALYTICAL AND INORGANIC CHEMISTRY
TIME : 3 HOURS

INSTRUCTIONS:
1. **THIS PAPER CONTAINS FOUR (05) QUESTIONS.**
2. **ANSWER ANY THREE (03) QUESTIONS.**
3. **EACH QUESTION CARRIES 15 MARKS.**
4. **SHOW ALL YOUR WORKING CLEARLY.**
5. **ESSENTIAL DATA TABLES ARE ATTACHED TO THE QUESTION PAPER.**

Question 1.

(a).

Calculate the Z_{eff} on a 5s, a 5p and 4d electron in a tin (Sn) atom. Which is the most loosely held electron? Explain why?

(b).

The calcium content of a powdered milk sample was analyzed five times by each of the methods, with similar standard deviations. Are the two mean values significantly different at the 95% confidence level?

Method 1	**Method 2**
0.271	0.0271
0.282	0.0268
0.279	0.0263
0.271	0.0274
0.275	0.0269

(c).

(i). If 6.28 g of the acid $KHC_2O_4.H_2C_2O_4$, (with three ionisable protons) having 15% inert impurities, and 8.02 g of a second acid $KHC_8H_4O_4$ (with one ionisable proton) are dissolved in water and diluted to 250 cm^3. Calculate the normality of the solution assuming complete ionisation of the acids in water.

(ii).

Use appropriate equations to explain your answer as you compare redox titration using dichromate ion, and Mohr titration using silver ions. Compare endpoint determination for the two methods.

(iii).

Use appropriate half-reaction equations to explain whether the following reaction below is redox or not. Determine which element is the oxidant, and which one is reductant.

$Fe_2O_3 + 2Al \rightarrow 2Fe + Al_2O_3$

Question 2

(a).

Why do you think most complexes of Zn(II) are colourless?

(b).

(i). What is the overall complex formation equilibrium constant (K_f) for the reactions: $Fe^{3+} + SCN^- \rightarrow Fe(SCN)^{2+}$ ($K_{f1} = 890$) and $Fe(SCN)_2^+ + SCN^- \rightarrow Fe(SCN)_2^+$ ($K_{f2} = 2.6$) Calculate the value of K_d for the above equilibrium.

(ii). An iron ore is analysed for iron content by dissolving in acid, converting the iron to Fe^{2+}, then titrating with standard potassium dichromate (0.0150 M) solution. If 35.6 mL titrant is required to titrate the iron in 1.85 g of an ore sample, how much iron is in the sample expressed as % Fe correct to 3 significant figures?

(iii). Citric acid is a triprotic organic acid, $HOC(CH_2COOH)_3$, characterised by the following acid dissociation constants $pK_{a1} = 3.1296$; $pK_{a2} = 4.7570$ and $pK_{a3} = 5.3990$. Determine the equilibrium concentration of the ionic species $HOC(CH_2COOH)_2^-$ in a 0.500 M solution of the acid at pH 3.

(c).

(i). What are the steps involved in a sampling operation of a blood sample?

(ii). A study is being performed to see if there is a correlation between the concentration of chromium in the blood and a suspected disease. The results of analysis of blood samples from a control group and a diseased group were as follows:

Control Group (ppb Cr): 15, 23, 12, 18, 09, 28, 11, 10

Diseased Group (ppb Cr): 25, 20, 35, 32, 15, 40, 16, 10, 22, 18

Determine, at 95% confidence level, whether they are real.

Question 3

(a).

A 2.645g sample of copper ore that contains 54.1% Cu is dissolved and diluted to 250 mL. A spectroscopic method gave the following results for the solutions: 5.84, 5.77, 5.73 and 5.71mg Cu/mL.

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

(ii) Calculate the standard deviation.

(b).

What are carbides? Show its (MC_2, M is the metal) reaction with (i) H_2O (ii) N_2. Name the products.

(c).

(i). Complex compounds exhibit isomerism, just like organic compounds. Compounds of chromium of empirical formula $[Cr(H_2O)_6]Cl_3$ occur as three distinctly coloured compounds.

(a). Name the compound $[Cr(H_2O)_6]Cl_3$

(b). Write down the formula of any one the isomers, other than the one shown in (i) above.

Question 3(c). Continued.

(ii). Ethylene diamminetetraacetic acid, EDTA represented by H_4Y, has the following acid dissociation constants $pK_{a1} = 2.008$; $pK_{a2} = 2.683$; $pK_{a3} = 6.098$; and $pK_{a4} = 10.181$. Calculate the equilibrium concentration of the undissociated acid.

(iii). What is a buffer solution? If 0.05 mole of NH_4Cl is added per litre of solution to a 0.01M aqueous ammonia solution, calculate the concentration of hydrogen ions in the resulting solution, given that for NH_3, $K_b = 1.8 \times 10^{-5}$.

Question 4

(a).

The Director of Mount Makulu was trying to decide whether or not to keep a young , recently hired CHE 2015 student. The Director decided to see if the student's work was of the same quality as that of the other staff. He asked both a Senior Technician and the student to analyze the same sample using the same procedure, reagents and instruments. They obtained the following results.

Senior Technician	**CHE 2015 Student**
1.38	1.28
1.33	1.36
1.34	1.35
1.35	1.40
1.30	1.31

Determine if there is a significant difference in the precision of the data at 95% confidence level.

(b).

(i). For redox equlibria what does the term "Conjugate pair" mean? Balance the following equation for reaction: $Cr^{3+} + BiO_3^- \rightarrow Cr_2O_7^{2-} + Bi^{3+}$ occurring in acidic solution:

(ii). Ethylene diamminetetraacetic acid, EDTA, is a polyprotic acid. EDTA is used in the determination of calcium content of water, forms a 1:1 complex with many metal ions, especially divalent ones.

(a). What is a Polyprotic acid?

(a). Classify EDTA as an acid

(b). Draw a sketch to show how EDTA bonds to metal ions.

(iii). Write down the chemical formula for the following complex ions and compounds

(a). Tetraammine copper (II) sulphate monohydrate

(b). Hexachloro platinate (IV) ion

(c).

Calculate the Z_{eff} on a 5s, a 5p and 4d electron in a tin (Sn) atom. Which is the most loosely held electron? Explain why.

Question 5

(a).

(i). Use salts sodium chloride and copper sulphate to explain, in detail, the difference in dissociation behavior of the two compounds that ionise completely in aqueous medium.

(ii). Carbonic acid is a diprotic acid with acid ionization constants given as $pK_{a1} = 6.361$, as well as pK_{a2} with a value of 10.324, determine equilibrium concentration of the conjugate base of the acid in a 01.M solution if the acid at pH2.

(iii). Bromate and chromate ions react spontaneously in a aqueous medium. Use the standard redox potentials given [$Cr_2O_7^{2-}/Cr^{3+}$; (E_o =1.43v), and BrO_3^-/Br_2 (E_o = 1.52v)] to determine the overall equation for the reaction.

(b).

A new method of determining nitrogen in an imported fertilizer 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.

(c).

Show the interaction of carbon and oxygen to form carbon monoxide using molecular orbital diagram. Predict the magnetic property and bond order.

END OF EXAMINATION

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

The Periodic Table of Elements

1	2											3	4	5	6	7	0 (8)
							1.0 H hydrogen 1										(18) 4.0 He helium 2
(1)	(2)	Key: relative atomic mass / atomic symbol / name / atomic (proton) number										(13)	(14)	(15)	(16)	(17)	
6.9 Li lithium 3	9.0 Be beryllium 4											10.8 B boron 5	12.0 C carbon 6	14.0 N nitrogen 7	16.0 O oxygen 8	19.0 F fluorine 9	20.2 Ne neon 10
23.0 Na sodium 11	24.3 Mg magnesium 12	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	27.0 Al aluminium 13	28.1 Si silicon 14	31.0 P phosphorus 15	32.1 S sulfur 16	35.5 Cl chlorine 17	39.9 Ar argon 18
39.1 K potassium 19	40.1 Ca calcium 20	45.0 Sc scandium 21	47.9 Ti titanium 22	50.9 V vanadium 23	52.0 Cr chromium 24	54.9 Mn manganese 25	55.8 Fe iron 26	58.9 Co cobalt 27	58.7 Ni nickel 28	63.5 Cu copper 29	65.4 Zn zinc 30	69.7 Ga gallium 31	72.6 Ge germanium 32	74.9 As arsenic 33	79.0 Se selenium 34	79.9 Br bromine 35	83.8 Kr krypton 36
85.5 Rb rubidium 37	87.6 Sr strontium 38	88.9 Y yttrium 39	91.2 Zr zirconium 40	92.9 Nb niobium 41	95.9 Mo molybdenum 42	[98] Tc technetium 43	101.1 Ru ruthenium 44	102.9 Rh rhodium 45	106.4 Pd palladium 46	107.9 Ag silver 47	112.4 Cd cadmium 48	114.8 In indium 49	118.7 Sn tin 50	121.8 Sb antimony 51	127.6 Te tellurium 52	126.9 I iodine 53	131.3 Xe xenon 54
132.9 Cs caesium 55	137.3 Ba barium 56	138.9 La* lanthanum 57	178.5 Hf hafnium 72	180.9 Ta tantalum 73	183.8 W tungsten 74	186.2 Re rhenium 75	190.2 Os osmium 76	192.2 Ir iridium 77	195.1 Pt platinum 78	197.0 Au gold 79	200.6 Hg mercury 80	204.4 Tl thallium 81	207.2 Pb lead 82	209.0 Bi bismuth 83	[209] Po polonium 84	[210] At astatine 85	[222] Rn radon 86
[223] Fr francium 87	[226] Ra radium 88	[227] Ac* actinium 89	[261] Rf rutherfordium 104	[262] Db dubnium 105	[266] Sg seaborgium 106	[264] Bh bohrium 107	[277] Hs hassium 108	[268] Mt meitnerium 109	[271] Ds darmstadtium 110	[272] Rg roentgenium 111							

Elements with atomic numbers 112-116 have been reported but not fully authenticated

140 Ce cerium 58	141 Pr praseodymium 59	144 Nd neodymium 60	[147] Pm promethium 61	150 Sm samarium 62	152 Eu europium 63	157 Gd gadolinium 64	159 Tb terbium 65	163 Dy dysprosium 66	165 Ho holmium 67	167 Er erbium 68	169 Tm thulium 69	173 Yb ytterbium 70	175 Lu lutetium 71
232 Th thorium 90	[231] Pa protactinium 91	238 U uranium 92	[237] Np neptunium 93	[242] Pu plutonium 94	[243] Am americium 95	[247] Cm curium 96	[245] Bk berkelium 97	[251] Cf californium 98	[254] Es einsteinium 99	[253] Fm fermium 100	[256] Md mendelevium 101	[254] No nobelium 102	[257] Lr lawrencium 103

*Lanthanide series

*Actinide series

Universal Statistical Tables:

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9	1.833	2.262	3.250	3.690
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15	1.753	2.131	2.947	3.252
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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

SCHOOL OF NATURAL SCIENCES

2013HALF-YEAREXAMINATIONS

CHE2219: CHEMICAL ANALYSIS
TIME: 3 HOURS

INSTRUCTIONS:
1. **THIS PAPER CONTAINS FIVE (05) QUESTIONS.**
2. **ANSWER ANY THREE (03) QUESTIONS.**
3. **EACH QUESTION CARRIES 20 MARKS.**
4. **SHOW ALL YOUR WORKING CLEARLY.**
5. **ESSENTIAL DATA TABLES ARE ATTACHED TO THE QUESTION PAPER.**

Question 1.

(a)

(i). What do you understand by the terms: complex formation constant; and, instability constant? Use the reaction: $Ag^+ + 2NH_3 \rightarrow Ag(NH_3)_2^+$ to illustrate your answers.

(ii). In one experiment, it was observed that copper metal reacted with hot concentrated sulphuric acid to form sulphurousacid and water. Write down a balanced equation for the reaction. Prove that this is a redox reaction by determining the oxidant and reductant.

(b). Arsenic acid, H_3AsO_4, is a weak acid which dissociates in water to yield several equilibrium species.

(i). Name any two ionic, and one molecular, dissociation species of the acid.

(ii). What is the equilibrium concentration of the hydrogen arsenate ion ($H_2AsO_4^-$) at pH 3.0 in a 0.200 M arsenic acid solution given that the dissociation constants for the successive ionisations are given as follows, $Ka_1 = 5.65 \times 10^{-3}$; $Ka_2 = 1.75 \times 10^{-7}$ and $Ka_3 = 2.54 \times 10^{-12}$.

(c).

(i). Explain the difference between systematic error and random error.

(ii). A ship of copper ore from Euresia was purchased by a local metal refiner. The analysis certificate, made out while the ship was being loaded, showed that %Cu = 14.66 with a standard deviation of 0.07% for 5 measurements. When the ore arrived at the refinery, it was analyzed with the following results: %Cu = 14.58, 14.61, 14.69 and 14.64. Should the refiner accept the ore?

Question 2

(a).

The three dissociation constants for the successive ionisation of phosphoric acid, H_3PO_4, are $Ka_1 = 7.5 \times 10^{-3}$; $Ka_2 = 6.2 \times 10^{-8}$ and $Ka_3 = 1.0 \times 10^{-12}$. Determine the equilibrium concentration of $H_2PO_4^-$ at pH 1 in a 0.100 M phosphoric acid solution.

(b).

(i). A certain barium halide exists as the hydrated salt $BaX_2.2H_2O$, where X is the halogen. A sample of the halide (0.2650 g) was dissolved in water (200 cm^3) and excess sulphuric acid added. The mixture was then heated and held at boiling for 45 minutes. A precipitate was filtered off, washed and dried.

(ii).Determine whether the reaction chemical $ClO_3^-_{(aq)} + 3Zn_{(s)} + 6H^+_{(aq)} \rightarrow Cl^-_{(aq)} + 3Zn^{2+}_{(aq)} + 3H_2O_{(l)}$ representsa redox reaction. Clearly show equilibria for both reductant and oxidant, and a balanced overall equation for the reaction.

Question 2 Continued.

(c).

(i). Explain why and how would you prepare a protein free filtrate sample?

(ii). A 2.645g sample of copper ore that contains 54.1% Cu is dissolved and diluted to 250 mL. A spectroscopotometric method gave the following results for the solutions: 5.84, 5.77, 5.73 and 5.71mg Cu/mL.

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

(b). Calculate the standard deviation.

Question 3

(a).

(i). Distinguish between a Q-test and an F-test.

(ii). The following results were obtained in the determination of calcium in serum by two methods, fluorimetry and atomic absorption spectrophotometry (AAS). Is there a significant difference in the precision of the two methods?

(b).

(i).By using lead chloride, $PbCl_2$, and sodium hydroxide, NaOH, explain what you understand by the terms solubility and solubility product of a salt. Please use appropriate equations to illustrate your answers.

(ii). Define the term buffer solution; and then, calculate the pH of a buffer prepared by adding 85 mL of a 0.20 M ethanoic acid solution to 115 ml of 0.50 M sodium ethanoate; given that for ethanoic acid, the value of $K_a = 1.75 \times 10^{-5}$.

(c).

(i). Phthalic acid is a diprotic acid (generally represented as H_2A) with$K_{a1} = 1.13 \times 10^{-3}$, and $K_{a2} = 3.90 \times 10^{-6}$. Determine the equilibrium fractional concentration of the species (A^{2-}) in a solution of the acid at pH 1.

(ii).Balance the following equations for reactions occurring in acidic solution:

(a). $Cr^{3+} + BiO_3^- \rightarrow Cr_2O_7^{2-} + Bi^{3+}$

(b). $ClO^- + S_2O_3^{2-} \rightarrow S_4O_6^{2-} + Cl^-$

Question 4

(a).

The precision of a new method is being evaluated. Several sets with different samples are performed to get a better estimate of the method. From the data collected, calculate the standard deviation for each set and the pooled standard deviation

Sample A: 0.826, 0.810, 0.880 and 0.865
Sample B: 0.682, 0.655, and 0.661
Sample C: 0.751, 0.702, 0.699 and 0.724

(b).

(i).What is selective precipitation? Give one example of the use of the phenomenon in analytical chemistry.

(ii). The first and second acidity constants of H_2S are 10^{-7} and 10^{-15} respectively. Calculate the equilibrium constant (K_a) for the reaction $H_2S + 2H_2O \rightarrow 2H_3O^+ + S^{2-}$, and the concentration of S^{2-} ions in a 0.1 M H_2S solution at pH 2.0.

Question 4 Continued

(c).

(i). A solution contains 75.0 ppm of dissolved $NaNO_3$. Calculate the concentration of nitrate ions in the solution, giving your answer in parts per billion.

(ii). Write and balance the equation for the reaction between nitric acid and hydrogen peroxide, given that the standard electrode potentials are listed as $E^{o}_{(O2/H2O2)} = 0.68v$ and $E^{o}_{(NO3^{-}/HNO2)} = 0.94v$. Calculate the cell voltage.

Question 5

(a).

(i). The three dissociation constants for the successive ionisation of citric acid, $HO(CH_2COOH)_3$, are $Ka_1 = 7.42 \times 10^{-4}$, $Ka_2 = 1.75 \times 10^{-5}$ and $Ka_3 = 3.99 \times 10^{-6}$. Determine the equilibrium concentration of the conjugate base of citric at pH 2 in a 0.500 M citric acid solution.

(ii). The following standard electrode potentials are needed for this question:

Zn^{2+}/Zn.....$E^{\circ} = -0.76v$

Cu^{2+}/Cu.....$E^{\circ} = +0.34v$

NO_3^{-}/HNO_2.....$E^{\circ} = +0.94v$

Use the conjugate pairsgiven above, and the values of E° to calculate the cell potential for the reaction between zinc and nitric acid and derive the overall equation.

(b).

(i). Tin (II) fluoride is used in the manufacture of some toothpaste types. The compound is produce by reacting tin metal with hydrogen fluoride gas. Determine the type of chemical equilibrium involved in the process, and the amount of tin fluoride (in mg) produced from the reaction of 0.1458 g HF with Sn?

(ii). A complex ion is composed of copper (II) metal, four ammonia ligands and two water ligands. Write down the formula, then determine the co-ordination number and charge on the central atom. Draw a diagram to show the shape of the complex.

(c).

(i). The concentration of sodium ions in an aqueous solution is 10 ppm. Calculate the molarity of the sodium ions in the solution. RAM of Na = 23.0

(ii). Zinc analysis ((%) in a soil sample gave the following results: 33.27, 33.37 and 33.34. calculate the coefficient of variation.

END OF EXAMINATION

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

The Periodic Table of Elements

1 (1)	2 (2)											3 (13)	4 (14)	5 (15)	6 (16)	7 (17)	0 (8) (18)
							1.0 H hydrogen 1										4.0 He helium 2
6.9 Li lithium 3	9.0 Be beryllium 4											10.8 B boron 5	12.0 C carbon 6	14.0 N nitrogen 7	16.0 O oxygen 8	19.0 F fluorine 9	20.2 Ne neon 10
23.0 Na sodium 11	24.3 Mg magnesium 12	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	27.0 Al aluminium 13	28.1 Si silicon 14	31.0 P phosphorus 15	32.1 S sulfur 16	35.5 Cl chlorine 17	39.9 Ar argon 18
39.1 K potassium 19	40.1 Ca calcium 20	45.0 Sc scandium 21	47.9 Ti titanium 22	50.9 V vanadium 23	52.0 Cr chromium 24	54.9 Mn manganese 25	55.8 Fe iron 26	58.9 Co cobalt 27	58.7 Ni nickel 28	63.5 Cu copper 29	65.4 Zn zinc 30	69.7 Ga gallium 31	72.6 Ge germanium 32	74.9 As arsenic 33	79.0 Se selenium 34	79.9 Br bromine 35	83.8 Kr krypton 36
85.5 Rb rubidium 37	87.6 Sr strontium 38	88.9 Y yttrium 39	91.2 Zr zirconium 40	92.9 Nb niobium 41	95.9 Mo molybdenum 42	[98] Tc technetium 43	101.1 Ru ruthenium 44	102.9 Rh rhodium 45	106.4 Pd palladium 46	107.9 Ag silver 47	112.4 Cd cadmium 48	114.8 In indium 49	118.7 Sn tin 50	121.8 Sb antimony 51	127.6 Te tellurium 52	126.9 I iodine 53	131.3 Xe xenon 54
132.9 Cs caesium 55	137.3 Ba barium 56	138.9 La* lanthanum 57	178.5 Hf hafnium 72	180.9 Ta tantalum 73	183.8 W tungsten 74	186.2 Re rhenium 75	190.2 Os osmium 76	192.2 Ir iridium 77	195.1 Pt platinum 78	197.0 Au gold 79	200.6 Hg mercury 80	204.4 Tl thallium 81	207.2 Pb lead 82	209.0 Bi bismuth 83	[209] Po polonium 84	[210] At astatine 85	[222] Rn radon 86
[223] Fr francium 87	[226] Ra radium 88	[227] Ac* actinium 89	[261] Rf rutherfordium 104	[262] Db dubnium 105	[266] Sg seaborgium 106	[264] Bh bohrium 107	[277] Hs hassium 108	[268] Mt meitnerium 109	[271] Ds damstadtium 110	[272] Rg roentgenium 111							

Key

relative atomic mass
atomic symbol
name
atomic (proton) number

Elements with atomic numbers 112-116 have been reported but not fully authenticated

*Lanthanide series	140 Ce cerium 58	141 Pr praseodymium 59	144 Nd neodymium 60	[147] Pm promethium 61	150 Sm samarium 62	152 Eu europium 63	157 Gd gadolinium 64	159 Tb terbium 65	163 Dy dysprosium 66	165 Ho holmium 67	167 Er erbium 68	169 Tm thulium 69	173 Yb ytterbium 70	175 Lu lutetium 71
*Actinide series	232 Th thorium 90	[231] Pa protactinium 91	238 U uranium 92	[237] Np neptunium 93	[242] Pu plutonium 94	[243] Am americium 95	[247] Cm curium 96	[245] Bk berkelium 97	[251] Cf californium 98	[254] Es einsteinium 99	[253] Fm fermium 100	[256] Md mendelevium 101	[254] No nobelium 102	[257] Lr lawrencium 103

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2013 ACADEMIC YEAR
MID-YEAR EXAMINATIONS
25th FEBRUARY 2014

CHE2511: BASIC ORGANIC CHEMISTRY

TIME: THREE HOURS

INSTRUCTIONS:

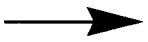
1. **Answer two questions from each section.**
2. **Each question carries 30 marks.**
3. **Use a separate booklet for each question.**

SECTION A

ANSWER TWO QUESTIONS ONLY

QUESTION A1

(a) In organic chemistry, each type of arrow has a specific meaning. It is, therefore, important that you use each type of arrow only for the purpose that it is defined. Briefly explain the meaning of each of the following arrows frequently encountered in organic chemistry: **(1 mark each)**

(i) 

(ii) 

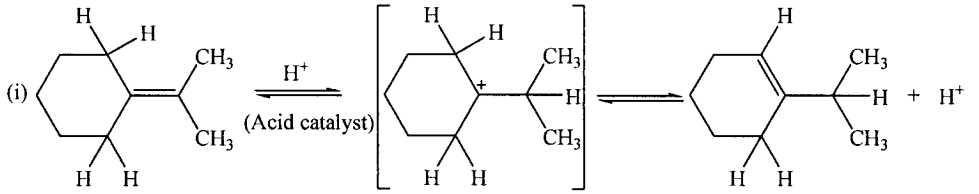
(iii) 

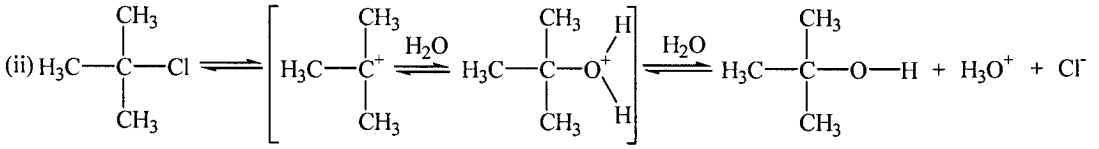
(iv) 

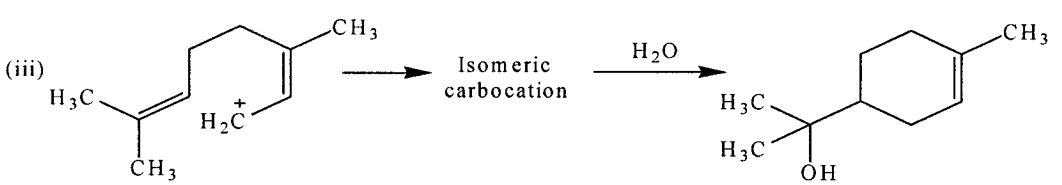
(v) 

(b) Add curved arrows to the mechanism below to indicate the electron movement in each step.

(10 marks)



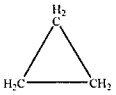




(c) Identify the following reactions as addition, elimination, substitution, or rearrangement.

(1 mark each)

(i) $CH_3CHClCHClCH_3 + Zn \longrightarrow CH_3CH{=}CHCH_3 + ZnCl_2$

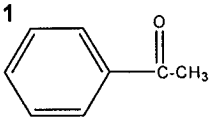
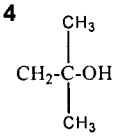
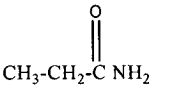
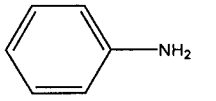
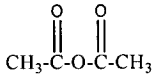
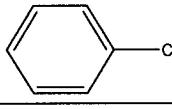
(ii)  $+ Br_2 \longrightarrow BrCH_2CH_2CH_2Br$

(iii) $NH_4^+(CNO)^- \xrightarrow{heat} H_2NCNH_2$ (O)

(iv) $C_2H_5OH + HCl \longrightarrow C_2H_5Cl + H_2O$

(v) 

(d) From the compounds in the grid below, which may be used in more than one answer, give the number of one compound where applicable (in the box) that: **(10 marks)**

1 	**2** $CH_3\text{-}CH_2\text{-}CO_2H$	**3** 	**4** 	**5** 	**6** HCHO
7 	**8** $(CH_3)_2CHCH_2CH_2OH$	**9** 	**10** $CH_3\text{-}O\text{-}CH_3$	**11** 	**12** CH_3CN

i. is an ether _____

ii. contains *sp* hybridized carbon _____

iii. is conjugated diene _____

iv. is an aldehyde _____

v. dissolves in water to give a pH< 7 _____

vi. is an amide _____

vii. would react with a Grignard reagent to give a ketone _____

viii. would hydrolyze to give ethanoic acid _____

ix. is an amine _____

x. would hydrolyze to give benzoic acid _____

QUESTION A2

(a) Briefly define each of the following terms and support your definition with one example.

(2 marks each)

(i) conformers

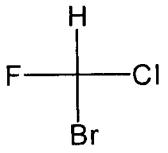
(ii) bridged bicyclic compound

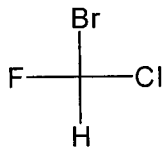
(iii) eclipsed conformation

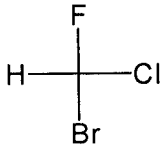
(iv) axial bond

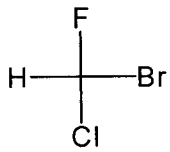
(b) Sketch a potential energy diagram for rotation around the C2-C3 bond of butane when the angles of the bulky groups are 0^{o}, 60^{o}, 120^{o}, 180^{o}, 240^{o}, 300^{0}, and 360^{o}.
Identify each potential energy maximum and minimum with a structural formula that shows the conformation of butane at that point and give an appropriate name to it. **(10 marks)**

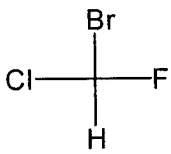
(c) Structures of CHClBrF are written below in **seven** Fişcher projection formulas. **(1 mark each)**

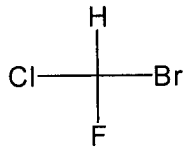
(i) 

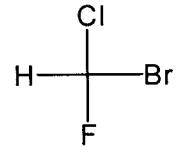
(ii) 

(iii) 

(iv) 

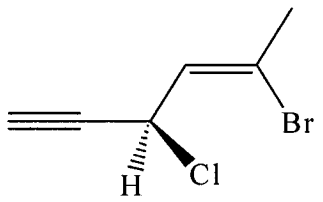
(v) 

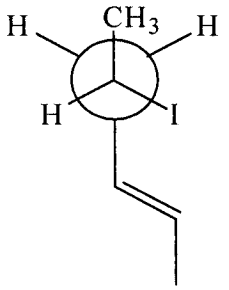
(vi) 

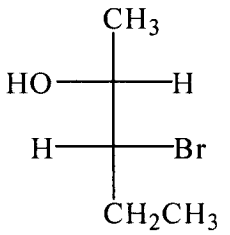
(vii) 

Relate structures (ii) through (vii) to structure **(i).**

(d) Give the names of the following compounds, using (*R*), (*S*) and (*E*), (*Z*) designations where necessary. **(2 marks each**

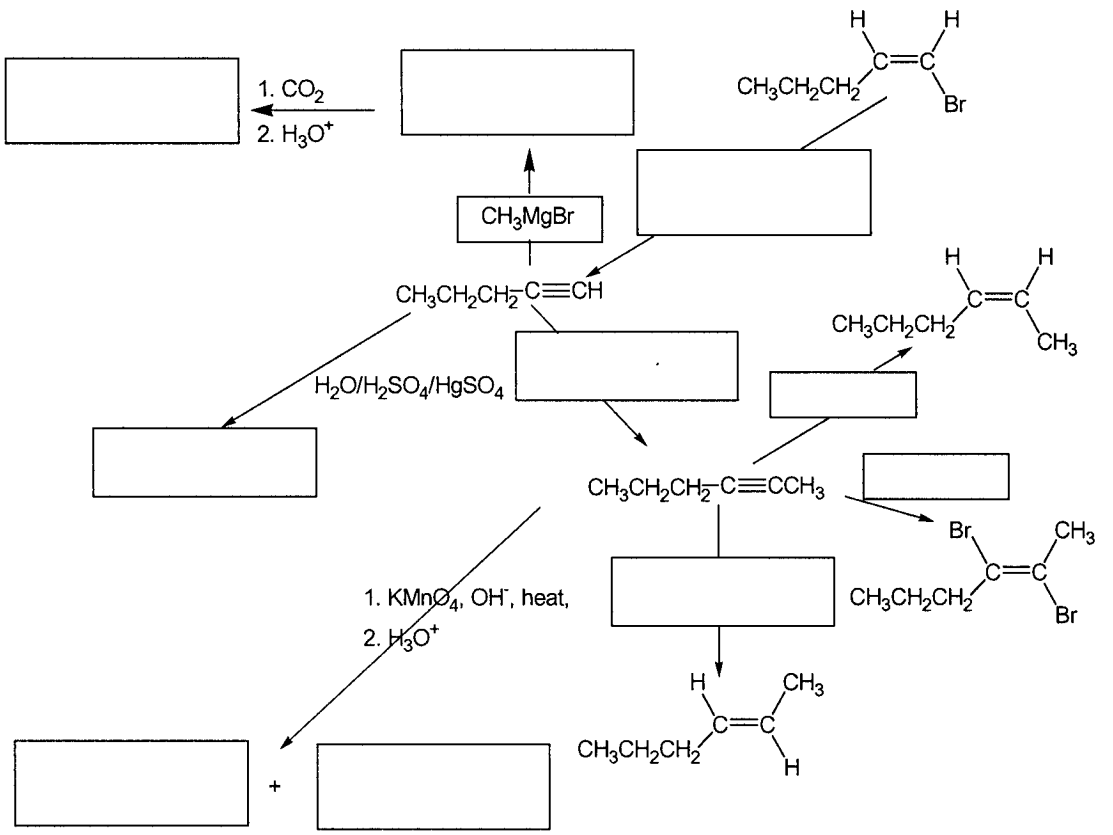
(i) 

(ii) 

(iii) 

QUESTION A3

a) Complete the following scheme by entering in the boxes the structures of the compounds formed, or the reagent(s) necessary, for the transformations given. **(10 marks)**



b) Outline the mechanisms of the following conversions:

(9 marks)

(i) But-2-ene-1,4-dioic acid to 2,3-Dibromo-1,4-butanedioic acid

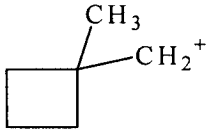
(ii) Ethane to chloroethane using chlorine and UV light.

(iii) 1-Hexene to 2-hexanol using sulphuric acid and water.

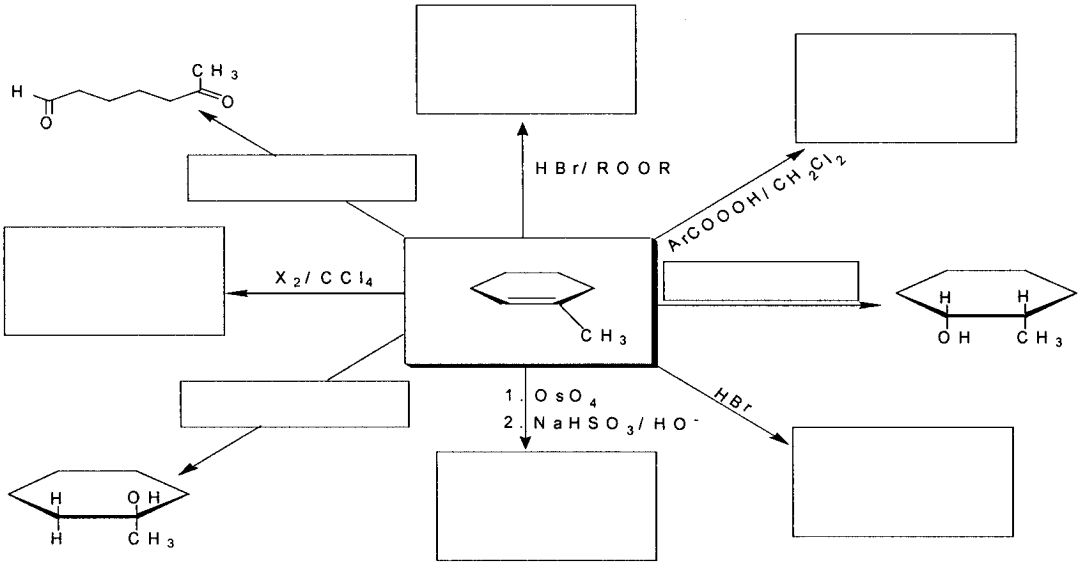
c) Each of the following carbocations can rearrange to a more stable ion. Propose structures for the likely rearrangement products. **(1 mark each)**

(i) $CH_3\text{-}CH_2\text{-}CH_2\text{-}CH_2^+$

(ii) $CH_3\text{-}\overset{\overset{+}{}}{C}H\text{-}\overset{\overset{+}{}}{C}H\text{-}CH_3$ with CH_3 branch

(iii) 

d) Complete the following scheme by entering in the boxes the structures of the compounds formed, or the reagent(s) necessary, for the transformations given. **(8 marks)**



SECTION B

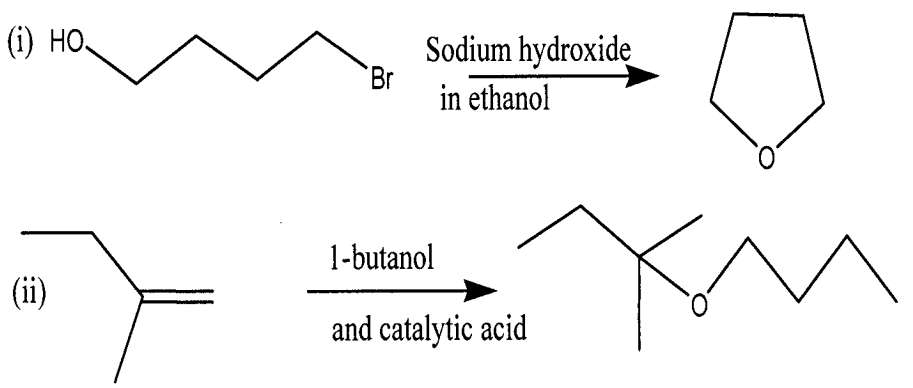
ANSWER TWO QUESTIONS ONLY

Question B1

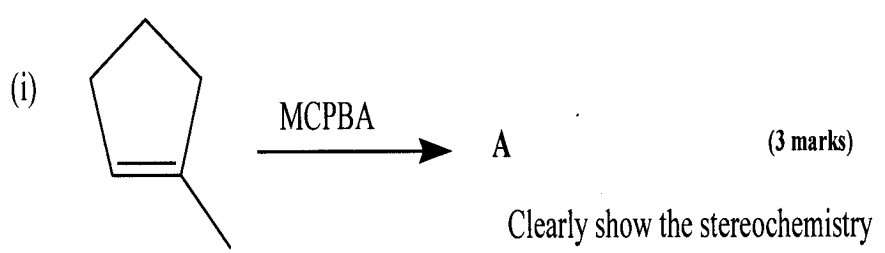
(a) What is a protic solvent and give two examples of such solvents which have different functional groups? **(3 marks)**

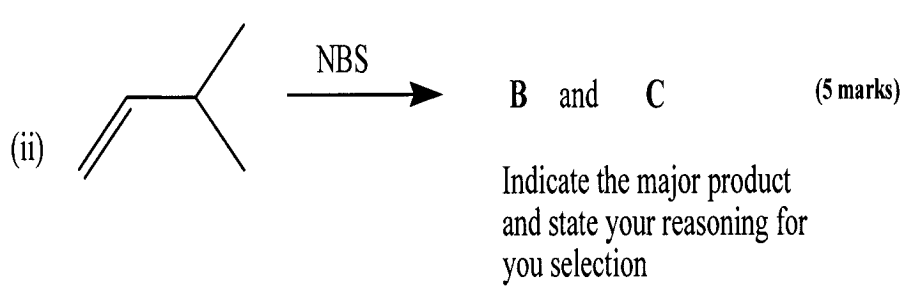
(b) Polar aprotic solvents are good for S_N2 reactions. Briefly explain using examples. **(3 marks)**

(c) Write reasonable mechanisms for the following reactions. **(4 marks each)**

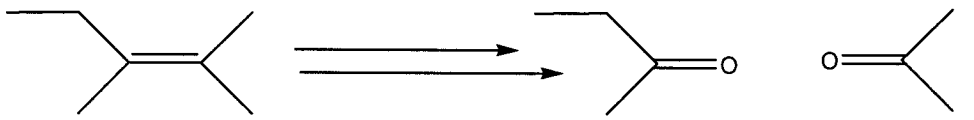


(d) For the given reactions provide the products.





(e) Write two procedures for cleaving the given alkene below to the indicated carbonyl compounds. **(8 marks)**

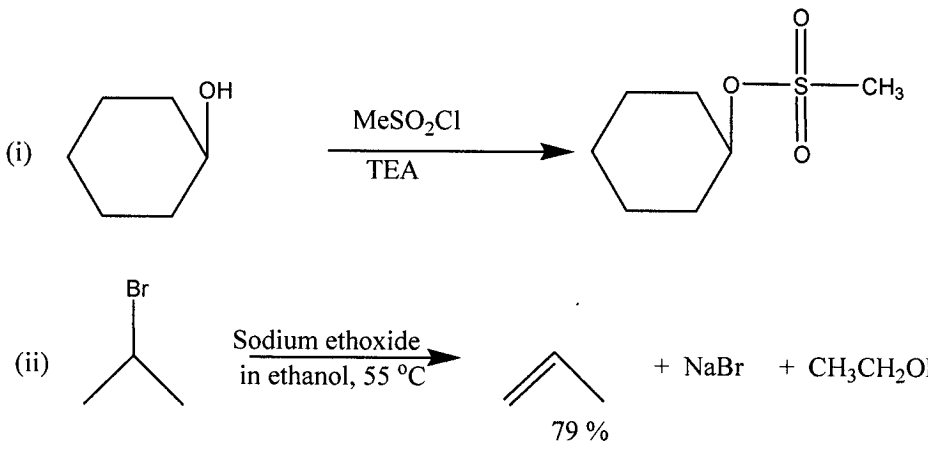


2,3-dimethyl-2-pentene Butanone Propanone

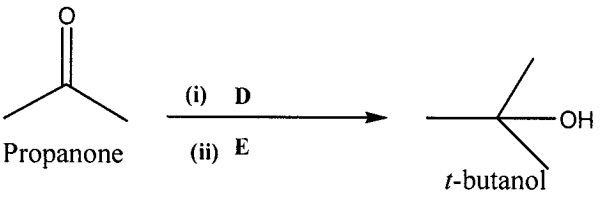
Question B2

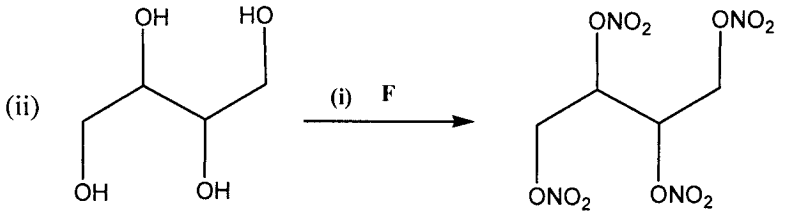
(a) Write structures and complete names for the following MCPBA, TEA, NBS, and THP. **(2 marks each)**

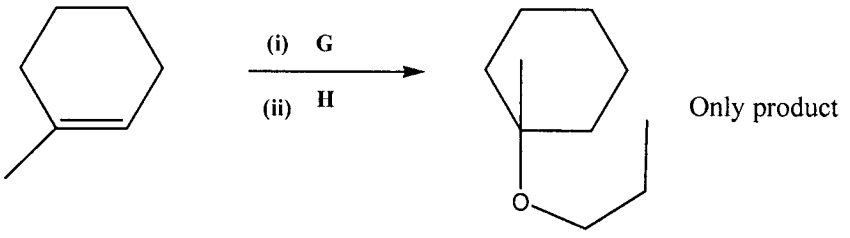
(b) Given below are mesylation and elimination reactions. What are the plausible mechanisms for the following reactions? **(4 marks each)**



(c) For the given reactions provide the reagents and conditions. **(2 marks each)**

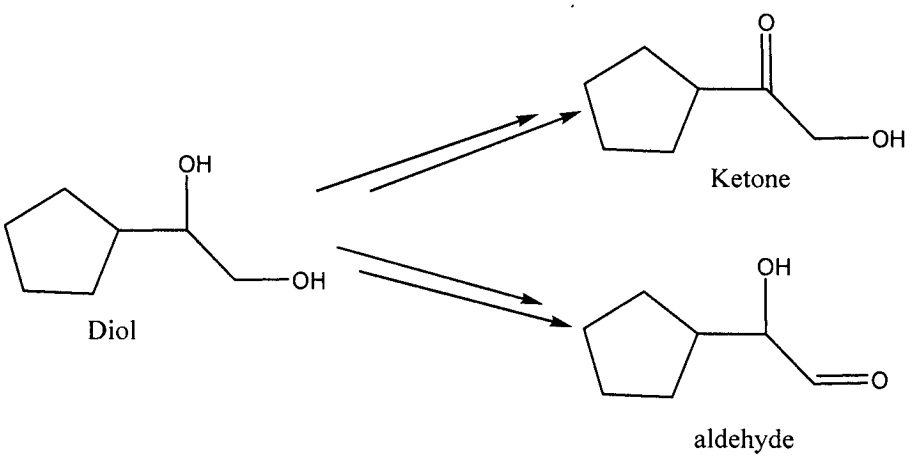
(i) 

(ii) 

(iii) 

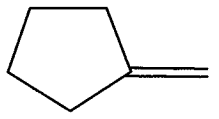
(d) Show how the following oxidation products may be prepared from the given starting materials.

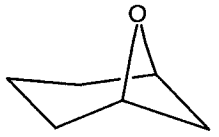
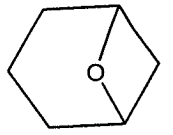
(4 marks each)



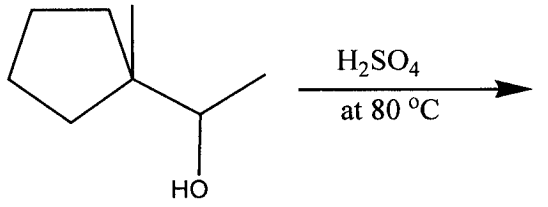
Question B3

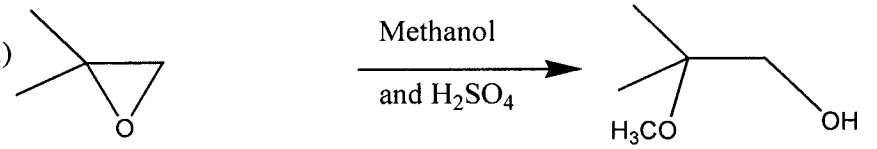
(a) Give the IUPAC names to the compounds with following structures. **(2 marks each)**

(i) 

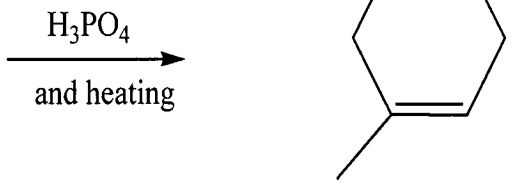
(ii)  or 

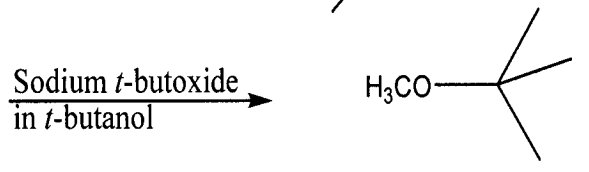
(b) Write reasonable mechanisms for the following reactions. **(8 marks)**

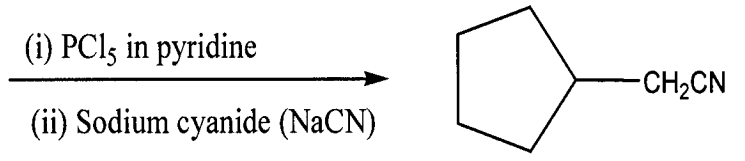
(i) 

(ii) 

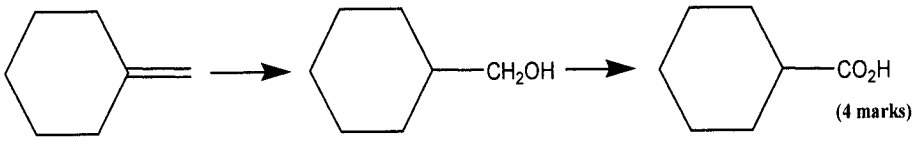
(c) What are the starting materials for the given reactions below? **(6 marks)**

(i) **J** 

(ii) **K** 

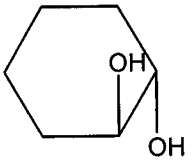
(iii) **M** 

(d) Provide reagents for converting methylenecyclohaxane to cyclohexanecarboxylic acid.



(4 marks)

Design a retrosynthetic procedure for each the compounds from the given starting materials and then clearly describe their syntheses. **(8 marks)**

(i) 

From cyclohexanol

(ii) $CH_3CH_2CH_2CH_3$ from starting materials having a maximum two carbons

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2013 ACADEMIC YEAR MID-YEAR
FINAL EXAMINATIONS

CHE 3111: CELLULAR BIOCHEMISTRY

TIME: **THREE HOURS**

INSTRUCTIONS:
1. Answer any **FIVE (5)** questions
2. There are **FIVE (5)** printed pages in this examination paper
3. Each question carries **TWENTY (20)** marks

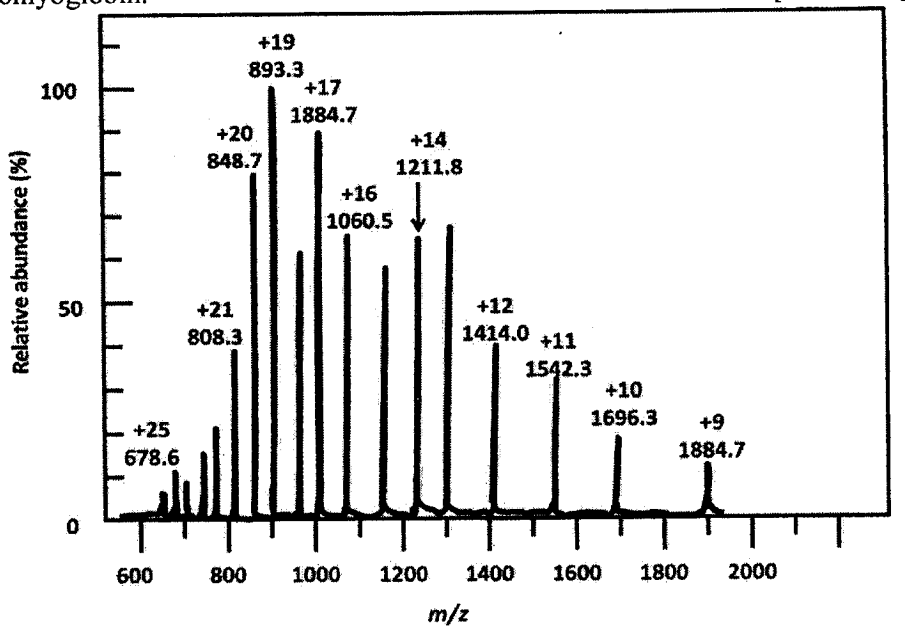
QUESTION 1

a) Briefly define the following: **[5 marks]**

i) Transcriptome
ii) Proteome
iii) Metabolome
iv) Proteomics
v) Genomics

b) Explain one cycle of the Edman degradation principle pictorially. **[5 marks]**

c) The figure below is an ESI spectrum of apomyglobin. Calculate the molar mass of apomyoglobin. **[10 marks]**



QUESTION 2

a) Chymotrypsin belongs to a group of proteolytic enzymes called the "serine proteases", many of which have an asp, his, and ser residue that are crucial to the catalytic mechanism. **Discuss** the role played by each of these amino acids in the catalytic mechanism of these enzymes. **[10 marks]**

b) A student was interested in studying the kinetics of a reaction involving ester bond hydrolysis of compound X using chymotrypsin which has a molar mass of 25 KDa. The turnover number for chymotrypsin with compound X is known to be 5,000 min^{-1}.

[S] mM	µmol/min
1	167
2	250
4	334
6	376
100	499
1000	499

i) From the following set of data, **estimate** the K_M and **calculate** the total mass of enzyme present in these experiments. **[5 marks]**

ii) **Explain** how increasing the total enzyme concentration affects the turnover number and the $V_{max.}$ **[5 marks]**

QUESTION 3

a) **What** is meant by substrate level phosphorylation? Give an example. **[2 marks]**

b) **How** might the following work as inhibitors of glycolysis? **[4 marks]**

i) 2-deoxyglucose

ii) Fluoride

c) Assuming you are given a cell extract containing all the enzymes of glycolysis, **what** would be the location of the label in pyruvate if ^{14}C labelled Glyceraldehyde 3-phosphate (GAP) at C-1 was added to it? Use complete structures with names in your answer. **[14 marks]**

QUESTION 4

a) It is stated in some reference works that the yield of ATP from the complete oxidation of a molecule of glucose in eukaryotic cells is either 30 or 32 molecules; in the case of *E. coli* it is stated that the yield is greater than this. **Why** does this difference in statements exist? **[3 marks]**

b)

i) **Complete** the following reaction: **[2 marks]**

GTP + ADP $\rightleftharpoons$

ii) **Name** the enzyme responsible for the reaction in question 4b i) above. **[2 marks]**

iii) **What** reaction is the TCA cycle leads to the production of GTP? (give structures and names of the substrates, products and the enzyme) **[8 marks]**

c) **What** is the chemical rationale for isocitrate being oxidized before loss of CO_2 occurs? **[5 marks]**

QUESTION 5

a) **Draw** up the oxidative part of the pentose phosphate pathway **showing all** the structures, enzymes and cofactors. **[10 marks]**

b) Briefly describe how this pathway is regulated. **[4 marks]**

c) Give **two** roles of NADPH in cells ***other than*** providing electrons in reductive biosynthesis. **[6 marks]**

QUESTION 6

a) **Explain** the Schiff base linkage associated with aminotransferase enzymes and pyridoxal-5-phosphate (PLP). Give a brief explanation of how the Schiff base linkage aids in the deamination of amino acids. **[11 marks]**

b) **Name** 2 diseases associated with deficiencies in amino acid metabolism **[2 marks]**

c) Fill in the table below **indicating** which amino acids are glucogenic and which are ketogenic. **[7 marks]**

Glucogenic metabolic intermediate	Amino acids
Pyruvate	
α-Ketoglutarate	
Succinyl-CoA	
Fumarate	
Oxaloacetate	

Ketogenic metabolic intermediate	Amino acids
Acetyl-CoA	
Acetoacetate	

QUESTION 7

a) Using a **diagram**, illustrate where each of the purine ring atoms originate from.

[5 marks]

b) Briefly **describe** the regulation of purine synthesis. **Explain** which compounds are involved and at which points of synthesis regulation occurs. **[9 marks]**

c) **Diagram** the interconversions of the following folates we have seen in this class

- Tetrahydrofolate (THF),
- N^5-methyl-THF
- N^5,N^{10}-methylene-THF,
- N^{10}- formyl-THF and N5-formyl-THF

- N^5,N^{10}-methenyl-THF and
- N^5,N^{10}-formimino-THF

You don't need any structures here, just names and arrows showing which THF derivative can be converted into another **BUT** give the names of the enzymes required. **[6 marks]**

END OF EXAMINATION

UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

2013 ACADEMIC YEAR

MID-YEAR EXAMINATIONS

27TH FEBRUARY 2014

CHE3511

SPECTROSCOPIC IDENTIFICATION OF ORGANIC COMPOUNDS AND AROMATIC CHEMISTRY

TIME: 3 HOURS

£££

INSTRUCTIONS

1. WRITE ALL ANSWERS IN INK

2. THE PAPER HAS TWO PARTS, SECTIONS A AND B
3. ANSWER TWO QUESTIONS FROM EACH SECTION
4. EACH QUESTION CARRIES 30 MARKS
5. USE SEPARATE BOOKLETS FOR EACH SECTION

This paper has eight (8) pages

SECTION A

ANSWER TWO QUESTIONS ONLY

Question A1

Using spectroscopic data tables or otherwise, clearly indicate or describe or state how you would differentiate between 3-butenone and butanone using:

(a) IR **(4 marks)**

(b) UV **(4 marks)**

(c) MS (excitations and fragmentations) **(6 marks)**

(d) ^{1}H-NMR (δ-values and splitting patterns) **(10 marks)**

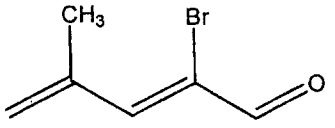
(e) ^{13}C-NMR DEPT **(6 marks)**

Question A2

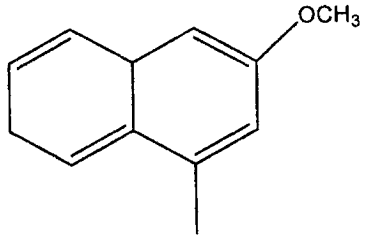
(a) From the tables or otherwise, find the δ-values for the protons of 3-hydroxyl-2-butanone, predict the multiplicity (splitting pattern) for each set of protons and sketch the ^{1}H-NMR spectrum for the compound. **(8 marks)**

(b) Calculate λ_{max} for each compound given below. **(6 marks)**

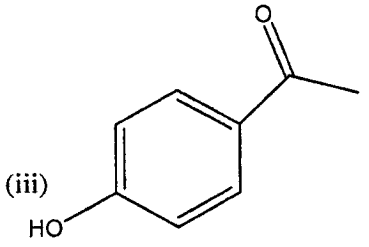
(i)



(ii)



(iii)



(c) Use your knowledge of MS excitation and fragmentation patterns to differentiate between 1-bromopentane and 2-bromopentane (The isotopic masses of bromine are 79 and 81 while C=12 and H=1. *(Hint: Consider fragmentations due to α-cleavage)*. **(6marks)**

(d) Some of the compounds with molecular formula C_4H_6O need the information revealed:

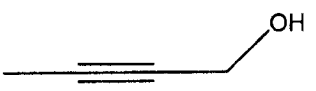
(i) What is the IHD of compounds with this MF and possible interpretations? **(3 marks)**

(ii) What is the IR peak for cyclobutanone? **(1 mark)**

(iii) What is the λ_{max} of 2-butenal? **(2 marks)**

(iv) Provide the IR peaks of the given alkynols and clearly state how you would differentiate between them. **(4 marks)**

(i) 

(ii) 

Question A3

Study the spectra given as Problem 71 (last page). Analyze each spectrum and identify the compound whose spectra are given. You may run through your analysis as follows:

(a) IHD **(2 marks)**

(b) ^{1}H-NMR **(8 marks)**

(c) ^{13}C-NMR **(3 marks)**

(d) ^{13}C-NMR DEPT **(3 marks)**

(e) IR **(3 marks)**

(f) UV **(1 mark)**

(g) MS **(5 marks)**

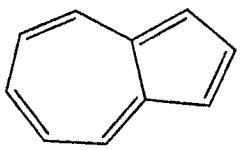
(h) Structure **(5 marks)**

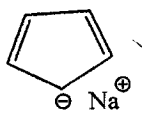
SECTION B

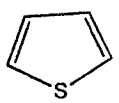
ANSWER TWO QUESTIONS ONLY

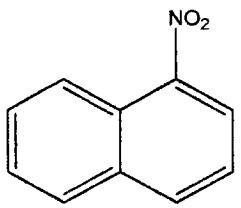
Question B1

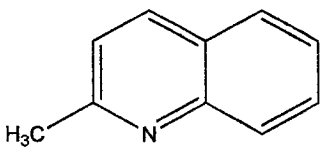
(a) Provide the reagents/products for the following reactions. Indicate the major product, where relevant. **(2 marks each)**

(i)  F-C acetylation / A: reagents? → **B**: Product?

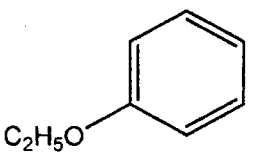
(ii) **C** NaOH →  **D**: reagents? → Ferrocene: structure?

(iii)  Ac_2O, 100 ^0C → **E**

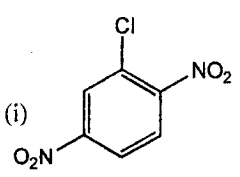
(iv)  Br_2, Fe → Products?: **F** + **G**

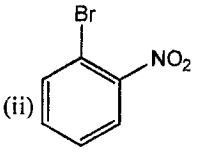
(v)  (i) EtONa; (ii) HCOOEt → **H**

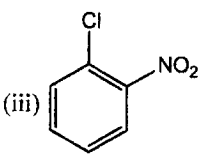
(b) Predict the product and give mechanism of the following Vilsmeier reaction. **(9 marks)**

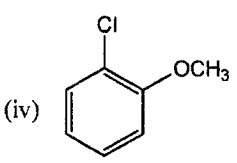
 (i) Me_2NCHO, $POCl_3$; (ii) H_2O → **J**

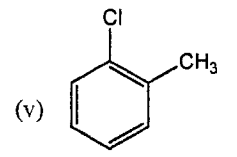
(c) Arrange the following compounds in order of increasing reactivity towards sodium hydroxide by S_N2Ar mechanism. **(4 marks)**

(i) 

(ii) 

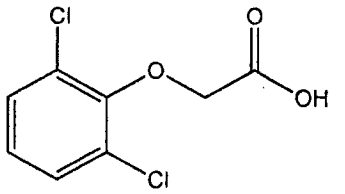
(iii) 

(iv) 

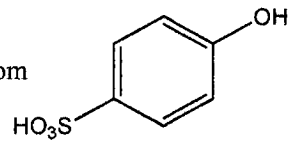
(v) 

Question B2

(a) Propose a synthesis for the herbicide **P**, shown below, from the indicated starting materials and any needed reagents. Clearly show all steps including the intermediates. (Please do not show any reaction mechanisms) **(7 marks)**



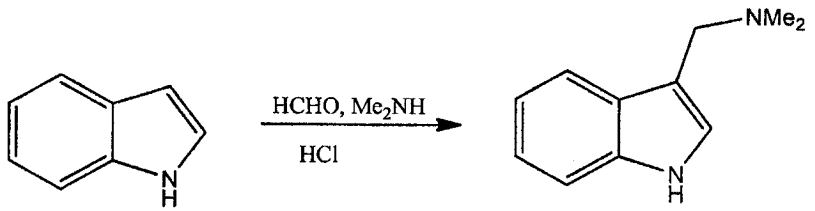
P

from 

and $ClCH_2COOH$

(b) (i) With the aid of appropriate resonance structures, briefly explain why electrophilic substitution in indole takes place at C-3 rather than at C-2. **(7 marks)**

(ii) An example of the electrophilic substitution in indole is shown below:



What is the electrophile in this reaction? (Mechanisms are not required to be shown) **(3 marks)**

(c) (i) Briefly explain why pyridine is highly reactive towards nucleophilic substitution. **(3 marks)**

(ii) Upon treatment with sodamide ($NaNH_2$) in an inert solvent, pyridine gives 2-aminopyridine in good yield. Suggest a mechanism for this reaction.

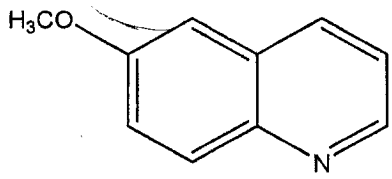
(7 marks)

(d) Arrange the following compounds in order of decreasing acidity. **(3 marks)**

(i) Phenol (ii) 4-Nitrophenol (iii) 4- Methylphenol (iv) 3-Nitrophenol

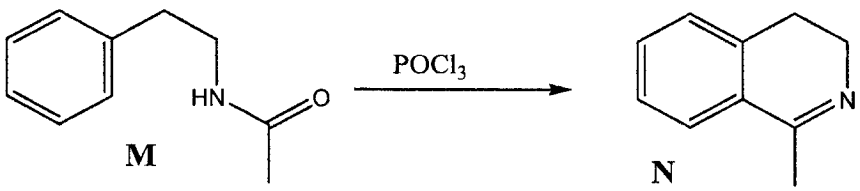
Question B3

(a) Outline a Skraup synthesis for quinolone **K**, shown below, and name it. (Reaction mechanisms are **not** required to be shown.) **(6 marks)**



K

(b) Bischler–Napieralski (B-N) reaction, an example shown below, is frequently used for synthesis of isoquinoline rings.



M **N**

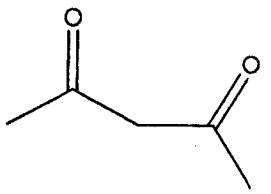
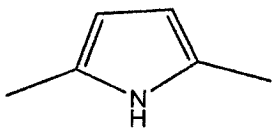
(i) Name the product **N**. **(2 marks)**

(ii) Provide a mechanism for this reaction. **(6 marks)**

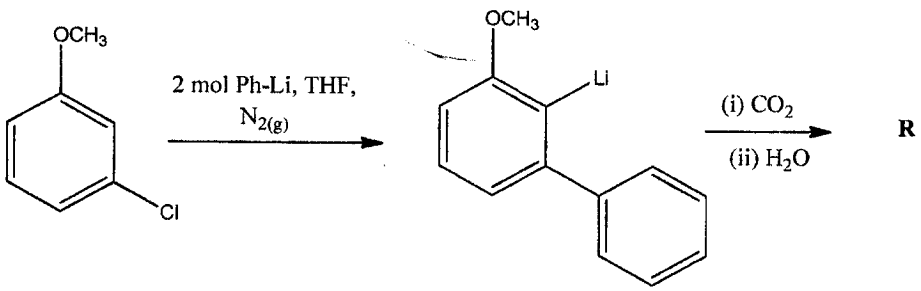
(iii) What amine and what acylhalide are required to make the starting material **M**. **(2 marks)**

(c) Clearly show all steps for the following conversions. (Please do not write reaction mechanisms). **(3 marks each)**

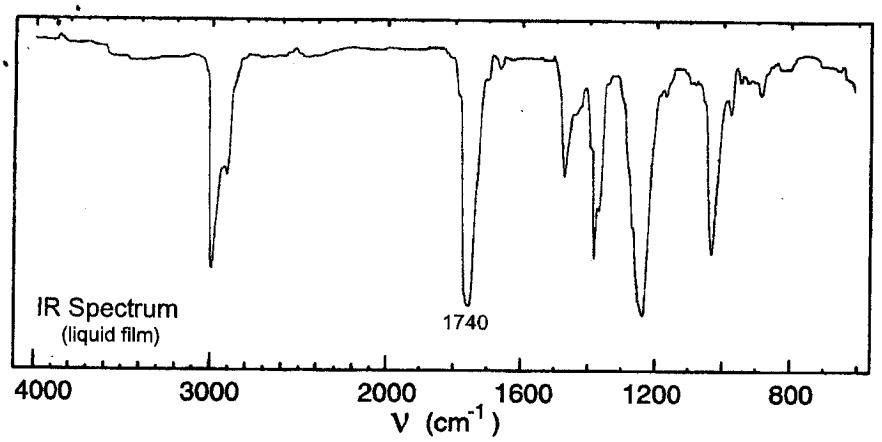
(i) 2- Aminonaphthalene **to** 2-Cyanonaphthalene

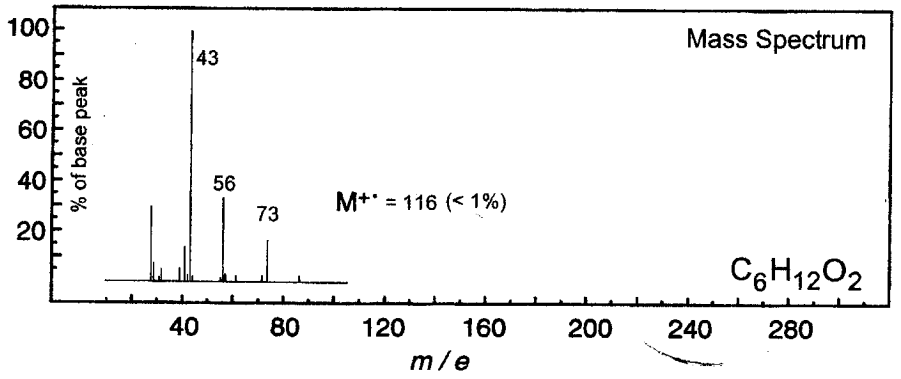
(ii)  **to** 

(d) Suggest a plausible mechanism for the following reactions: **(8 marks)**

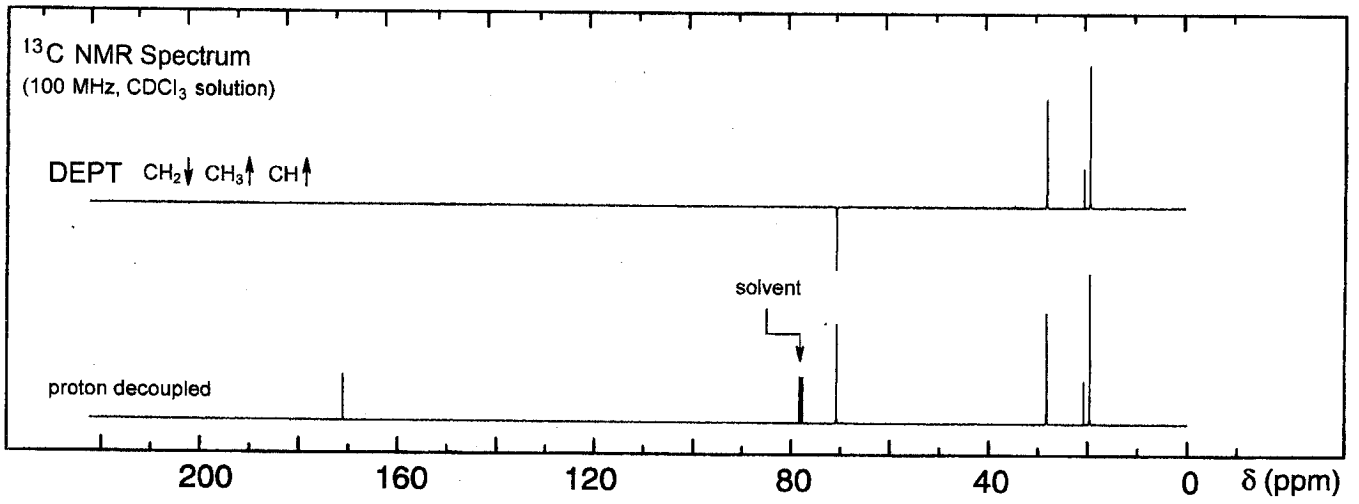


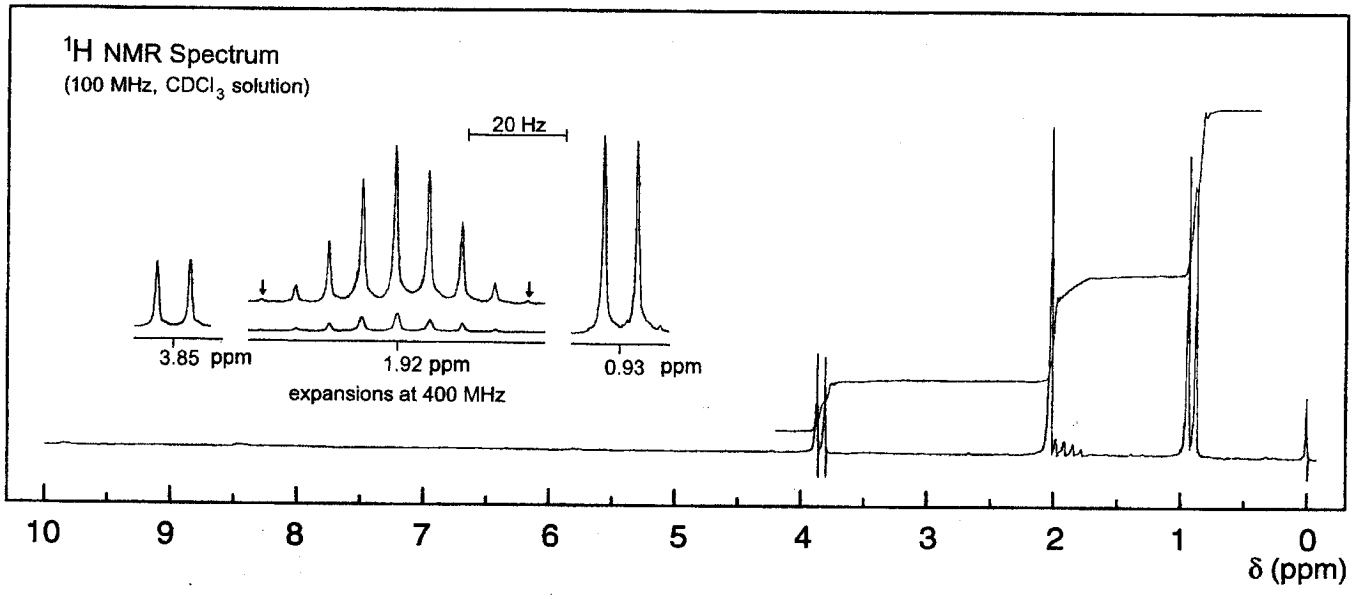
Problem 71





No significant UV absorption above 220 nm





THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES
DEPARTMENT OF CHEMISTRY

2013/14 ACADEMIC YEAR MID - YEAR FINAL EXAMINATION

CHE 4811: INORGANIC INDUSTRIAL CHEMISTRY

TIME : THREE HOURS

INSTRUCTIONS:

Answer any **five questions.**
All questions carry equal mark and use illustrations where necessary.

1.

a) Compare Laminar and Turbulent flow and state the range of Reynolds's number for laminar and turbulent flow in a pipe.
b) Sketch the boundary layer formation for the following;
   I. Development of a boundary layer in a straight tube.
   II. Development of a boundary layer on a flat plate.
c) Name and briefly explain the factors to be determined when viscous fluid flows through the circular pipe?
d) A black 20-by-20 cm plate has air forced over it at a velocity of 2 m/s and a temperature of 0 °C. The plate is placed in a large room whose walls are at 30 °C. The back side of the plate is perfectly insulated. Calculate the temperature of the plate resulting from the convection-radiation balance given that $h_c = 12$ W/m^2 °C.

2.

a) Express shear stress in terms of Viscosity and Eddy viscosity and explain the difference between the two kinds of quantities.
b) Explain in Detail the following terms.
   I. Laminar boundary layer.
   II. Transition zone.
   III. Turbulent boundary layer
c) Explain the major losses of a fluid flowing in a pipe.
d) A plate having a thickness of 4.0 mm has an internal heat generation of 200 MW/m^3 and a thermal conductivity of 25 W/m°C. One side of the plate is insulated and the other side is maintained at 100 °C. Calculate the maximum temperature in the plate.

3.

a) List three grinding laws in terms of half empirical models used for different grain size.
b) List the three main classes of Jaw Crushers and briefly explain the position and mechanism of operations for each class?
c) Sketch three types of Grinding Equipment and briefly explain the mechanism of operation.

d) A small radiant heater has metal strips 6 mm with a total length of 3 m. The surface emissivity of the strips is 0.85. To what temperature must the strips be heated if they are to dissipate 2000 W of heat to a room at 25 °C?

4.

a) List three major uses of Acetylene as an Industrial gas.

b) Describe in detail the manufacturing process of Acetylene. Write the reaction equations involved in this Production.

c)

I. Outline the basic functions of the series of trays containing mainly ferric chloride.

II. Name the major by-product of this process and list its industrial uses.

d) With the aid of a flow Diagram outline the manufacturing process of Acetylene.

5.

a) List the major uses of Hydrogen in industry.

b) Briefly describe the two hydrogen manufacturing processes.

I. Electrolytic process.

II. Steam-hydrocarbon reformation process.

c) Briefly describe the hydrogen purification process.

d) With the aid of a flow Diagram outline a simplified hydrogen production process.

6.

a) List the major uses of Carbon dioxide in industry.

b) Briefly describe the absorption system used for the concentration of Carbon dioxide.

c) Described in detail the Carbon dioxide manufacturing process from the combustion of fuel oil.

d) With the aid of a flow chart describe the major stages in the production of CO_2 from fuel oil or natural gas.

WISH YOU WELL, THE END.

THE UNIVERSITY OF ZAMBIA

School of Natural Sciences

Department of Computer Studies

MID YEAR - FINAL EXAMINATION

ALGORITHMS AND COMPLEXITY
CSC 3011

Date:	4TH MARCH, 2014
Time:	09:00hrs – 12:00hrs
Duration:	3 Hours
Venue:	Upper Dining Hall

Instructions

1. *Read the instructions carefully before you start answering the questions.*
   a) *There are **SEVEN** sections in this paper and you required to answer **ONLY FIVE** of them in any order and according to the instructions given.*
   b) ***ALL** questions have the **SAME** weight*

1.

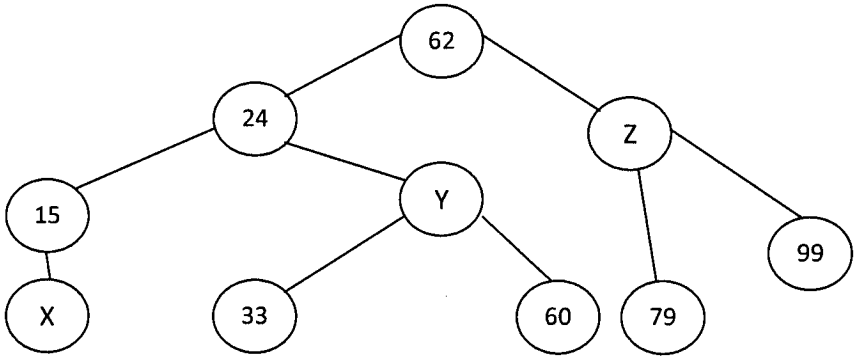
a. Define the following
   i. T(n) = O(f(n)) [2]
   ii. T(n) = θ(f(n)) [2]

b. Given an array of integers L and a number z,
   i. write an algorithm looks for the numbers x and y in L such that z = x + y. [8]
   ii. Do a Big-Oh analysis on the algorithm above [8]

2.

a. Define a binary search tree

b. Consider the binary tree below



c. What is the height of this tree? [2]

d. What values or ranges of values are to be placed in the X, Y and Z nodes for this tree to be a binary search tree? [2]

e. Show the order in which the nodes of the tree above are processed the following tree traversal algorithms
   i. Breadth-first search [4]
   ii. Pre-order DFS [4]
   iii. In-order DFS [4]
   iv. Post-order DFS [4]

3.

a. Define what a queue data structure is. [2]

b. Describe the two basic operators on a queue. [4]

c. Give four applications of a queue. [4]

d. Write an algorithm that implements the breadth-first traversal of a tree using a queue: describe or the operations that you use in this algorithm. The header of your algorithm should be as follows: [10]

```
Algorithm BFS(T)
        Input: T the tree to be traversed
        Output: none
```

// your pseudocode here

End.

4.

a. Define what a stack data structure is.

b. Given the following arithmetical expression $5 - 4 * (1 - 3 * (4 + 2))$, by showing the state of the stack show how,

   i. it is converted to postfix notation.

   ii. the expression tree is generated from the postfix notation generated above

---

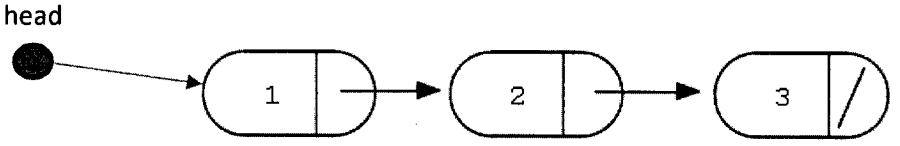
5.

a. Define what a linked list is? [2]

b. Give two comparative advantages [4]

c. and one disadvantage of the linked list over an array. [2]

d. Consider the linked list below



   i. Using graphical illustration, show the sequence of steps how a new node is inserted between 2 and 3 [4]

   ii. Implement a liked list of number with the insert and delete operations. [8]

---

6. Consider the following array of numbers, 19, 3, 34, 35, 6, 40, 5, 25, 13, 24, 20, 18

Show how the following sorting algorithms will rearrange the numbers in ascending order

a. Bubble sort (Indicate comparisons and swaps in each iteration) [8]

b. Heap sort [12]

7.

a. Define the following

   i. AVL tree [2]

   ii. MinHeap [2]

Hence insert the following numbers into an initially empty

19, 3, 34, 35, 6, 40, 5, 25, 13, 24, 20, 18

b. AVL tree [8]

c. MinHeap [8]

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

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

2013 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.

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1. Explain the concept of regional economic base multiplier and show how its estimate may be inflated due to the impact of income transfers.
2. Discuss local economic development (LED) as an instrument of regional development.
3. 'Despite the importance of social and political goals, most regional economic planning efforts are still centred on economic objectives'. Discuss.
4. Analyse the relevance of the Central Place Theory in regional planning.
5. 'Planning for sustainable regional development must take a *systems approach*'. Elucidate.
6. With reference to the liberal perspective:
   (a) Describe four major forms of liberalism;
   (b) State with reasons the form of liberalism Zambia is currently pursuing.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

2013 ACADEMIC YEAR FINAL EXAMINATIONS

GES 4181: URBAN GEOGRAPHY AND PLANNING

TIME: THREE (3) hours
ANSWER: FOUR QUESTIONS
NOTE: CANDIDATES SHOULD USE ILLUSTRATIONS WHEREVER RELEVANT

---

1. Write short explanatory notes on **ALL** of the following :
   (a) Postmodernism
   (b) Concepts of space and place in urban geography
   (c) Nature and scale of world urbanisation
   (d) Sustainable cities
   (e) Informal urban land markets

2. Using a cross–section graph, explain the transport and land trade-off theory in determining housing location.

3. Outline five (5) major factors responsible for the level of infrastructure development in developing countries.

4. Discuss the four classical elements of rational comprehensive urban planning.

5. Urban Competitiveness of cities can be resource–driven, efficiency–driven or innovation-driven. Explain which of these applies to Lusaka City?

6. Explain the causes and problems of urban sprawl in developing countries.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES

Department of Mathematics & Statistics

MID YEAR FINAL EXAMINATIONS

27th February, 2014.

MAT3401—TOPOLOGY

Time allowed : THREE(3) HOURS

Instructions : There are seven(7) questions. Answer **ANY FIVE (5)** questions. All questions carry equal marks. Show all your working to earn full marks.

---

1. (a)(i) Define a quasi-metric on a non empty set X.

   (ii) Define a metric on a set X.

   (b) Define the function $d : \mathbb{R}^2 \to \mathbb{R}^+$ by

$$d(\overline{x}, \overline{y}) = \begin{cases} |x_1 - y_1|, & x_2 = y_2 \\ |x_1| + |x_2 - y_2| + |y_1|, & x_2 \neq y_2 \end{cases}$$

   Show that d is a metric.

   (c) Find $f(E)$ and $f^{-1}(E)$ given that $f(x) = |x^2 - 2|$ and $E = (1, 2]$.

2. (a) Let (X, d) be a metric space. Define the following:

   (i) An open ball in a metric space (X, d).

   (ii) An open set in a metric space $X, d)$.

   (b) In any metric space (X, d), prove that an open ball is an open set.

(c)(i) Prove that the union of two closed subsets of a metric space is closed.

(ii) Give an example to show that an infinite union of closed sets need not be closed.

3. (a) Let A be a subset of a metric space (X, d). Define each of the following:

(i) The closure ,$\overline{A}$, of A.

(ii) The boundary, bd(A), of A.

(b) If $A = \{z \in \mathbb{C} : \ Rez = 1\}$, find the boundary of A.

(c)(i) Define the interior, int(A), of a subset A of a metric space (X, d).

(ii) If A is a subset of a metric space (X, d). prove that

$$\text{int}(A) = (\overline{A}')'.$$

(iii) Let (X, d) be a metric space and A a subset of X. Prove that a point $x \in X$ is an interior point of A if and only if there is an $r > 0$ such that $B(x; r) \subset A$.

4. (a) Let X be a set. Define a topology on X.

(b) Let X be a topological space. Prove that the intersection of any collection of closed sets is a closed set.

(c) Let $X = \{a, b, c, d, e, f\}$ and

$$\mathcal{T} = \{X, \emptyset, \{a\}, \{f\}, \{a, f\}, \{b, c\}, \{a, c, f\}, \{b, c, d, e, f\}\}.$$

Determine why $\mathcal{T}$ is not a topology on X.

5. (a) Let X be a set and $\mathcal{B}$ be a basis for a topology on X. Define the topology $\mathcal{T}$ generated by $\mathcal{B}$.

(b) Let X be a set and $\mathcal{B}$ be a basis for a topology on X. Show that U is open in the topology generated by $\mathcal{B}$ if and only if for each $x \in U$ there exists a basis element $B_x \in \mathcal{B}$ such that $x \in B_x \subset U$.

(c) Determine whether or not the following set is a basis for a topology on $\mathbb{Z}$:

$$\mathcal{B} = \{B(n) : n \in \mathbb{Z}\}$$

where

$$B(n) = \begin{cases} \{n\}, & n = odd \\ \{n-1, n, n+1\}. & n = even \end{cases}$$

6. (a) Let (X, d_x) and (Y, d_y) be metric spaces and $f : X \to Y$ be a bijection.

(i) When is f said to be a homeomorphism?.

(ii) If $f : X \to Y$ and $g : Y \to Z$ are homeomorphisms, prove that so is the composition $g \circ f : X \to Z$.

(b)(i) When is a topological space X said to be connected?

(ii) Show that a topological space X is connected if and only if there are no non empty proper subsets of X that are both open and closed in X.

(c)(i) Let $X = \{a, b, c, d, e\}$ and $\mathcal{T} = \{X, \emptyset, \{a\}, \{c, d\}, \{a, c, d\}, \{b, c, d, e\}\}$. Use the fact that the closure of a set is the smallest closed set containing that set, and that a set is closed if its complement is open to find $\overline{\{b\}}$ and $\overline{\{a, c\}}$.

(ii) Let $X = \{a, b, c, d, e\}$ and $\mathcal{T} = \{X, \emptyset, \{a\}, \{c, d\}, \{a, c, d\}, \{b, c, d, e\}\}$. Show that $(X, \mathcal{T})$ is not connected.

7. (a) Prove that $\text{Int}(A \cap B) = \text{Int}(A) \cap \text{Int}(B)$.

(b) For $z, w \in \mathbb{C}$, define the metric d by

$$d(z, w) = \begin{cases} 0, & z = w \\ |z| + |w|, & z \neq w \end{cases}.$$

(i) For the metric d, sketch the ball $B(-4i, 4)$ in $(\mathbb{C}, d)$.

(ii) Given that $A = \{z \in \mathbb{C} : Re z < 3\}$, find $d(-3, A)$.

(c)(i) When is a topological space X said to be compact?

(ii) Determine whether or not the set $\mathbb{Z}^+$ is compact or not, with respect to the usual topology. Give reasons.

(iii) Let $f : X \to Y$ be a continuous function and let A be compact in X. Prove that $f(A)$ is compact in Y.

THE UNIVERSITY OF ZAMBIA
PHYSICS DEPARTMENT
UNIVERSITY EXAMINATIONS
2013/14 ACADEMIC YEAR MID-YEAR EXAMINATIONS
P3531 - QUANTUM MECHANICS

TIME: 3 HOURS

MAX MARKS: 100

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

You may use the following information:

Electron rest mass m_0	= 9.1 x 10^{-31} Kg
Boltzmann constant k	= 1.38x10^{-23} J/K
Proton rest mass M_p	= 1.67 x 10^{-27} Kg
Planck's constant h	= 6.6 x 10^{-34} J.s
Speed of light c	= 3 x 10^{8} m/s
$\hbar/2\pi$	= 1.05 x 10^{-34} Js
1 e.V.	= 1.6 x 10^{-19}J
Stefan's constant σ	= 5.67 x 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

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

Q.1

(i) Briefly explain Planck's postulate for the derivation of the formula for blackbody radiation and how it departed from classical concepts. [2]

(ii) Briefly explain if the uncertainty relation holds true and is of any practical relevance in the case of a macroscopic object like a football. [2]

(iii) Without calculations, write down the values of the following commutators: $[x, p_y]$, $[p_x, p_y]$, $[z, p_y]$, $[x, y]$, $[x, x^2]$, $[p_x p_y, p_z]$, $[L_x, L_y]$ *and* $[L^2, L_z]$. [4]

(iv) Show that the expectation value of the momentum operator is real. [4]

(v) Prove the basic commutation relation between the position and momentum operators. [4]

(vi) What do we mean when we say that two operators A and B commute? What is the physical significance of this statement? [2]

(vii) Using the classical expression for the angular momentum, obtain the quantum mechanical operator expressions for the three components of the angular momentum in cartesian coordinates. [3]

(viii) What quantum numbers characterize an electron in an atomic orbit? State the possible values of each quantum number. What is the maximum number of electrons in an orbit with principal quantum number $n = 3$ and orbital angular momentum quantum number $l = 2$? [4]

Q.2 (a) What are compatible observables? Prove that two compatible observables commute. [7]

(b) Prove the commutation relation [A, B+C] = [A, B] + [A, C] [4]

(c) Prove that AA^+ is Hermitian for any operator A. [4]

(d) Consider the Hermitian operator H that has the property $H^4 = 1$. What are the eigenvalues of H? What are the eigenvalues if H is not restricted to being Hermitian? [5]

(e) Show that eigenvalues of a Hermitian operator are real. [5]

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

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

$= 0$ outside the well, i.e. $|x| \geq a$.

(a) Show that for a normalized wave function $C = 4/\sqrt{33a}$ [10]

(b) If a measurement of the total energy is made, what are the possible results of such a measurement? [7]

(c) Calculate the probability of measuring each of the energy values. [8]

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, obtain all the commutation relations among the orbital angular momentum operators L_x, L_y, L_z. State, with reason, if the three components of the angular momentum can be measured simultaneously. [10]

(b) For a general angular momentum, let $J_\pm = J_x \pm iJ_y$. Using the commutation relations derived in (a) above, show that $[J_z, J_\pm] = \pm\hbar J_\pm$. [6]

(c) Let ψ_{jm} be an eigenstate of J^2 and J_z with eigenvalues $j(j+1)\hbar^2$ and $m\hbar$, respectively. Show that $J_\pm\psi_{jm}$ is likewise an eigenstate of J^2 and J_z. What are the eigenvalues? [9]

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

(a) Write down the time-independent Schrodinger equation for the particle and the boundary conditions. [5]

(b) Use the method of separation of variables to solve the Schrodinger equation. Hence obtain the allowed energy levels and the normalized eigenfunctions. [16]

(c) Discuss the degeneracy of the first two energy levels. [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 equation 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. [7]

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

$$E_n = \left(n + \frac{1}{2}\right)h\omega \quad ; n = 0, 1, 2$$ [4]

(f) In what ways is the quantum mechanical result in (e) different from that in classical mechanics? [2]

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

The University of Zambia

School of Natural Sciences

Department of Physics

2013/2014 Academic Year

Mid-Year University Examinations

PHY2231 – Thermodynamics and Properties of Matter

Duration: Three (3) Hours

Instructions

- This paper contains seven (7) questions.
- This paper has a total of 100 marks.
- All questions carry equal marks. Attempt any five (5).
- Marks allocated for each question are indicated in square brackets [ ].

Physical Constants

- Acceleration due to gravity $g = 9.8$ m.s^{-2} ,
- Universal gas constant $R = 8.314$ J/mole.K,
- Density of mercury, $\rho_{\text{mercury}} = 13600$ Kg/m^3,
- Density of water, $\rho_{\text{water}} = 1000$ Kg/m^3,
- Specific heat capacity of water $c_w = 4184$ J/Kg.K

FORMULAE THAT MAY BE USEFUL

$Y = \frac{F/A_{\perp}}{\Delta L/L_o}$	$K = -\frac{dP}{dV/V_o}$	$\frac{P}{\rho} + gh + \frac{1}{2}u^2 = \text{constant}$	$\eta = \frac{Y}{2[1+\sigma]}$
$3K = \frac{1}{\alpha[1-2\sigma]}$	$dq = Tds$	$\Delta P = 2\gamma\left[\frac{1}{R_1} + \frac{1}{R_2}\right]$	$c = \frac{\pi\eta}{2L}r^4$
$Pv = RT$	$\frac{dT}{dt} = k[T - T_a]$	$\left[P + \frac{a}{v^2}\right][v-b] = RT$	$\sigma = \frac{\beta}{\alpha}$
$\Delta Q = mc_p\Delta T$	$\dot{Q} = -\kappa A\frac{dT}{dr}$	$\dot{V} = a_1u_1 = a_1a_2\sqrt{\frac{2hg}{a_1^2 - a_2^2}}$	$c_P - c_v = R$
$\dot{V} = \frac{\pi P}{8\eta l}r^4$	$\rho = \frac{m}{V}$	$c_p = \left[\frac{\partial q}{\partial T}\right]_p = \left[\frac{\partial h}{\partial T}\right]_p = T\left[\frac{\partial s}{\partial T}\right]_P$	$dq = du + Pdv$
$\eta = 1 - \frac{T_2}{T_1}$	$dw = \gamma dA$	$c_v = \left[\frac{\partial q}{\partial T}\right]_v = \left[\frac{\partial u}{\partial T}\right]_v = T\left[\frac{\partial s}{\partial T}\right]_v$	$f = u - Ts$
$h = u + Pv$	$g = h - Ts$	$T = T_a + [T_0 - T_a]e^{kt}$	$h = g + Ts$
$\left[\frac{\partial s}{\partial v}\right]_T = \left[\frac{\partial P}{\partial T}\right]_v$	$\left[\frac{\partial s}{\partial P}\right]_T = -\left[\frac{\partial v}{\partial T}\right]_P$	$\left[\frac{\partial T}{\partial v}\right]_s = -\left[\frac{\partial P}{\partial s}\right]_v$	$\left[\frac{\partial T}{\partial P}\right]_s = \left[\frac{\partial v}{\partial s}\right]_P$

1 (a) Lead has a density $\rho = 11400.0\ \text{Kg/m}^3$ and Bulk modulus $\kappa = 8.0\times10^9\ \text{N/m}^2$.

(i) Define Bulk modulus of a material. [2]

(ii) Write down its formula for the Bulk modulus, defining all variables. [1]

(iii) If this sample of lead is subjected to a pressure of $2\times10^8\ \text{N/m}^2$, show that

a) the volume strain is $1/40$. [1]

b) the new volume of the lead sample is

$$\frac{39}{40}V_0,$$

where V_0 is the original volume of the lead sample. [2]

c) the new density of lead will be

$$\rho_{new} = \frac{40}{39}\rho = 11692.3\ \text{Kg/m}^3$$

[4]

(b) A gold wire, 0.32 mm in diameter, elongates by 1.0 mm when stretched by a force of 3.234 N and twists through 1 radian when equal and opposite torques of 145×10^{-7} N-m are applied at its ends. Let the initial length of the gold wire be L.

(i) Show that the Young's modulus for the gold wire is

$$Y = 4.043L\times10^{10}\ \text{N/m}^2,$$

[2]

(iii) What is the torsion rigidity for this wire? [2]

(iv) Show that the coefficient of rigidity of the gold wire is

$$\eta = 1.409L\times10^{10}\ \text{N/m}^2,$$

[2]

(v) Show that the Poisson's ratio for gold is $\sigma = 0.435$. [4]

2 (a) Consider a cube whose sides have length L_i, area A_i and volume V_i at temperature T_i. After undergoing thermal expansion the cube then has length L, area A and volume V at another temperature T. Assuming the cube to be isotropic, show that the ratio of coefficient of linear expansion α to coefficient of superficial expansion β to coefficient of cubic expansion γ is approximately

$$\alpha : \beta : \gamma \approx 1 : 2 : 3. \quad \textbf{[10]}$$

(b) A detective arrives at a crime scene where a body has just been found. The temperature of the body is taken at 06:55 AM and found to have an average value of $22.8^{\circ}\mathrm{C}$. 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 $20.0^{\circ}\mathrm{C}$ 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 $22.3^{\circ}\mathrm{C}$. Assuming that the victim's body temperature was normal (i.e. $37.0\ ^{\circ}\mathrm{C}$) prior to death, use Newton's law of cooling to

(i) calculate the radiation cooling constant for the body, **[6]**

(ii) estimate the victims time of death, **[4]**

3 (a) A horizontal steel wire of length 1.0 m and cross section area 10^{-6} m^2 is stretched between two fixed supports. When a load of 0.04 Kg is applied to the midpoint, a sag of 5.0×10^{-3} m is produced. For a load of 0.6 Kg the sag is 15.0×10^{-3} m. Calculate the Young's modulus of the wire. **[10]**

(b) (i) An ice box is built of wood 1.80 cm thick , lined inside with cork 3 cm thick. If the temperature of the inner surface of the cork is $0^{\circ}C$ and that of the outer surface of wood is $12^{\circ}C$, what is the temperature of the wood-cork interface? Take the thermal conductivities of wood and the cork as $0.251\ W\,m^{-1}\,K^{-1}$ and $0.0502\ Wm^{-1}K^{-1}$ respectively. **[6]**

(ii) Find the efficiency of a Carnot engine working between $127^{\circ}C$ and $27^{\circ}C$. **[4]**

4 (a) A number of little droplets of water, all of the same radius r, coalesce to form a single drop of radius R. Show that the rise in temperature of water will be

$$\Delta T = \frac{3\gamma}{c_p \rho}\left(\frac{1}{r} - \frac{1}{R}\right)$$

where ρ and c_p are density and specific heat capacity at constant pressure for water, respectively while γ is the surface tension of water. **[10]**

(b) 50 g of water at $15^{\circ}C$ is mixed with 80 g of water at $40^{\circ}C$. Given that the specific heat capacity of water does not change in this temperature range, calculate the

(i) final temperature of the water mixture, **[5]**

(ii) change in entropy of the system. **[5]**

5 (a) (i) A horizontal pipe of a non-uniform bore has water flowing through it such that the velocity of flow is $0.4m/s$ at a point where the pressure is 2×10^{-2} m of mercury column. Given that the density of mercury is $13600\ Kg/m^3$ while the density of water is $1000\ Kg/m^3$, use Bernoulli's theorem to determine the water pressure at a point where the velocity of flow is $0.6\ m/s$. **[5]**

(ii) The diameters of water main pipe where a venturimeter is connected to it are 20 cm and 10 cm . What is the volume rate of water flow if the water levels in the two piezometer tubes differ by 5 cm ? **[5]**

(b) Consider a cylindrical tube of length L, inner radius r_i and outer radius r_o. Heat is conducted radially across the walls of the tube such that the inner temperature is T_i while the outer temperature is T_o. Use Fourier's law of heat conduction to show that the steady state amount of heat rate is

$$\dot{Q} = \frac{2\pi L\kappa}{\log_e[r_o/r_i]}[T_i - T_o],$$

where κ is the thermal conductivity of the material of the tube. **[10]**

6 (a) Consider a horizontally fixed cantilever, of length L and negligible mass, is loaded at one end by a mass M. If Y, g and I_g are the young's modulus, acceleration due to gravity and geometric moment of inertia, respectively, show that the depression, y, of the cantilever at any given point that is distance x from the fixed end is given by

$$y = \frac{Mg}{YI_g}\left[\frac{Lx^2}{2} - \frac{x^3}{6}\right].$$ **[10]**

(b) Show that the change in specific entropy of a perfect gas [between state "a" and state "b"] is generally given by

$$s_b - s_a = c_v \log_e\left(\frac{T_b}{T_a}\right) + R\log_e\left(\frac{v_b}{v_a}\right)$$

where v_a, v_b are the specific volumes, T_a, T_b are the temperature values, c_v is the specific heat capacity at constant volume, R is the universal gas constant while s_a, s_b are the specific entropy values at state "a" and "b" respectively. **[10]**

7 (a) A cylindrical vessel of radius 8 cm is filled with water to a height of 50 cm . It has a capillary tube 10 cm long, 0.2 mm radius, protruding horizontally at its bottom. If the coefficient of viscosity of water is 10^{-3} Pa-s and $g = 9.8$ m/s^2, compute the time in which the water level will fall to a height of 25 cm . **[10]**

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

(i) Write down the expression for pressure P as a function of specific volume v, temperature T and van der Waals constants a and b. **[1]**

(ii) Write down the expression for the work done, in terms of pressure P, by the gas as its volume changes from v_1 to v_2. **[1]**

(iii) Hence, or otherwise, 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. **[5]**

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

$$\Delta s = R \log_e \left(\frac{v_2 - b}{v_1 - b} \right) + \frac{a}{T} \left[\frac{1}{v_2} - \frac{1}{v_1} \right].$$ **[3]**

--- END OF PHY2231 EXAMINATION ---

THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
DEPARTMENT OF PHYSICS
2013/14 ACADEMIC YEAR

MID YEAR UNIVERSITY EXAMINATIONS

PHY 2511: CLASSICAL MECHANICS I

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.**
- **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:

$$1=\cos^2\alpha+\sin^2\alpha, \qquad \vec{r}=r\hat{r}=r\hat{r}(\theta), \qquad \vec{F}(x,y,z)=-\nabla V, \qquad \vec{r}_{CM}=\frac{\sum_i m_i\vec{r}_i}{\sum_i m_i}$$

Q1 A particle describes a path with position vector

$$\vec{r}(t) = A\cos\omega t\hat{i} + B\sin\omega t\hat{j}$$

Show that

(i) the path is an ellipse whose equation is $\frac{x^2}{A^2} + \frac{y^2}{B^2} = 1$, **[8 marks]**

(ii) the acceleration is directed towards the origin, **[4 marks]**

(iii) $\int_{t}^{t+t_1} \vec{r} \times d\vec{r} = \omega AB t_1 \hat{k}$ [8 marks]

Q2(a) A particle moves in a plane elliptical orbit described by the position vector

$$\vec{r}(t) = 2b\sin(\omega t)\hat{i} + b\cos(\omega t)\hat{j}$$

(i) Find the velocity vector $\vec{v}$ **[2 marks]**

(ii) Show that the speed v of the particle is **[3 marks]**

$$v = b\omega\left(3\cos^2(\omega t) + 1\right)^{1/2}$$

(iii) Find the angle between $\vec{v}$ and $\vec{a}$ at the time $t = \frac{\pi}{2\omega}$ **[10 marks]**

(iv) Find the value of c such that the force given by

$$\vec{F} = \left(\frac{z}{y}\right)\hat{i} + \left(\frac{cxz}{y^2}\right)\hat{j} + \left(\frac{x}{y}\right)\hat{k}$$

is conservative **[5 marks]**

Q(3) A particle moves in a region where the potential energy is given by

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

(i) Sketch a free-hand graph of the potential for both positive and negative values of x. **[8 marks]**

(ii) Find the positions of stable and unstable equilibrium **[2 marks]**

(iii) Show that the particle cannot escape to $x = \pm\infty$ if $|v_0| < \sqrt{\frac{8}{m}}$ where v_0 is the initial speed of the particle **[8 marks]**

(iv) Give a physical example of this motion. **[2 marks]**

Q(4)(a) Consider the central force $F(\vec{r}) = -\frac{\lambda}{r^2}$. Starting from the fact that central-force motion is planar and is characterized by conservation of angular momentum, show that the equation of conservation of energy for a particle of mass m moving under the given force is **[16 marks]**

$$\frac{1}{2}m\dot{r}^2 + U(r) = E \text{ where } U(r) = \frac{L^2}{2mr^2} - \frac{\lambda}{r}$$

(b) The position of a particle moving along the x-axis depends on the time according to the relation

$$x = A\lambda\left(1 - e^{-t/\lambda}\right)$$

in which A and λ are constants. Find its

(i) Velocity **[2 marks]**
(ii) Acceleration **[2 marks]**

Q5 A charged particle having charge Q is placed in a static magnetic field of magnitude B pointing in the z-direction.

Show that

(i) The equations describing the motion of the particle in component form are: **[8 marks]**

$$m\ddot{x} = QB\dot{y}, \qquad m\ddot{y} = -QB\dot{x} \text{ and } m\ddot{z} = 0$$

(ii) Decouple the first two equations in (i) above and show that **[6 marks]**

$$\ddot{x} + \omega^2 x = \omega^2 a$$

where $\omega = QB/m$, $a = c_2/\omega$ with c_2 being a constant.

(iii) Given that the solution for x in (ii) above can be written as

$x = a + A\cos(\omega t + \theta_0)$ and that for the y-component as $y = b - A\sin(\omega t + \theta_0)$, show that the projection of the path of motion of the particle is a circle of radius A centered at the point (a, b) in the xy-plane **[6 marks]**

Q6(a) A system of N particles of masses $m_1, m_2, ...m_N$ are located at positions $\vec{r}_1, \vec{r}_2, ...\vec{r}_N$ from the origin. Show that the expression for the *momentum theorem* for the system of particles is given by

$$\frac{d\vec{P}}{dt} = \vec{F}$$

where $\vec{F}$ is the external force acting on the system of particles **[9 marks]**

(b) A system comprising three particles A, B, C of masses $5kg$, $2kg$ and $3kg$ are at positions (in meters) $\vec{r}_A = 4\hat{i} - \hat{j}$, $\vec{r}_B = 2\hat{i} + 5\hat{j}$, and $\vec{r}_C = \hat{i} + 3\hat{j}$, respectively. The particles are acted on by forces (in Newtons) $\vec{F}_A = 3\hat{i} + 4\hat{j}$, $\vec{F}_B = 2\hat{i} + 2\hat{j}$, and $\vec{F}_C = 6\hat{i} - 7\hat{j}$. Find

(i) the initial position of the center of mass of the particles, **[5 marks]**

(ii) the acceleration of the center of mass. **[4 marks]**

(iii) Explain the principle of conservation of momentum as applied to rocket technology. **[2 marks]**

Q7(a) A particle of mass m moves in a straight line, say along the x-axis, under the influence of the position-dependent force $F(x)$.

(i) Show that the equation of motion of the particle leads to the conservation of energy equation,

$$\frac{1}{2}mv^2 + U(x) = E$$

where $U(x)$ is the potential energy and E is the total energy. **[6 marks]**

(ii) From your result in (i) above, show that the connection between the position of the particle and time is

$$t = \int \frac{dx}{\sqrt{\frac{2}{m}[E - U(x)]}} + t_0$$

where t_0 marks the initial time of the motion. **[4 marks]**

(b) Show that a body of mass m at a distance x from the earth's surface experiences a force given by:

$$F = \frac{-r_e^2 mg}{(r_e + x)^2}$$

where r_e is the radius of the earth. Explain how you would proceed to obtain the maximum height from the expression you find if the body is thrown vertically with a velocity of v_0 from the earth's surface. **[10 marks]**

**********END OF PHY2511 EXAMINATION**********

UNIVERSITY OF ZAMBIA

SCHOOL OF NATURAL SCIENCES
DEPARTMENT OF PHYSICS
MID-YEAR UNIVERSITY EXAMINATIONS
2013/2014 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, 24th February 2014.

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

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.

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

17.

$$y = \sum_{m=0}^{\infty} a_m x^m.$$

QUESTION 1

(i) Use the definition of differentiation to test whether or not the function $f(z) = \overline{z} - z^2$ is differentiable.. (10 marks)

(ii) By representing complex numbers as vectors give a graphical interpretation of $|z - z_0| \leq \alpha$, where z_0 is constant and z is variable. On a separate diagram shade the region it represents. (5 marks)

(iii) Show that the function

$$u = 2x - x^3 + 3xy^2$$

is harmonic. Find the conjugate harmonic function v and thus write the complex function defined by $u(x, y)$ and $v(x, y)$. (10 marks)

QUESTION 2

(i) Using the method of path, integrate

$$\int_C z^2 - iz \, dz$$

along the curve C which is the quarter circle about the origin from 2 to $2i$ clockwise. (8 marks)

(ii) Use the derivative formula to integrate

$$\int_C \frac{e^{-z}}{(z+2)^5} \, dz,$$

where C is the circle $|z| = 3$. (7 marks)

(iii) Is the following series convergent or divergent:

$$\sum_{n=0}^{\infty} \frac{n+1}{2^n n}.$$

(5 marks)

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

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

(5 marks)

QUESTION 3

(i) Find the Laurent series of

$$f(z) = \frac{e^z}{z^5}.$$

Write down the residue. Give all of the poles and find their order.

(7 marks)

(ii) Use the method of residues to evaluate the integral

$$\int_C \frac{12z - 7}{(z-1)^2(2z+3)}\, dz, \qquad C: \quad |z+i| = \sqrt{3}$$

Hint: Find the values of x where the contour C cuts the x-axis (18 marks)

QUESTION 4

Find the eigenvalues and eigenfunctions of

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

(25 marks)

QUESTION 5

Legendre's differential equation is

$$(1 - x^2)y'' - 2xy' + n(n+1)y = 0 \tag{1}$$

(i) Use the power series method to obtain the recurrence relation

$$a_{s+2} = -\frac{(n-s)(n+s+1)}{(s+2)(s+1)} a_s$$

for the coefficients of the series solution of eq.(1). (9 marks)

(ii) Show that for n a positive integer, the infinite series solution of eq.(1) reduces to a polynomial. (5 marks)

(iii) The coefficient of the highest power of the polynomial solutions of eq.(1), a_n, is chosen to be

$$a_n = \frac{(2n)!}{2^n (n!)^2}.$$

This definition corresponds to choosing the arbitrary constants a_0 and a_1 so that the solutions $y_n(x)$ correspond to the standard definition of Legendre polynomials. Use this value for a_n and the recurrence relation to find the coefficients a_{n-2m} of the normalized polynomial solutions of eq.(1), i.e, the Legendre polynomials, and hence write a formula for these polynomials. (11 marks)

QUESTION 6

(i) Derive the Euler-Lagrange Equations

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

where $F = F(y, \dot{y}, x)$ (17 marks)

(ii) Show how the Euler-Lagrange Equations simplify when $F = F(y, \dot{y})$. (8 marks)

END

The University of Zambia

School of Natural Sciences

Department of Physics

2013/2014 Academic Year

Mid-Year University Examination

Computational Physics II-PHY 4031

Instructions **Total Marks 100**

- **Time Allocation:** Three (3) Hours.
- **All questions carry equal marks.**
- Marks for each question are shown in the square brackets [ ].
- Whenever necessary, use the information given in the **appendix**
- **Answer:**
  - i) Question one (1) and
  - ii) Any three (3) questions from 2, 3, 4, 5 and 6.

Q.1 **(a)** Consider the following segment from a C code;

```
int y, *py=&y;
printf("Enter an Integer:  ");
scanf("%d",&y);
printf("Enter another Integer: ");
scanf("%d",py);
printf("y=%d     *py=%d\n",y,*py);
```

If the values 3 and 8 are entered consecutively at the prompt, what values will be printed by the last printing statement? Explain your answer.

[5]

(b) If a three dimensional integer array is initialised as follows;

```
int y[2][3][4]={{{1,1,8,0},{3,2,10,5},{7,8,8,8}},\
                {{9,2,9,7},{1,3,8,7},{6,1,7,1}}};
```

Write the following array elements using the pointer notation

i) `y[1][2][3]` ii) `y[1][1][0]` iii) `y[0][0][2]` iv) `y[1][1][1]`

[8]

(c) Give short answers to the following questions

i) What is a pointer variable?

ii) Give an example of a discrete random variable that occurs in nature and the distribution that describes it.

iii) What advantage has the Fourier series over the Taylor series?

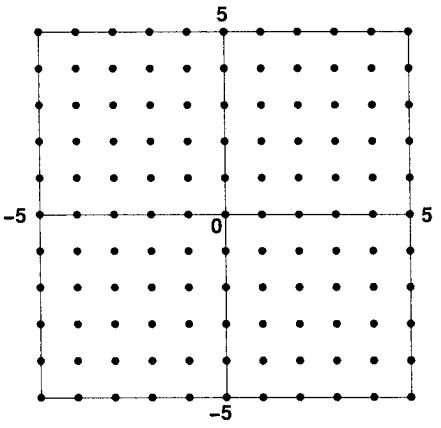
iv) What is the difference between curve fitting and function appproximation?

v) Given that a signal is sampled at 2^9 uniformly spaced points, by what percentage does the Fast Fourier Transform reduce the number of complex multiplications required by the standard Discrete Fourier Transform?

vi) Write an expression in C for generating float random numbers between `min` and `max` given a random number generator `rand()` which generates integer random numbers between 0 and `RAND_MAX`.

[12]

Q.2 The figure below shows a square grid, with an equal probability of moving on this grid in any four directions. A random number generator, `rand()` which generates integer random numbers between 0 and `RAND_MAX`, is called upon to generate the directions: if between 0 and 0.25, move north, between 0.25 and 0.50, move east, between 0.50 and 0.75, move south and between 0.75 and 1.0 move west. If each step is unit length, write a C program to simulates this random walk starting from the origin and print the average radial distance from the origin after 50 trials of 100 steps each. (*Note the boundaries*).



[25]

Q.3 **(a)** Which of the following would not allow you to calculate a correlation? Give a reason for your answer.

i) a negative relationship between X and Y

ii) a positive relationship between X and Y

iii) a curvilinear relationship between X and Y

iv) a linear relationship between X and Y

[2]

(b) Heating and combustion analyses were performed in order to study the composition of moon rocks. Recorded here are the determinations of hydrogen (H) and carbon (C) in parts per million (*ppm*) for 11 specimens

Hydrogen	120	82	90	8	38	20	2.8	66	2.0	20	85
Carbon	105	110	99	22	50	50	7.3	74	7.7	45	51

i) Calculate the correlation coefficient (r, work to 2 decimal places),

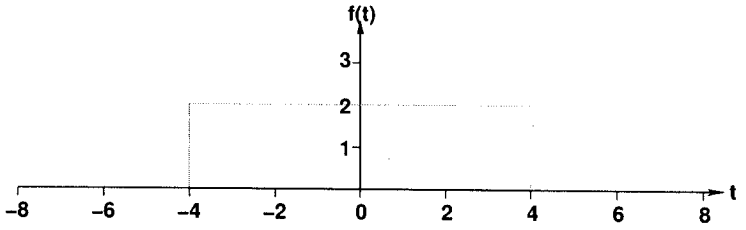
ii) Write a C program to calculate r for the above data.

[23]

Q.4 **(a)** A square signal is given by the following function

$$f(t) = \begin{cases} A & -\frac{T}{2} \leq t \leq \frac{T}{2} \\ 0 & |t| > \frac{T}{2} \end{cases}$$

and shown grapically below



Given that $A = 2.0$ and $T = 8.0$, write a C program that prints out the values for t and $f(t)$ to a file, `square.dat`, for $-T \leq t \leq T$ in steps of unit.

[10]

(b) Let the continous signal be

$$f(t) = e^{-|t|}\cos(\pi t)$$

Sample the signal at $t_0 = 0$, 0.5, 1.0 and 1.5 and find

i) the values of the discrete samples,

ii) the Discrete Fourier Transform.

[15]

Q.5 The drag coefficient C for a baseball is a function of velocity v (km/h). The following data shows values of C for different values of v.

v	0	50	75	100	125
C	0.5	0.5	0.4	0.28	0.23

Using the above data and Lagrange interpolation,

i) write a C program that will approximate the drag coefficient for a baseball at 90 km/h,

ii) what is the approximate value for the drag coefficient for a baseball at 90 km/h.

[25]

Q.6 Given the following data

i	1	2	3	4	5
x_i	0	0.25	0.50	0.75	1.0
y_i	1.0	1.284	1.649	2.117	2.783

Fit this data with a non-linear least square polynomial of degree 2. Work to three decimal places.

[25]

******* **End of Examination** *******

Appendix

Commonly Used Library Funcitons:

Function	Type	Purpose
`abs(i)`	`int`	Returns the absolute value of `i`
`cos(d)`	`double`	Returns the cosine of `d`
`exp(d)`	`double`	Raises e to the power `d` ($e = 2.7182818\ldots$)
`fabs(d)`	`double`	Returns the absolute value of `d`
`log(d)`	`double`	Returns the natural logarithm of `d`
`log10(d)`	`double`	Returns the logarithm (base 10) of `d`
`pow(d1,d2)`	`double`	Returns `d1` raised to the `d2` power
`sin(d)`	`double`	Returns sine of `d`
`sqrt(d)`	`double`	Returns the square root of `d`
`tan(d)`	`double`	Returns the tangent of `d`

Lagrange Polynomial:

A Lagrange polynomial of order n given $n+1$ points is given by

$$P_n(x) = \sum_{k=0}^{n} L_k(x) f(x_k) \quad \text{where} \quad L_k(x) = \prod_{\substack{i=0 \\ i \neq k}}^{n} \left(\frac{x - x_i}{x_k - x_i} \right)$$

Correlation Coefficient:

$$r = \frac{S_{xy}}{\sqrt{S_{xx}}\sqrt{S_{yy}}} \quad \text{where} \quad S_{xy} = \sum (x - \bar{x})(y - \bar{y}), \quad S_{xx} = \sum (x - \bar{x})^2$$

$$S_{yy} = \sum (y - \bar{y})^2$$

Discrete Fourier Transform:

For N sample points, the DFT is given by

$$G[n] = \sum_{k=0}^{N-1} g[k] e^{-i \frac{2\pi}{N} nk} \quad \text{for} \quad n = 0 \quad \text{to} \quad N - 1$$

where $g[0] = g(t_0), g[1] = g(t_1), \cdots$ and so on.

Non-linear Least Squares fit:

A general problem of approximating a set of data $\{(x_i, y_i) | i = 1, 2, \cdots, m\}$ with an algebraic polynomial

$$P_n(x) = \sum_{j=0}^{m} a_j x^j$$

of degree $n < m - 1$, the coefficients $a_0,\ a_1\ , \cdots\ ,\ a_n$ that minimize the least square error can be obtained by solving the following system of equations;

$$\begin{aligned}
a_0 \sum_{i=1}^{m} x_i^0 + a_1 \sum_{i=1}^{m} x_i^1 + a_2 \sum_{i=1}^{m} x_i^2 + \cdots + a_n \sum_{i=1}^{m} x_i^n &= \sum_{i=1}^{m} y_i x_i^0 \\
a_0 \sum_{i=1}^{m} x_i^1 + a_1 \sum_{i=1}^{m} x_i^2 + a_2 \sum_{i=1}^{m} x_i^3 + \cdots + a_n \sum_{i=1}^{m} x_i^{n+1} &= \sum_{i=1}^{m} y_i x_i^1 \\
\vdots \qquad\qquad\qquad\qquad &\vdots \quad \vdots \\
a_0 \sum_{i=1}^{m} x_i^n + a_1 \sum_{i=1}^{m} x_i^{n+1} + a_2 \sum_{i=1}^{m} x_i^{n+2} + \cdots + a_n \sum_{i=1}^{m} x_i^{2n} &= \sum_{i=1}^{m} y_i x_i^n
\end{aligned}$$