THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS – 1998

FIRST SEMESTER AND SECOND SEMESTER

SCHOOL OF MINES

1.	GG	201	-	Introduction to Geology (practical paper II)
2.	GG	201	-	Introduction to Geology (Theory Paper I)
3.	GG	201	-	Physical Geology paper II practical
4.	GG	202	-	Physical Geology paper I theory
5.	GG	301	-	principles of Geology paper II practical
6.	GG	311	-	Crystallography and mineralogy (paper II practical)
7.	GG	311	-	Crystallography and mineraiogy (paper I theory)
8.	GG	312	-	Mineralogy and petrology Theory paper I
9.	GG	312	-	Mineralogy and petrology paper II
10	GG	322	-	Stratigraphy and remote sensing practical: paper I
11.	GG	322	-	Stratigraphy and remote sensing theory, paper I
12.	GG	331	-	Structural Geology paper I
13.	GG	331	-	Structural Geology paper II practical
14	GG	361	-	Engineering Geology (paper I theory)
15	GG	402	-	Geology of Zambia
16.	GG	411	-	Igneous petrology paper II practical
17.	GG	411	-	Igneous petrology paper I – Theory
18.	GG	412	-	Metamorphic petrology paper II practical
19.	GG	412	-	Metamorphic petrology paper I Theory
20.	GG	421	-	Sedimentology paper II practical
21.	GG	421	-	Sedimentology paper I Theory
22.	GG	431	-	Structural geology and plate Tectonics paper II practical
23.	GG	431	-	Structural geology and plate Tectonics paper I theory
24.	GG	442	-	Economic geology of metallic ore deposits paper II practical
25.	GG	442	-	Theory paper I
26.	GG	471	-	Introduction to Geo-chemistry paper II

27.	GG	472	-	Applied Geochemistry practical paper I
28.	GG	472	-	Theory paper I
29.	GG	542	-	Geology of Non - Metallic mineral deposits paper II practical
30.	GG	542	-	Geology of Non - Metallic mineral deposits paper I theory
31.	GG	551	-	Exploration, Mining geology and management (paper II practica
32.	GG	551	-	Exploration, Mining geology and management (paper I theory)
33.	GG	561	-	Engineering geology
34.	GG	572	-	Hydrogeology
35.	GG	581	-	Applied geophysics
36.	MG	319	-	Computer techniques
37.	MG	319	-	Paper 2
38.	MG	319	-	Computer techniques paper II
39.	MI	209	-	Introduction to mine development
40.	MI	315	-	Rock mechanics
41.	MI	322	-	Statistics and computer applications
42.	MI	411	-	Drilling and Blasting
43.	MI	411	-	Drilling and Blasting - Sup
44.	MI	431	-	Underground mine design
45.	MI	431	-	Underground mine design - Sup
46.	MI	435	-	Surface mine design
47.	MI	455	-	Operations Research
48.	MI	455	-	Operations Research - Sup
49.	MI	456/MM/571	-	Mineral Economics
50.	MI	465/MM/571	-	Mineral Economics management and economics
51.	MI	475	-	Mining and the Environment.
52.	MI	515	-	Rock mechanics
53.	MI	535	-	Coal mining methods
54.	MI	562	-	Investment Analysis
55.	MI	585	-	Materials handling
56.	MM	205	-	Introduction to metallurgy (practical paper)
57.	MM	205	-	Introduction to metallurgy
58.	MM	321	-	Physical metallurgy I

59.	MM	331	-	Chemical Thermodynamics paper I
60.	MM	332	-	Chemical Thermodynamics
61.	MM	411	-	Mineral processing I
62.	MM	412	-	Mineral processing II
63.	MM	415	-	Mineral processing
64.	MM	422	-	Physical metallurgy II
65.	MM	441	-	Pyrometallurgy
66.	MM	442	-	Hydrometallurgy
67.	MM	451	-	Transport phenomena
68.	MM	452	-	Process control and instrumentation
69.	MM	481	-	Ferrous metallurgy Jan
70.	MM	481	-	Ferrous metallurgy march
71.	MM	515	-	Special topics in mineral processing
72.	MM	525	-	Mechanical metallurgy
73.	MM	545	-	Special topics in extractive metallurgy
74.	MM	525	-	Mechanical metallurgy - Jan
75.	MM	552	-	Process design
76.	MM	562	-	Foundry

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

GG 201

INTRODUCTION TO GEOLOGY

(THEORY: PAPER I)

TIME: THREE (3) HOURS

INSTRUCTIONS: ANSWER QUESTION 1 AND ANY THREE (3) USING NEAT SKETCHES WHENEVER POSSIBLE.

---

1. (a) If the number of electrons in an atom is 35 and its atomic number is 80, calculate the following:
   (i) The number of protons
   (ii) The atomic number
   (iii) The number of neutrons (3 marks

   (b) Describe with examples the ionic and covalent bonds (6 marks

   (c) Why might it be difficult to identify a mineral by its colour? (2 marks

   (d) If you found a glassy-like mineral while rock hunting and had hopes that it was diamond, what simple test might help you make a determination? (1 mark)

   (e) On what basis are minerals chemically classified? (1 mark)

   (f) Distinguish between fracture and cleavage. (4 marks

   (g) When a mineral fractures, what does it imply in terms of chemical bonds? (2 marks

   (h) Give chemical formulae for the following minerals:
   (i) Galena
   (ii) Sphalerite
   (iii) Diamond
   (iv) Magnetite
   (v) Corundum
   (vi) Fluorite
   (vii) Dolomite
   (viii) Anhydrite (4 marks

   (i) What is a crystal? (2 marks

2. (a) What is a rock? Is it a compound or mixture? (1 mark)

(b) Describe the rock cycle. (3 marks)

(c) How does the rate of cooling influence the texture of an igneous rock? (2 marks)

(d) What is fractional crystallisation? (3 marks)

(e) Dinstinguish between a lava flow and sill. (4 marks)

(f) Describe the following:

(i) Dyke

(ii) Pegmatite

(iii) Obsidian

(iv) Vesicle

(v) Amygdale (10 mark)

(g) Classify the common igneous rocks according to the Bowen's reactions series. (3 marks)

3. (a) Briefly describe:

(i) Lithification

(ii) Compaction

(iii) Cementation (3 marks)

(b) Name the 3 common types of cementing material (1.5 mar

(c) Describe the following sedimentation structures and indicate what interpretations can be drawn from each:

(i) Cross-bedding

(ii) Graded bedding

(iii) Oscillation ripple marks (6 marks)

(d) Write brief notes on the following sedimentary rocks:

(i) Arkose

(ii) Pure sandstone

Comment on the maturity and length of transport of the sediment that formed the rocks in (i) and (ii). (6 marks)

(e) What is:

(i) Porosity

(ii) Permeability (4 marks)

(f) If a sediment has pore space volume of $20cm^3$ while the remaining volume is $80cm^3$ calculate its porosity. (2 marks)

(g) Give the particle size range for:
(i) Mud
(ii) Sand
(iii) Gravel (1.5 marks)

(h) What is fissility? (1 mark)

4. (a) Name and briefly describe the three types of metamorphism. (9 marks)

(b) Which metamorphic rock underlies most part of Lusaka? What are its main mineral constituent(s)? (1 mark)

Name 3 uses. (3 marks)

(c) Shale Slate Phyllite Schist Gneiss is a metamorphic rock sequence indicating an increase in metamorphic grade and what? (1 mark)

(d) What is foliation? (2 marks)

(e) What is an Aureole? (2 marks)

(f) Write brief notes on the following rocks in terms of texture and mineral composition:
(i) Gneiss of sedimentary origin
(ii) Quartzite (6 marks)

(g) Which feature would easily distinguish Schist and Gneiss from Quartzite and Marble? (1 mark)

5. (a) Define Stress and Strain. (2 marks)

(b) Distinguish between elastic and plastic deformation of materials. (4 marks)

(c) Describe Anticline and Syncline (6 marks)

(d) What is a fault? (2 marks)

(e) Dinstinguish between normal and reverse faults (4 marks)

(f) At which of the 3 types of plate boundaries does:
(i) Normal Faulting
(ii) Reverse Faulting
(iii) Strike-slip Faulting Predominate? (3 marks)

(g) What is a joint? (1 mark)

(h) A rock that is strongly jointed easily weathers both chemically and mechanically. Why? (4 marks)

(i) What is an attitude? (1 mark)

END OF EXAMINATION....GOOD LUCK!!

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

GG 201

INTRODUCTION TO GEOLOGY

(PRACTICAL: PAPER II)

TIME: THREE (3) HOURS

INSTRUCTIONS: ANSWER ALL QUESTIONS

---

1. (a) The following crystal faces have the given parameters. Determine their miller and indices.

Face	Parameters
A	1/2a, ∞b, 1/7c
B	a, 1/6b, 1/8c
C	∞a, b, ∞a
D	1/20a, 1/7b, 1/2c (4 marks)

(b) Determine elements of symmetry present on models 5,6, and 8; and classify models into systems. (12 marks)

(c) Determine the following physical properties on and name the provided mineral specimens:
Streak, Hardness, Cleavage, Fracture, Lustre Reactions to HCL 1, 2, 3 (15 marks)

(d) Identify rock specimens 4 - 6 giving the characteristic features in each case. (15 marks)

2. Bore-holes were sunk at A, B, C, which are at the same altitude above sea level and which lie at the corners of an equilateral triangle whose length of side is 6000m, C being West of B, and A North of the midway point between B and C. A coal seam was intersected at a depth of 600m in borehole A, 400m in B and 200m in C. Assume the coal seam to have a constant dip, draw a plan of the area, using a scale of 2.5cm = 1000m and determine the direction, amount of dip and strike of the coal seam. (24 marks)

2/..

3. Fig 1. shows a geological map of an area. Using this map answer and/or do the following:

(a) What evidence shows that the strata are inclined? (1 mark)

(b) Draw structure contour. (8 marks)

(c) Determine the strike, dip and dip direction (5 marks)

(d) Draw a cross section along line XY (8 marks)

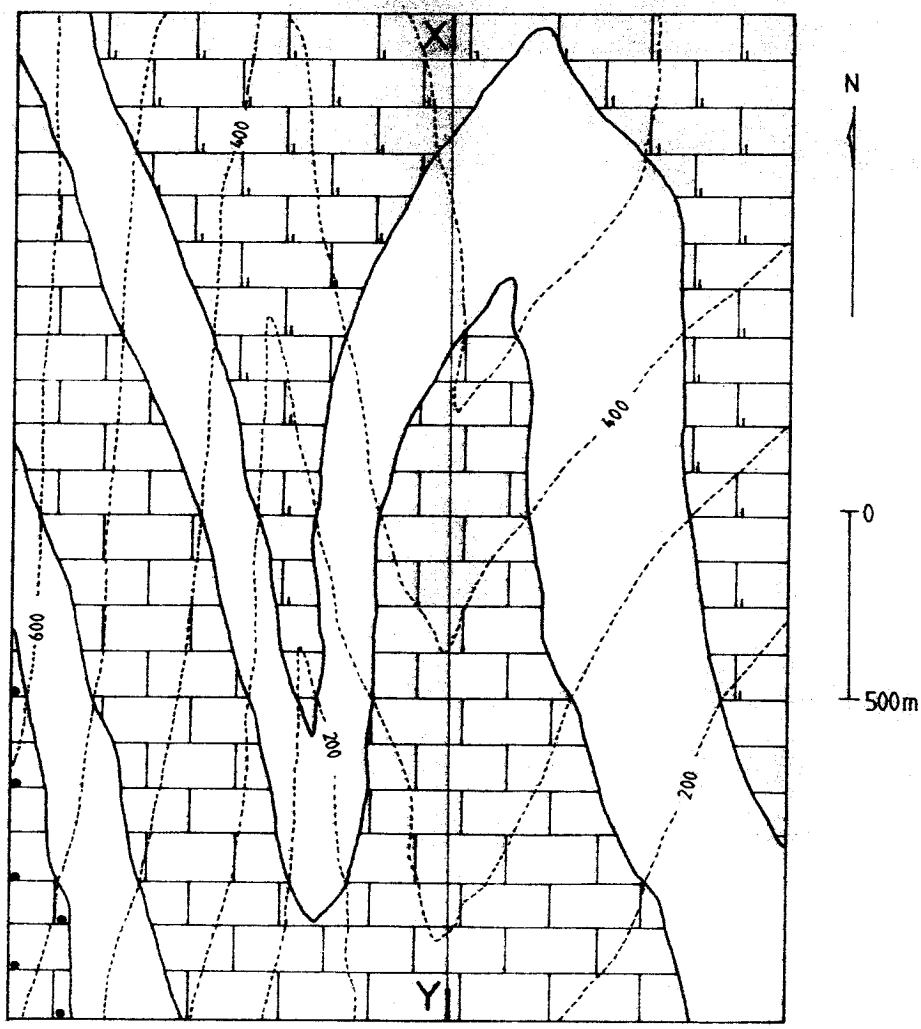
(e) Write a brief geological history (6 marks)

END OF EXAMINATION...GOOD LUCK!!

UNIVERSITY EXAMINATIONS — MARCH 1998

GG201 - INTRODUCTION TO GEOLOGY

Figure 1



THE UNIVERSITY OF ZAMBIA
UNIVERSITY EXAMINATION- AUGUST/SEPTEMBER 1998
GG202
PHYSICAL GEOLOGY
PAPER I
THEORY

TIME: Three hours

ANSWER: Five questions. All questions carry equal mark

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1 (a) What is lithification?
(b) Name and define three main processes by which sediments are transformed into rocks
(c) List any five features of sedimentary rocks
(d) How are biochemical sediments formed?

2. (a) Name the main agents of denudation and deposition
(b) Name three processes involved in Chemical weathering?
(c) Briefly describe the chemical weathering of granite and limestone
(d) What residual deposits are produced as a result of chemical weathering in humid climates?

3. (a) A block of marble has the following dimensions:

Length (L)	=	10 metres
Width (W)	=	2 metres
Height (H)	=	3 metres

A direct current is introduced into the block and flows along its length. The amount of current its length. ~~The amount of current~~ is 100 milliamps. Given that the resistivity of the marble is 5,000 ohmmeter, calculate:

(i) Resistance to the current flow
(ii) Resulting potential difference due tot current flow

(b) By completing the table below, indicate which geophysical method you would use to search for the resource shown. List where, in Zambia, the respective resource would be explored.

RESOURCE	METHOD	WHERE IN ZAMBIA EXPLORE
Disseminated sulphide		
Emerald hosted in magmatitic rocks		
Petroleum		
Geothermal water		
Borehole water specific capacities of 50 litres/sec/m		
Uranium		
Kimberlite pipes		
Artesian waters		
Salt Dome		
Coal		

4. (a) What is the difference between magma and lava?
   (b) Briefly discuss the mode of occurrence of igneous rocks
   (c) How and why do textures of extrusive and intrusive igneous rocks differ?
   (d) Name four major intrusive rocks and their extrusive equivalents

5. Describe briefly the processes which lead to the formation of the following mineral deposits:
   (a) Pegmatitic deposit of Sn and beryl
   (b) Hydrothermal deposits of Zn, Ag and Au
   (c) Sedimentary deposits of Uranium and Copper

6. (i) Give brief accounts of the following
   (a) Metamorphism and its main causative factors
   (b) Schist
   (c) Foliation

   (iii) Briefly discuss the main characteristics of contact metamorphism

END OF EXAM
GOOD LUCK!

THE UNIVERSITY OF ZAMBIA
SCHOOL OF MINES
UNIVERSITY SECOND SEMESTER EXAMINATION-AUGUST/SEPTEMBER 1998
GG 202
PHYSICAL GEOLOGY
PAPER II
PRACTICAL

TIME : Two and half hours ($2^1/_2$)
ANSWER : All questions

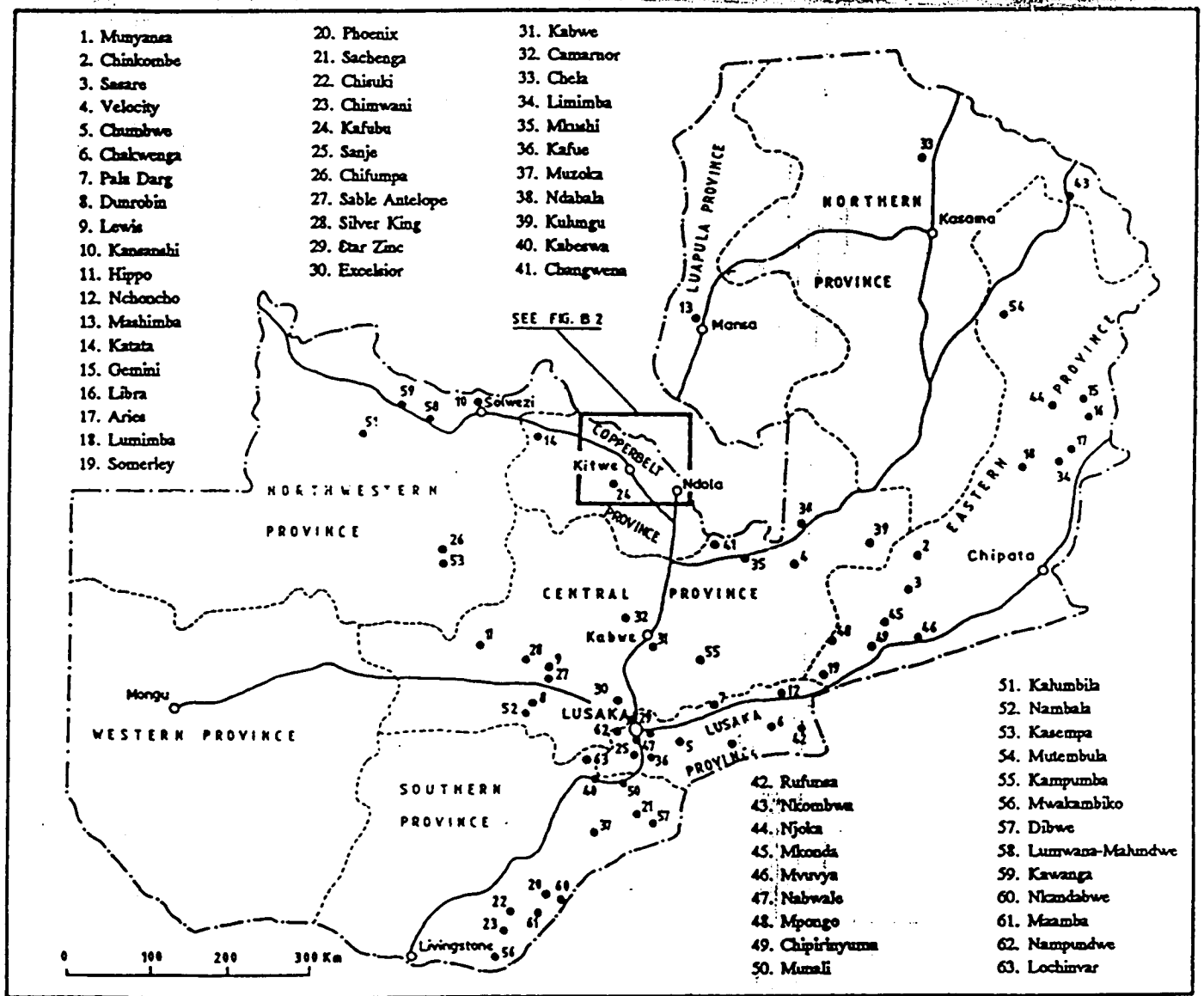
---

1. Describe the rock specimens A and B, paying special attention to their mineralogy and texture. Name the rocks.

2. Use the sketch map of Zambia and specimens A, B, C, D, E to answer the following question:

   (a) Describe briefly the properties of the specimens and identify the minerals. Name two uses of each mineral
   (b) Mark the area on the Map where the given specimens occur

END OF EXAMINATION


1. Munyanza
2. Chinkombe
3. Sasare
4. Velocity
5. Chumbwe
6. Chalwenga
7. Pala Darg
8. Dunrobin
9. Lewis
10. Kansanshi
11. Hippo
12. Nchoncho
13. Mashimba
14. Katata
15. Gemini
16. Libra
17. Aries
18. Lumimba
19. Somerley
20. Phoenix
21. Sachenga
22. Chisuki
23. Chimwani
24. Kafubu
25. Sanje
26. Chifumpa
27. Sable Antelope
28. Silver King
29. Star Zinc
30. Excelsior
31. Kabwe
32. Camarnor
33. Chela
34. Limimba
35. Mkushi
36. Kafue
37. Muzoka
38. Ndabala
39. Kulungu
40. Kaberwa
41. Changwena
42. Rufunsa
43. Nkombwa
44. Njoka
45. Mkonda
46. Mvuvya
47. Nabwale
48. Mpongo
49. Chipirinyama
50. Mumali
51. Kalumbila
52. Nambala
53. Kasempa
54. Mutembula
55. Kampumba
56. Mwakambiko
57. Dibwe
58. Lumwana-Malundwe
59. Kawanga
60. Nkandabwe
61. Mzamba
62. Nampundwe
63. Lochinvar
SEE FIG. B 2
LUAPULA PROVINCE
NORTHERN PROVINCE
Kasama
Mansa
Solwezi
Kitwe
Ndola
COPPERBELT PROVINCE
NORTHWESTERN PROVINCE
CENTRAL PROVINCE
EASTERN PROVINCE
Chipata
Kabwe
LUSAKA
LUSAKA PROVINCE
Mongu
WESTERN PROVINCE
SOUTHERN PROVINCE
Livingstone
0 100 200 300 Km

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

GG 301

PRINCIPLES OF GEOLOGY

(PAPER II: PRACTICAL)

TIME: TWO (2) HOURS

INSTRUCTIONS: ANSWER ALL QUESTIONS.

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1. A, B, C and D, A situated at the North-west, North-east, South-east and South-west corners respectively of a square of level country, the sides of which are 5km long, while E is situated exactly in the centre of the area. Boreholes at A, B and E pass through the following formations (depths in metres below surface):

	A	B	E
Base of Permian Sandstone	700	100	200
Coal - Seam	1000	700	400

Draw a plan of the area on the scale of 2.5cm = 1000m (5 marks)

(i) Determine the Strike, Dip and Dip-direction of the rocks. (5 marks)

(ii) Indicate the area underlain by the coal-seam. (5 marks)

2. Three beds crop out: Conglomerate (circles), Sandstone (stippled) and Shale (dashed).
Complete the geological boundaries between these beds, assuming that all beds have the same dip. Indicate on the map inlier and outlier. (15 marks)

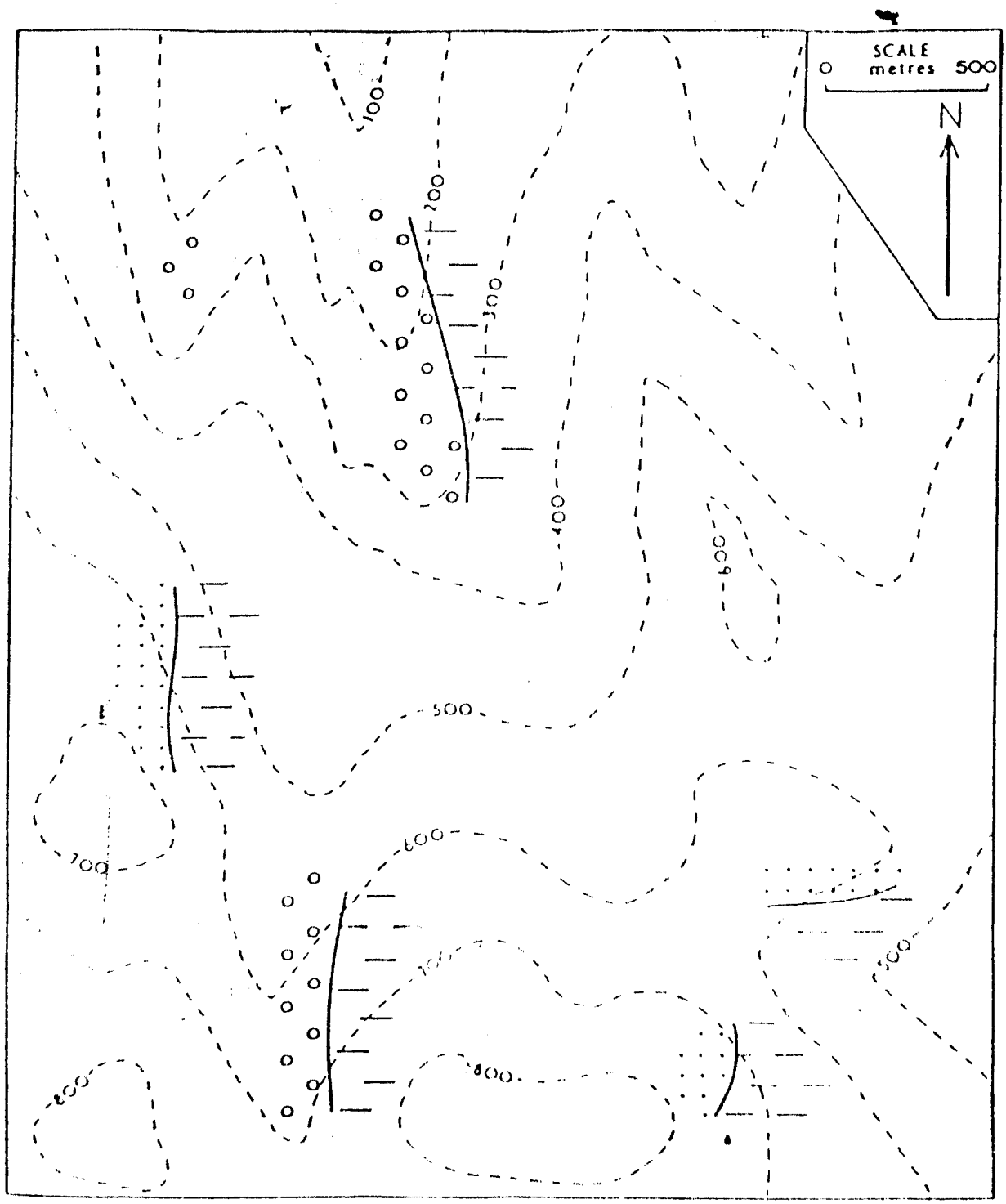
(NOTE: It may be necessary to interpolate extra contour lines and strike lines to find the complete outcrops).

END OF EXAMINATION - GOOD LUCK!!!

UNIVERSITY OF ZAMBIA EXAMINATIONS - MARCH 1998

GG301 - PRINCIPLES OF GEOLOGY

FIGURE 1: Dipping Strata



THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

GG 311

CRYSTALLOGRAPHY AND MINERALOGY

(PAPER I: THEORY)

TIME: THREE (3) HOURS

INSTRUCTIONS: ANSWER 1 AND ANY FOUR (4) OTHER QUESTIONS.

---

1. (a) Determine the chemical formula of chalcopyrite whose composition in weight % is:

	Wt.%	Atomic Wt.
Fe	29.58	55.85
Cu	35.06	63.55
S	35.41	32.06

(b) Calculate the unit cell context for chalcopyrite given that it is tetragonal with cell edges $a = 5.25\ A^{\circ}$, and $c = 10.32\ A^{\circ}$, and a specific quantity of 4.2.

2. (a) Find the indices of a face A in a zone between (011) and (110) as well as in a zone between (010) and (101).

(b) Calculate the axial ratros a:b:c for an orthorhombic crystal whose interfacial angles between (011) and (001) is 40° and that between (101) and (001) is 60°.

3. Explain the following terms from crystal optics:

(a) Extinction and extinction angle.

(b) Retardation

(c) Birefirgence

(d) Pleochroism

4. With reference to the crystal morphology of the tetragonal system, answer the following:

(a) What is the arrangement of four (4) pairs of faces related to one another by a four-fold axis called?

2/..

(b) What are the form indices of a crystal containing eight (8) faces, four at the top and four at the bottom, and what is its shape?

(c) What is the shape of a face whose pole plots at at the centre of a stereogram and how many such faces are present?

(d) How many times is a pole that plots within a representative triangle repeated and what is the crystal shape called?

5. Define the following terms:

(a) crystal

(b) cleavage

(c) chromophore

(d) translucency

(e) activator

6. With reference to the unit cell of the monoclinic system, answer the following:

(a) What is the cell shape?

(b) What is the highest symmetry possible?

(c) What is the characteristic symmetry?

(d) What are the nuteraxral angles and cell edges?

END OF EXAMINATION.

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

GG 311

CRYSTALLOGRAPHY AND MINERALOGY

(PAPER II: PRACTICAL)

TIME: THREE (3) HOURS

INSTRUCTIONS: ANSWER ALL QUESTIONS.

---

1. (a) Plot a stereogram of the crystal model provided.
   (b) Calculate the interaxial angles α β γ
   (c) Calculate the axial ratios a:b:c
   (d) To which crystal system does the model belong? (Give five reasons).

2. Determine the physical properties of the minerals A, B, and C provided, and identify them.

3. Determine the following optical properties of the mineral in the thin section provided:
   (a) optical class
   (b) optical sign
   (c) sign of elongation
   (d) extinction angle
   (e) birefrigence
   (f) pleochroism
   (g) Name the mineral

END OF EXAMINATION.

THE UNIVERSITY OF ZAMBIA
SCHOOL OF MINES
UNIVERSITY EXAMINATION-AUGUST/SEPTEMBER 1998
GG 312
MINERALOGY AND PETROLOGY
THEORY
PAPER I

TIME : Three Hours

SECTION A

ANSWER: THREE QUESTIONS ONLY

1. (a) State the general formula of the feldspars and indicate the atomic substitution that takes place.

(b) Name three diagnostic optical properties of feldspars.

(c) Describe the silicate structure of the feldspars.

(d) Name the characteristic igneous rocks for albite, oligoclase, orthoclase, and microcline.

(15%)

2. (a) Describe the silicate structure of the amphiboles.

(b) Indicate at least three cations found in the W_1, X_1, Y_1 and Z sites of amphiboles from the general formula:

$W_{0-1}\ X_2\ Y_5\ Z_8\ O_{22}\ (OH, F, Cl)_2$

(c) Which cation substitute for each other in the pyroxene structure?

(d) How does the structure of pyroxenes differ from that of amphiboles?

(15%)

3. Garnets have the general composition $X_3\ Y_2\ (S_i\ O_4)_3$.

(a) Which atomic substitution takes place extensively in garnets?

(b) Explain the variation in composition between almandine, spessartine and pyrope garnets.

(c) What is the significance of the rare garnet knorringite ($Mg_3\ Cr_2\ Si_3\ O_{12}$) and chrome-pyrope?

(d) What does olivine and the aluminum silicate minerals have in common with garnets?

(15%)

(15%)

4. (a) Describe the structure of the phyllosilicates, indicating how the tetrahedral and octahedral layers are built up.

(b) What is the difference between di-octahedral and tri-octahedral micas?

(c) Indicate the principal occurrences of muscovite philogopite and biotite in igneous and metamorphic rocks.

(15%)

SECTION B

ANSWER ALL QUESTIONS

5. (a) A granite may be pink, red or various shades of gray and may be coarse, medium, or fine grained. What characteristics are found in all granites which serve to distinguish them from other rock types?

(10%)

(b) What minerals are likely to form phenocrysts in a basalt? Why?

(5%)

6. Give brief account on the followings

(a) gneiss
(b) dyke
(c) diagnesis
(d) arkose
(e) cataclastic texture

(20%)

7. (a) What properties are common in all limestones regardless of texture? What features of limestone indicate that it is not igneous?

(10%)

(b) What are the effects of metamenphism? (5%)

(c) What is the difference between slate and quartzite? (5%)

END OF EXAM

THE UNIVERSITY OF ZAMBIA
SCHOOL OF MINES
UNIVERSITY SECOND SEMESTER EXAMINATION- AUGUST/SEPTEMBER 1998
GG 312
MINERALOGY AND PETROLOGY
PAPER II

TIME: Three hours
ANSWER: All Questions

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1. Describe the six hand specimens provided, indicating
   (a) Mineralogy
   (b) Texture
   (c) Name the rock

   30%

2. Give a full petrographic description of the three thin sections provided paying particular attention to:

   (i) optical properties of the constituents minerals 30%
   (ii) identification of the major, minor, secondary and accessory minerals 10%
   (iii) textures of the rock 21%
   (iv) Name the rock and give reasons 9%

END OF EXAM

THE UNIVERSITY OF ZAMBIA
SCHOOL OF MINES
UNIVESITY SECOND SEMESTER EXAMINATION- AUGUST/SEPTEMBER, 1998
GG 322
STRATIGRAPHY AND REMOTE SENSING

THEORY: PAPER I

TIME : Three hours
ANSWER : Any five questions. All questions carry equal marks use sketches where possible

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1. With an aid of sketches, define the following terms

   (a) Pinchout
   (b) Principle of superposition
   (c) Lithostratigraphy
   (d) Planar stratified
   (e) Transgressive

2. (a) With an aid of simple labelled diagrams outline the four types of unconformities indicating how each one could have been formed and how you can recognised it.

   (b) List the seven stratal units used in sequence stratigraphy commenting on their definition, thickness and tool resolution.

3. (a) State the Law of Facies Successions.
   (b) Using well labelled diagrams, explain Walther's Law
   (c) Distingiush between
      (i) bed and lamina
      (ii) hiatus and diastem
      (iii) biofacies and lithofacies

4. (a) Life occurred in the Pre-Cambrian as well. Outline the 5 evidence for this.

   (b) In a descending order of scale, list the formal units of time units and their corresponding time-rock units in chronostratigraphy
   (c) Trace fossils can be of environmental significance. Outline three major environmental changes with depth indicating the parameters they would affect.

5. Fill in Blanks

EON	----------	PERIOD	----------	AGE
		QUATERNARY	**RECENT**	**2.0MY**
			PLIOCENE **PALEOCENE**	
	MESOZOIC	**JURASSIC**		
		PREMIAN **CAMBRIAN**		**570/590 MY**
----------	**PROTEROZOIC**			

6. (a) Fill in the following table showing the principle methods of radiometric age determination

PARENT NUCLIDE	DAUGHTER NUCLIDE	HALF-LIFE (YEARS)	APPROXIMATE USEFUL DATING RANGE (YEARS B.P)	MATERIALS COMMONLY DATED
CARBON -14				
Protactinium-231 (Daughter nuclide of Uranium-235)				
Uranium-238	Lead-206			
Potassium-40				
Rubidium-87				

(b) Give the five purpose for which fossils are used in biostratigraphy.

END OF EXAMINATIONS

THE UNIVERSITY OF ZAMBIA
SCHOOL OF MINES
UNIVERSITY SECOND SEMESTER EXAMINATION-AUGUST/SEPTEMBER 1998
GG 322
STRATIGRAPHY AND REMOTE SENSING
PRACTICAL
PAPER II

TIME . Three Hours
ANSWER All questions

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1 (a) With an aid of a diagram, present the electromagnetic spectrum between 10^{-8} µm and 1000m emphasing the optical range. 10 Marks

(b) What name is given to the geometrical centre of the air photograph 2 Marks

2 (a) How do you obtain the scale of an air photograph 5 Marks
(b) List the five steps in image registration 5 Marks
(c) Distinguish between the following terms
(i) texture and tone 2 Marks
(ii) parallax and vertical exaggeration 2 Marks
(iii) atmospheric scattering and atmospheric absorption 2 Marks

3. You have been offered a geological mapping work by the Geological Survey of Zambia. The Survey has provided you with aerial photographs to enable you undertake a preliminary photogeological interpretation of the area. You have decided to start your work using three photographs and defining the working boundaries on the provided transparent paper.

(a) Provide a fully annotated photogeological interpretation of the central air photograph of the three photographs you have selected 45 Marks

(b) Write a brief account of the photogeological map you have produced stressing the following: 25 Marks
(i) drainage patterns
(ii) structural trends
(iii) geomorphic features
(iv) reasons for your choice of geological boundaries and lithologies

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

GG 331

STRUCTURAL GEOLOGY

PAPER I

TIME: THREE HOURS

INSTRUCTIONS: ANSWER FIVE QUESTIONS ONLY

Q1. a) Give a brief definition of the following terms:

(i) elastic deformation
(ii) critical shear stress
(iii) strain hardening simple shear

b) Briefly describe the conditions under which brittle and ductile deformation occur. In your description show typical stress-strain curves and name the characteristic types structures that are produced. (20%)

Q2. Figures 1a - c show three orientations of the principle stresses σ_1, σ_2 and σ_3. Figures 3a - c show three orientations of fault sets which formed under one of the conditions shown in figures 1a - c.

a) Indicate which fracture set corresponds to which stress orientation.

b) What type of faults are represented in Fig. 2.

c) Indicate the sense of movement for each fault plane.

d) Give an example of each fault type in Zambia. (20%)

Q3. Describe the main types of foliation and state how they are formed. (20%)

Q4. Describe the main types of lineation and state how they are formed. (20%)

Q5. Discuss the types of cleavage that can occur in deformed rocks and show how cleavage orientation can be used to distinguish an antiform from a synform. (20%)

Q6. If you are making a geological map and find on the basis of stratigraphic evidence (repeated or missing strata) that a fault is likely, what features would you look for in the field as evidence in favour of the fault that you would like to put on your map.

Consider all types of features, whether or not you can find an out crop along the fault. (20%)

Q7. There are three basic mechanisms of fold deformation.

(a) For each type, describe the mechanism by which folding takes place, the type of fold profile that is produced and the physical conditions under which each type of folding typicall occurs.

(b) Give one reason for what these simple mechanisms of folding can not be strictly applied to the majority of folds in nature. (20%)

END OF EXAMINATION

GG 331 I

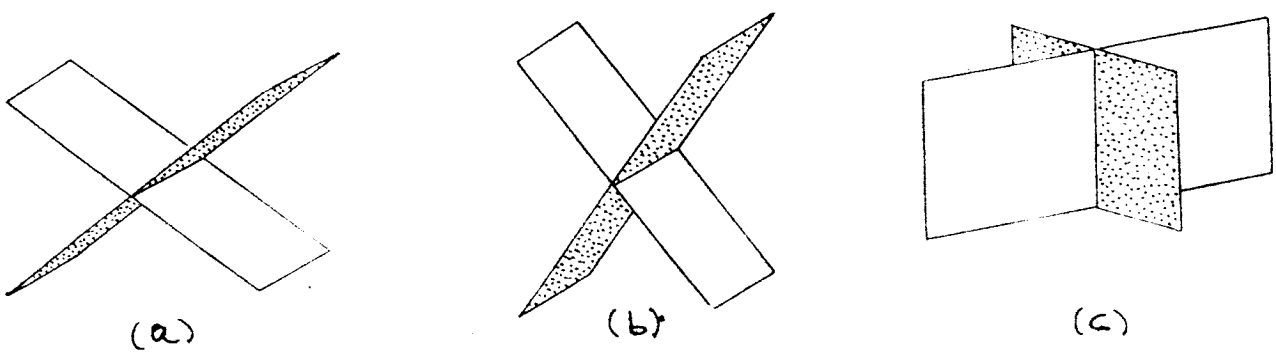


Figure 1

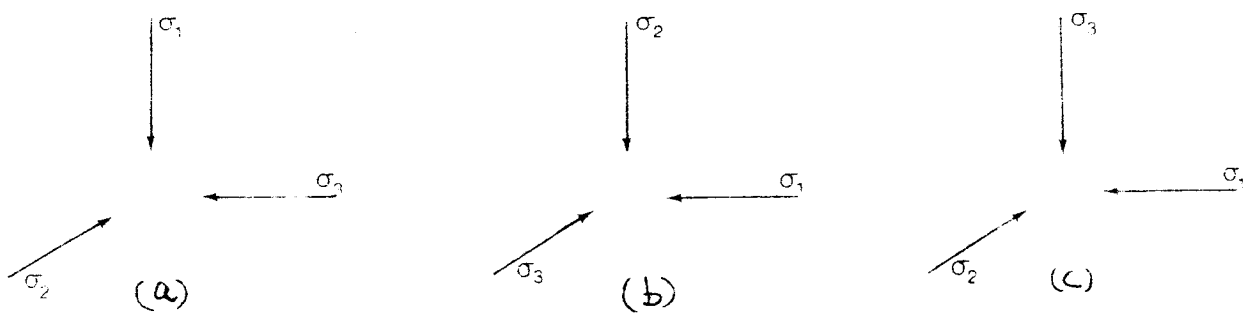


Figure 2

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

GG 331

STRUCTURAL GEOLOGY

PAPER II - PRACTICAL

TIME: THREE HOURS

INSTRUCTIONS: ANSWER ALL QUESTIONS

Study the geological map carefully giving attention to features such as:

- topography (from drainage and spot-heights)
- succession of rock formations
- run of outcrops
- 'V'-ing of outcrops across valleys
- nature of lithologies
- dip arrows
- recent sediments

Take your time to make and combine all your observations and try to form a complete geological picture. Only then start to answer the questions.

1. Outline on the map all unconformities in red and igneous contacts in blue. (5%)

2. Deduce the type of fault no. 1 and fault no. 2. Indicate, if apppropriate the upthrown (U) and downthrown (D) side on the map. (5%)

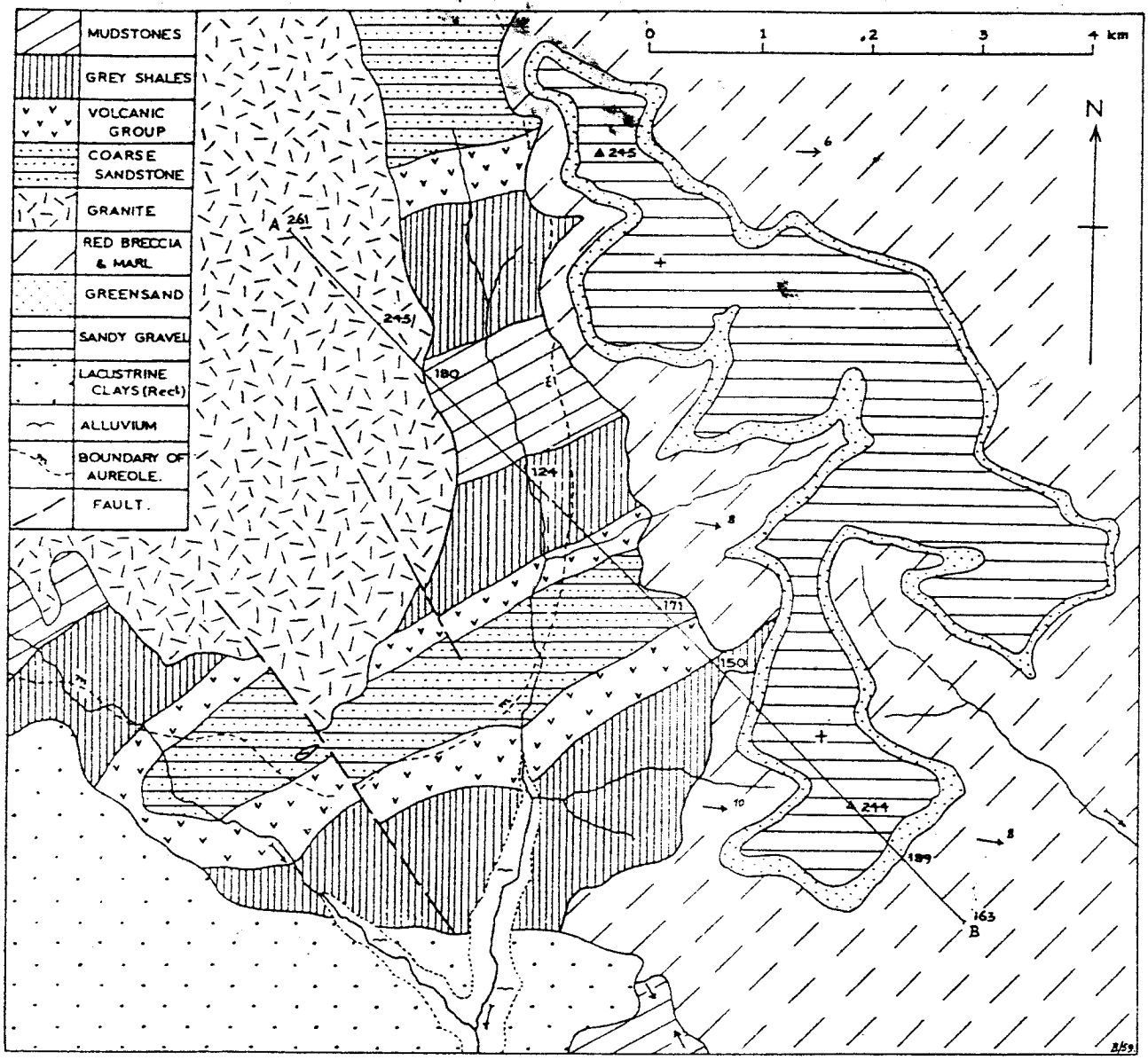
3. Add map symbols for dip/strike, fold axes and axial plane traces to indicate the structure, wherever appropriate. (5%)

4. Draw a section along AB, using the spot lights given to obtain an approximate topographic profile. (35%)

5. Write a comprehensive geological account of the map area. (Do not merely list the geological events, but give a full geological description of the area. (50%)

END OF EXAMINATION

GG 334 II Structural Geology – Practical
Paper II



THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1999

GG 361

ENGINEERING GEOLOGY

(PAPER I - THEORY)

TIME: THREE (3) HOURS

INSTRUCTIONS: ANSWER ALL QUESTIONS

1a. Illustrate, with the aid of diagrams, the terms that fit the following descriptions:

(i) A fold that opens upwards and has the youngest rocks in its core.

(ii) A line in a fold connecting points of maximum curvature

b. A block weighing 500 KN rests on a discontinuity plane with a dip of 40°. The block has a contact area of $200m^2$. If the contact surface has cohesion of $10Nm^{-2}$ and an angle of friction of 35°, determine its factor of safety. Would the plain fail in shear? Explain your answer.

2a. After deposition, sediments are acted upon by different processes to transform them into rocks. Define three main processes by which this happens.

b. Describe three factors by which igneous and sedimentary rocks are transformed into metamorphic rocks.

c. Describe the modes of occurrence of extrusive and intrusive rocks. What is the reason for the difference in textures between these two groups of rocks?

3a. Compare and contrast illite and montmorillonite.

b. Describe how the Atterberg limits vary in these two clay minerals. What is the significance of this variation on the performance of a completed engineering or building structure constructed over them?

4. After the construction of the new block of the School of Engineering, it was discovered that there was a discontinuity inclined at 30° underlying the structure. It was determined that the structure imposed a stress (σ_1) of 500 KNm^{-2}. If,

2/..

as a result of this stress, the structure also induced a horizontal stress (σ_3) of 200kNm^{-2}, determine the normal and shear stress induced on the discontinuity plane.

5a. What is the difference between a mineral and a rock?

b. List any five properties of minerals.

c. Silicate minerals constitute the major minerals of the Earth's crust. Mention eight major elements of the crust that make-up these minerals.

d. Name four groups of silicate minerals and give one mineral from each group.

END OF EXAMINATION.

THE UNIVERSITY OF ZAMBIA
SCHOOL OF MINES

UNIVERSITY EXAMINATION- AUGUST/SEPTEMBER 1998

GG 402
GEOLOGY OF ZAMBIA

TIME: Three hours
ANSWER: Any Five Questions

---

1. (a) The Archean eon is characterized by the formation of distinctive rock types which are rare or absent elsewhere in the geological record.

   (i) Name the major lithological assemblages that characterized the Archean
   (ii) Why are these rocks mainly restricted to the Archean?
   (iii) Discuss two models of Archean crustal development.

   (b) One of the most significant "chronological milestones" for Africa occurred at 2.5 Ga during which a number of igneous intrusions, among them, the Great Dyke were emplaced:
   (i) What type of magmatism and in which tectonic environment did the Great Dyke form.
   (ii) What was the significance of this process in the crustal evolution of Africa?
   (iii) Describe the main rock types found in the Great Dyke.
   (iv) What economic mineralisation is associated with the Great Dyke?
   (v) Name two other igneous complexes in southern Africa, which were formed in the same time period as the Great Dyke.

2. Some of the oldest rocks in Zambia occur in the Bangweulu craton
   (a) During which geological time period did the Bangweulu craton form?
   (b) Discuss the main stages of the magmatic evolution of the Bangweulu craton using the geochemical data given below:

Rock unit	Age (Ma)	$^{87}Sr/^{86}Sr$ initial ratio
Mambwe Granodiorite	1869±40	0.7072
Kate Granite	1838±86	0.7016
Mansa Volcanics	1833±18	0.7033
Luchewe Granite	1824±124	0.7063
Mansa Granitoids	1816±22	0.7033
Lusenga Syenite	1134± 8	0.7042
Lwakwa Granite	1108±43	0.7085
Mambwe Dolerite	709± 12	-
Songwe Syenite	671± 62	0.7058

   (c) How does the Bangweulu craton differ from a typical Archean craton?
   (d) What evidence is there to indicate that the Bangweulu cratonic block extended further than its present boundaries?

3. The Zambezi belt is an example of a Neoproterozoic intracratonic orogenic belt whose geological evolution is interpreted using either ensialic or modern day plate teconic models.

   (a) What do you understand by the terms intracratonic and ensialic?
   (b) Describe the essential features which indicate that the Zambezi belt rocks formed in a continental rift setting?
   (c) Discuss the tectonic significance of the eclogitic rocks that are found in the northern part of the Zambezi belt?
   (d) What evidence is there to suggest that the sedimentary rocks of the Zambezi belt contained some evaporite horizons?
   (e) Describe what types of mineralisation are associated with the Zambezi belt rocks?

4. (a) Briefly describe the main tectono-stratigraphic units of the Irumide belt.
   What do you understand by the terms "thin-skinned" and "thick-skinned" tectonics?
   What is the relationship between the two?
   What types of mineralisation are found in the Irumide belt and in which rocks do they occur? Where in Zambia does this mineralisation occur?

   (b) Explain why the Choma-Kalomo Block is considered to be the southward extension of the Irumide belt

5. (a) (i) Give a general stratigraphy of the mid-Zambezi Valley Basin
   (i) Outline the tectonic evolution of the Sinakumbe and Karoo depostional systems in the mid-Zambezi Valley. In your answer include the environment of deposition for each formation.

6. Discuss the formalisation for the Gwembe Coal Formation in the mid-Zambezi Valley Basin outlining the procedures used in a logical manner including major headings - such as historical background.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

GG 411

IGNEOUS PETROLOGY

THEORY - PAPER I

TIME: THREE HOURS

INSTRUCITONS: ILLUSTRATE YOUR ANSWERS WITH FIGURES, DIAGRAMS, etc. WHEREVER POSSIBLE.

SECTION A

ANSWER ALL QUESTIONS

Q1. Fig. 1 is an illustration of the binary system Albite-orthoclase (Alkali feldspar) at P_{H_2O} = 5 Kb.

a) Describe the crystallization of liquid A assuming equilibrium conditions. Pay also attention to the process taking place at temperatures below 700°C.

b) How can the resulting rock be classified assuming that a third component SiO_2 is present which produces 30 volume percent of quartz.

c) What is the effect of an increase in the lithostate pressure on the system?

d) What would be the effect of a decrease in the water pressure P_{H_2O} to 2Kb on the crystallization of liquid A and on the mineralogy of the resulting rock.

(30%)

Q2. Write short notes, with diagrams and exmples where possible, on the following:

a) Incongruent melting
b) Laccolith
c) Solvus line
d) Composite volcano
e) Ophitic texture

(25%)

SECTION B

ANSWER THREE QUESTIONS ONLY

Q3. Summarise the main characteristics of anorthosite massifs, including age occurence and discuss their petrogenesis. 15%

Q4. Define the following terms. For each, draw a phase diagram to explain the term

a) liquid immiscibility
b) incompatible minerals
c) Eutectic crystallization (15%)

Q5. Various processes can account for the diversity of magmas that may be derived from one single parent magma.

Describe these processes and indicate their relative importance. 15%

Q6. Give the sequence of layers that constitute the oceanic crust. Illustrate your answer with a cross section. Where would it be possible to study oceanic crust at the Earth's surface. (15%)

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

GG 411

IGNEOUS PETROLOGY

PAPER II - PRACTICAL

TIME: THREE HOURS

INSTRUCTIONS: ANSWER ALL QUESTIONS

Q1. The modal composition of six plutonic rocks is given below:

(a) Plot the rocks on AQP diagram
(b) Name the rocks
(c) List the main elements in them
(d) Name their volcanic equivalents (if any)

(i) Orthoclase 48%; Plagioclase (An_{26}) 39%; Quartz 3%; Augite 4%; Biotite 6%

(ii) Olivine (FO_{88}) 82%; Enstatite 11%; Diopside 7%

(iii) Quartz 30%; Oligoclase 46%; Orthoclase 8%; Plagioclase (An_4) 4%; Hornblende 8%; Biotite 4%

(iv) Labradorite 46%; Augite 32%; Pigeonite 16% Iron ore 6%

(v) Orthoclase 35%; Quartz 33%; Plagioclase (An_{22}) 24%; Biotite 4%; Hornblende 4%

(vi) Orthoclase 65%; Oligoclase 11%; Quartz 15%; Biotite 6%; Hornblende 3%

(30%)

Q2. Identify, define and discuss briefly the textures in the two thin section provided. (20%)

Q3. Thin Section A:-

(a) Describe fully all the minerals
(b) Estimate their modal percentage
(c) Classify the rock according to the IUGS system

(30%)

Q4. Thin Section B:-

(a) Identify the minerals present
(b) Describe the texture of the rock
(c) Is this a volcanic or a plutonic rock? Why?
(d) Name the rock

(20%)

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY SECOND SEMESTER EXAMINATIONS - AUGUST 1998

GG 412

METAMORPHIC PETROLOGY

PAPER I

THEORY

TIME: THREE (3) HOURS

INSTRUCTIONS: ILLUSTRATE YOUR ANSWERS WITH FIGURES, DIAGRAMS ETC WHEREVER POSSIBLE. ANSWER ANY FIVE QUESTIONS

Q1. Describe the characteristic mineral assemblages of each facies of regional metamorphism for pelitic and basic rocks, paying particular attention to those minerals which are diagnostic of each facies. Briefly discuss the geologic environments in which each facies characteristically occurs.

Q2. A metamorphic rock shows the following paragnesis:

muscovite - andalusite - sillimanite - quartz - alkali feldspar

a) To what chemical type does the rock belong?

b) Is it more likely that the rock underwent regional metamorphism? Explain your answer.

c) Draw your conclusions about the metamorphic grade.

Q3. Define and discuss briefly.

a) anatexis
b) crystallobastic series
c) metasomatism
d) staurolite zone
e) index mineral

Q4. Discuss in detail the concept of metamorphic zones using Barrovian zones of Scotland as an example.

Q5. Metamorphic rocks at two localities have the following mineral assemblages:

Locality A:	Qtz	+ enstatite	+	phlogopite		
	Qtz		+	phlogopite	+	orthoclase
Locality B:	Qtz	+ enstalite			+	orthoclase
		enstalite	+	phlogopite	+	orthoclase

a) List three possible sets of three components that can be used to describe the minerals from the two localities on an anhydrous basis.

b) Construct triangular mineral facies diagrams for each localities using one set of components listed in (a). Could these assemblages belong to the same facies? Explain your answer.

c) Which locality would have experienced the highest temperature during metamorphism and why?

Q6. The minerals enstatite (En), talc (Tc) magnesite (Mag), and quartz (Q) are related by the following reactions:

[En] $3Mag + 4Q + H_2O = Tc + 3CO_2$
[Tc] $Mag + Q = En + CO_2$
[Q] $Mag + 3Tc = 4En + H_2O + CO_2$
[Mag] $Tc = 3En + Q + H_2O$

a) Show each reaction on a separate T-X_{CO_2} diagram, labeling each curve.

b) These reactions meet at an isobaric invariant point at $X_{CO_2} = 0.9$. on the isobaric T - X_{CO_2} diagram and use Schreinemakers' rules to obtain correct arrangement of stable and unstable curves around the invariant point.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY SECOND SEMESTER EXAMINATIONS - AUGUST 1998

GG 412

METAMORPHIC PETROLOGY

PAPER II

PRACTICAL

TIME: THREE (3) HOURS

ANSWER ALL QUESTIONS

---

1. Give a complete petrographic description of thin section A. Emphasize the following:

   a) mineralogy
   b) texture
   c) metamorphic history
   d) metamorphic grade
   e) name the rock 50%

2. Thin section B

   a) Identify the minerals present
   b) Describe the texture of the rock
   c) To what chemical type does the rock belong
   d) Name the rock 30%

3. Discuss the texture of thin section C and name the rock accordingly 20%

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

GG 421

SEDIMENTOLOGY

(PAPER I - THEORY)

TIME: THREE (3) HOURS

INSTRUCTIONS: ANSWER ANY FIVE QUESTIONS. ALL QUESTIONS CARRY EQUAL MARKS. SKETCHES ARE NECESSARY FOR A FULL MARK.

---

1. (a) Outline the four main factors that control colour in siliciclastic sediments and rocks.

   (b) Distinguish between the following:

   (i) arenite and wacke

   (ii) Ooliths and peloids

   (iii) dessication cracks and syneresis cracks

   (iv) flutes and current crescents

   (v) bed and laminae

   (c) With aid of sketches, state briefly the four categories of Dunham (1962) carbonate classification.

2. (a) Draw fully labelled diagrams (with explanatory text) to explain the following:

   (i) The ideal Bouma Sequence indicating grain size, sedimentary structures and possible energy conditions.

   (ii) The various parts of a delta (a plan view and a section).

   (iii) Classification of deltas.

   (b) Outline the three broad categories of sedimentary environments indicating the sub-environments in in each.

2/..

3. (a) Describe the processes involved in the transport of sediments by water currents in rivers and streams, and deposition of sediments.

(b) With an aid of a sketch, label the main parts of the meandering river system.

(c) Outline the characteristics features of debris flow deposits.

4. (a) Outline three ways in which carbonate minerals are formed.

(b) In carbonate sedimentology, the fundamental depositiona system is the carbonate platform. Outline the characteristics features of the three general platform types.

(c) With aid of a sketch, label the main parts of a reef profile.

5. (a) Write short notes on cross-stratification and its significance.

(b) What rock types are included in the term mudrocks?

(c) (i) What is skewness?

(ii) What is its significance?

(iii) Give reasons for the type of skewness indicated in the following sands; beach sands, river sands and dune sands.

6. (a) With an aid of a diagram show the principal features of the continental margin and ocean basin.

(b) Outline the general features, conditions and processes that characterise the 3 principal features you have indicated in 6(a) above.

7a. (i) What are evaporites? Name five evaporite minerals indicating their chemical formula as well.

(ii) What characterizes evaporites?

(iii) what are the main reasons for studying evaporites?

b. Among the most common surface markings are the biogenic sedimentary structures called trace fossils. These markings are as a result of generally six types of activi by animals living on or beneath the substrate. Outline the six types of acitivity.

c. Outline briefly the sedimentary deposits found in the Ocean Basin.

END OF EXAMINATION.

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

GG 421

SEDIMENTOLOGY

(PAPER II - PRACTICAL)

TIME: THREE (3) HOURS

INSTRUCTIONS: ANSWER ALL QUESTIONS

---

1. (a) Briefly define the following terms:

(i) Lime mud (1 mark)

(ii) Textural maturity (1 mark)

(iii) Kurtosis (1 mark)

(iv) Imbrication (1 mark)

(v) Matrix as applied to siliciclastic rocks (1 mark)

(b) What name will you give to a sedimentary rock with modal grain size of 0.30mm with a composition of framework grains as follows:

Quartz	-	50%
Orthoclase	-	5%
Plagioclase	-	5%
Biotite	-	2%
Muscovite	-	3%
granite fragments	-	10%
gneiss fragments	-	25%

(15 marks

A trough cross-bedded, nearly horizontal sandstone unit of the Escarpment Grit in the mid-Zambezi Valley has the following palaeocurrent estimates at a particular station. Construct a rose diagram to represent the palaeocurrent distribution. Comment on the distribution of the palaeocurrent.

127°, 211°, 057°, 222°, 137°, 122°,
186°, 133°, 207°, 143°, 126°, 209°,
129°, 141°, 207°, 088°, 115°, 125°,
235°, 118°, 127°, 128°, 120°, 130°,

(20 marks)

..

(a) Describe the three handspecimens and corresponding thin sections, providing the full mineralogy, structures, features and provenance. (50%)

(b) Classify the rocks in 3(a) using the appropriate classification procedures and state the possible depositional environment for each rock. (10%)

END OF EXAMINATION....GOOD LUCK!!!!

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

GG 431

STRUCTURAL GEOLOGY AND PLATE TECTONICS

PAPER I

TIME: THREE HOURS

INSTRUCTIONS: ANSWER FIVE QUESTIONS. ILLUSTRATE YOUR ANSWER WITH SKETCHES WHEREVER POSSIBLE.

---

1. a) Explain the geodynamic mechanism responsible for generating the Earth's magnetic field. (12)

   b) What evidence is there for this process and how long has it been operating? (8)

2. a) Describe the composition and structure of the Earth's upper mantle. (15)

   b) Outline the type of studies used to determine its physical and chemical properties. (5)

3. a) Explain the processes responsible for the creation of new oceanic crust at mid-ocean ridges and its destruction at subduction zones. (12)

   b) What evidence exists for such processes? (8)

4. a) What is the central concept of plate tectonics?

   b) How must this concept be modified to explain the evolution of continental crust?

   c) How could you reconcile the conflicting ideas of the Uniformitarian and Non-uniformitarian Shools of Precombrian plate tectonics with regard to the Zambezi mobile belt?

5. Discuss the origin and development of divergent plate boundaries , indicating:

   (i) how rifting is initiated;
   (ii) the type of sediments that accumulate in continental environments;
   (iii) the dominant structures that develop.

6. What are the characteristic rock types, petrological-metamorphic features, and structural styles in the following plate tectonic environments:

(i) oceanic plate;
(ii) continental collision zone.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

GG 431

STRUCTURAL GEOLOGY AND PLATE TECTONICS

PAPER II - PRACTICAL

TIME: THREE HOURS

INSTRUCTIONS: ANSWER ALL QUESTIONS

---

1. Draw a cross-section A-B on the map provided at a suitable scale indicating:

   a) Orientation of major structures
   b) Extrapolation of lithological units at depth
   c) A brief geological history of the area

2. An anticline has a fold axis oriented 30/010, an east limb oriented 341/50 NE, and a west limb oriented 050/40° NW. If the east limb contains sole marks trending east;

   (a) Determine the orientation of the sedimentary lineation before folding.

   (b) What is the present orientation of the sole marks on the west limb?

3. A fault oriented 090/40°S displaces a dike oriented 330/35°E and a bed oriented 030/60°W (see Figure 2). The positions where the dike and bed are exposed are indicated on the fault.
   Determine:

   a) The azimuth of the horizontal projection of net slip.

   b) The plunge of net slip.

   c) The rake of net slip on the fault plane.

   d) The amount and relative movement direction of net slip.

END OF EXAMINATION

GG 451 Fig. 1


Scale 1:100 000
0 1 2 3 4 Km
KATANGAN
FORMATION
QUARTZ BIOTITE SCHIST – CHUNGA
UNCONFORMITY
BASEMENT COMPLEX
QUARTZITE
GARNET-MICA-KYANITE
– RUFUNSA QUARTZITE
QUARTZITE & SCHIST
UNCONFORMITY
METAVOLCANICS
– RUFUNSA VOLCANIC
UNCONFORMITY
GRANITE-GNEISS
– RUFUNSA GNEISS
INTRUSIVE ROCKS
METADOLERITE
GEOLOGICAL BOUNDARY
GEOLOGICAL BOUNDARY, INFERRED
BEDDING, STRIKE AND DIP
FOLIATION, STRIKE AND DIP
FAULT, NORMAL, WITH DOWNTHROW
FAULT, INFERRED, WITH DOWNTHROW
FAULT, TRANSCURRENT, DIRECTION OF ARROWS SHOWS SENSE OF MOVEMENT
THRUST, INFERRED (TEETH ON HANGING WALL)
N
15°15'S
15° 15'
28°52'E
A
B

THE UNIVERSITY OF ZAMBIA
SCHOOL OF MINES
UNIVERSITY SECOND SEMESTER EXAMINATION-AUGUST/SEPTEMBER 1998
GG 442
ECONOMIC GEOLOGY OF METALLIC ORE DEPOSITS
THEORY
PAPER I

TIME : Three (3) Hours

ANSWER : ANY FOUR QUESTIONS. ALL QUESTIONS CARRY EQUAL MARKS
ILLUSTRATE YOUR ANSWERS WITH SKETCHES WHEREVER POSSIBLE

1. (a) Define the following categories of ore reserves in an active mining operation:

(i) proven
(ii) probable
(iii) possible

(b) Explain the following terms:

(i) mineral resources
(ii) magmatic segregation
(iii) metallogenic province
(iv) sedimentary exhalative

2. (a) Compare and contrast between chromite deposits in layered igneous complexes and in Alpine-type ores in terms of :

(i) known age range of deposits
(ii) host rock composition and structure
(iii) morphology and orebodies
(iv) major ore minerals and associated metals
(v) main ore forming processes

(b) What other deposit types are associated with chromite deposits in layered igneous complexes and Alpine-type ores, respectively and why?

3. (a) Which ore and gangue minerals are typically found in :

(i) anorthosite massifs
(ii) Kambalda-type Ni-sulphide deposits

(b) Describe the main textural, structural and mineralogical differences between:

(i) layered anorthosites and anorthosite massifs.
(ii) Kambalda-type and Sudbury-type Cu-Ni sulphide deposits.

4. (a) With reference to the Kuroko-type massive sulphide deposit, discuss the following:

(i) ore type
(ii) economic minerals
(iii) structural and stratigraphic controls of ores
(iv) ore genesis.

(b) Indicate briefly with respect to Cyprus- and Primitive-types of massive sulphide deposits the following

(i) associated volcanic rocks
(ii) depositional environment
(iii) plate-tectonic setting.

5. (a) State three(3) deposit types of base and precious metals related to intermediate felsic intrusions.

(b) Describe the environment of formation and emplacement for porphyry copper deposits.
(c) What are the typical tonnages and grades of such porphyry copper deposits?
(d) Which hydrothermal alterations are associated with quartz-monzonite rocks of copper porphyries and what hypogene mineralisation is found within such alteration zones?

6. (a) Discuss the distribution of ore on the Copperbelt with respect to the stratigraphy of the Lower Roan rocks.

(b) What geological and isotopic evidence indicates:

(i) the source of copper and cobalt in these ores?
(ii) the time of emplacement of metals within the sediments?

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY SECOND SEMESTER EXAMINATIONS - AUGUST 1998

GG 442

PAPER II

PRACTICAL

TIME: THREE (3) HOURS

ANSWER: BOTH QUESTIONS. ILLUSTRATE YOUR ANSWERS WITH SKETCHES WHEREVER POSSIBLE

---

1. Identify the five ore specimen provided, indicating the following:

   (i) mineralogy
   (ii) structure
   (iii) type of ore deposit.

2. Determine the ore minerals in the three (3) polished secti provided, indicating:

   (i) diagnostic optical properties,
   (ii) the texture of the ore minerals,
   (iii) the structure of the ore,
   (iv) the paragenesis of the ore minerals in each secti

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER FINAL EXAMINATIONS - MARCH 1998

GG 471

INTRODUCTION TO GEO-CHEMISTRY

PAPER II

TIME: THREE (3) HOURS

INSTRUCTIONS: ANSWER ALL QUESTIONS

1. (a) Describe the theoretical basis of Atomic Absorption Spectrometry (AAS).
   (b) Use a schematic diagram to explain the functions of of the main components of an AAS Spectrophotometer.

2. (a) Define the following terms:

   (i) sensitivity (ii) detection limit
   (iii) characteristic spectrum (iv) fluorescence
   (b) What information is given by the detection limit, and how does it differ from that given by the sensitivity.

3. Describe the emission process in a hollow cathode lamp.

4. List the main analytical interferences in AAS and explain how they are overcome.

5. The following blank - corrected readings were obtained for the determination of nickel in steel using nickel standards dissolved in iron solution. The determination was performed by AAS using air - acetylene flame and the 232nm line for nickel.

Ni (ppm)	1	2	4	6	8	10	12
Absorbance	0.06	0.11	0.22	0.34	0.44	0.55	0.60

(a) Find the sensitivity for nickel in iron solution.

(b) If a 1% solution of steel gave an absorbance of 0.36. What would be the concentration of nickel in this solution and hence in the steel sample as a percentage?

END OF EXAMINATION

THE UNIVERSIRY OF ZAMBIA
SCHOOL OF MINES
UNIVERSITY SECOND SEMESTER EXAMINATIONS - AUGUEST/SEPTEMBER 1998

GG 472

APPLIED GEOCHEMISTRY

THEORY: PAPER I

TIME : Three hours

INSTRUCTIONS: Answer question 1 and any other three questions.
All questions carry equal marks.
(use chemical equations, diagrams and the supplied geochemical data where ever it is necessary

---

1. Use the location map of the Zambian Copperbelt (Fig. 1) to design a geochemical environmental survey for assessing the impact of mining operations on the quality of the pedosphere and hydrosphere.

2. (a) Discuss briefly the major factors/processes which control Eh-pH of natural environments.

(b) Use the data below to construct an E-pH diagram for the system Fe-0-H at 25° C and 1 bar pressure.

Species	$\triangle G^{\circ}_f$ (K. Cal/gfw)
Fe^{2+} (aq)	-18.86
Fe^{3+}(aq)	-1.12
$Fe(OH)_{3(s)}$	-166.47
$FeS_{2(s)}$	-39.89
$H_20_{(aq)}$	-56.69
$Fe(OH)_{2(s)}$	-116.30

$Fe^{2+} \leftrightarrows Fe^{3+} + e^-$

$Fe^{3+} + 3H_20 \leftrightarrows Fe(OH)_3 + 3H^+$

$Fe^{2+} + 3H_20 \leftrightarrows Fe(OH)_3 + 3H^+ + e^-$

$Fe^{2+} + 2H_20 \leftrightarrows Fe(OH)_2 + 2H^+$

$Fe(OH)_2 + H_20 \leftrightarrows Fe(OH)_3 + H^+ + e^-$

$2H_20 \leftrightarrows 4H^+ + 0_{2(g)} + 4\ e^-$

$H_2(g) \leftrightarrows 2H^+ + 2e^-$

$\triangle G = - RT\ln K_e = -1.364 \log K$

$\triangle G^{\circ}_f = nFE^{\circ}$ F = 23.06 Kcal/Volt -gram equivalent

$$Eh = E^{\circ} + \frac{0.059}{n} \log \frac{(C)^y (D)^z}{(A)^W (B)^x}$$

(b) Discuss briefly what the various fields and lines on your diagram imply.

3. The major components of river water and sea water in an area underlain by igneous rocks is given in table 1

Parameter	Sea water (ppm)	River water (ppm)
Na^+	51,600	6.3
K^+	2,650	2.3
Ca^{2+}	1,360	15
Mg^{2+}	1720	4.1
SO_4^{2-}	3680	11.2
Cl^-	86,600	7.8
HCO_3^-	2,800	58.4
pH	8,1	7.3

Use the thermodynamic data in table 2 and the information below to answer the following questions:

(a) Calculate the ratio $[HCO_3^-]/[CO_3^{2-}]$ in sea water.

(b) Calculate the solubility product (Ksp) of magnesite ($MgCO_3$) and calcite($CaCO_3$).

(c) Calculate I.A.P for magnesite in sea water and determine if precipitation of magnesite is taking place in the sea or river.

$$\text{Log } \gamma = \frac{-AZ^2\sqrt{I}}{1+Ba_o\sqrt{I}} + bI$$

$$\text{Log } \gamma = \frac{-AZ^2\sqrt{I}}{1+Ba_o\sqrt{I}}$$

A= 0. 5085 B = 0.3273 x 10^{-8}

Ion	b	a_o
Mg^{2+}	0.20	$8x10^{-8}$
Ca^{2+}	0.165	$6x10^{-8}$
CO_3^{2-}	0.0	$5x10^{-8}$
HCO_3	0.0	4 x 10^{-8}

4. Discuss briefly the role of surficial geochemical processes in the formation of the following mineral deposits.
   (a) Bauxite deposits
   (b) Supergene enrichment deposits of copper
   (c) Sediment-hosted manganese deposit

5. Describe briefly the dispersion patterns of Pb, Zn, Cu and S which would form as a result of chemical weathering of an arkose-hosted Cu-Pb-Zn sulfide deposit (fig.2) which is exposed in a well-drained area that lies within the tropical region.

END OF EXAMINATION

Figure 1

GG 472

PAP

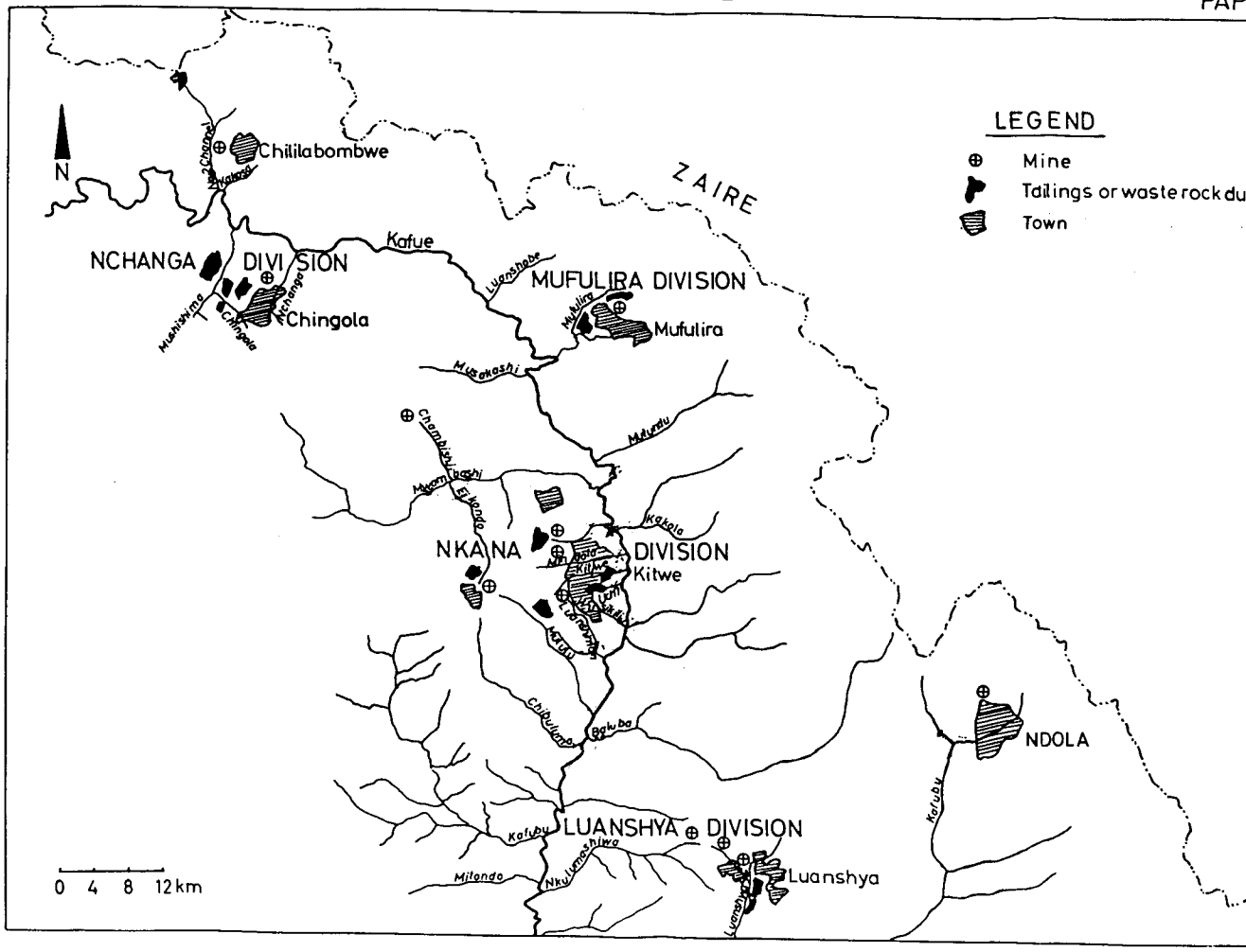


Table 2. Enthalpy and Free Energy of Formation of Species Commonly Found in Water

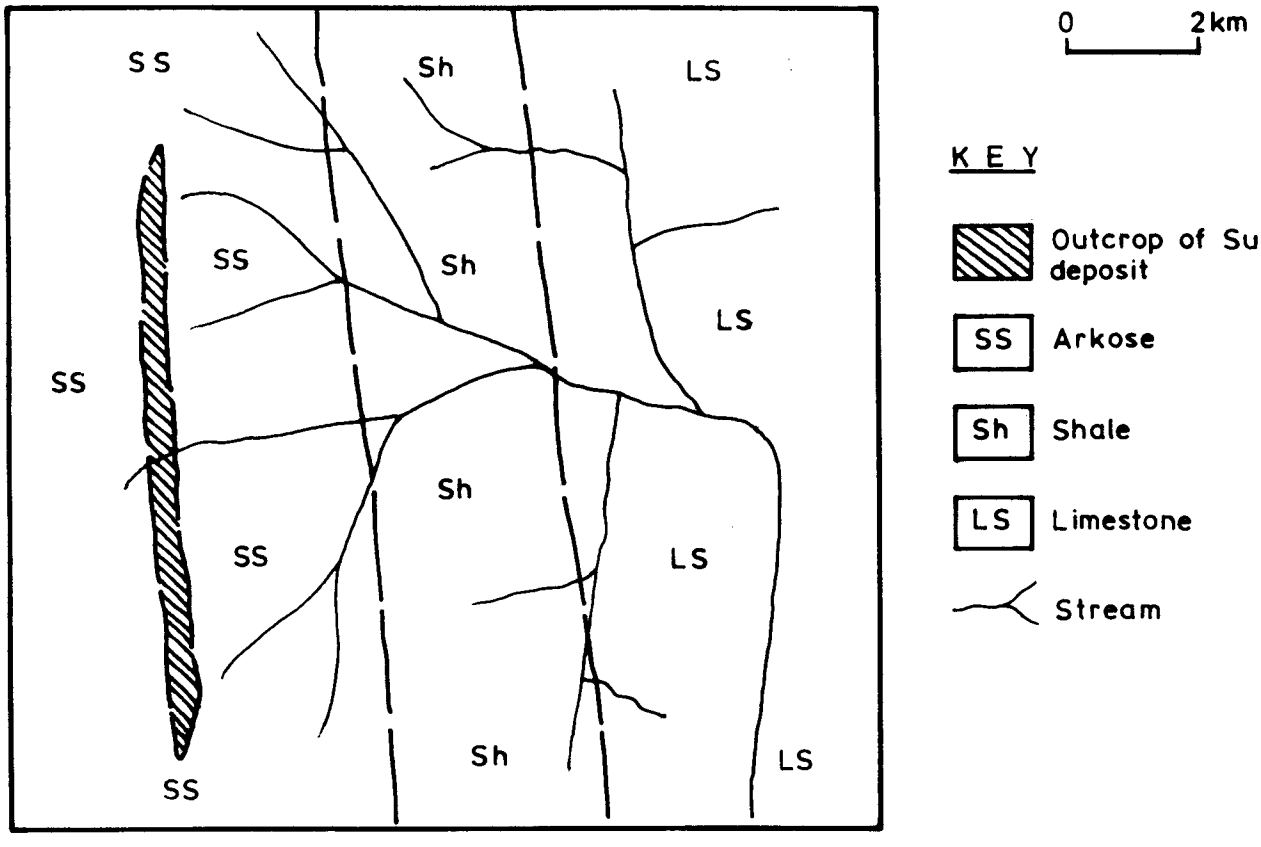
Temperature of 298.15 K (25°C)

Species and formula	Formula weight	$\Delta H°_f$ kcal/mol	$\Delta G°_f$ kcal/mol	Source[a]
Ba^{2+} (aq)	137.34	−128.50	−134.02	1
$BaSO_4$ (barite)	233.402	−352.1	−325.6	1
Ca^{2+} (aq)	40.08	−129.74	−132.30	1
$Ca(OH)_2$	74.095	−235.68	−214.76	1
CaF_2 (fluorite)	78.077	−291.5	−279.0	1
$CaSO_4$ (anhydrite)	136.142	−342.76	−315.93	1
$CaSO_4 \cdot 0.5H_2O$	145.149	−376.85	−343.41	1
$CaSO_4 \cdot 2H_2O$ (gypsum)	172.172	−483.42	−429.60	1
$CaCO_3$ (calcite)	100.089	−288.46	−269.80	1
$CaCO_3$ (aragonite)	100.089	−288.51	−269.55	1
$CaAl_2Si_2O_8$ (anorthite)	278.210	−1009.2	−955.5	1
$CaMg(CO_3)_2$ (dolomite)	184.411	−556.0	−517.1	1
$Ca_2Mg_5Si_8O_{22}(OH)_2$ (tremolite)	812.410	−2954.0	2780.0	1
CO_2 (aq)	44.0100	−98.90	−92.26	1
CH_4 (aq)	16.0430	−21.28	−8.22	1
HCO_3^- (aq)	61.0174	−165.39	−140.26	1
CO_3^{2-} (aq)	60.0094	−161.84	−126.17	1
H_2CO_3 (undissociated)	62.0253	−167.22	−148.94	1
Cl^- (aq)	35.453	−39.952	−31.372	1
F^- (aq)	18.9984	−79.50	−66.64	1
H^+ (aq)	1.0080	0	0	1
OH^- (aq)	17.0074	−54.970	−37.594	1
H_2O (liq)	18.0153	−68.315	−56.687	1
Fe^{2+} (aq)	55.847	−21.3	18.85	1
Fe^{3+} (aq)	55.847	−11.6	−1.1	1
Fe_2O_3 (hematite)	159.6922	−197.0	−177.4	1
FeOOH (goethite)	88.8538	−133.6	−117.21	1,2
$Fe(OH)_3$ (precipitated)	89.8617	−196.7	−166.5	1
FeS_2 (pyrite)	119.975	−42.6	−39.9	1
Mg^{2+} (aq)	24.312	−111.58	−108.7	1
$MgSO_4 \cdot 7H_2O$ (epsomite)	246.4810	−809.92	−686.4	1
$MgCO_3$ (magnesite)	84.3214	−261.9	−241.9	1
$Mg(OH)_2$	58.3267	−220.97	−199.23	1
Mg_2SiO_4 (forsterite)	140.7076	−519.6	−491.2	1
Mn^{2+} (aq)	54.9380	−52.76	−54.5	1
MnO_2 (pyrolusite)	86.9368	−124.29	−111.18	1
NO_3^- (aq)	62.0049	−49.56	−26.61	1
NH_4^+ (aq)	18.0386	−31.67	−18.97	1
K^+ (aq)	39.102	−60.32	−67.70	1
$KAl_2Si_3O_{10}(OH)_2$ (muscovite)	398.3133	−1430.3	−1340.5	1
SiO_2 (quartz)	60.0848	−217.72	−204.75	1
Na^+ (aq)	22.9898	−57.39	−62.593	1
$NaAlSiO_4$ (nepheline)	142.0549	−500.2	−472.8	1
Sr^{2+} (aq)	87.62	−130.45	−133.71	1
$SrSO_4$ (celestite)	183.682	−347.3	−320.5	1
$SrCO_3$ (strontianite)	147.629	−291.6	−272.5	1
SO_4^{2-} (aq)	96.0616	−217.32	−177.97	1
H_2SO_4 (aq)	98.0775	−217.32	−177.97	1
H_2S	34.08	−9.5	−6.66	1

[a] (1) Weast, 1989; (2) Hem, 1992.

Figure 2

PAPER I THEORY



THE UNIVERSITY OF ZAMBIA
SCHOOL OF MINES

UNIVERSITY EXAMINATIONS - AUGUST/SEPTEMBER 1998
GG 472
PAPER II
PRACTICAL

TIME : Three hours

INSTRUCTIONS: Answer all the questions

---

1. The approximate volumetric composition of ore formations at three copper mines are given in table 1. Use this data and appropriate chemical equations to discuss the potential for generation of acid rock drainage in mine workings and waste dumps. (25 marks)

Mineral		Volumetric Proportion	
	Mine A	Mine B	Mine C
Carbonates	45%	7%	5%
Biotite	25%	40%	-
Quartz	20%	25%	70%
Feldspar	5%	20%	5%
Sulfide (Py, Cp, Bn)	5%	7%	5%
Sericite	-	-	15%

2. The results of a reconnaissance stream sediment survey for copper are given in Figure 1. Use this data to design an appropriate sampling pattern for the follow up stage. (25 marks)

3. Use the data in Figure 2 to calculate the threshold and outline the anomalous area (50 marks)

Figure 1

PAPER II PRACTICAL

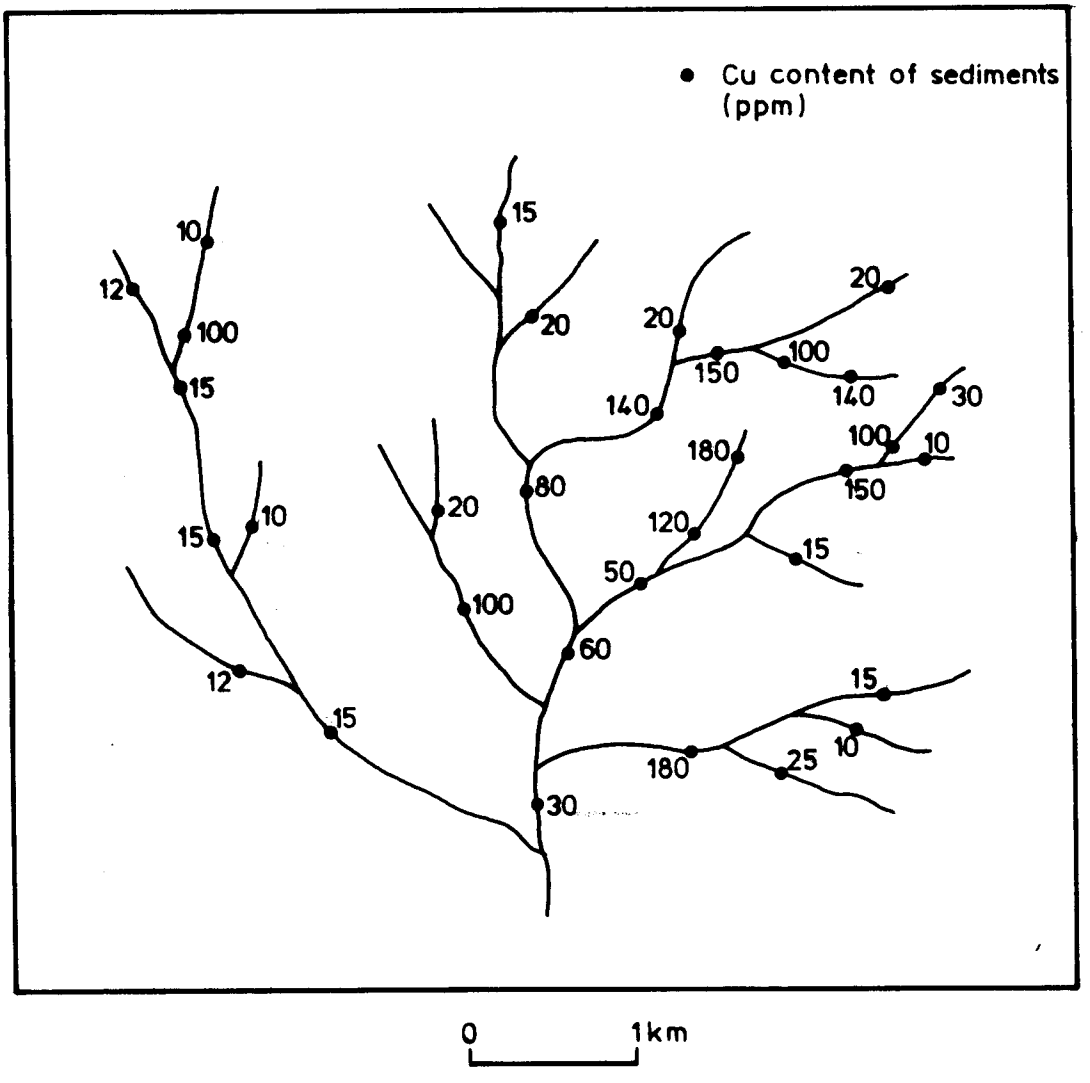
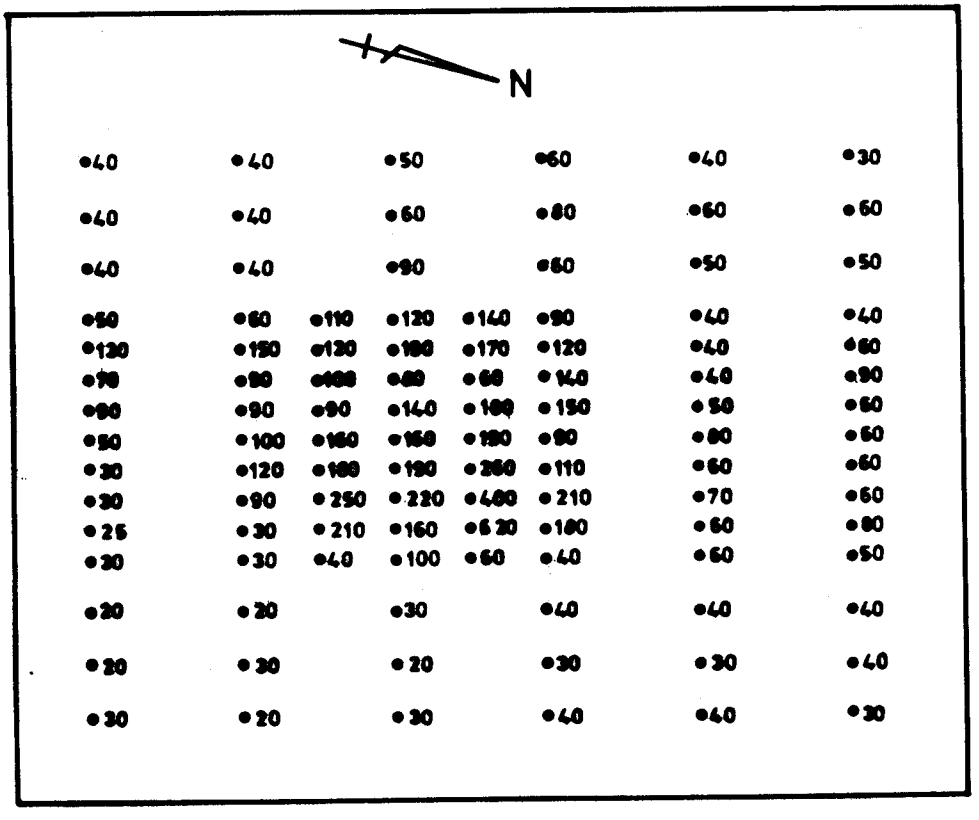


Figure 2

PAPER II PRACTICAL



300 metres

• Total Cu in - 80 mesh fraction (ppm)

THE UNIVERSITY OF ZAMBIA

UNIVERSITY SECOND SEMESTER EXAMINATIONS - AUGUST 1998

GG 542

GEOLOGY OF NON-METALLIC MINERAL DEPOSITS

PAPER I

THEORY

TIME: THREE (3) HOURS

ANSWER: QUESTION 1 AND 4 OTHERS. ALL QUESTIONS CARRY EQUAL MARKS.

---

1. Industrial minerals represent a large and hetrogenous group of rocks and mineral deposits which are worked because of various technological characteristics

   i) Discuss classification of industrial minerals by their end uses giving examples of raw materials for each group

   ii) Discuss exploration scenarios employed in the search for raw materials.

   iii) What role do industrial minerals play in national economies.

2. i) What are the constructional and bulk materials

   ii) Discuss five parameters that all these raw materials have in common

   iii) Discuss physical characteristics of rocks used as dimension stone.

3. i) Outline the raw materials and processes involved in making portland cement

   ii) What are the principal raw materials used in glass production. Discuss the role these materials play in the production process.

4. Discuss the following minerals stating their geological occurrence, economic properties and uses

   i) Feldspar
   ii) Beryl
   iii) Lepidolite

5. Assume that you have located a deposit of limestone that contains more than 95% $CaCO_3$.

   i) Detail the factors which will determine whether it is economic to open up and operate the deposit

   ii) For each of the above factors, state how you might go about evaluating them.

6. Discuss the main technological characteristics which define the quality of non-metallic minerals.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY SECOND SEMESTER EXAMINATIONS - AUGUST 1998

GG 542

GEOLOGY OF NON-METALLIC MINERAL DEPOSITS

PAPER II

PRACTICAL

TIME: THREE (3) HOURS

ANSWER: ALL QUESTIONS

Q1. A cement works requires raw materials for its factory. Three raw material mixtures A, B and C have been presented to the factory by a vendor. Using the chemical analyses given in the table below determine which of the three mixtures is best in terms of

a) Lime saturation factor
b) Silica ratio
c) Alumina ratio

Table 1 Raw material mixtures

	A	B	C
S_1O_2	12.00	21.10	12.50
Al_2O_3	5.00	7.90	3.30
Fe_2O_3	2.60	4.23	2.10
CaO	40.75	64.20	42.28
MgO	1.13	1.80	0.60
Na_2O	0.21	0.21	0.30
K_2O	0.10	0.70	0.20
S	0.63	0.40	0.50
LOI	6.09	2.50	35.60

d) Make comments on the suitability of the above raw material mixtures on the manufacture of portland cement.

Q2. Assume the Chalimbana area occupies a 400,000m^2 site on a formation 20m thick. If it were converted into a small brickworks using these clay reserves and accepting that the clay has an average density of 1600kg/m^3, that the weight of an average unfired brick is about 4kg and the annual output of the Chalimbana works is 16 million bricks.

i) What are the reserves of clay present in cubic metres

ii) How many cubic metres would be used up each year

iii) At the given rate of production, what would be the life expectancy of the given works.

Q3. Classify the resources listed below according to each of the five parameters given:

	Resource		Parameter
i)	Sand and gravel	a)	Intrinsic value
ii)	Gold	b)	Place value
iii)	Bricks	c)	Formation process of raw materials
iv)	Copper	d)	Land demand
v)	Cement	e)	Processing
vi)	Coal		
vii)	Iron		
viii)	China clay		

Q4. Outline and discuss the laboratory procedure for the evaluation of aggregate potential of carbonate rock.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

GG 551

EXPLORATION, MINING GEOLOGY AND MANAGEMENT

(PAPER I - THEORY)

TIME: THREE (3) HOURS

INSTRUCTIONS: ANSWER ALL QUESTIONS.

---

1. Given that an initial drill-core sample was 0.3m long and a diameter of 3.5m and contained 3% Zn as sphalerite (ZnS), calculate the sampling reduction error variance at 95% confidence level when:

   (a) 100g of the sample is split from the crushed sample and sent direct for assay.

   (b) the 100g samle is first pulverised to -200m mesh (<74mm) and 5g taken for analysis.

   Assume that:

   (i) sphalerite density = $4.1g/cm^3$

   (ii) host-rock density = $3.2g/m^3$

   (iii) 90% of the discharge from the crusher is -10 mesh (<1.65mm)

   (iv) the particle liberatron size to release the valuable mineral is 0.2mm.

   (v) the particle shape factor (f) = 0.5 and the particle size range (g) = 0.25.

   (vi) there is 7.5% sphalerite and 92.5% gangue in the core.

2. (a) In explaining over large areas airborne surveys have many advantages over ground surveys. Discuss these advantages and any limitations.

   (b) There are no known geophysical methods that are directly applicable to the search for bauxite, the main source of aluminium, and yet geophysical exploration is an important tool. Explain and discuss two (2) methods which may be applied indirectly.

2/..

3. Table 1 represents assay information for a drill-hole intersection of a stratiform copper deposit. The assays are sub-divided into intervals A, B and C on the basis of a strict 1% cut-off grade. Determine the potentially economic intersection given that:

(a) the minimum mining grade = 2% Cu.

(b) the minimum stoping width = 2.5m

(c) the average intersection angle = 70°.

Table 1: Sampling information from a drill-hole

Interval	A			B		C				
%Cu	1.9	3.8	1.4	0.6	0.6	1.8	2.4	3.5	4.1	3.2	1.1
IT	0.5	0.5	0.5	0.5	0.3	0.5	0.5	0.2	0.2	0.3	0.3

IT = Intersected thickness.

4. In an area that is characterised by gently rolling topography occurs, according to literature survey, a 1km wide NO45E striking ultrabasic dyke intruding the surrounding schistose quartzites. This area has been deeply chemically weathered to produce a 20m thick residual soil. The dyke is suspected to be rich in pentlandite, phyrrhotite and chacopyrite. The size of the area to be investigated is 5km x 10km. The area is located about 100km south of Lusaka.

(a) On what grounds would you recommend a detailed investigation?

(b) Describe how you would plan the investigation and travenses, if you decide to explore.

(c) Recommend and discuss exploration methods, geophysical and geochemical, most suitable for investigating the area, if you decide to explore.

END OF EXAMINATION.

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

GG 551

EXPLORATION, MINING GEOLOGY AND MANAGEMENT

(PAPER II - PRACTICAL)

TIME: THREE (3) HOURS

INSTRUCTIONS: ANSWER ALL QUESTIONS.

---

1. A ground magnetic survey was conducted in an area suspected to have a vertical magnetite - pentlandite - chalcopyrite rich cylindrical body of limited length buried at depth. This body is a vertically induced magnetisation due to a vertical geomagnetic field. The following data were collected during a survey.

STATION	1E	2E	3E	4E	0	1W	2W	3W	4W
FIELD (gamma)	32000.1	32008.2	32010.1	32011.7	32020.1	32012.1	32009.9	32007.8	32000.3

NOTE: The station interval is 10m; the scale of survey is 1:1000; the geomagnetic field for the area is 32000 gamma.

(a) Calculate the residual magnetic field.
(b) Draw a magnetic profile
(c) Estimate the thickness of the separating soil cover.

2. A block of ore has been sampled at different sections levels at sample distances of 100m. The levels are 100m apart and the grades are in per cent (%) as follows:

Level 1	2.5	2.6	2.6	2.8	2.7	1.8	1.8	1.9
Level 2	2.3	2.3	2.7	2.3	2.6	2.9	2.7	2.6
Level 3	2.6	2.2	2.8	2.2	1.5	1.3	2.3	2.1

Level 1	0.6	0.5	1.6	1.6	1.8	2.0	3.0	3.2
Level 2		1.6	1.8	2.3	2.3	2.6	3.1	1.6
Level 3		3.2	2.5	3.0	3.1	2.3	1.1	1.7
Level 1	0.6	1.0	3.2	2.5	2.3	1.6	1.7	1.8
Level 2	1.6	2.0	3.2		3.3	3.2	1.8	1.3
Level 3	3.0	3.0		2.6	4.0	1.8	2.0	1.7
Level 1	1.6	1.7	3.0	3.3	1.6	1.8	1.0	1.8
Level 2	1.7	1.8	1.3	4.1	1.3	2.0		
Level 3	1.8	1.3	2.8	4.2	1.5	3.3	1.6	1.7

(a) Calculate and plot the E - W semi-vairogram at logs 1, 2, 3, 4 and 5.

(b) What model type does the semi-vairogram represent?

(c) What method would be best suited for evaluating the orebody and why?

END OF EXAMINATION.

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

GG 561

ENGINEERING GEOLOGY

TIME: THREE HOURS

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

---

1. Mention two aims of a site investigation. Describe the various stages of a site investigation.

2. During the course of a site investigation for a new students' hostel next to Africa Hall of residence, a number of tests were performed to determine different parameters for the design of the foundation:

   (a) A soil sample of length 12 cm collected from the site was subjected to a vertical load of 30 kN. At failure, the sample experienced 1 mm and 0.5 mm changes in length and diameter, respectively. Calculate;

   (i) the sample's longitudinal and diametral strains

   (ii) the modulus of elasticity

   (iii) Poisson's ratio

   (Diameter of the sample is 4 cm).

   (b) A seismic survey was also carried at the site. Body waves had the following velocities:

   Compressional waves - 10 Km/s
   Transverse waves - 6 Km/s

   Determine the Poisson's ratio. Give two possible reasons for the difference in value with that determined in (a).

3. (a) Explain the following terms:

   Strength, strain, liquid limit, plastic limit and cohesion.

(b) A soil sample collected from the site mentioned in Question 2 gave the following results:

Grain Size (mm)	10	6	2	1	0.6	0.3	0.2	0.06
Mass retained on the sieve (grams)	0	5.5	25.7	23.1	22	17.3	12.2	6.9

The total mass of the sample was 115.5 grams.

Determine:

(i) the effective particle size
(ii) the Uniformity Coefficient
(iii) the percentages of clay, silt, sand and gravel. Would this soil have a relatively high or low permeability? Give a reason for your answer.

(c) The fine fraction of this soil sample was used in Atterberg limits test to determine its water holding capacity, and gave the following results:

Number of blows	6	8	12	26	28	31
% Water Content	55.6	52.8	48.3	39.6	38.8	38

Determine:

(i) the liquid limit of this soil
(ii) the plastic limit if its plasticity index is 20%

4. A shear box test was eventually carried out on this soil to determine its shear strength parameters for the determination of the ultimate bearing capacity. The following results were obtained:

Normal stress (kNm^{-2})	35	70	105
Shear stress (kN^{-2})	29	58	87

If the proposed structure has been designed to transmit load to the underlying groundmass through square pad footings measuring 2 m in width cast at 1.5 m below ground surface, calculate the safe bearing capacity under each footing if a factor of safety of 1.5 has been encorporated into the structure against shear failure given that:

$$Qult\ (strip) = C * Nc + \gamma * D * Nq + \tfrac{1}{2} * B * \gamma * N\gamma$$

$$Nc\ (rect) = Nc\ \{strip\} * (1 + 0.3\ B/L)$$

$$N\gamma\ (rect) = N\gamma\ \{strip\} * (1 - 0.2\ B/L)$$

$$Nq\ (rect) = Nq\ \{strip\}$$

5. (a) Use the Mohr Circle to find the normal and shear stresses acting on each of the two planes inclined at 30° and 45° with respect to major and minor stresses of 640 kNm^{-2} and 30 kNm^{-2}, respectively.

(b) In a falling head permeameter test, the head decreased from 130 cm to 80 cm in 130 seconds. If the permeameter had a diameter of 80 mm and was 150 cm long, calculate the coefficient of permeability of the sample in m/s. (Diameter of the standpipe is 1.5 cm).

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF MINES
UNIVERSITY SECOND SEMESTER EXAMINATION - AUGUST/SEPTEMBER 1998
GG 572
HYDROGEOLOGY

TIME: Three Hours

ANSWER: Question 1 and any other four. All questions carry equal marks

1. (a) Describe how you would determine transmissivity, T, and storage coefficient, S for an aquifer given two nearby wells,

(b) Determine S and T from the following data obtained from a dewatering exercise of the Shimabala Quarry in 1981

ime nce umping arted ninutes)	2.5	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	15.0	20.0	30.0	40.0	50.0	100
rawdown n)	0.6	0.5	2.0	2.5	3.0	3.5	4.2	4.5	4.8	5.5	6.5	7.5	7.5	7.5	7.5

Pumping rate = 460188cm^3/min
Distance of observation well from pumped well = 1000 cm

2. (a) Sketch the Hydrologic cycle and explain the various components involved in the cycle

(b) Given that Lusaka receives an average of 1000 millimetres of rainfall annually. Estimate how much of this precipitation contributes to groundwater in the carbonate areas of Lusaka. Give reasons for any estimate of a parameter involved in your determination of the groundwater resources. (10 marks)

3. (a) Briefly discuss:

(i) Three types of excreta disposal systems in Lusaka (5 marks)

(ii) The suitability of Leopards Hill Cemetery as a burial site (5 marks)

(b) A Lusaka businessman intends to transform the flooded Chawama Quarry into a recreation facility. What environmental impacts would be envisaged if the plan went ahead? How would you prove such impacts ahead of the establishment of the facility? (10 marks)

4. (a) By use of Taylor Series, briefly explain how to obtain Finite Difference method of approximation

(~~10~~ 5 marks)

(b) In a numerical modelling programme such as MODFLOW, describe the following terms

(i) Model grid (3 marks)
(ii) Boundary conditions (5 marks)
(iii) Initial conditions (3 marks)
(iv) Temporal parameters (5 marks)
(v) Effective porosity (5 marks)

5. Problems in the selection for a new and suitable landfill site have beset the Lusaka Municipality. Discuss:

(i) At least two criteria that would be used to recommend a site for this purpose (10 marks)

(ii) Investigation procedure(s) that would be used to verify these criteria (10 marks)

6. (a) Describe the continuity equation, defining all terms (10 marks)

(b) The Partial Differential Equation in homogeneous, isotropic media for a steady state, is given by

$$\nabla^2 h = 0$$

(i) Write the equation in cylindrical co-ordinates (5 marks)

(ii) Give the general solution to the equation for a unidirectional flow along the x-direction.

(5 marks)

END OF EXAMINATION
GOOD LUCK!

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

GG 581

APPLIED GEOPHYSICS

TIME: THREE (3) HOURS

ANSWER: FIVE QUESTIONS. ALL QUESTIONS CARRY EQUAL MARKS.

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1. A buried geological Salt Dome gives the following residual gravity values:

x(km)	g(mgals)
0	-13.9
2	-13.7
4	-12.7
6	-11.4
8	-10.0
10	- 8.6
15	- 5.7
20	- 3.6
25	- 2.3
30	- 1.5
40	- 0.7

QUESTIONS:

(a) Determine the depth to the top of te Dome (15 marks)

(b) What is the economic significance of such a geologic structure? Explain. (5 marks)

2. (a) State Faraday's Law. (5 marks)

(b) A coil of 500 turns of area 80 sq. cm is rotated at 1200 revolutions per minute about an axis at right angles to a magnetic field of flux density 0.25 Weber per sq. metre.
Calculate the maximum e.m.f. induced in the coil.
(15 metres)

3. (a) Explain, briefly, the following phenomena indicating their importance in magnetic exploration surveys:

3.1 Paramagnetism
3.2 Diamagnetism
3.3 Ferromagnetism
3.4 Ferrimagnetism
3.5 Hysteresis (10 marks)

2/..

(b) Describe the geologic setting and the lithology of the Zambian Emerald deposits found in the Copperbelt that are used, or may be used for exploration of Emeralds using magnetic methods. (10 mark

4. (a) List any five elastic constants or moduli, explaining their usefulness in the understanding of the physical properties of the Earth. (15 mark

(b) In the derivation of Stresses acting on the six faces of a cuboid, pairs of shear stresses acting on the opposite faces of the body form couples. Assuming that the cuboid remains in equilibrium, explain how the couples are compensated for. (5 marks

5. Explain the following seismic data processing operations giving reasons why they are performed:

5.1 Stack Muting
5.2 Gain Recovery
5.3 Deconvolution (DECON) I
5.4 Velocity Analysis
5.5 Normal Moveout (NMO)
5.6 Demultiplexing
5.7 Migration
5.8 CDP Gather
5.9 Deconvolution (DECON)II
5.10 Plot (20 mark

6. (a) Describe the role of Borehole Geophysics in the exploration for Petroleum and Gas. (5 marks)

(b) Draw the principal parts of a rotary drill used in exploration for oil and gas. (5 marks)

(c) Explain how the following parameters are derived from Well Logs for oil and gas:

(i) Pore fluid Resistivity (Rw)
(ii) Comentation Factor (m)
(iii) Formation Sonic Wave Speed (Vo)
(iv) Water Saturation (S)
(v) Solid matrix density (Sm) (10 marks

END OF EXAMINATION.

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

MG 319

COMPUTER TECHNIQUES

TIME: THREE (3) HOURS

INSTRUCTIONS: ANSWER ALL QUESTIONS.

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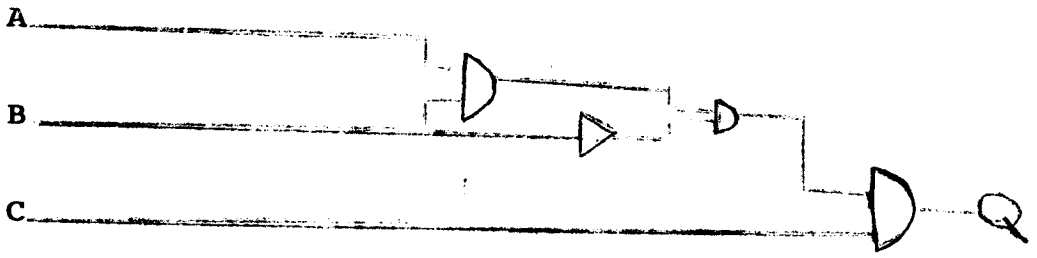
1. Is the sum of the following numbers correct? Explain?
$4E3F09_{16} + 24164422_8 = 8002257_{10}$

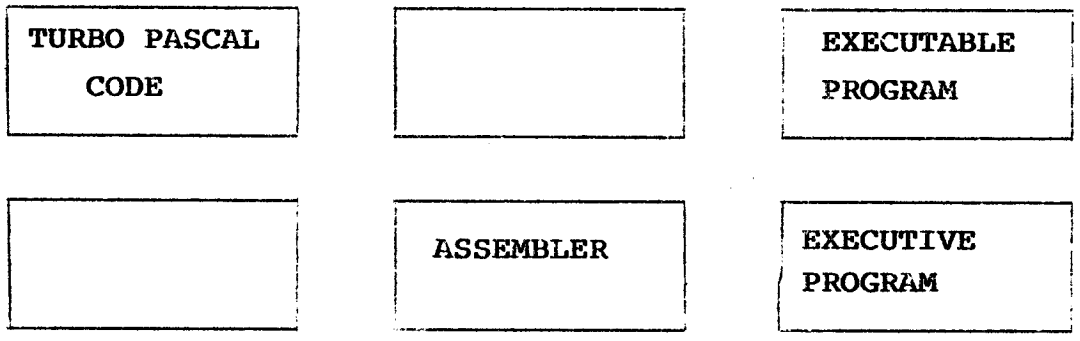
2. Compare and contrast the binary coded decimal system and the hexadecimal system. Explain why computers use the hexadecimal system, rather than the binary coded decimal system.

3. Given is the following circuit.



Make up the truth table for the circuit.

4. Complete the following diagram:



5. Define and Explain:

(a) Disk surface scan
(b) R.O.M
(c) Cold boot
(d) Megabyte
(e) F.A.T
(f) VGA Card
(g) Command.com
(h) extended memory
(i) parent directory
(j) windows clipboard

6. Upon scanning a disk for viruses:
describe all steps to be taken when the computer comes up with a message " 1 file appears to be infected with the ANTI-EXE virus."

END OF EXAMINATION.

G O O D L U C K!!

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

MG 319

(PAPER 2)

TIME: THREE (3) HOURS

INSTRUCTIONS: ANSWER ALL QUESTIONS

1. Pascal statements can be classified into SIMPLE and STRUCTURED statements.

   (a) Give three SIMPLE statements.

   (b) List seven STRUCTURED statements. [10 marks]

2. Define the following terms as applied in Pascal Programming Language.

   2.1 Standard Data Type
   2.2 Function
   2.3 Expression
   2.4 Scalar Data Type
   2.5 Structured Data Type
   2.6 Readkey Statement
   2.7 Writeln
   2.8 Write
   2.9 Standard Identifiers
   2.10 User - Defined Identifer [20 marks]

3. By means of examples illustrate the Form of Declaration, in Turbo Pascal, for the following Data types.

   3.1 Array Data Type
   3.2 Record Data Type [30 marks]

4. Prepare a Turbo Pascal Computer Program called 'Program Sum Items' to do the following:

(a) Read in "Items" which are of Real Data type;

(b) Count the Number of the Real Items by using a Counter "Count"

(c) Find the sum, "Sum", of the Items

(d) Calculate the average "Average"

(e) Print all the input data

(f) Print all the output information

NOTE: Your Program should include:

(i) An Algorith

(ii) A Flowchart

(iii) Coding

(iv) Documentation [40 marks]

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF MINES
UNIVERSITY SECOND SEMESTER EXAMINATION - AUGUST/SEPTEMBER 1998
MG 319 - COMPUTER TECHNIQUES
PAPER II

TIME: 3.5 hours
INSTRUCTIONS: Answer all questions

Write a program in Turbo Pascal to do the following:

1. Display a menu with the following choices:
   (a) Average values
   (b) Median values
   (c) Sum values
   (d) Highest value
   (e) Lowest value
   (f) Quit the program

2. After the user enters the choice (a, b, c, d, or e), the user is asked the following:

How many values do you wish to enter?

3. Store the entered integer value variable n.
4. Create a program module to make an n-sized array, and read n real values.
5. Calculate in another module the desired result ("result") according to the initial choice (a, b, c, d, or e), and display the result in a screen (e.g. if the initial menu choice was b, the result screen should say "The median value of your entered number is *result*" where *result* is the calculated median value.
6. Upon pressing any key, display the initial menu again.
7. If the choice is f on the menu, then quite the program to DOS

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY SECOND SEMESTER EXAMINATIONS SEPTEMBER, 1998

MI209 : INTRODUCTION TO MINE DEVELOPMENT

INSTRUCTIONS : ANSWER ANY 5 QUESTIONS

1. Write short notes on the following topics :
   (a) General principle of force application at the rock-bit interface for the two main types of rock drills
   (b) Drilling machines used in surface mining
   (20 Marks)

2. Underground mining methods are normally classified into three groups. Explain these groups citing one example from each group
   (20 Marks)

3. (a) Complete the table below by indicating the word/s numbered 1 to 10

Classification of Mining Methods			
Locale	Class	Subclass	Method
Surface	Mechanical	-------	3..... 4..... 5..... 6.....
Surface	Aqueous	1..... 2.....	7..... 8..... 9..... 10.....

   (b) Describe one mining method from each class
   (20 Marks)

4. The life of a mine could be divided into stages. Explain these stages clearly indicating the objective/s and general scope of work involved in each stage
   (20 Marks)

5. Explain the methods of supporting/reinforcement of underground mine excavations
   (a) Rock bolts (b) Wire mesh
   (c) Dowels (d) Grouting
   (20 Marks)

6. (a) The deleterious effects of mining on the environment could be divided into four categories. Explain these categories citing one example in each category
   (b) Explain the properties of explosives used in the mining industry
   (20 Marks)

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

MI 209

INTRODUCTION TO MINE DEVELOPMENT

TIME: 3 HOURS

INSTRUCTIONS: ANSWER ALL QUESTIONS

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1. (a) Describe the stages involved in the life of a mine. (10 marks)

   (b) Discuss the surface mining methods indicating the general criterion/criteria for each class. (10 marks)

2. (a) Explain the techniques used in prospecting. (10 marks)

   (b) State the negative impacts of mining giving one example for each category of impact. (10 marks)

3. (a) Describe the four main functional components of drilling machines. (4 marks)

   (b) State and explain briefly the properties of explosives that indicate their performance under field conditions. (16 marks)

4. (a) What are the special methods of shaft-sinking? State the circumstances under which these methods are used. State their limitations.

   (b) A shaft 6 m in diameter is to be sunk through the rock consisting of sandstone. Describe the arrangements of shotholes.

   The diagram attached shows the general arrangement and equipment for shaft sinking. Label the equipment used in this diagram and write their uses.

5. (a) Explain with the help of diagrams the supporting action of steel bolts for underground roof support. How this supporting action differs from conventionall supports?

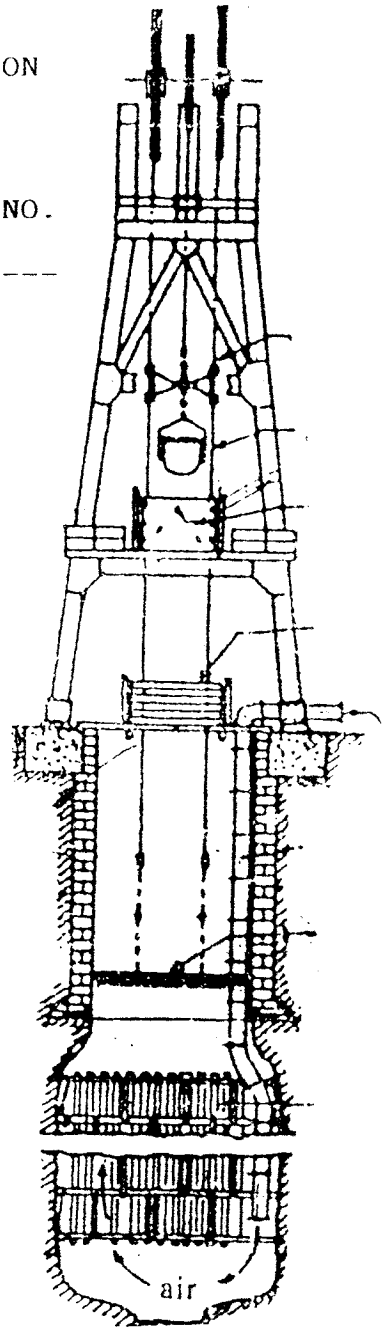
   (b) Explain with the aid of diagram method of roof stitching used in underground mining. State the advantages compared to conventional type of support.

END OF EXAMINATION

FIGURE FOR QUESTION NO. 4 (b).

STUDENT COMPUTER NO.

_____



THE UNIVERSITY OF ZAMBIA
SCHOOL OF MINES

END OF SEMESTER EXAMINATION
(Thursday 11th September, 1998)

MI 315 ROCK MECHANICS

TIME 3 HOURS
FULL MARKS: 100

INSTRUCTIONS FOR STUDENTS

- Answer question No 1 and any other five (5).
- Answers to be done in sequence.
- Neat and orderly presentation will be credited.
- Show all the steps in your calculations.

1. (a) A mining company is interested in setting up a rock Mechanics laboratory for safe and efficient operation of their both surface and underground mines.
Suggest the equipment you would like to acquire for such laboratory giving brief descriptions of the tests to be performed and the usefulness of the test.
(12 marks)

(b) Asandstone core is 70mm in diameter and 140 mm long. On saturation in water its wet weight is 21 N; after oven drying its weight is 20 N. Calculate its:
(i) Wet unit and dry unit weights. (ii) Porosity.
(ii) Express the answer for (i) in KN/m^3 AND (ii) in percentage. (8 marks)

2. (a) What are the different theories which explain failure of rock? Explain with the help of diagram the Mohr-Coulomb 'failure criterion' and the physical interpretation of equation.
$Tp = S_i + \sigma \tan \phi$
(8 marks)

(b) In a triaxial compression test on a rock sample the following values were obtained:

Test	σ_3 (MPa)	σ_1 (MPa)
1	1.0	9.0
2	5.0	28.0
3	10.0	50.0
4	15.0	75.0

Determine the value of S_i and ϕ for the best fit curve. (8 marks)

3. (a) List <u>five</u> mechanical properties of rock and explain their applications in mining. (8 marks)

(b) From the results given below, plot a graph and find value of Young's Modulus E in GN/m2. Take diameter of rock = 70 mm

Load (KN)	ε_1(Micro Units)	ε_2(Micro Units)
0	0	0
20	2700	- 244
40	4100	- 700
60	5000	- 1600
80	6500	- 2500

(8 marks)

4. (a) Show by means of a neat diagram the nine stress components acting on the face of a cube element of a rock. Explain what are the causes of these stresses. (8 marks)

(b) An adit is to be driven into granite. Determine the RMR for the values given below and comment on the description of rock. Use Brieiawski,s geomechanics Classification Table (Given).

(i) Uniaxial compressive strength of rock in which adit is driven = 80 Mpa
(ii) Drill Core Quality RQD = 60%
(iii) Joint Spacing (m) 2.5 m
(iv) Condition of joints --- Slicken sided surfaces.
(v) Ground water general condition --- water under moderate pressure.

(8 marks)

, Classification parameters and their ratings

Parameter		Ranges of values						
trength of intact ock material	point-load strength index (MPa)	>8	4–8	2–4	1–2	for this low range, uniaxial compression test is preferred		
	uniaxial compressive strength (MPa)	>200	100–200	50–100	25–50	10–25	3–10	1–3
ating		15	12	7	4	2	1	0
rill core quality *RQD* (%)		90–100	75–90	50–75	25–50	<25		
ating		20	17	13	8	3		
oint spacing (m)		>3	1–3	0.3–1	0.05–0.3	<0.05		
ating		30	25	20	10	5		
ondition of joints		very rough surfaces, not continuous, no separation, hard joint wall rock	slightly rough surfaces, separation <1 mm, hard joint wall rock	slightly rough surfaces, separation <1 mm, soft joint wall rock	slickensided surfaces or gouge <5 mm thick or joints open 1–5 mm, continuous joints	soft gouge >5 mm thick or joints open >5 mm, continuous joints		
ating		25	20	12	6	0		
oundwater	inflow per 10 m tunnel length (ℓ min^{-1}) or joint water pressure	none		<25	25–125	>125		
	major principal stress or general conditions	0		0.0–0.2	0.2–0.5	>0.5		
ting		completely dry		moist only (interstitial water)	water under moderate pressure	severe water problems		
		10		7	4	0		

5. (a) Discuss the working principle of 'Flat Jack' method for determining in-situ stress in rockmass. State advantage and limitations, if any, of this method.

(b) what will be approximate value of such stress at 1000 m depth in axial direction and in horizontal direction if unit weight (avergate) of rock 27 KN/m^3 and Possion's ratio is 0.25. Express your answer in Mpa. (8 marks)

6. (a) Discuss the factors on which the strength of pillar in case of room and pillar mining depends. How this strength can be determined?

(b) Given:

	S (Strength of Pillar)	=	20 Mpa
	Z (Depth from surface	=	500 m
	Y (Unit weight)	=	25 KN/m^3
	A (Total plan area)	=	100 m x 100 m
	α (Combined cross-sectional)	=	3,000m^2

Calculate (i) Factor of safety (F.S) of the pillar and

(ii) Extraction ratio for the above F.S (8 marks)

7. (a) Describe the basic mechanics of failure of slopes in rock. How the slope failures may be controlled? (8 marks)

(b) Calculate the safety factor and comment on the stability of the opening for the following situation.

Shape of the opening - Reactangular
Height/width ratio = 2
Stress concentrator factor for the Height/width ratio 2 = 1.7 in compression.
Type of field is Uniaxial (K = 0)
AV. Unit weight of rock = 26 KN/m^3
Depth = 1000 m
Uniaxial compressive strength of rock in which opening is made is 200 Mpa. (8 marks).

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

MI 322

STATISTICS AND COMPUTER APPLICATIONS

TIME: THREE HOURS

INSTRUCTIONS: ANSWER ALL QUESTIONS

1a. Distinguish, in TABULAR form, between *statistics* and *parameters* ***[12 points]***

1b. Give ALTERNATIVE NOMENCLATURE for the *mean of the population, frequency diagram, experimental error and hypothesis testing* ***[8 points]***

2. Mining Engineer MI322 was asked to monitor ore tonnages loaded per hour by a new EIMCO loader, in order to assess its performance. The data obtained is as recorded in the table below:

AMOUNT OF ORE (TONS/HOUR)	NUMBER RECORDED
60 – 62	5
63 – 65	18
66 – 68	42
69 – 71	27
72 – 74	8
TOTAL	**100**

2i. Plot the frequency diagram for the data ***[15 points].***

2ii. If
N = total number of observations
i = interval number
n_i = the number of observations in that interval
what is the frequency in interval number i = 4 ? ***[5 points].***

3. Consider the drill bit penetration data (in cm) in the following table:

DRILL A	DRILL B	DRILL C
66	65	68
66	66	67
68	120	66
65	65	67
67	68	66
66	67	65

3i. Compute the data in the table using analysis of variance ***[15 points].***

3ii. Is there any difference in the performance of the bits ? ***[5 points].***

4. At a mine, on the Copperbelt, management decided to investigate the performance of a supposedly advanced top-hammer drilling equipment from MI322 Hightech Company Ltd. The following data represent the measured performance y (in drilled meters/shift) of this equipment:

27.8, 24.3, 22.8, 26.0, 24.2

For these y data, calculate the variance assuming

(i) that the mean performance of this type of drilling machine is known to be $\eta = 25.0$ meters per shift.

[10 points]

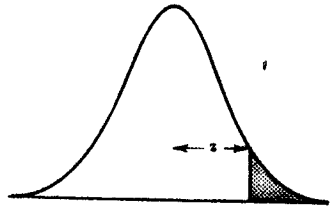
(ii) that the mean performance is unknown ***[10 points]***

5. Given the data below from a randomized paired design, calculate the t-statistic for testing the hypothesis $\delta = 0$ and the probability associated with the two-sided significance test

A	B	A	B	B	A	A	B	B	A
3	5	8	12	11	4	2	10	9	6

[20 points]

END OF EXAMINATION



ABLE A. Tail area of unit normal distribution

	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
	0.5000	0.4960	0.4920	0.4880	0.4840	0.4801	0.4761	0.4721	0.4681	0.4641
	0.4602	0.4562	0.4522	0.4483	0.4443	0.4404	0.4364	0.4325	0.4286	0.4247
	0.4207	0.4168	0.4129	0.4090	0.4052	0.4013	0.3974	0.3936	0.3897	0.3859
	0.3821	0.3783	0.3745	0.3707	0.3669	0.3632	0.3594	0.3557	0.3520	0.3483
	0.3446	0.3409	0.3372	0.3336	0.3300	0.3264	0.3228	0.3192	0.3156	0.3121
	0.3085	0.3050	0.3015	0.2981	0.2946	0.2912	0.2877	0.2843	0.2810	0.2776
	0.2743	0.2709	0.2676	0.2643	0.2611	0.2578	0.2546	0.2514	0.2483	0.2451
	0.2420	0.2389	0.2358	0.2327	0.2296	0.2266	0.2236	0.2206	0.2177	0.2148
	0.2119	0.2090	0.2061	0.2033	0.2005	0.1977	0.1949	0.1922	0.1894	0.1867
	0.1841	0.1814	0.1788	0.1762	0.1736	0.1711	0.1685	0.1660	0.1635	0.1611
	0.1587	0.1562	0.1539	0.1515	0.1492	0.1469	0.1446	0.1423	0.1401	0.1379
	0.1357	0.1335	0.1314	0.1292	0.1271	0.1251	0.1230	0.1210	0.1190	0.1170
	0.1151	0.1131	0.1112	0.1093	0.1075	0.1056	0.1038	0.1020	0.1003	0.0985
	0.0968	0.0951	0.0934	0.0918	0.0901	0.0885	0.0869	0.0853	0.0838	0.0823
	0.0808	0.0793	0.0778	0.0764	0.0749	0.0735	0.0721	0.0708	0.0694	0.0681
	0.0668	0.0655	0.0643	0.0630	0.0618	0.0606	0.0594	0.0582	0.0571	0.0559
	0.0548	0.0537	0.0526	0.0516	0.0505	0.0495	0.0485	0.0475	0.0465	0.0455
	0.0446	0.0436	0.0427	0.0418	0.0409	0.0401	0.0392	0.0384	0.0375	0.0367
	0.0359	0.0351	0.0344	0.0336	0.0329	0.0322	0.0314	0.0307	0.0301	0.0294
	0.0287	0.0281	0.0274	0.0268	0.0262	0.0256	0.0250	0.0244	0.0239	0.0233
	0.0228	0.0222	0.0217	0.0212	0.0207	0.0202	0.0197	0.0192	0.0188	0.0183
	0.0179	0.0174	0.0170	0.0166	0.0162	0.0158	0.0154	0.0150	0.0146	0.0143
	0.0139	0.0136	0.0132	0.0129	0.0125	0.0122	0.0119	0.0116	0.0113	0.0110
	0.0107	0.0104	0.0102	0.0099	0.0096	0.0094	0.0091	0.0089	0.0087	0.0084
	0.0082	0.0080	0.0078	0.0075	0.0073	0.0071	0.0069	0.0068	0.0066	0.0064
	0.0062	0.0060	0.0059	0.0057	0.0055	0.0054	0.0052	0.0051	0.0049	0.0048
	0.0047	0.0045	0.0044	0.0043	0.0041	0.0040	0.0039	0.0038	0.0037	0.0036
	0.0035	0.0034	0.0033	0.0032	0.0031	0.0030	0.0029	0.0028	0.0027	0.0026
	0.0026	0.0025	0.0024	0.0023	0.0023	0.0022	0.0021	0.0021	0.0020	0.0019
	0.0019	0.0018	0.0018	0.0017	0.0016	0.0016	0.0015	0.0015	0.0014	0.0014
	0.0013	0.0013	0.0013	0.0012	0.0012	0.0011	0.0011	0.0011	0.0010	0.0010
	0.0010	0.0009	0.0009	0.0009	0.0008	0.0008	0.0008	0.0008	0.0007	0.0007
	0.0007	0.0007	0.0006	0.0006	0.0006	0.0006	0.0006	0.0005	0.0005	0.0005
	0.0005	0.0005	0.0005	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0003
	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0002
	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
	0.0002	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

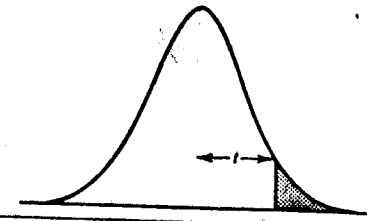


TABLE B1. Probability points of the *t* distribution with ν degrees of freedom

	tail area probability									
ν	0.4	0.25	0.1	0.05	0.025	0.01	0.005	0.0025	0.001	0.0005
1	0.325	1.000	3.078	6.314	12.706	31.821	63.657	127.32	318.31	636.62
2	0.289	0.816	1.886	2.920	4.303	6.965	9.925	14.089	22.326	31.598
3	0.277	0.765	1.638	2.353	3.182	4.541	5.841	7.453	10.213	12.924
4	0.271	0.741	1.533	2.132	2.776	3.747	4.604	5.598	7.173	8.610
5	0.267	0.727	1.476	2.015	2.571	3.365	4.032	4.773	5.893	6.869
6	0.265	0.718	1.440	1.943	2.447	3.143	3.707	4.317	5.208	5.959
7	0.263	0.711	1.415	1.895	2.365	2.998	3.499	4.029	4.785	5.408
8	0.262	0.706	1.397	1.860	2.306	2.896	3.355	3.833	4.501	5.041
9	0.261	0.703	1.383	1.833	2.262	2.821	3.250	3.690	4.297	4.781
10	0.260	0.700	1.372	1.812	2.228	2.764	3.169	3.581	4.144	4.587
11	0.260	0.697	1.363	1.796	2.201	2.718	3.106	3.497	4.025	4.437
12	0.259	0.695	1.356	1.782	2.179	2.681	3.055	3.428	3.930	4.318
13	0.259	0.694	1.350	1.771	2.160	2.650	3.012	3.372	3.852	4.221
14	0.258	0.692	1.345	1.761	2.145	2.624	2.977	3.326	3.787	4.140
15	0.258	0.691	1.341	1.753	2.131	2.602	2.947	3.286	3.733	4.073
16	0.258	0.690	1.337	1.746	2.120	2.583	2.921	3.252	3.686	4.015
17	0.257	0.689	1.333	1.740	2.110	2.567	2.898	3.222	3.646	3.965
18	0.257	0.688	1.330	1.734	2.101	2.552	2.878	3.197	3.610	3.922
19	0.257	0.688	1.328	1.729	2.093	2.539	2.861	3.174	3.579	3.883
20	0.257	0.687	1.325	1.725	2.086	2.528	2.845	3.153	3.552	3.850
21	0.257	0.686	1.323	1.721	2.080	2.518	2.831	3.135	3.527	3.819
22	0.256	0.686	1.321	1.717	2.074	2.508	2.819	3.119	3.505	3.792
23	0.256	0.685	1.319	1.714	2.069	2.500	2.807	3.104	3.485	3.767
24	0.256	0.685	1.318	1.711	2.064	2.492	2.797	3.091	3.467	3.745
25	0.256	0.684	1.316	1.708	2.060	2.485	2.787	3.078	3.450	3.725
26	0.256	0.684	1.315	1.706	2.056	2.479	2.779	3.067	3.435	3.707
27	0.256	0.684	1.314	1.703	2.052	2.473	2.771	3.057	3.421	3.690
28	0.256	0.683	1.313	1.701	2.048	2.467	2.763	3.047	3.408	3.674
29	0.256	0.683	1.311	1.699	2.045	2.462	2.756	3.038	3.396	3.659
30	0.256	0.683	1.310	1.697	2.042	2.457	2.750	3.030	3.385	3.646
40	0.255	0.681	1.303	1.684	2.021	2.423	2.704	2.971	3.307	3.551
60	0.254	0.679	1.296	1.671	2.000	2.390	2.660	2.915	3.232	3.460
120	0.254	0.677	1.289	1.658	1.980	2.358	2.617	2.860	3.160	3.373
∞	0.253	0.674	1.282	1.645	1.960	2.326	2.576	2.807	3.090	3.291

Source: Taken with permission from E. S. Pearson and H. O. Hartley (Eds.) (1958), *Biometrika Tables for Statisticians*, Vol. 1, Cambridge University Press.

Parts of the table are also taken from Table III of Fisher and Yates: *Statistical Tables for Biological, Agricultural and Medical Research*, published by Longman Group Ltd., London (previously published by Oliver and Boyd, Edinburgh), by permission of the authors and

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER FINAL EXAMINATIONS - MARCH 1998

MI 411

DRILLING AND BLASTING

TIME: THREE (3) HOURS

INSTRUCTIONS: ANSWER QUESTION 1 AS COMPULSORY, AND ANY OTHER 4 QUESTIONS, 2 FROM EACH SECTION.

COMPULSORY QUESTION

1a. (i) Using well labelled DIAGRAMS, show the drilling parameters associated with percussive and rotary drilling techniques. (5 points).

(ii) What are the respective functions of the respective drilling parameters? (5 points)

1b. A parallel - series circuit is composed of 480 short - delay electric detonators of 2.5m lead wires connected in 16 series with 30m of 23 gange connecting wire and 200m of heavy duty firing cable with resistance of 0.02Ω/m. Will a 415V dc mains supply adequate current per series if the minimum current requirement per detonator is 1.5 A dc. (10 marks).

The resistance for wires used for detonator lead (leg) wires, bus wires and connecting wire are given in tables below.

Gange	Diameter [mm]	Area [mm^2]	Minimum breaking [kg]	Maximum resistance per 1000m [Ω]
21	0.8	0.50	11	2
23	0.6	0.28	6	64
25	0.5	0.20	4.5	92

2/..

Resistance of Electric Detonators

Lead wire length [m]	Resistance: Instanteneous electric detonator [Ω]	Resistance: half second & short period delaly electric detonator [Ω]
1.8	1.0 - 2.2	1.0 - 1.9
2.5	1.1 - 2.3	1.1 - 1.9
3.6	1.4 - 2.6	1.3 - 2.2
5.0	1.8 - 2.8	1.4 - 2.3
10.0	2.5 - 3.2	1.9 - 2.8
15.0	-	2.7 - 3.5
20.0	-	3.2 - 4.2

SECTION ONE: DRILLING

2a. Mention the four main FLUSHING MEDIA for hole drilling in rock. What are the respective drilling conditions in which such flushing media are mainly applied? [10 points]

2b Complete the table below on the types of drills used in relation to rock type

ROCK TYPE	ROCK PROPERTIES	TYPES OF PERCUSSIVE EQUIPMENT USED	TYPES OF ROTARY EQUIPMENT USED
Igneous	Generally hard & massive	Designated percussive machines	Low insert rotatary machines
Metamorphic	Generally hard to very hard and even grained		
Sedimentary			

3. For nearly circular holes,

3a. show that

$$d = R[1-\text{Cos}2\{\arccos(R-D_h)/R\}]$$

where d = hole deviation
R = radius of hole curvature
D_h = hole diameter
α = some angle at the centre of hole curvature

[10 points]

3b. When viewing a reflector inside a hole from an edge of the hole, approximately how large would be the deviation before the reflector can no longer be seen?

[10 points]

3c. For a hole diameter of say, 105 mm how much would be the deviations be for hole radii of 10m, 50m and 100m respectively.

[6 points]

(4)

4 Using RESULTS of your determinations in the table below and the Figure provided, select the appropriate drilling equipment.

CONDITIONS	**CHOICE/OUTPUT**
Rock type	Limestone
Density, t/m^3	2.6
Annual production, tons	1,000,000
Annual ore production **Q**, m^3	1,000,000/2.6 = 385,000
Normal hole diameters for benching, 35 - 165 mm	102
Inclination factor **I**	1.05
Burden **V**, m	
Spacing **E**, m	
Under-drilling **U**, m	
Bench height **K**, m	
Hole depth **H**, m	
Volume per hole **M/hole**, m^3	
Hole density **a**, DM/ m^3	
Annual **DM** requirement, m	
Shifts/year	250
DM/shift	

[20 Points]

SECTION TWO: BLASTING

5. (a) Explain the three forms of Chemical transformation of explosives [12 marks]

(b) What is oxygen balance of an explosive? [2 marks]

(c) Calculate the oxygen balance of nitroglycerine of molecular formula $C_3H_5(NO_3)_3$ [3 marks]

(d) Derive the expression for the proportion of each explosive in a two-component explosive to yield zero oxygen balance [3 marks]

6. (a) Explain the sequence of events in firing electric detonators, illustrating your answer with clearly labelled diagram. [10 marks]

(b) Describe the following initiation devices indicating the principle of application and show their general construction on a clearly labelled diagram.

(i) nonel detonator [5 marks]

(ii) delay electric detonator [5 marks]

7. (a) Discuss the chain reaction sequence of blasting and illustrate your answer with a clearly labelled flow sheet [15 marks]

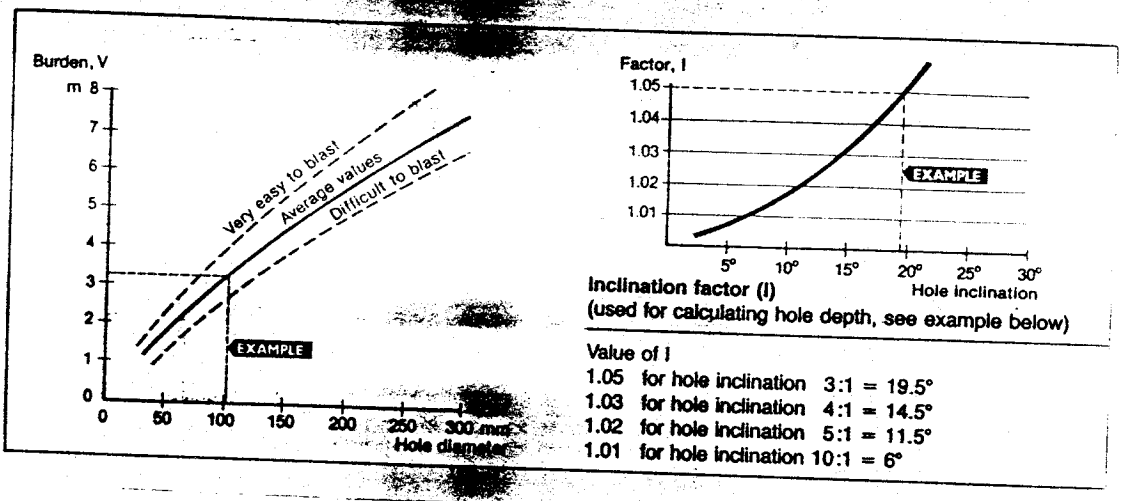
(b) State and explain the detonating properties of Explosives. [5 marks]

END OF EXAMINATION

FOR QUESTION 4

Bench drilling formulae

V	**= burden**	**DM**	**= drill metre**
E	**= spacing**	**b**	**= hole density (specific drilling)**
K	**= bench height**	**Q**	**= volume of rock**
H	**= hole depth**	**I**	**= inclination factor**
U	**= underdrilling**		

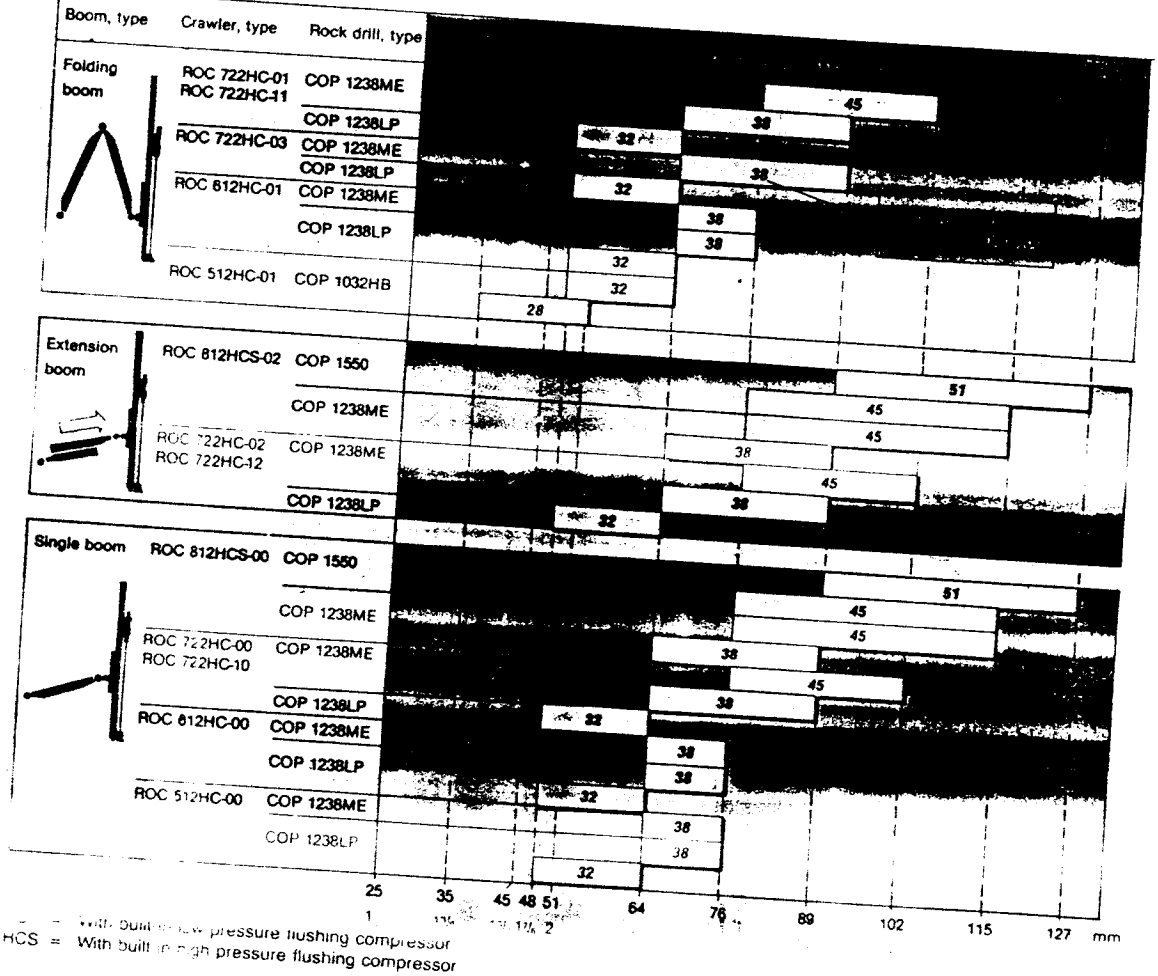


Inclination factor (I)
(used for calculating hole depth, see example below)

Value of I
- 1.05 for hole inclination 3:1 = 19.5°
- 1.03 for hole inclination 4:1 = 14.5°
- 1.02 for hole inclination 5:1 = 11.5°
- 1.01 for hole inclination 10:1 = 6°

The Atlas Copco complete range of bench drilling rigs

Hydraulic top-hammer drill rigs



HCS = With built-in high pressure flushing compressor

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATION - MARCH 1998

MI 431

UNDERGROUND MINE DESIGN

TIME: THREE (3) HOURS

INSTRUCTIONS: ANSWER QUESTION 7 AND ANY OTHER FOUR.

1. Consider a parcel of ore containing 200,000 tonnes at a grade of 3% Cu processed through a plant with a concentrator recovery of 80% and a combined smelter and refinery efficiency of 90%

   (a) What is the tonnage of recoverable copper from the ore parcel? (4 marks)

   (b) At a copper price of £1350 per tonne, what would be the value of 1 tonne of this ore? (4 marks)

   (c) Describe the schemes for estimating production capacities of underground mines? (8 marks)

   (d) The minable reserves for a given deposit has been estimated to be 3.5 million tonnes. What would be the daily capacity if the mine is operated for 250 days per year over a life of 8 years at a recovery of 94%. (4 marks)

2. List the salient factors to be considered in a mine project feasibility study. Clearly indicate the information under each factor. (20 marks)

3. Sublevel caving is a mass production underground mining method. Describe this method under the following titles:

   (a) Suitable ore body (2 marks)

   (b) Variations of the mining methods (2 marks)

   (c) Stope Development (4 marks)

   (d) Production Drilling (4 marks)

   (e) Production blasting (2 marks)

   (f) On an appropriate section show a typical layout of the mining method showing the operations. (6 marks)

4. (a) What is an ore reserve? (2 marks)

(b) Describe the methods of estimating ore reserves illustrating your answer with suitable diagrams. Clearly indicate the estimation procedure. (18 marks)

5. Explain the factors to be considered in choosing an underground hard rock mining method indicating the influence of each factor on this selection. (20 marks)

6. The following is a description of an ore deposit:

- Thickness - 20 metres
- Dip - 65°
- Footwall - hard and firm
- Hanging wall - hard and firm
- Ore zone is of medium hardness
- It's bedlike in shape with irregular contours
- Depth of cover: 400m
- Ore is of moderate to rich value
- Reserves: 4 million tonnes
- High production rate is desired.

(a) Suggest a suitable mining method, defending your choice. (10 marks)

(b) Show the typical layout of the mining method on an appropriate view. (5 marks)

(c) Describe the stoping sequence of the chosen mining method. (5 marks)

7. An ore body is mined by sublevel stoping. It has a dip of 80°, thickness of 14 metres and a specific gravity of 3. A typical panel has a length of 40 metres and height of 100 metres. The level and sublevel intervals are 80 metres and 20 metres respectively. The rib pillar width is 11 metres and the crown pillar is 20 metres thick. The cut through is developed on the footwall side.
The table below is a summary of the Development required for a panel

Development end End	Quantity	Cross-Sectional dimension [mxm]	Length in ore	Length in waste
Haulage level drive	1	4.0 x 4.0	-	40
Loading crosscuts	2	3.7 x 3.7	-	14
Coning drive	1	3.7 x 3.7	40	-
Service raises	2	1.4m diameter	-	60
Sublevel drilling drives	3(1 per sublevel	3.7 x 3.7	40	-
Slot raise	1	1.8m diameter	65	-

(i) Show the layout of the panel indicating the cut through, rib pillar, crown pillar, the sublevels, levels, crosscuts, coning drives and the draw points. (10 marks)

(ii) Calculate

(a) the gross tonnage in the panel (2 marks)

(b) the total development ore tonnes (2 marks)

(c) the net tonnage of the panel (2 marks)

(d) the specific development per tonne of fully developed reserve of a panel (2 marks)

(e) if the ring design requires drilling of holes to cover ore to the sublevel above. Calculate the tonnage produced from one ring given a ring burden of 1.2m (2 marks)

END OF EXAMINATION.

THE UNIVERSITY OF ZAMBIA

SCHOOL OF MINES

DEPARTMENT OF MINING ENGINEERING

UNIVERSITY EXAMINATION 1996/1998

MI 435 SURFACE MINE DESIGN

ANSWER: ANY FIVE (05) QUESTIONS
TIME: THREE (03) HOURS
ALL QUESTIONS CARRY EQUAL MARKS

Q1 Using corresponding sketches, write brief notes on:

(i) Stripping Ratio, and types
(ii) Cut-off grade and significance
(iii) Ultimate Pit Limits and significance
(iv) Slope angles in open pit mining
(v) Open Pit bench nomenclature
(vi) Haul road schemes to and from the working faces in open pits. (20)

Q2 (a) Write brief notes on the determination of a Mineral Inventory under the following sub-headings
(i) Definition
(ii) Objectives
(iii) Principles and Methods (5)

(b) Following average copper grades were determined from a logging exercise of cores obtained from a reconnaisance drilling campaign

	Coordinates		
Hole No.	Eastings	Northings	Grade (%Cu)
1	2200	3300	1.8
2	2500	3400	1,4
3	2300	3500	0,5
4	2600	3600	0,8
5	2100	3600	1,4
6	2500	3700	1,3
7	2300	3700	1,2
8	2600	3900	0,95
9	2100	3900	1,70
10	2400	4000	2,1

Estimate the grades at points A (2400E, 3500N) and B (2300E, 3900N) using
(i) The inverse of the distance squared method
(ii) The method of Triangles (Linear Interpolation)
(iii) Comment on the results obtained in (I) and (ii) above. (15)

Q3 (a) List and briefly discuss the main factors that govern the choice of the method of opening up a deposit in open pit mining. (10)

(b) (i) List the main elements of a capital trench and give the recommended gradients for the various haulage systems as applied in open pit mining. (10)

(ii) State and briefly describe the main elements of an open pit mine.

Q4 (a) Write and briefly comment on the application of the positive moving cone technique and its restrictions as applied in ultimate pit design. (5)

(b) The following table, gives block coordinates (i,j) and corresponding block economic values in one cross section of a regular block model.

Given that the maximum allowable slope angle on both the highwall and footwall can be represented by 1:1, determine the ultimate Pit Design giving maximm valued pit using:

(i) The positive moving cone method
(ii) The dynamic programming Algrithim.
(iii) Comment on the results obtained in (i) and (ii) above. (15)

BLOCK COORDINATES I(lEVELS)	J(cOLUMN)	BLOCK ECONOMIC VALUES
1	1	-3
1	2	-3
1	3	-3
1	4	-3
1	5	-3
1	6	-3
1	7	-3
1	8	-3
2	1	-7
2	2	+6
2	3	+6
2	4	+6
2	5	+6
2	6	+6
2	7	+6
2	8	-7
3	1	-8
3	2	-3
3	3	-3
3	4	-3

3	5	-3
3	6	-3
3	7	-3
3	8	-8
4	1	-9
4	2	-9
4	3	-9
4	4	+4
4	5	-9
4	6	-9
4	7	-9
4	8	-9

(15)

Q5 (a) With the aid of sketches and diagrams, lay down and describe the various types of stripping strategies, stating the merits and demerits of each as applied in open pit mining. (10)

(b) Given that:-

(i) Required (Target) Production----3 Blocks/period
(ii) Equipment capacity ----3 Blocks/period
(iii) Ore and Waste Blocks have the same tonnage
(iv) Blocks are to be mined complete.

Establish the possible number of mining variants applicable to the exploitation of the 2-D cross-section of an orebody given below.

Knowing that the maxim slope angle restriction on both the hanging and footwall is 1:1, indicate the amount of ore and waste excavated in each period.

-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	+8	+8	-1	-1	-1	-1	-1	-1	-1	-1	-1
-2	-2	+7	+7	-2	-2	-2	-2	-2	-2	-2	-2
-1	-1	-1	+6	+6	-1	-1	-1	-1	-1	-1	-1
-2	-2	-2	-2	+5	+5	-2	-2	-2	-2	-2	-2
-1	-1	-1	-1	-1	+4	+4	-1	-1	-1	-1	-1

Q6 (a) Write brief notes on

(i) the manual approach to Surface mine design
(ii) Computerised approach to Surface mine design. (10

(b) With the aid of corresponding sketches, explain how the problem of variable slopes is dealt with in computer aided approach to Surface mine design. (10)

Q7 (a) Give the following information:-

Maximum Selling price---- p = 4 mU/kg

Total Recovery along the production line----a = 0,75

Ore Cost----------K = 1,5 mU/T
Waste Cost ----------W = 1,8 mU/T
Ore grade variation----------d = 0,25-1,75%

(i) On the graph paper (provided) plot the stripping curves
(ii) Comment briefly on the stripping curves obtained. (10)

(b) Given the following mining situation and assuming that the cut-off grade is equivalent to Break-even grade, what metal price would justify the setting of the cut-off grade at 1,25% metal?

Mining cost/tonne-ore	=	15 mU
Treatment and all subsequent costs per tonne-ore	=	40mU
Concentrator recovery	=	85%
Smelter recovery		95%
Refinery efficiency		98%

(10)

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER SUPP/DEFFERED EXAMS - APRIL 1998

MI 455

OPERATIONS RESEARCH

TIME: THREE HOURS

ANSWER: ANSWER 5 QUESTIONS

---

1. Mine has two production shafts A. and B The production statistics for each shaft are as follows:

	Shaft A	Shaft B
Hoisting capacity, t/day	4,000	3,000
Mining output, t/manship	20	28
Haulage performance, t/unit/shift	300	190

The underground force operates on a two shifts per day basis. Production miners are restricted to 120 per day.

Haulage fleet in the mine consists of 10 units. However, since the shafts are close together, a unit can work a portion of a shift at another shaft without loss of production. Mill capacity including surface bin is limited to 5,000 tonnes per day. The profit per tonne averages $2.00 for production from Shaft A and $3.00 for output from Shaft B.

If the objective is to maximise profit find:

(i) The maximum daily profit (7 points)
(ii) The number of tonnes to mine daily from each shaft (6 points)
(iii) The best allocation of resources for each shaft (7 points)

2. Consider a project which has 8 events (even 1 = project start and event 8 = project finish). The three PERT time estimates (in days are given in the following table:

Activity	a	m	b
1,2	1	2	6
1,3	3	4	6
2,4	3	5	6
2,5	3	4	6
3,7	5	6	7
4,6	1	3	4
5,6	2	3	5
5,7	2	2	3
6,7	3	5	7
6,8	1	2	4
7,8	2	3	4

(i) Construct an arrow diagram for the project. (5 points)
(ii) Using PERT assumptions, find the mean and variance of times of each activity. (5 pints)
(iii) Define the term "Critical path" (5 points)
(iv) Find the critical path using the mean times in (i') (5 points)

3. (i) What are the characteristics that define a linear programming problem? (5 pints)
(ii) Discuss the difference between a feasible solution and an infeasible solution. (5 points)
(iii) What constitutes the solution to LP model? (5 points)
(iv) An optimal solution can be an infeasible solution under special conditions. (TRUE OR FALSE)? (5 points)

4. Discuss with examples the application of OR techniques in mining. (20 points)
5. For the following transportation problem, determine the transportation cost using the North-west corner method.

To / From	W_1	W_2	W_3	W_4	Supply
P_1	2	5	9	8	40
P_2	4	1	8	4	60
P_3	7	10	9	2	50
Demand	35	45	30	40	

The unit cost of transportation from Plan P_1 to warehouse W_1 is indicated in the table. (20 points)

6. The demand for underground battery operated torches is assumed to be a constant 1,000 per month. the mining company must pay $2 for each torch from the supplier, with the cost of setting up each order amounting to $9. The storage/insurance cost per unit of stock held per month is 12.5% of the purchase price.

(a) Find the economic order quantity. (10 points)
(b) The appropriate time between orders. (5 points)
(c) Find the total cost per year (5 points)

(Assume that there are no shortages allowed and that there are 20 working days per month).

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

MI 455

OPERATIONS RESEARCH

TIME: THREE (3) HOURS

INSTRUCTIONS: ANSWER ALL FIVE QUESTIONS

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1. Find the minimum spanning tree of the network shown in the figure below. The numbers on branches represent distances between the corresponding nodes. Find the minimum distance path connecting nodes A and H.

[SEE FIGURE ATTACHED]

2. Three operating mines, Mine 1, Mine 2 and Mine 3 whose daily production capacities are 300, 200 and 400 tonnes of ore respectively, supply their ore to three concentrators, Concentrator 1, Concentrator 2 and Concentrator 3. Concentrator 1 requires 50, Concentrator 2 60 and Concentrator 3 70 tonnes of ore per day. If the transport costs are as follows:

	Concentrator 1	Concentrator 2	Concentrator 3
Mine 1	K10,000/t	K30,000/t	K50,000/t
Mine 2	K20,000/t	K40,000/t	K60,000/t
Mine 3	K50,000/t	K20,000/t	K10,000/t

Determine the minimum cost schedule.
Perform the optimality test to confirm your solution.

3a. The table below shows the project network activities and the corresponding times (in days) required for each activity, which are assumed to be predictable constants. Construct the project network. Find the earliest time, the latest time and the slack for each event. Also identify the critical path.

2/..

Activity	(1,1)	(1,2)	(1,3)	(1,4)	(2,7)	(3,5)	(4,5)	(4,6)	(5,7)	(6,8)	(7,9)	(8,9)
Duration(days)	5	2	6	8	9	7	13	10	11	12	3	

b. Using the PERT three -estimate approach, the three estimates for one of the activities are as follows: Most likely estimate is 42 days, expected value and standard deviation of the time required by the activity are 43 days and 3.667 days respectively.
What are the resulting estimates of the optimistic and pessimistic time values required by the activity and how big is the variance.

4 The demand for a mine's gold ore is 700 tonnes per week, and the ore is withdrawn from the stock pile uniformly. The set up cost for the ore stock pile is K25,000. The unit cost of each tonne of gold ore is K3,000, and the stock piling cost K50 per tonne of ore per week.

a. Assuming shortages are not allowed, determine how often to make a production run and what quantity of gold ore is required?

b. If shortages cost K2000 per tonne of ore per week, determine how often the mine should make a production run and how much gold ore should be produced. Calculate the ore stock on hand at the beginning of the stock piling cycle. Find the maximum shortage as well as the fraction of time that no shortage exists. Depict this situation graphically.

5. Metallic Ore from No. 1, No. 2 and No. 3 shafts of Chililabombwe Mines Ltd., is separated in two grades before transportation; daily hoisting capacities of both shafts, as well as their daily operating costs, are as follows:

Mine	High Co-grade Cu-Ore	Low Cograde Cu-Ore	Operating cost K1000/day
No. 1 Shaft	80	40	15
No. 2 Shaft	60	70	20
No. 3 Shaft	50	90	25

Chililabombwe Mines Ltd. has supply contracts that commit the company to delivering 600 tonnes of high Co-grade Cu-ore and 800 tonnes of low Co-grade Cu-ore per week. The company has also labour contracts with the unionised employees that guarantee the employees a full day's pay for each hoisting day or fraction of it the shafts are operated.

FInd the number of hoisting days each shaft should be operated in a week if the company is to reach its target at a minimum total cost. State the minimum total cost.

END OF EXAMINATION.

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER SUPP/DEFERRED EXAMS - 1998

MI465/MM571

MINERAL ECONOMICS

TIME: THREE HOURS

ANSWER: FIVE QUESTIONS

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1. Dynatech limited produces explosives for mining purposes. After having anlysed their sales and profits over the past ten years, they have determined their marginal revenue function to be:-

   100,000 - 20n where n is the total amount of all types of dynamite products in units.

   Estimates of the next years costs has yielded the following total cost relationship:

   $0.2n^2 + 10{,}000{,}000$

   What volumes of production would have the following characteristics:

   (a) Breakeven point (6 points)
   (b) Maximum profit. (7 points)
   (c) Minimum average cost. (7 points)

2. A mining operation may be operated at 4 different levels of production, with costs and incomes given in the following table. consider the investment life to be 10 years, without any salvage value at the end of life.

	Units Production/Year	Initial Investment	Annual Cost	Unit Selling price
Level 1	12,000	$100,000	$36,000	$5
Level 2	18,954	150,000	60,000	5
Level 3	23,116	185,000	80,000	5
Level 4	29,180	260,000	90,000	5

The minimum acceptable rate of return is 10%

Note that these production alternatives are mutually exclusive.

(a) What is the economically most attractive level of production on the basis of:

(i) the payback period (5 points)

(ii) the net present value (5 points)

(iii) the rate of return (5 points)

(b) What is the incremental net present value from level 1 to level 2? (5 points)

3. (a) Why is a well structured mineral policy considered essential for the successful development of mineral resources in any given country? (10 points)

(b) Discuss briefly the basic elements of a government mineral policy. (10 points)

4. Discrete probability distributions for operating and maintenance costs per tonne respectively are given in Table 1. Estimate the total cost per tonne distribution by Monte Carlo simulation using 10 random numbers as given in Table 2.

Table 1

Operating cost per tonne (OC/t)	Probability of OC/t	Maintenance cost per tonne (MC/t)	Probability MC/t
200	0.05	100	0.15
250	0.25	150	0.40
300	0.15	200	0.30
350	0.35	250	0.15
400	0.15		
450	0.05		

Table 2 Random numbers

OC/t	MC/t
0.555	0.428
0.708	0.523
0.750	0.291
0.916	0.182
0.554	0.966
0.195	0.445
0.026	0.118
0.974	0.061
0.325	0.626
0.294	0.904

(i) Determine the expected total cost based on probabilities in Table 1.

(ii) What is the expected total cost from 10 simulations?

(iii) Why does the value in (i) above differ from that obtained in (ii) using 10 simulations?

(iv) Determine the standard deviation of the value obtained in (ii).

5. Outline some of the main sources of finance for a typical new mineral development project. Why is small-scale mining not favoured from traditional lending institutions? (20 points)

6. Market conditions are characterized by the supply and demand conditions.

(i) What factors influence the demand function of a product?

(ii) What do you understand by the term "market equilibrium price"?

(iii) What conditions arise if the price is higher than the equilibrium price?

(iv) Consider the following demand function:

$$P = 940 - 48Q + Q^2$$

What is the price elasticity of demand at $Q = 10$ units?

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

MI 465/MM 571

MINERAL ECONOMICS/MANAGEMENT AND ECONOMICS

TIME: THREE HOURS

ANSWER: FIVE QUESTIONS

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1. (a) Discuss factors that influence the Supply and Demand of a mineral product. (6 points)

(b) What do you understand by the term "Market equilibrium price"? (4 points)

(c) What conditions arise if the price is either lower or higher than the equilibrium price? (2 points)

(d) Define the term "price elasticity of demand." (2 points)

(e) Suppose the demand function for commodity Y is given by the equation:-

$$Q_y = 1665 - 0.5\ P_y^3 - 0.1\ P_x^2 - 0.051$$

(i) Determine the cross elasticity of demand for Y with respect to commodity X when $P_y = 10$. $P_x = 20$. and I = 2,500. (5 points)

(ii) Are X and Y Substitutes or Complements? (2 points)

2. During a detailed feasibility of a new mine development opportunity. the following data was assembled:-

Underground Cut-and-fill cu - Zn - Ag

Mill Capacity (tpy)	2,000,000
Pre-production period (years)	2
Productive life (years)	8
Expected annual revenue ($) million)	8.0
Cost of capital	12%

...../2.

Capital Costs ($ Million)

Mine acces or shippinσ	2.0
Mine plant and equipment	2.9
Mill	5.6
Infrastructure	4.0
Workinσ capital	0.9
Total:	15.4

Operatinσ Costs ($/t. milled)

Mine	6.30
Mill	4.75
Overheads	2.20
	13.25

Notes:

(i) All assessments made on pre-tax basis.

(ii) Capital cost evenlv expended over pre-production period.

(iii) Workinσ capital recovered at the end of mine life.

As part of the studv. determine the new Mine development's:-

(i) Pavback period (5 points)

(ii) Net present value (5 points)

(iii) Present value ratio (5 points)

(iv) Rate of return (5 points)

3. Mine manaσement is contemplatinσ replacinσ their old fleet of front-end-loaders. The costs of the new loader (1998) is $ 300.000. Equipment suppliers have provided the followinσ cost data for the proposed new loader:-

Year	Salvaσe value ($)	Operatinσ costs ($)
1	21.000	10.000
2	14.000	11,000
3	10.200	12.000
4	7,000	13.000
5	5.000	15.000
6	3.000	17.000
7	2.500	21.000
8	2.000	25,000

...../3.

(i) What would be the optimum economic life for the new loader? (15 points)

(ii) Give 3 reasons for the replacement of processes and equipment (5 points)

4. Nonel Systems PLC produces explosives for mining purposes. Over the years, the company has determined its Total revenue function to be:-

$TR = 100.000Q - 10Q^2$

Q = Total production output of explosives

TR = Total revenue

Similarly, the following total cost function was established:-

Total cost $= 0.2Q^2 + 10.000.000.$

What volumes of production would have the following characteristics:-

(i) Break-even point (6 points)

(ii) Maximum profit (7 points)

(iii) Minimum average cost (7 points)

5. Discuss the essential elements of a mineral policy. (20 points)

6. Major corporates objectives of a mining firm include Profit, growth and survival. Briefly discuss why each of these objectives are considered essential. (20 points)

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

SEMMESTER II EXAMINATION, 1998

MI475 MINING AND THE ENVIRONMENT

TIME: THREE HOURS

ANSWER: 5 QUESTIONS, Questions 1 is compulsory

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1. (a) What is the composition of atmospheric air, by mass and volume ?

[2 points]

(b) Name the six categories of impurities in mine air, stating two examples under each category.

[3 points]

(c) Name the three main properties of dust affecting the development and severity of lung diseases, and which of these is the most important parameter that governs the physiological effect ?

[3 points]

(d) What do you understand by "wet-bulb temperature" ?

[2 points]

(e) A volume flow rate of 5 m^3 /s is delivered by a fan into a 0.76 m diameter duct at a density of 0.96 kg/m^3. The length of the duct is 600 m and has a total leakage of 40%. At the delivery end of the duct, the density is 1.12 kg/m^3. Calculate the pressure produced by the fan. The friction factor for the duct is 0.0038 NS^2/m^4. (10 marks)

2. (a) Tabulate mining operations (including prospecting/exploration, underground mining, surface mining, mineral processing and mine closure) and their associated environmental issues in mining industry. The tabulation should be in 3 columns headed thus: "Main Operation", "Typical Activities" and "Environmental Issues".

[8 points]

(b) (i) What is settling velocity ? **[2 points]**

(ii) What is the most dangerous size range of dust ?

[2 points]

(II) Show, in clear steps, that for turbulent motion the terminal settling velocity of a particle at ordinary temperatures is given as

$v_t = 4.95\rho^{1/2}D^{1/2}$

where $v_t D\rho_a/\mu > 10^3$ or $D > 0.021/\rho^{1/3}$

v_t = terminal velocity, ms^{-1}

ρ = density of particle, kg/m^3

D = diameter of particle, m

μ = viscosity of gas = $1.8x10^{-5}$ Pas for ordinary temperatures

[8 points]

3. (a) A downcast shaft is 500m deep. The barometer reads 102 kPa at the shaft bottom. The surface air temperature being 295 K, calculate the air temperature at the bottom of the shaft assuming the temperature of the air to be affected by auto-compression only. For specific heat of air (C_p), use 1005 J $kg^{-1}K^{-1}$.

[6 points]

(b) Briefly discuss three sources of heat in underground mines.

[6 points]

(c) Briefly discuss three ways in which one can refrigerate an underground mine, outlining advantages and disadvantages.

[8 points]

4. A smooth steel duct 450x600 mm in size circulates 0.5 m^3 of air per second. Calculate the coefficient of resistance of the duct and the friction pressure loss in a 100 m length of the duct. Assume:

Kinematic viscocity $\gamma = 0.16 \times 10^{-4}\ m^2s^{-1}$,
Air density $\rho = 1.2\ kg\ m^{-3}$, and
Coefficient of friction $k = 0.00294\ Ns^2m^{-4}$ for smooth ducts.

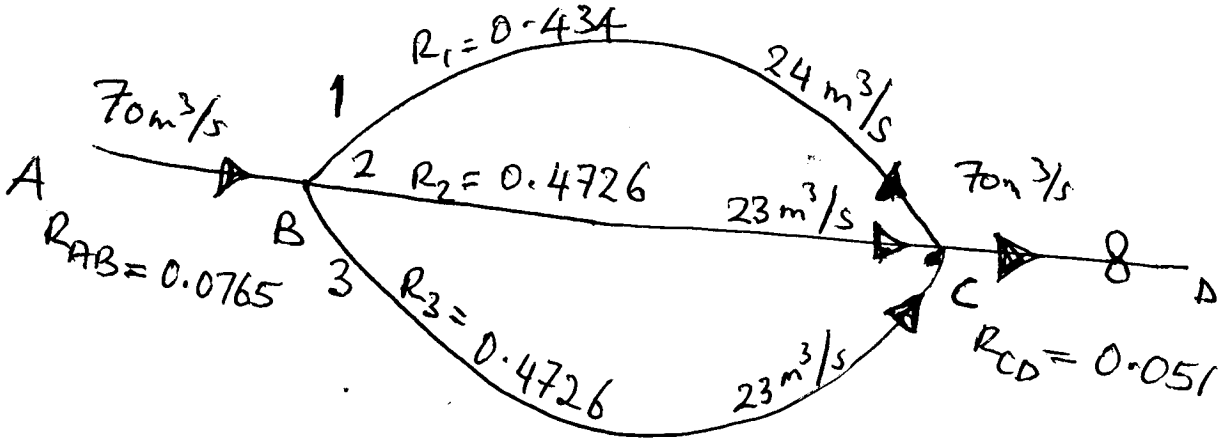
[20 points]

5. The sketch below shows a network of airways with their resistances in Ns^2/m^8 and the volume flow rates through them. the characteristics of the fan at a speed of 20 r.p.s are as follows:

Volume flow rate m^3/s	Pressure pa
40	1080
60	960
80	760
100	490

(a) It is proposed to circulate 33 m^3/s through split 1 by regulating splits 2 and 3. What will be the new operating point of the fan? (10 marks)

(b) A volume flow rate of 23.6 m^3/s is required in each split 2 and 3 (a total of 80.2 in segment B-C). What is the new operating point and at what speed must the fan run? (10points)



6. There are 3 splits A, B and C in parallel. their resistances are 0.24, 7.48 and 0.61 Ns^2/m^8 respectively. The desired volume flow rates in the splits are:-

A - $40m^3/s$
B - $10m^3/s$
C - $25m^3/s$

In order to evaluate the relative merits of the three methods of establishing the desired volume flow rates i.e. by regulation, by booster fan(s) or by reducing the resistance. Calculate

a) The position and size of regulator(s) required (5 marks)
(b) The position, volume flow rate and pressure of booster fan (5 marks)
(c) The split in which the resistance is to be reduced. (5 marks)
(d) The total air power involved in each case. (5 marks)

7. Write short notes on the following topics illustrating your answer with clearly l abelled diagrams.

(a) Ventilation of dead ends (10 marks)
(b) Types of fans (10 marks)

END

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER EXAMINATIONS - MARCH 1998

MI 535

COAL MINING METHODS

TIME: THREE HOURS **TOTAL MARKS:** 100

ANSWER: QUESTION 6 AND ANY OTHER FOUR. TOTAL QUESTIONS TO BE ANSWERED FIVE. ALL QUESTIONS CARRY EQUAL MARKS.

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1. Discuss the effect of geological instrusions on mining layout and extraction. What precautions should be taken when a sill or dyke is encountered during mining operations?

2. The methods of coal mining in present-day are completely different than the past. Describe the operation of such a coal cutting machine and give layout of the face where it can be used.

   Give an approximate figure for the productivity and OMS likely to be achieved for the system described.

3. For the situation given below, describe a mining method giving details of the equipment required and their position on the face.

   State the reasons for the method you choose for the situation given below:

   - Depth 900 metres
   - Thickness of seam 4.5 metres
   - Dirtband 0.5 m thick present in the coal seam
   - Seam is highly gassy and prone to spontaneous combustion

4. Explain the 'tributary area method' of coal mining pillar design and state the factors on which strength of pillar depend on.

   In a room-and-pillar coal mining the extraction ratio (R) is equal to 80%. The coal deposit is at a depth of 900 m from the surface and the average unit weight of the overlying rock is 25 KNm^{-3}. Calculate the pillar strength for the above condition.

5. What are the general Coal Mine Safety Regulations as regards to the following:

(a) Methane detection and control

(b) Dust control

(c) Mine fires

(d) Inundations

6. Write short notes on any two of the following:-

(i) Adverse environmental impact of surface coal mining.

(ii) Equipment and its selection for overburden removal for coal mining.

(iii) Productivity analysis in coal mining.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
UNIVERSITY EXAMINATIONS

MI 362 INVESTMENT ANALYSIS

TIME: 3 HOURS
ANSWER: ALL QUESTIONS

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1. Mineral resources development is confronted by a number of risks. Briefly discuss major mining investment risks. (25 points)

2. Stock Exchanges play an important role in mobilizing investment funds. Discuss the structure of a typical Stock Exchange and briefly explain how it functions mentioning the roles of the key players. (25 points)

3. Texamin Inc. spent 10 years of interrupted exploration work in former Zaire. The target was the rich copper mineralization in the eastern part of the country known for its frequent civil wars and unlawlessness. However, exploration costs had already amounted to $1.5 million per year.

   Because of poor security, the company decided to abandon the project and sold it to Exploite Afrique Minero. The new project owners were soon to receive the change of the political leadership and change of the country's name from Zaire to Congo-DR with a lot of hope for the future.

   A pre-feasibility study was soon launched at a cost of $2 million to justify further financial commitment which lasted one year. The report was exciting, a new mining venture could soon be commissioned. However, management decided to undertake further exploration work which took another two years at a cost of $2.5 million per year in order to acquire conclusive geological information. Copper grade averaged 3.5% and reserves amounted to 15 million tonnes with prospects for more reserves within the unexplored part of the concession.

   International Mining Consultants (IMC) were contracted to undertake the final detailed feasibility study to ascertain the technical, economic and financial viability of the project. This cost $2 million and lasted one year.

Summary of Project details:

Reserves:	15 million tonnes
Mine recovery	85%
Mining rate	1 million tonnes per year
Mill recovery	90%
Operating costs	$17 million per year
Estimated price	$2,000 per tonne refined copper
Tax rate	40%
Capital costs	$100 million to be amortized by straight-line depreciation in 5 years from start of production.
Cost of capital	10%

(i) Determine the cashflows for this project Note: use end-of-year convention in cashflow analysis (20 points)

(ii) As a project manager, would you consider the investment portfolio to be financially viable? Justify your answer (20 points)

(iii) Should the project turn out to be financially viable, what other factors would influence other foreign prospective investors buying shares in this company. Note that as at 12 August, 1998, world media reports indicate that the region has once again erupted into fierce fighting between government forces and various factions. (10 points).

THE UNIVERSITY OF ZAMBIA

SCHOOL OF MINES

DEPARTMENT OF MINING ENGINEERING

MI 585 MATERIALS HANDLING

ANSWER ANY FIVE (05) QUESTIONS
ALL QUESTIONS CARRY EQUAL MARKS

Q1 (a) List the main materials handling operations and corresponding equipment selection for general hard rock mining. (10)

(b) Write brief notes and comments on the main factors affecting the selection of materials handling equipment in both underground and open pit mining. (10)

Q2 Given that a quarry with consolidated rock formations requires to extract a total volume of 5 million cubic meters/annum of basalt rock to satisfy a construction project requirements, determine the number of front-end-Loaders or Hydraulic Shovels and truck type knowing:

(a) Materials Characteristics
Material ----------Basalt
Specific (Gravity (loose)----------2,4 t/m^3
Specific Gravity (bank)----------2,5 t/m^3

(b) Loading machines' alternatives:

	F.E.L. Caterpillor 994	Hydraulic Shovel Demag H-185
Bucket Capacity (m^3)	----16	----16
Bucket Fill Factor (%)	----90	----95
Average Cycle Time (sec)	--40	----25
Minutes per Hour (min)	---50	----50
Availability (%)		----90
Utilization (%)		----90

(c) Haulage truck alternatives:

	Type 1 CAT 777	**Type 2 CAT 785**	**Type 3 CAT789**
Body Capacity	51m3	78m3	105m3
Pay Load (max)	86 Tonnes	136 Tonnes	177 Tonnes
spot time at loader	20 sec	20 Sec	20 Sec
Waiting time	10 sec	10 Sec	10 Sec
Traveldistance (one way)	4 000 Meters	4 000 Secs	4 000 Meters
Travel speed (loaded)	30 Km/hr	30 Km/hr	30 Km/hr
Travel speed (empty)	60 Km/hr	60 Km/hr	60 Km/hr
Mannoeuvere and dump time	30 Secs	30 Secs	30 Secs

(a) Knowing that the quarry operates 3 x 8 hr Shifts/day and 260 days/annum,

(i) Determine the maximum production achievable by each loading equipment type in BCM/hr and T/hr. (5)

(b) Select and justify which loader type and truck size combination you would deploy in the quarry. (5)

(c) From the three truck sizes given, select the one you would couple to the loader and determine

(i) Number of passes to fill the truck

(ii) Loading time per truck

(iii) Loaded trucks per hour

(iv) Truck production in T/hr and BCM/hr

(v) Loaders and truck fleet size to be made available to satisfy the 5 million m^3/annum requirements. (10)

Q3 (a) Write brief notes on Hoisting under the following sub-headings:-

- Composition, classification and types of hoisting systems.
- Shaft tasks and types
- Headgears (Headframes)
- Winding tower types. (15)

(b) Discuss the principles of operations and underlying design criteria of Friction (KOEPE) hoists. (5)

Q4 Given a BWE of following operating parameters and specifications for a brown coal open pit mine:

- Single bucket capacity	2500 litres
- Number of buckets on the wheel	15
- Duration of shift	7,25 hrs
- Number of shifts per day	3.0
- Time use factor	0,90
- Bucket fill factor	1,25
- Bulking factor	1,15
- Wheel diameter	18,5m
- Cutting speed	1,25m/s

(a) Determine the theoretical and effective annual output of the BWE knowing that the total number of days is 265 days/annum. (10)

(b) Will a trank conveyor belt of specifications given below be capable of evacuating the material excavated by the BWE? Justify your answer with the aid of corresponding sketches and calculations.

Belt width	2100 mm
troughing angle	30°
Material's angle of repose	15°
Specific weight of material	1,25 ~~m^3/t~~ t/m^3
Belt speed	2,5 m/s
Belt ~~and~~ loading factor	95% (5)

(c) If the answer to (b) is NO, what conveyor belt design alterations would you advocate for in order to accommodate BWE production? (5)

Q5 (a) Write brief notes on the principles and purpose of drilling in mining with emphasis on principles, application and limitations of:-
- Percussions drilling
- Rotary drilling
- Roto-percussive drilling (5)

(b) Following average figures are for:-

(i) Rotary blasthole drilling parameters:
- Compressive strength of formation = $30x10^3$ psi
- Pull-down pressure of drill string = $110x10^3$ psi
- Revolutions perminute of drill string = 90 rpm
-Blast hole diameter = 15 inches(381mm)

(ii) Blasting parameters:
- Bench height = H = 12 m
- Highwall angle = = 60°
- Rock density = = 2,85 g/cm^3
- Explosive density = = 0,85 g/cm^3
- Coefficient of spread = C = 1,5-2
- number of rows per blast n = 3 + delay sequencing. (6)

Calculate:

(i) Penetration rate of Rotary Blasthole drill
(ii) Blast design parameters
(iii) Explosives consumption per hole
(iv) Rock broken per hole
(v) Powder factor
(vi) Spread of broken muck-pile. (15)

Q6 (a) Write brief notes on the applicability of ripping machines in open-pit mining with special emphasis on:-

(i) Contribution of tractor to ripping productivity
(ii) Working tool of a ripper
(iii) Production estimation in ripping. (10)

(b) Given the following:-

- Machine type	D9N with 90 single shank ripper
- Rip speed (slips and stalls)	1,75 km/hr
-Rip spacing	975 mm
Ripper penetration	750 mm
Rip distance	200 m
Manoeuvre time	0,45 min

and assuming a 55 min-working - hour and $150 ownership and operating cost per hour, calculate:

(i) Actual ripping production per hour
(ii) Loosening cost range. (10)

Q7 Write short notes on the role and importance of auxilliary equipment in mining operations. (20)

THE UNIVERSITY OF ZAMBIA
SCHOOL OF MINES

SECOND SEMESTER EXAMINATIONS - AUGUST/SEPTEMBER 1998.

MM205 - INTRODUCTION TO METALLURGY

TIME: THREE HOURS
ANSWER: Any five and all questions carry equal marks

Section I: Geology

1.0 (a) Name the different classes of minerals and give two examples of each.

(b) Write brief notes on how silicate minerals are classified.

2.0 Discuss briefly the role of base metal sulfide deposits in the economic development of Zambia.

3.0 (a) Classify the following rock units as precisely as possible: basalt, shale, marble, coal, pegmatite, sandstone, rhyolite, conglomerate, limestone, schist, gabbro, gneiss, syenite, granodiorite, quartzite, amphibolite.

(b) Describe very briefly how each of the rock units listed above is formed.

Section II: Metallurgy and Mineral Processing

4.0 (a) What do you understand by a **native** metal and what do you understand by a **secondary** metal?

(b) What do you understand by **recycleable** resources?

(c) The following three metals are almost solely produced as by-products in other metallurgical extraction processes. State for each of these three metals the metal(s) of which it is a by-product:
- cadmium (one metal)
- selenium (one metal)
- cobalt (two metals)

(d) Name the four main copper "**provinces**" in the world and state for each of these four regions with what metal the copper occurring in it is typically associated.

(e) What is **bauxite** and what is it used for?

5.0 (a) Many metallurgical processes involve chemical reactions. Why are such processes usually stopped long before chemical equilibrium has been reached?

(b) What do you understand by the **rate determining step** in a heterogeneous reaction?

(c) What are the three main parameters that are used to control the rate of metallurgical processes?

For each of these parameters, describe and explain briefly how they influence the process rate.

(d) What do you understand by the **average residence time** of material in a metallurgical process unit in continuous operation and what do you understand by short-circuiting of material in such a process?

(e) Chemical and metallurgical processes are often carried out in '**stages**'.

Give three possible reasons for this and give a practical example for each of these cases.

6.0 (a) The bulk of Zambian copper ores currently being mined are sulphidic and average around 2.0 - 2.5% Cu. Upgrading (concentrating) of these ores is practiced before various techniques in pyro-metallurgy , hydro-metallurgy and electro-metallurgy are subsequently used. Write brief notes on the underlined titles and state how each technique may apply to our copper sulphide ores.

(b) (i) What is size reduction of a run-of-mine ore and what is the objective in this operation?

(ii) Name one type of equipment used in crushing and one type used in grinding.

(iii) What important function do screens (classifiers) serve in a crushing circuit.

(c) What is froth flotation and what principle is employed in the separation of valuable mineral from gangue material?

End of Examination

THE UNIVERSITY OF ZAMBIA
SCHOOL OF MINES

SECOND SEMESTER EXAMINATIONS - AUGUST/SEPTEMBER 1998.

MM205 - INTRODUCTION TO METALLURGY
(PRACTICAL PAPER)

TIME: THREE HOURS
ANSWER: Both questions.

1.0 Describe and identify the rock specimens numbered 1 to 5 on the basis of mineralogical composition, texture and structure (30 %).

2.0 (a) Describe and identify the mineral specimens numbered A to H. (48 %)

(b) Classify mineral specimens numbered A to H and calculate the percentage of the most useful component in the mineral. (16 %)

(c) Use the supplied sketch map of Zambia to name and mark areas in which the minerals numbered A to F occur. (6 %)

End of Examination

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS- MARCH 1998

MM321

PHYSICAL METALLURGY I

ME: THREE HOURS
SWER: ALL THE QUESTIONS

What materials would you select for the following applications and why?
(a) soft solders
(b) surgical implants
(c) crankshaft
(d) plumbing accessories

(a) Why was the crystal defect "dislocation" proposed before there was any direct evidence for its existence?

(b) Explain, with the aid of appropriate sketches, how two edge dislocations with opposite Burgers vectors and under the action of a shear stress meet to form a row of vacancies or interstitials.

(c) {110}, {112} and {123} planes have all been identified as slip planes in bcc materials. On how many slip planes does this imply that a single a/2[111] dislocation might be able to move?

(a) Figure 1 is a projection of a hexagonal close packed lattice along [0001]. Assign an index (hkil) to the planes whose traces on (0001) are indicated as 1-3. You may assume that all the planes lie in the zone [0001].

(b) The formation of ordered phases is a common occurence in most alloy systems. Figure 2 shows a unit cell of an ordered phase in the Cu-Au system. Given that the unit cell exhibits cubic symmetry,
(i) upon what composition (i.e. Cu_xAu_y) is the ordered phase based?
(ii) What is the lattice type of this ordered phase (i.e. is it primitive, bcc, etc)? Explain your reasoning.

(a) What is the phenomenon of yielding as applied to engineering materials?

(b) A uniaxial compressive load of 300,000 N causes yielding of a solid cube of side 100 mm. What load would be required to produce yielding if the other sides were constrained by compressive loads of 150,000 and 400,000 N, respectively. Assume that the Maximum-Shear-Stress Theory (Tresca theory) $\sigma_0=\sigma_1-\sigma_3$ is applicable.

(c) An axial tensile force of 100 kN is applied to a steel rod 4 cm diameter and 50 cm long. Deduce the change in volume if E=210,000 N/mm^2 and υ=0.26

NOTE:

$$Volumetric\ Strain = \epsilon_x + \epsilon_y + \epsilon_z$$

The strain in the x-direction is

$$\epsilon_x = \frac{1}{E}[\sigma_x - \nu(\sigma_y - \sigma_z)]$$

Similar expressions for the y and z-directions can be obtained.

5. Figure 3 is the Hafnium-Molybdenum phase diagram. There are four solid phases in this system:
β-Hf---which is bcc and is the stable allotrope of Hf at high temperatures.
α-Hf---which is hcp and is the stable allotrope of Hf at low temperatures.
γ---which is a hexagonal intermediate phase based on the composition Mo_2Hf.
δ-Mo-----which is bcc.

(a) Label the phase diagram.
(b) Locate and identify the invariant points on the phase diagram.
(c) For an Hf-40w/o Mo alloy, determine the amounts and compositions of the phases present at 1600^{0}C.
(d) Draw schematic free enrgy/composition curves at 1300^{0}C.
(e) Describe in detail the equilibrium cooling behaviuor of an Hf-10w/o Mo alloy from 2800 to 1000^{0}C.

END OF EXAMINATION IN MM321

FIGURE 1

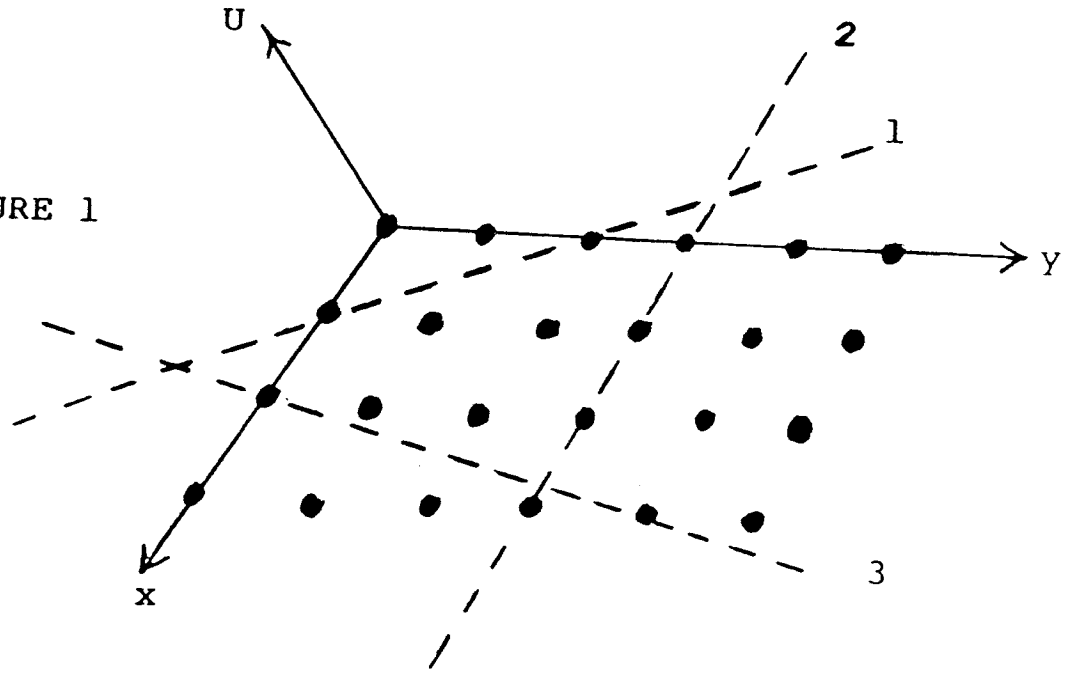
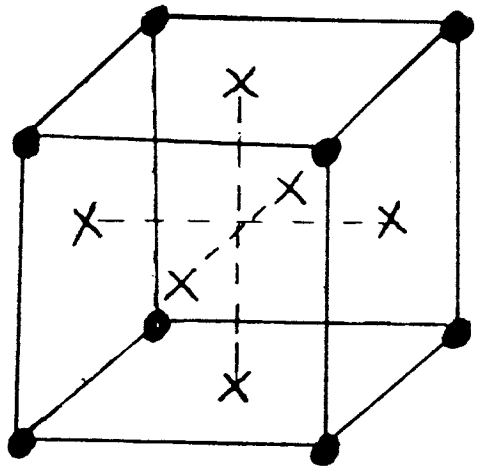


FIGURE 2



Au

Cu

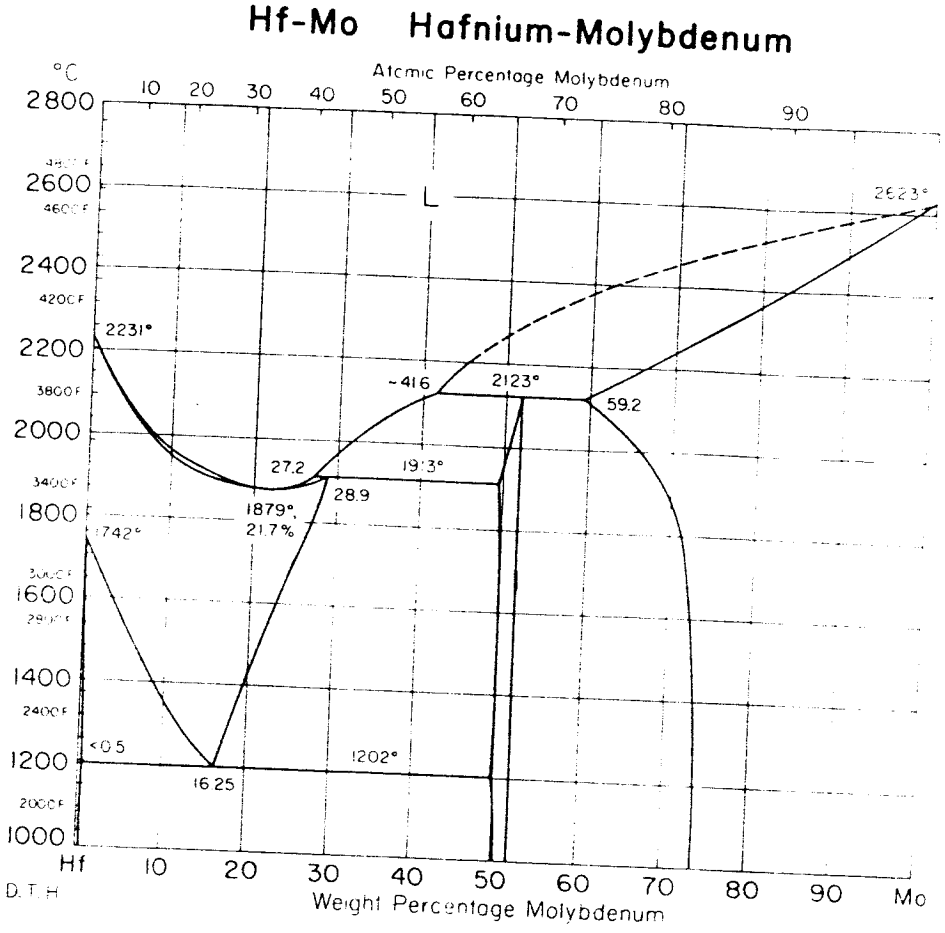

Hf-Mo Hafnium-Molybdenum
°C
Atomic Percentage Molybdenum
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
10 20 30 40 50 60 70 80 90
L
2623°
2231°
~41.6
2123°
59.2
27.2
1913°
28.9
1879°,
21.7%
1742°
<0.5
1202°
16.25
Hf
10 20 30 40 50 60 70 80 90
Mo
D.T.H.
Weight Percentage Molybdenum

FIGURE 3

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - FIRST SEMESTER, MARCH,1998

MM 331

CHEMICAL THERMODYNAMICS PAPER 1

Time: Three Hours

ANSWER : Five questions

---

1. (a) Show that for constant pressure, the heat of any reaction:

$$bB + dD = gG + rR$$

Can be written as

$$\frac{d(\Delta H)}{dT} = \Delta C_p$$

(b) The molar integral heat of mixing of Si - Mn is given as:

$$\Delta H^M = -140.7N_{Si} + 104.7N^3_{Si} \quad KJ/Mol$$

Calculate the partial molar heat of mixing of Manganese at 0.5 Si given the partial molar heat of mixing for manganese as:

$$\Delta \bar{H}^M_{Mn} = \Delta H^M - N_{Si} \frac{\partial \Delta H^M}{\partial N_{Si}}$$

2. Solid Au - Cu are regular in their thermodynamic behaviour. The integral enthalpy of mixing, ΔH^M at 447°C (720K) is given below as a function of composition.

X_{Cu}	:	0.2	0.3	0.4	0.5
ΔH^M J/Mol	:	-2448	-3556	-4498	-5104

Calculate the integral molar free energy of mixing of the above solution at $X_{Cu} = 0.2$

3. The molar heat capacities of lead at constant pressure over a range of temperatures, are given below.

Temp K	:	15	30	40	70	150	300
C_p,J/K/Mol	:	8.41	16.40	19.75	23.26	25.02	26.36

Calculate the standard entropy of lead at 25°C (298K) from the third law of thermodynamics. Assume that the entropy continuation below - 258°C (15K) follows Debye's equation.

4. (a) Show how the Gibbs-Helmhotz equation is derived.

(b) The partial pressures of A exerted by A-B alloys at 1000 K

X_A	1	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2
P_A 10^6	5	4.4	3.75	2.9	1.8	1.1	0.8	0.6	0.4

Determine (a) the composition range over which Henry's law is obeyed by the solution and (b) The value of Henry's law constant at 1000 K. If the temperature variation of the Henry's law constant is given as

$$\log K_A = -\frac{109.3}{T} - 0.2886$$

(c) calculate $\Delta \bar{H}_A^M$ in the composition range over which A obeys Henry's law

(d) write an equation for the for the variation of ΔH^M with composition over the same composition range.

5(a) The excess partial molar free energy of zinc in liquid Cu-Zn alloys at 1027°C (1300 K) can be represented as

$$G^{XS}_{Zn} \text{ (cal/mole)} = -5150\ (1 - x_{Zn})^2.$$

Calculate the activity of copper at 1027°C (1300 K) in an equiatomic solution.

(b) Liquid brases conform to the following relationship:

$$RT \ln \gamma_{Zn} = -5000\ x^2_{Cu}$$

where R and T are in cal/deg/mole and degree Kelvin respectively. The vapour pressures of pure copper and pure zinc (in mm Hg) are given as

$$\log P_{Cu} = \frac{-17520}{T} - 1.21 \log T + 13.21$$

and $$\log P_{Zn} = \frac{-6850}{T} - 0.755 \log T + 11.24.$$

Calculate (i) the vapour pressure of copper over a brass containing 40 atom%

6(a) The partial molar entropy of mixing of gold in solid Au-Cu alloys, determined at 500°C (773 K) over the complete solution range, is tabulated below.

X_{Au}	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
$\bar{S}^{M}_{Au}$, Cal/deg/mole	4.56	2.87	2.20	1.84	1.42	1.04	0.72	0.44	0.21
S^{M}_{Au}, J/K/mole	19.08	12.00	9.20	7.70	5.94	4.35	3.01	1.84	0.88

Calculate the partial molar entropy of mixing of copper and integral molar entropy of mixing of the solution containing 40 atom% copper.

(b) The excess partial molar free energy of iron at 1600°C (1873 K) in Fe-Ni solutions at different compositions is given below.

X_{Ni}	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
$\bar{G}^{XS}_{Fe}$, cal/mole	0	-15	-40	-90	-260	-620	-1330	-2030	-2730
($\bar{G}^{XS}_{Fe}$, J/mol	0	-63	-167	-377	-1088	-2594	-5565	-8494	-11422)

Calculate the excess partial molar free energy of nickel in an equiatomic solution.

7. The activity coefficient of zinc in Mg - Zn alloys may be represented by

$$\log \gamma_{Zn} = \left[\frac{-1750}{T} + 0.831\right)\left(X^{2.5}_{Zn} - 1.667\, X^{1.5}_{Zn} + 0.667\right]$$

Calculate the activity coefficient and the activity of Magnesium in a Mg - Zn alloy containing 0.32 atom fraction of magnesium at 727°C (1000K).

End of PAPER IN MM 331

UNIVERSITY OF ZAMBIA

SCHOOL OF MINES

UNIVERSITY EXMINATIONS - AUGUST/SEPTEMBER, 1998

MM 332 - CHEMICAL THERMO DYNAMICS

Time: 3 Hours

Answer 4 Questions

All Questions Carry Equal Marks

==========

1. (a) The concentration of sulphur in pig iron after desulphurisation with a basic slag at 1743 K at various intervals of time is as follows:

Time in seconds	: 0	540	1200	2400	3840
Conc. of sulphur, Kg/m^2 of interface	: 87.1	57.4	30.2	10.0	2.75

Show that the desulphurisation is a first order reaction.

(b) Show that the time required for the reaction of any given fraction of the material initially present is independent of the initial concentration for a first - order reaction, but varies with the initial concentration for a second - order reaction.

2. (a) From the given reaction:

$$2Ca + ThO_2 = 2CaO + Th$$

the following emf values were obtained in a reversible electro chemical cell at 1 atm. (101325 N/m^2) pressure:

Temp. K :	1275	1375	1475
E^o, V :	0.0738	0.0542	0.0345

Calculate the values of ΔG , ΔS and ΔH for the cell reaction at 1375 K. What would be the maximum temperature at which calcium will reduce thorium dioxide at 1 atm.(101325 N/m^2) Pressure?

(b) Calculate the change in enthalpy ΔH and the amount of heat q given out by the following reversible galvanic cell reaction

$CuSO_4 + Zn = Cu\ ZnSO_4$

if the e.m.f. of the cell for two temperatures is

T, K : 273 276

E, V : 1.0960 1.0961

3. During carbon dioxide arc welding, carbon and oxygen from the CO_2 enter into solution in iron at 1600°C (1873K) according to

$$(CO_2) = \left[C\right]_{Fe,wt\%} + 2\left[O\right]_{Fe,\ wt\%} ;$$

$G^\circ = 183,489 - 47.70\ T$ Joules

The final oxygen content of the weld is represented by

$$\log \left[\%O\right] = - \frac{6320}{T} + 2.734.$$

Calculate the equilibrium carbon content of the weld if the partial pressure of CO_2 is 1 atm ($101325 N/m^2$) assume the following interaction parameter values :

$$e^c_o = -0.13\ ,\quad e^o_c = -0.1,\quad e^o_o = -0.2$$

and $e^c_c = 0.22.$

4. For the change of standard state $V_{(s)} = V_{(1wt\%\ in\ Fe)}$

$G^\circ = -15,480 - 45.61\ T$ Joules

Calculate the value of γ°_v at 1600°C. If a liquid Fe-V solution is equilibrated with pure solid VO and a gas containing $Po_2 = 4.72 \times 10^{-10}$ atm, calculate the activity of V in the liquid solution (a) with respect to solid V as the standard state, (b) with respect to liquid V as the standard state, (c) with respect to the Henrian standard state, and (d) with respect to the 1 wt% in iron standard state.

Use the following additional information

$2V_{(s)} + O_2 = 2VO_{(s)}$ $\Delta G^\circ = -861{,}485 + 150\ T$

$V_{(s)} \rightleftharpoons V_{(l)} = \Delta H_{(f)}$ 17,573J at 2188K

$V_{(s)} = V$ $\Delta G^\circ = -15{,}481 - 45.6\ T$

Atomic masses : V = 50.95 ; Fe = 55.85

5. Two hypothetical metals, A and B, whose melting-points are 700°C and 500°C respectively, are miscible in all proportions in the liquid state and are partially soluble in one another in the solid state, the maximum solubilities being 5%B and 25%A by weight. The solubilities are 2% and 5% respectively at O°C.

The two metals form a compound A_2B which melts at 750°C and in which neither metal is soluble. The atomic weights of A and B are 30 and 50 respectively. Eutectic are formed at 22% and 60% by weight of B and at temperatures of 450° and 300°C respectively.

(a) Construct and label the equilibrium diagram, assuming that all the lines on it are straight.

(b) Find, in an alloy containing 45% by wt. of A:

(i) Temperatures at which melting begins on heating and at which melting is complete and

(ii) the composition and distribution of the phases at 100°C.

♦ ♦ ♦

END OF EXAMINATIONS AND GOOD LUCK

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FIRST SEMESTER FINAL EXAMINATIONS - MARCH 1998

MM411

MINERAL PROCESSING I

TIME: **THREE HOURS**

INSTRUCTIONS: **ANSWER QUESTION 1 AND ANY OTHER FOUR.**

---

1. State briefly what you understand by the following terms used in mineral processing:-

   - Closed circuit/open circuit
   - Mesh number
   - Grindability of an ore
   - Gape of a Crusher
   - End peripheral discharge mill
   - Autogenous mill
   - Cut-size or separation size
   - "Roping" in hydro syclone underflow
   - Arrested or free crushing
   - Comminution

2. (a) Derive the expressions for the settling velocities of a particle settling in laminar and turbulence flow.

   (b) What is understood by the "free settling ratio" and "hindered settling ratio" of two minerals particles?

   (c) Explain briefly, but clearly, why hindered settling ratios are larger than the free settling ratios for the same minerals particles.

   (d) Using quartz (S.G=2.7) and galena (SG=7.5) outline the size ranges in which you would expect the above equations to be applicable.

3. (a) Give the definition of Bond's work index.

(b) The equation for Bond's work index can be written as follows:

$$W_i = W\left[\frac{F^{\frac{1}{2}}}{F^{\frac{1}{2}} - P^{\frac{1}{2}}}\right]\left(\frac{P}{100}\right)^{\frac{1}{2}}$$

What do the symbols, used in the above equation represent and in which units should they be expressed?

(c) Broken rock of 80% passing 2500μm. This size reduction required 7kWh per tonne feed.

(i) How much energy would be required per tonne to reduce this rock from the same feed size to 80% passing 100μm in the same ball mill?

(ii) If you want to know the energy required per tonne of this material in the size range 2500μm to 36μm (80% passing size), could you simply use the same equation that you used under (3c)i? Explain your answer in a few work.

(iii) If it is required to mill 11000 tonnes/day of this material from 2500μm to 100μm in 3 shift operations with an expected mill availability of 92%, what minimum horsepower should be installed in the grinding section, based upon the above data? (1hp=0.75kW).

4. Draw a functional sketch of a hydrocyclone in operation, name its main parts and describe its separating action. Briefly discuss with Schematic diagram. Describe how the cyclone efficiency can be expressed and draw two rough diagrams, illustrating this for a high efficiency and a low efficiency cyclone respectively. Next, discuss some of the operation features of a hydrocyclone, used as a classifier in a grinding circuit.

5. (a) What can you say about the relation between the energy input to a mill and ball mill charge? Draw a simple sketch to illustrate this relation.

(b) What are the essential differences between the grinding action in a rod mill and the grinding action in a ball mill? What is the effects of these differences in the grinding action on the size of distribution in the respective mill products?

(c) What is the effect of the residence time in a ball mill upon the sizing of the mill product.

(d) How many type of mills do you know and by using diagrams explain how they operate.

(e) Draw a detailed cross section of tumbling mill showing its rotation direction.

6. Consider a simple crushing circuit as sketched below. The capital letters (F,P,etc) represent mass letters (f, p, etc) represent the weight percentages of the ore particles in each stream that are smaller than the screen size (in this case that is smaller than 25mm).

(a) How high is the circulating load, R on the screen expressed as a percentage of the fresh feed, F?

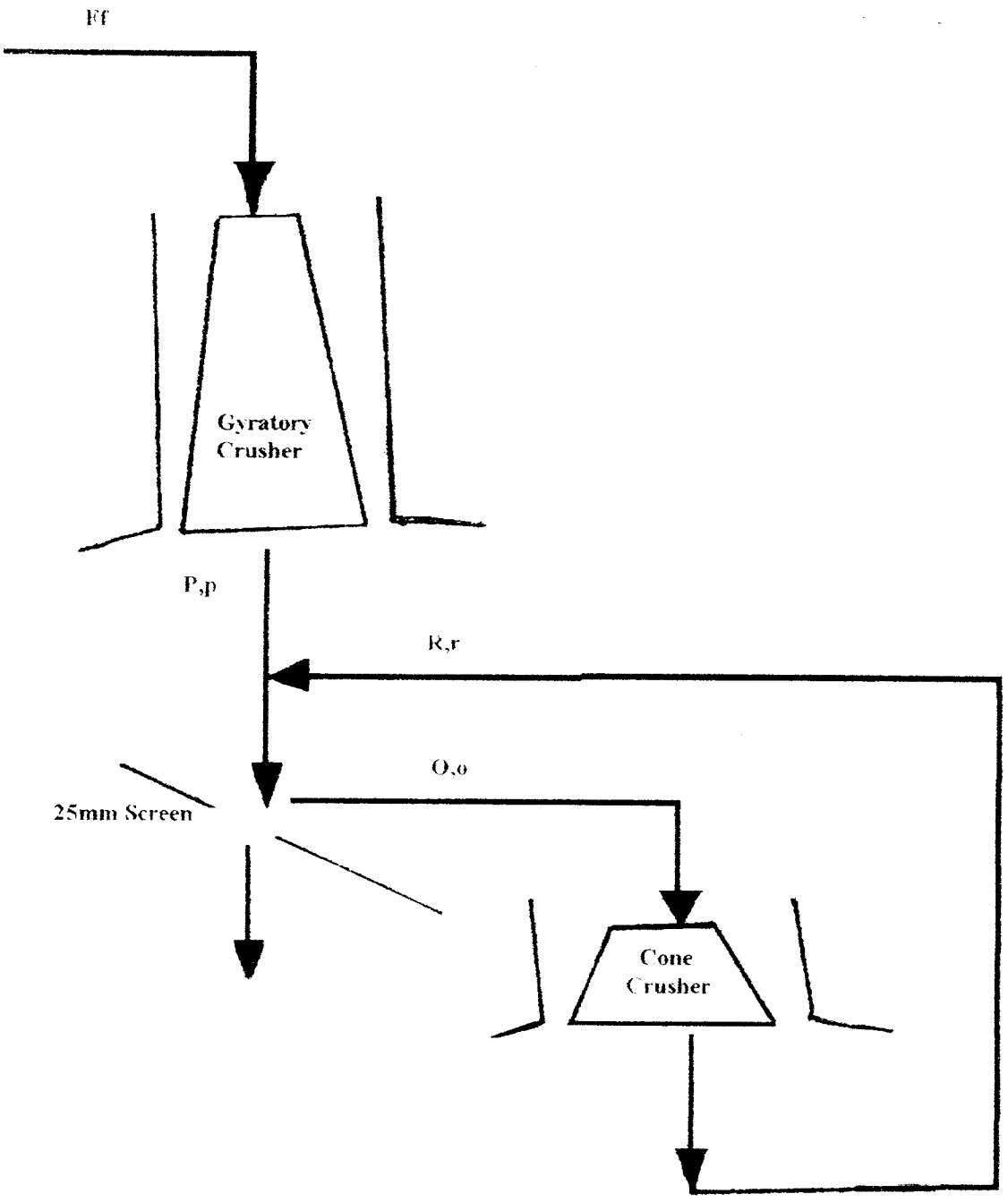
(b) If F=380 t/hr, how high ore O and U?

(c) What is the efficiency of this screening operation? For these calculations, you may assume the circuit to be in equilibrium, so that there will be no accumulation of material in the circuit.

(d) Name the various reasons why screening is carried out.

END OF EXAMINATION.

GOOD LUCK FOLKS


Ff
Gyratory Crusher
P,p
R,r
O,o
25mm Screen
Cone Crusher

THE UNIVERSITY OF ZAMBIA
SCHOOL OF MINES

FINAL EXAMINATION SEPTEMBER/OCTOBER 1998

MM 412 - MINERAL PROCESSING II

Time: THREE HOURS

Answer: QUESTION ONE AND ANY OTHER FOUR

Define the following terms used in mineral processing

1. a) Concentration criterion

   b) Hydrophobicity

   c) Collectors

   d) Modifiers

   e) Hydrophilicity

   f) Direct flotation

   g) Reverse flotation

   h) Flash flotation

   I) Point of Zero charge

   j) Filtration

2 Outline clearly the role of the following in froth flotation of the mineral particles giving examples where appropriate

- Particle - bubble collision and forces involved
- Wettability and contact angles
- collectors
- Regulators
- pH - E_h of the system
- Surface charges of particles and bubbles

- Induction time

- Critical pH of flotation of a mineral

- Flotation rates

3 a) Briefly explain the differences between diamagnetism, paramagnetism and ferromagnetism.

Using a rough diagram, show how the intensity of magnetism varies in relation to the applied magnetic field for each of these three groups of behaviour.

b) Draw a working diagram of an induced roll magnetic separator in operation and briefly example how it works. For what purposes is this widely used?

c) What is the main advantage of wet high-intensity magnetic separators over dry-high intensity magnetic separators?

d) What factors limit in practice the intensity of the applied magnetic field in magnetic separation equipment.

e) Apart from increasing the intensity of the applied magnetic field, what else can be done to achieve a large magnetic force upon the particles to be separated. How is this done in most modern magnetic separation equipment.

f) What are the main fields of application for low-intensity magnetic separation (LIMS), dry-high intensity magnetic separation (DHIMS), wet high intensity magnetic separation (WHIMS) and high gradient magnetic separation (HGMS)?

4 a) Draw a vertical cross-section of a thickener in operation, showing and naming its most important parts and the various zones that can be distiguished.

b) What are the functions of the rakes in a thickener? Briefly explain the circumstances that would necessitate raising the rakes and subsequently lowering of the rakes.

c) What circumstances would necessitate recirculation of the thickener underflow and how this affect the operation of the thickener?

d) The main design parameters of a thickener are its surface area and its depth. What quality is controlled by the surface area and the depth?

e) Describe briefly the differences between 'coagulations' and flocculation.

f) Discuss very briefly the effect of

- solid concentration
- pulp temperature
- flocculant dosage

Upon coagulation and flocculation.

g) Using a few words, explain the effect flocculation upon the settling

rate in

free settling

hindered settleing

5 a) Why is the disposal of tailing very important in any given mineral processing operation? What factors plays a role in determining the nature of the disposal of tailing.

b) Draw cross sectional view of the upstream tailings dam and describe how it is constracted using a central line and subsequently cyclones?

c) What are the main advantages and disadvantages of water reclamatio. With a diagram, show how the downstream method of tailing dam differs from upstream. What are the main drawback in this method?

6 a) Modeling of flotation processes requires the knowledge of hydrodynamic and surface forces in bubble-particle interaction. Define flotation in term of the probability (P) of a particle being collected by a bubble in the pulp phase and give its simplified form for fine particles. Show how the various probabilities could be determined and how the flotation rate constant is eventually determined. Name the various force in bubble-particle interaction and what role they play to effect flotation.

b) Draw a detailed diagram of a standard flotation column labeling all important parts. Briefly explain how the columns differ in their operations from the ordinary cell.

Compare the operation of a Davcra to that of Flotation column and point out their similarities.

(c) Show a detailed diagram of an Hallimond tube and explain how the data obtained could be used to determine the recovery of the mineral flotated.

(d) Give a simple flotation circuit and explain how this differs from a Rougher Scavanger - Cleaner system. Give the graphs of:

(i) Recovery of metal to concentrates versus time

(ii) Recovery versus grade.

END OF MM 412 EXAMINATION.

THE UNIVERSITY OF ZAMBIA
SCHOOL OF MINES

FINAL EXAMINATION SEPTEMBER/OCTOBER 1998

MM 415 - MINERAL PROCESSING

Time: THREE HOURS

Attempt: QUESTION 1 AND ANY OTHER FOUR

ALL QUESTIONS CARRY EQUAL MARKS

---

1. State briefly but clearly what you understand by the following terms used in mineral processing:-

   (a) Mineral

   (b) liberation

   (c) Critical speed of a tumbling mill

   (d) 80% passing reduction ratio

   (e) middlings fraction

   (f) Hindered - settling ratio of two minerals

   (g) Reverse flotation

   (h) near-mesh particles

2. (a) Write short but clear notes on ore handling and storage.

   (b) Write short but cleat notes of reasonable length on:-

   (i) jaw crusher

   (ii) Gyratory crusher

   (iii) Cone crusher

   (iv) Hardinge mill

   Make neat sketches and number each individual working component.

3. (a) The cyclone overflow line is instrumented with a magnetic flow meter and nuclear density gauge, and the mass of dry ore to flotation is 25t/hour. The feed from the fine ore bins is sampled, and is found to contain 5% moisture. The cyclone feed contains 33% solids, the cyclone underflow 65% solids, and the overflow 15% solids.

Required:

(a) circulating load on the circuit,
(b) amount of water needed to dilute the ball mill discharge,
(c) draw the operating flow sheet and indicate whether it is an open-or closed-circuit grinding operation.

Hint: Input to circuit = output

(b) Broken rock of 80% passing 2500μm is ground wet in a ball mill to a product of 80% passing 225μm. This size reduction required 8kWh per tonne feed.

(i) How much energy would be required per tonne to reduce this rock from the same feed size to 80% passing 100μm in the same ball mill.

(ii) If it would be required to mill 11000 tonnes/day of this same rock from 2500μm to 100μm (80% passing sizes) in 3 shift operation with an expected mill efficiency of 89%, how much energy would that require per 24 hour day.

(iii) What minimum horse power should be installed in the grinding section based upon the above data?
(1hp = 0.75kW).

4. (a) Name and discuss briefly the factors that affect screen performance.

(b) What are the advantages of hydrocyclones over mechanical classifiers? Briefly describe the efficiency of a cyclone.

(c) What is jigging and what are its main applications?.

5. (a) What is froth flotation? Describe the role of the following chemical reagents in flotation:-

(i) Collectors

(ii) . Frothers, and

(iii) Activators

Give examples in each case.

(b) (i) How do you define the Work of Adhesion in froth flotation,
(ii) What is the contact angle

(c) What is the importance of p^H in froth flotation?

6. (i) How are coals classified?

(ii) What are the main impurities in any given coal sample?

(iii) What are the objectives of coal washing?

(iv) How do you define recovery efficiency during washing?

(v) Write short but clear notes on heavy medium separation as used in the coal industry.

END OF EXAMINATION
MM 415

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - AUGUST/SEPTEMBER 1998

MM 422

PHYSICAL METALLURGY II

TIME: THREE HOURS
ANSWER: ALL THE QUESTIONS

---

1. Using appropriate sketches, describe the strengthening mechanisms of materials by:

   (a) strain hardening

   (b) strain ageing

2. (a) Show why a diffraction pattern is said to be in reciprocal space with respect to the actual material from which it is obtained. You may use the [001] projection of the fcc lattice or any other projection of any lattice to illustrate the difference between real, and reciprocal space.

   (b) A sketch of a diffraction pattern that was obtained from an fcc material is attached.
   (i) Index the pattern
   (ii) What is the beam direction?
   (iii) If the camera constant λL=50 mm Å, what is the lattice parameter?

3. (a) Describe the Jominy End-Quench test and state its purpose.

   (b) A typical high-strength structural steel has the following composition:-

   0.20 w/o C, 0.75 w/o Mn, 0.08 w/o P, 0.25 w/o Si, 0.35 w/o Cu, 0.75 w/o Ni, 0.25 w/o Cr and 0.30 w/o Mo. Compute the ideal critical diameter assuming the grain size is ASTM 6 and that the multiplying factor for Cu is 1.00

   (c) If the steel in part (b) were given a poor water quench with no agitation, what would be the actual critical diameter? How about if the steel were quenched in brine with no agitation?

   (d) From your answers in part (c), what is the effect of the two quenching media on the hardenability?

4. (a) How are Tafel slopes used to determine the effectiveness of corrosion inhibitors?

(b) Water taps with brass bodies frequently start to drip after a few years of use. The standard culprit is the rubber washer. Indeed, renewing the washer often stops the leak, but usually only for a few weeks. If the brass seating is examined at this stage it will appear red in colour, in contrast to the original bright yellow. If the seating is machined back with a tap-seat cutter it is found that a depth typically of 0.5 mm has to be removed before the whole seating is coloured yellow again. If this is done the tap will function perfectly even with an old washer. The red metal that is removed is in fact porous copper which allows water to seep through underneath the washer. Why does this type of corrosion take place?

5. (a) What is the endurance limit and in which materials is it most likely to be significantly noticeable?

(b) Explain the significance of Miner's Law with respect to the prediction of service life of engineering components.

$$\sum_{i=1}^{\infty} \frac{n_i}{N_i} = 1$$

where n_i = number of cycles applied at stress S_i
N_i = number of cycles to fail at stress S_i

(c) In class it was stated that for engineering components, the ASME has recommended that a curve which is less than the experimental curve by two orders of magnitude for stress or twenty for number of cycles to failure should be used in design. Justify why this should be so.

(d) An aero-engine gas-turbine disc contains defects which may be treated as internal cracks of half-length, a=50 μm. The critical crack half length in the material is 2 mm. During each flight, of average duration 3 hours, the disc is subjected to one large "take-off/landing" cycle, which produces a stress amplitude of 1000 MPa. The crack growth rate, da/dN (mm/cycle), is related to the alternating stress intensity, ΔK (MPa $m^{\frac{1}{2}}$), through the expression:

$$\frac{da}{dN} = 4 \times 10^{-11} (\Delta K)^3$$

Thus

$$\int_{a=a_o}^{a_f} \frac{da}{4 \times 10^{-12} (\Delta K)^3} = \int_{N=0}^{N_f} dN$$

Treating this defect as a crack in an infinite plate i.e.

$$\Delta K = \Delta\sigma(\pi a)^{1/2}$$

Calculate

(i) the life of the disc limited by the take-off/landing cycles

(ii) the maximum value of the vibrational stress which could be allowed in an engine running at 5000 revolutions per minute, if the life of the disc is not to be reduced by more than 5%.

END OF EXAMINATION IN MM422

Table A6.1 Angles between crystallographic planes (and between crystallographic directions) in crystals of the cubic system [After Barrett (1971)]

{HKL}	{hkl}	Values of angles between HKL and hkl planes (or directions)						
100	100	0°	90°					
	110	45°	90°					
	111	54°44′						
	210	26°34′	63°26′	90°				
	211	35°16′	65°54′					
	221	48°11′	70°32′					
	310	18°26′	71°34′	90°				
	311	25°14′	72°27′					
	320	33°41′	56°19′	90°				
	321	36°42′	57°41′	74°30′				
110	110	0°	60°	90°				
	111	35°16′	90°					
	210	18°26′	50°46′	71°34′				
	211	30°	54°44′	73°13′	90°			
	221	19°28′	45°	76°22′	90°			
	310	26°34′	47°52′	63°26′	77°5			
	311	31°29′	64°46′	90°				
	320	11°19′	53°58′	66°54′	78°4			
	321	19°6′	40°54′	55°28′	67°48′	79°6′		
111	111	0°	70°32′					
	210	39°14′	75°2′					
	211	19°28′	61°52′	90°				
	221	15°48′	54°44′	78°54′				
	310	43°6′	68°35′					
	311	29°30′	58°31′	79°59′				
	320	36°49′	80°47′					
	321	22°12′	51°53′	72°1′	90°			
210	210	0°	36°52′	53°8′	66°25	78°28′	90°	
	211	24°6′	43°5′	56°47′	79°29	90°		
	221	26°34′	41°49′	53°24′	63°26	72°39′	90°	
	310	8°8′	31°57′	45°	64°54	73°34′	81°52′	
	311	19°17′	47°36′	66°8′	82°15			
	320	7°7′	29°45′	41°55′	60°15	68°9′	75°38′	82°53′
	321	17°1′	33°13′	53°18′	61°26	68°59′	83°8′	90°
211	211	0°	33°33′	48°11′	60°	70°32′	80°24′	
	221	17°43′	35°16′	47°7′	65°54	74°12′	82°12′	
	310	25°21′	49°48′	58°55′	75°2′	82°35′		
	311	10°1′	42°24′	60°30′	75°45	90°		
	320	25°4′	37°37′	55°33′	63°5′	83°30′		
	321	10°54′	29°12′	40°12′	49°6′	56°56′		
		70°54′	77°24′	83°44′	90°			
221	221	0°	27°16′	38°57′	63°37	83°37′	90°	
	310	32°31′	42°27′	58°12′	65°4′	83°57′		
	311	25°14′	45°17′	59°50′	72°27	84°14′		
	320	22°24′	42°18′	49°40′	68°18	79°21′	84°42′	
	321	11°29′	27°1′	36°42′	57°41	63°33′	74°30′	
		79°44′	84°53′					

MM 422

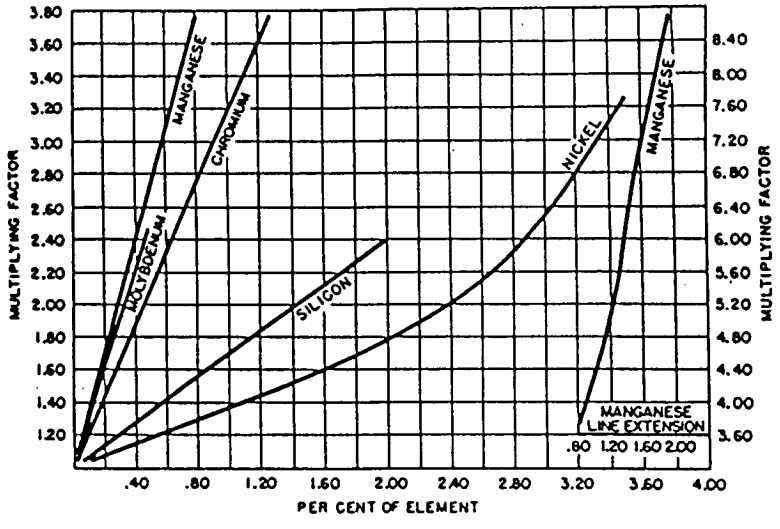
APPENDIX 10
QUADRATIC FORMS OF MILLER INDICES

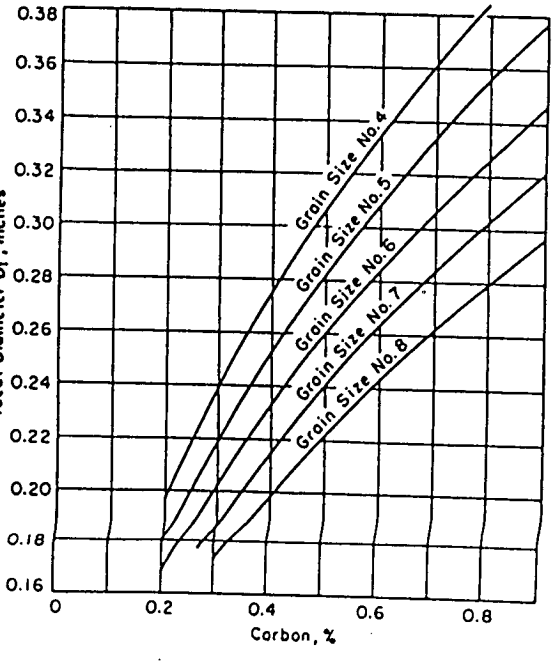
Cubic					Hexagonal	
	hkl					
$h^2 + k^2 + l^2$	Simple	Face-centered	Body-centered	Diamond	$h^2 + hk + k^2$	hk
1	100				1	10
2	110	. . .	110		2	
3	111	111	. . .	111	3	11
4	200	200	200		4	20
5	210				5	
6	211	. . .	211		6	
7					7	21
8	220	220	220	220	8	
9	300, 221				9	30
10	310	. . .	310		10	
11	311	311	. . .	311	11	
12	222	222	222		12	22
13	320				13	31
14	321	. . .	321		14	
15					15	
16	400	400	400	400	16	40
17	410, 322				17	
18	411, 330	. . .	411, 330		18	
19	331	331	. . .	331	19	32
20	420	420	420		20	
21	421				21	41
22	332	. . .	332		22	
23					23	
24	422	422	422	422	24	
25	500, 430				25	50
26	510, 431	. . .	510, 431		26	
27	511, 333	511, 333	. . .	511, 333	27	33
28					28	42
29	520, 432				29	
30	521	. . .	521		30	
31					31	51
32	440	440	440	440	32	
33	522, 441				33	
34	530, 433	. . .	530, 433		34	
35	531	531	. . .	531	35	
36	600, 442	600, 442	600, 442		36	60
37	610				37	43
38	611, 532	. . .	611, 532		38	
39					39	52
40	620	620	620	620	40	
41	621, 540, 443				41	
42	541	. . .	541		42	
43	533	533	. . .	533	43	61
44	622	622	622		44	
45	630, 542				45	
46	631	. . .	631		46	
47					47	
48	444	444	444	444	48	44
49	700, 632				49	70. 52

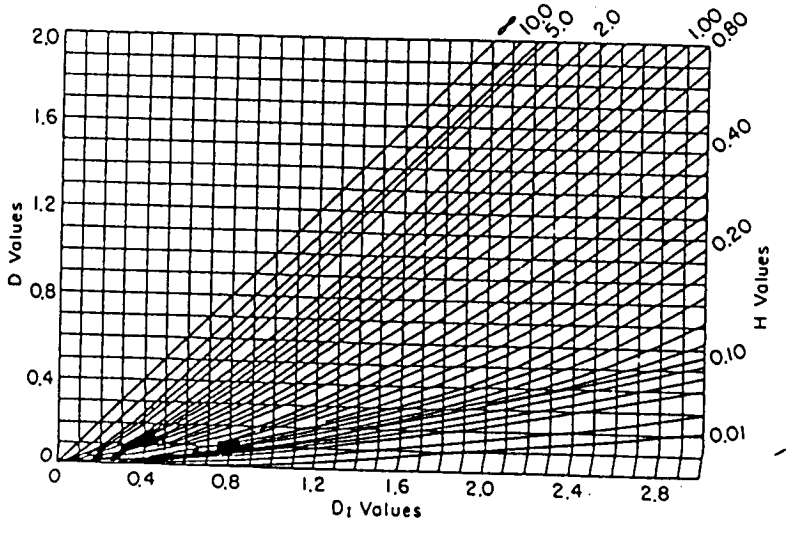
MM 422

Table 18.1 Severity of Quench Values for Some Typical Quenching Conditions.

H Value	*Quenching Condition*
0.20	Poor oil quench – no agitation
0.35	Good oil quench – moderate agitation
0.50	Very good oil quench – good agitation
0.70	Strong oil quench – violent agitation
1.00	Poor water quench – no agitation
1.50	Very good water quench – strong agitation
2.00	Brine quench – no agitation
5.00	Brine quench – violent agitation
∞	Ideal quench







THE UNIVERSITY OF ZAMBIA
UNIVERSITY EXAMINATIONS – FIRST SEMESTER, 1996/97/98

MM 441 – PYROMETALLURGY

TIME: THREE HOURS.
ANSWER: ALL QUESTIONS. THE CREDIT FOR A FULL ANSWER IS SHOWN IN BRACKETS BESIDES EACH QUESTION.

1.a. Copper matte smelting may be conducted in blast, reverberatory, electric, or flash furnaces. What are the relative advantages and disadvantages of using each of these units? (4%)

b. A copper sulphide concentrate that is due to be smelted in an electric furnace analyzes: 30.8% total Cu, 20.0% total Fe, 4.62% Al_2O_3, 1.87% MgO, 26.7% SiO_2, and 1.43% CaO. Calculate how much limerock (with 54.0% CaO) must be added per tonne of the concentrate so that the normalized slag composition is: 59% SiO_2, 31% CaO, and 10% Al_2O_3. State any assumptions made in your calculation. (8%)

c. Assuming that Cu_2S and FeS behave ideally in a matte produced by smelting a copper sulphide concentrate at 1200 °C, and that the activity of FeO in the slag in equilibrium with the matte is 0.5, calculate the activity of Cu_2O in the slag if the matte has 55.9% Cu. Use the thermodynamic data shown below which can all be taken as valid at 1200 °C. (Relative atomic weights: Cu=63.5; Fe=55.8; S=32.0 and the universal gas constant = 1.986 cal/(mol.K) (8%)

i. $4Cu + O_2 = 2Cu_2O$
$\Delta G^\circ_T = -86400 + 37.32T$ cal/mol

ii. $2Fe + O_2 = 2FeO$
$\Delta G^\circ_T = -126400 + 30.94T$ cal/mol

iii. $4Cu + S_2 = 2Cu_2S$
$\Delta G^\circ_T = -50920 + 6.0T$ cal/mol

iv. $2Fe + S_2 = 2FeS$
$\Delta G^\circ_T = -60520 + 16.6T$ cal/mol

/2.....

2.a. A pyrite concentrate is roasted in a fluidized bed roaster with the objective of producing SO_2 gas for use in the manufacture of sulphuric acid. The pyrite cinder is found to contain 7% FeS_2 indicating incomplete reaction while the SO_2 in the flue gas at 7% is thought to be rather low. As a metallurgist in charge of the roaster and acid plant, discuss as fully as possible what measures you would take in order to increase both the FeS_2 conversion and the SO_2 content of the roaster off-gas. Point out the demerits of any measures you suggest. (6%)

b. Use the thermodynamic data given below to construct three lines that would form part of the Ni-S-O predominance area diagram at 527 °C. Assume that all solid phases are in their pure states. (10%)

c. A nickel sulphide concentrate is roasted in a furnace in which the temperature has to be constant at 527 °C. If the furnace atmosphere is found to have an SO_2 partial pressure of 10^{-1} and an O_2 partial pressure of 10^{-8}, state, assuming equilibrium is attained, what nickel phase or phases will be present in the calcine. (2%)

Thermodynamic Data

Gas constant, R = 1.986 cal/(deg.mol)

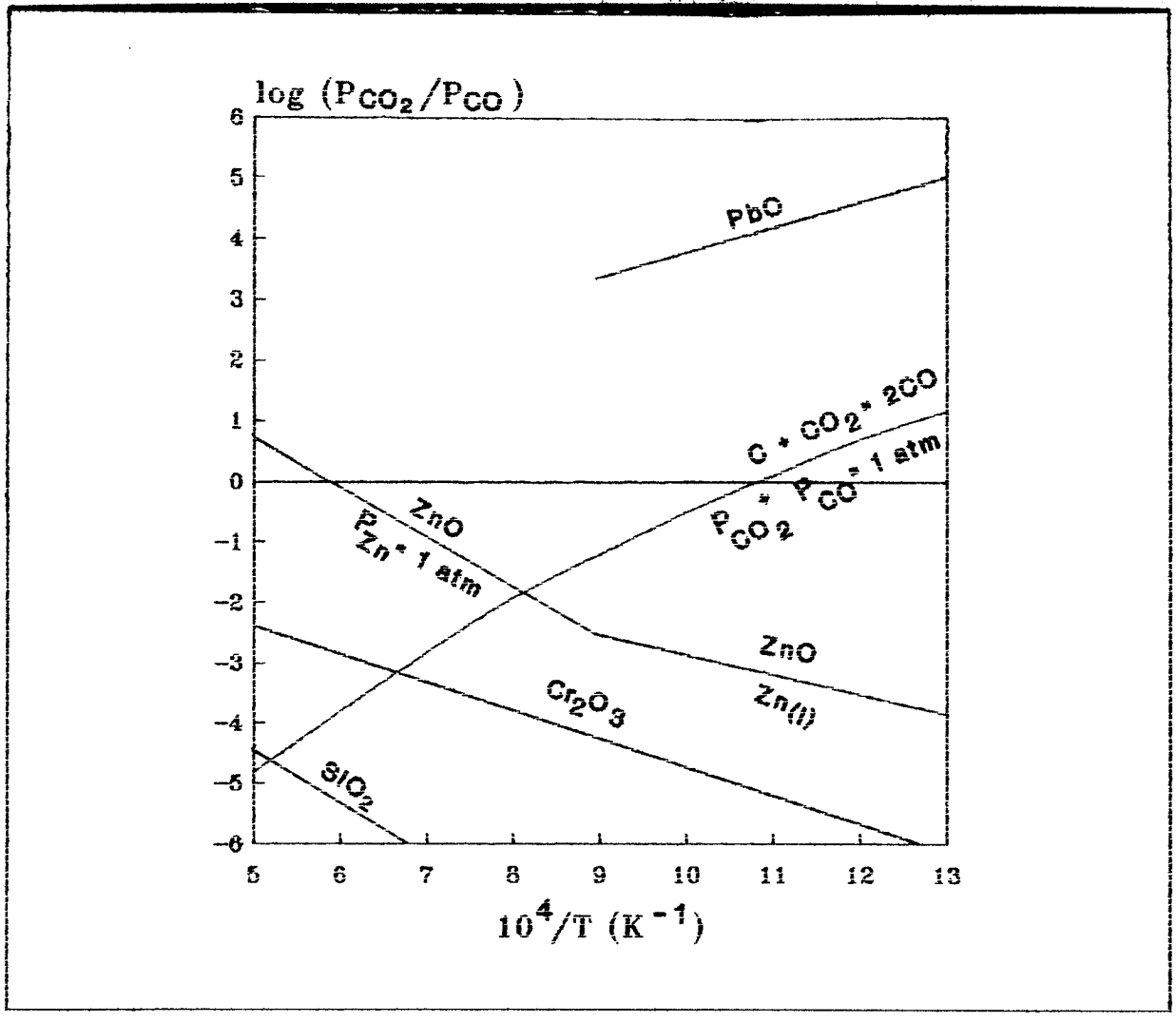
i. $3NiO + 3SO_2 = 3NiS + 4.5O_2$
$\Delta G^\circ_T = 292470 - 61.695T$ cal/mol

ii. $NiSO_4 = NiS + 2O_2$
$\Delta G^\circ_T = 189805 - 89.70T$ cal/mol

iii. $NiSO_4 = NiO + SO_2 + 0.5O_2$
$\Delta G^\circ_T = 92315 - 69.13T$ cal/mol

In the chemical equations above all substances other than O_2 and SO_2 are solid at 527 °C.

3.a. Distinguish between sintering and nodulizing. (3%)



b. On the basis of the figure shown above and for a (CO_2 + CO) total pressure of 1 atmosphere:

i. Give the temperature in °C at which carbon may reduce PbO and SiO_2. (2%)

ii. Is it possible for Si to reduce Cr_2O_3, and if so, at what temperature (in °C)? (2%)

iii. Give the temperature in °C at which carbon may reduce ZnO if the pressure of $Zn_{(g)}$ and (CO_2 + CO) are both one atmosphere. State, also, the approximate composition and total gas pressure of the resulting gas mixture. (4%)

3.c. In an Imperial Smelting Furnace, the sinter charged consists of 50% ZnO, 20% PbO, 20% FeO and 10% SiO_2. Coke which may be regarded as pure amorphous carbon is also charged. Preheated air (21% O_2, 79% N_2) is blown in through the tuyeres. In the furnace, all the coke charged reacts, and the carbon leaves the furnace only as CO and CO_2 of the top gas. All ZnO is reduced to Zn vapour and PbO to liquid Pb, whereas FeO and SiO_2 form a molten slag. The gas after reduction, leaving as top gas, contains 7 volume percent Zn and its CO_2/CO ratio is 0.5. Calculate:

i. The weight of coke required per 100 g of sinter charged. (4%)
ii. The composition of the top gas. (7%)

Relative atomic weights: C = 12.0, Pb = 207.2, Zn = 65.4, O = 16.0, N = 14.0

4.a. Explain the following:

i. Why copper matte converters are never bottom blown. (2%)
ii. What advantages Hoboken copper matte converters have compaired to Peirce-Smith converters. (4%)

b. During the copper blow of the Hoboken converter, white metal at 1200 °C is blown to copper using air enriched with oxygen to 28% O_2. The balance of the air can be taken as nitrogen. If the air blown into the converter is at ambient temperature (25 °C), calculate the amount of copper scrap that has to be charged to the converter per tonne white metal in order for the converting temperature to remain constant at 1200 °C. Assume that air used is 20% in excess of stoichiometric requirements and that heat losses from the converter amount to 10% of the heat evolved by the converting reaction. (18%)

Thermochemical Data

Relative atomic weights: Cu = 63.5; S = 32.1

Heat capacities for copper:

$Cu_{(s)}$: $C_p = 5.41 + 1.50 \times 10^{-3}T$ cal/deg/mol (range: 298 K – m.p.)

$Cu_{(l)}$: $C_p = 7.50$ cal/deg/mol (range: m.p. – 1600 K)

Latent heat of fusion of copper at 1083 °C, $L_f = 3.12$ kcal/mol.

The enthalpy for the substances shown below is to be calculated using the formula:

$$H^0_T - H^\circ_{298} = aT + 0.5bT^2 + c/T + d \quad \text{cal/mol}$$

Substance	a	b x 10^3	c x 10^{-5}	d	H°_{298}
Cu_2S	24.10	–	–	−7152	−19000
O_2	7.16	1.00	−0.40	−2044	–
N_2	6.66	1.02	–	−2030	–
Cu	7.50	–	–	−2235	–
SO_2	10.38	1.54	−1.42	−2729	−70940

5.a. For the following metal refining processes, outline the principles involved:

i. Liquation of tin. (2%)

ii. The Mond process. (2%)

iii. The Parkes process. (2%)

b. Given the data shown below, what is the minimum temperature at which the Pidgeon process can be carried out with a partial pressure of magnesium over the solid reactants of 1 mm Hg? (10%)

$$2MgO_{(s)} + 2CaO_{(s)} + Si_{(s)} = 2Mg_{(g)} + 2CaO.SiO_{2\,(s)}$$

$$\Delta G^\circ_T = 122400 + 11.74T\log T - 100.38T \quad \text{cal}$$

END OF EXAMINATION QUESTION PAPER

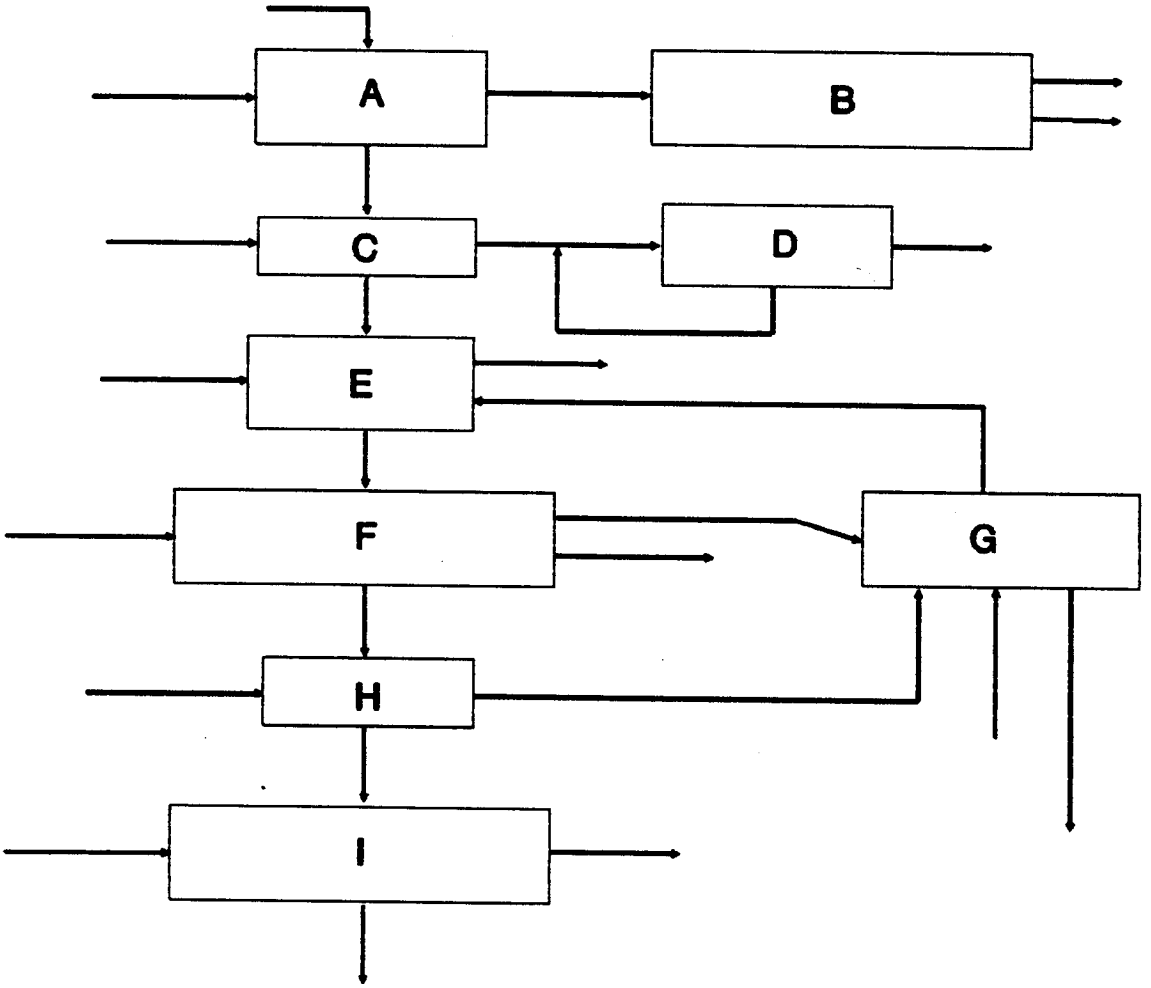
THE UNIVERSITY OF ZAMBIA
UNIVERSITY EXAMINATIONS - SECOND SEMESTER, 1996/98

MM 442
HYDROMETALLURGY

TIME: THREE HOURS.
ANSWER: ALL QUESTIONS. THE CREDIT FOR A FULL ANSWER IS SHOWN IN BRACKETS BESIDES EACH QUESTION.

1.a.(i) As used in the electrorefining of copper anodes derived from copper sulphide concentrates, what is meant by "anode slimes"? (2%)

(ii) Give an indication of the elements and phases present in the slimes. (4%)



1.b. Consider the blank block flow diagram shown on the first page which is for the treatment of copper anode slimes so as to produce separate metals from it. The diagram does not however include recovery of platinum-group-metals.

(i) Name all the steps marked A-I on the diagram. (4%)

(ii) State the inputs and products of each step in the diagram. (6%)

c. Starting sheets each with a submerged cross section of 95 cm X 95 cm are used in a copper electrolytic refining process. The potential drop between anodes and cathodes is maintained at 0.25 V. The average current density is 200 A/m^2.

(i) At a current efficiency of 92%, calculate the time required to deposit 100 kg of copper per starting sheet placed between two anodes. (9%)

(ii) Compute the energy required in kWhr to electrorefine 1 kg of copper. (5%)

Data: Relative atomic weight of Cu = 63.5; F = 96500 C/mol.

2.a. It is known that when carbon dioxide is bubbled through water it forms a weak dibasic acid H_2CO_3 whose overall dissociation constant at 25 °C is $2.08 * 10^{-18}$.

If carbon dioxide is bubbled through an aqueous solution containing Zn^{2+} so as to precipitate zinc carbonate, calculate the minimum solution pH for the residual Zn^{2+} activity in solution not to exceed 10^{-3}. Take the solution temperature as 25 °C and the equilibrium activity of H_2CO_3 in solution as 0.1. The solubility product of zinc carbonate is $1.00 * 10^{-10}$ at 25 °C. (12%)

b. Briefly explain the methods available for crystallizing metal salts from solution in the metallurgical industry. (4%)

2.c. What differences and similarities would you expect when nickel

is precipitated from solution with H_2 or using H_2S? (4%)

3.a. What is the full name of the solvent extraction extractant D2EHPA and into what category of extractant type is it classified? (2%)

b. With reference to the extraction of zinc by D2EHPA, explain the difference between a pH isotherm and an equilibrium extraction isotherm. How are these isotherms determined? (6%)

c. A leach solution with 0.975 g/l Zn^{2+} is used to study Cross-current extraction with D2EHPA dissolved in Escaid as the organic phase. At each stage of extraction, 30 cm^3 of fresh organic is equilibrated with the aqueous phase. If in the first stage of extraction 100 cm^3 of the leach solution is used yielding at equilibrium an extract and raffinate with 1.98 and 0.381 g/l zinc respectively, determine the least number of equilibrium (Cross-current) stages required to yield a final raffinate with not more than 0.013 g/l zinc. Assume a constant distribution coefficient of zinc at each stage and that the organic and aqueous phases are immiscible. (12%)

4. In a continuous agitation leaching operation 2 tonnes of solute-free lixiviant is used for every 1.25 tonnes of a concentrate. The concentrate contains 20% of leachable values, 4% moisture, and the remainder is insoluble material. All leachable values dissolve in the leaching vessel before the pulp is introduced into the first thickener of a 3 stage counter current decantation washing unit. For every 1.25 tonnes concentrate leached, three tonnes of pure wash water is added in the last thickener which yields a disposable residue.

(i) Draw a clearly labelled diagram which would best represent the operation as described above. (3%)

4.(ii) What is the amount of pregnant solution produced for every 1.25 tonnes of concentrate leached, assuming the underflow has 30, 40, and 50 weight percent solids in thickeners 1, 2, and 3, respectively? (5%)

(iii) Assuming a repulping efficiency of 90% in every thickener and thickener underflow densities as stated in the question above, calculate the percentage of dissolved values recovered into the pregnant solution. (7%)

5.a. State the factors that need to be considered and selected in order to obtain optimal results when a material has to be leached. (3%)

b. Construct a Pourbaix diagram for the $Zn-H_2O$ system at 25 °C over the pH range 0 to 11 and indicate the stability regions for the various species. Take the concentration of Zn^{2+} in solution as 10^{-3} mol.dm^{-3}. The boundary between Zn and ZnO should also be calculated and indicated on the diagram. (9%)

$$Zn^{2+} + H_2O = ZnO_{(s)} + 2H^+ \qquad K = 1.1 \times 10^{-11}$$

$$Zn^{2+} + 2e^- = Zn_{(s)} \qquad E^\circ = -0.763\ V$$

c. In the industrial leaching of Zn from scrap metal with an acidic leachant, would hydrogen be evolved or would oxygen need to be supplied?. Explain your answer with the aid of the standard reduction potentials shown below. (3%)

$$2H^+ + 2e^- \leftrightharpoons H_2 \qquad E^\circ = O\ V$$

$$O_2 + 4H^+ + 4e^- = 2H_2O \qquad E^\circ = 1.23\ V$$

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

SCHOOL OF MINES

FIRST SEMESTER FINAL EXAMINATION - MARCH 1998

MM451

TRANSPORT PHENOMENA

TIME: THREE hours
ANSWER: FIVE questions

All questions carry equal marks

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1. (a) Dimensional analysis is useful in the design of centrifugal pumps. The pressure rise across a pump P(this term is proportional to the "head" developed by the pump) may be considered to be affected by the fluid density ρ, the angular velocity ω, the impeller diameter D, the volumetric flowrate Q and the fluid viscosity μ. Find the pertinent dimensionless groups, choosing them so that P, Q and μ each appear in one group only.

   (b) If we have a pressure distribution in a fluid given as

   $$P = xy + (x + z^2) + 10 \text{ kPa}$$

   Calculate the force per unit volume on an element of the medium in the direction of $\vec{e} = 0.95\,\vec{i} + 0.32\,\vec{j}$ m at position x = 10 m, y = 3 m, z = 4 m.

2. (a) A cube of material 300 mm on an edge and weighing 445 N is lowered into a tank containing a layer of water (density, 1000 kg/m^3) over a layer of mercury (specific gravity, 13.6). If the block is completely immersed, determine its position, in terms of its height in the water layer, when it has reached equilibrium. Assume g is 9.81 m/s^2.

   (b) A well-stirred vessel contains 10 000 kg of solution of a dilute methanol solution (w_A = 0.05 mass fraction alcohol). A constant flow of 500 kg/min of pure water is suddenly introduced into the tank and a constant withdrawal of 500 kg/min of solution is started. These two flows are continued and remain constant. Assuming that the densities of the solutions are the same and that the total contents of the tank remain constant at 10 000 kg of solution, calculate the time for the alcohol content to drop to 1.0 wt %.

3. (a) Water issues out as a free jet to the atmosphere from a 180° elbow-nozzle assembly. The interior volume of the assembly is 0.1 m^3; the water enters the elbow at 1.5 m/s with an entrance diameter of 0.3 m and a gauge pressure of 100 kPa. The nozzle exit diameter is 0.15 m. The density of water is 1000 kg/m^3 and atmospheric pressure is 101.3 kPa. Neglecting frictional effects, calculate the force components on the elbow-nozzle assembly from the water.

(b) In a vertical wetted-wall tower, the fluid flows down the inside of a thin film δ m thick in laminar flow in the vertical y direction. Using the Navier-Stokes equations or otherwise, derive the equation for the velocity profile v_y as a function of x, the distance from the liquid surface to the wall. Also, derive expressions for v_{yav} and v_{ymax}.

4. Hot water in an open storage tank at 82.2°C is being pumped at the rate of 0.379 m^3/min from this storage tank. The line from the storage tank to the pump suction is 6.1 m of 53 - mm i.d. steel pipe (e/D = 0.001) and it contains three 90° elbows (Le/D = 35). The discharge line after the pump is 61 m of 53 - mm i.d. steel pipe and contains two 90° elbows. The water discharges to the atmosphere at a height of 6.1 m above the water level in the storage tank.

(a) Calculate all frictional losses in J/kg
(b) Make a mechanical energy balance and calculate W_s of the pump in J/kg
(c) What is the kW power of the pump if its efficiency is 75%?

Density of water = 970 kg/m^3
Viscosity of water = 0.345×10^{-3} Pa.s
$h_L = 2 f_f L v^2/gD$
$g = 9.81\ m/s^2$

5. A composite wall is to be constructed of 6 mm stainless steel (k = 17.3 W/m. K), 80 mm of corkboard (k = 0.043 W/m.K) and 12 mm of plastic (k = 2.6 W/m.K). The gases adjacent to the inner (steel) and outer surfaces are at 120°C and 21°C. The convective heat-transfer coefficients at the inner and outer surfaces are 230 $W/m^2.K$ and 30 $W/m^2.K$ respectively.

Determine

(a) the heat flux,
(b) the maximum temperature reached within the plastic,
(c) which of the individual resistances is controlling and the maximum temperature within it.

6. (a) A heated vertical wall 0.3 m by 0.3 m of an oven for baking food is in contact with air at 38°C. The rate of heat loss by natural convection is 127 W. Calculate the surface temperature of the oven wall in °C.

$h = 1.37 (\Delta T/L)^{0.25}$ W/m^2.K

(b) A spherical vessel, 1.2 m diameter, is to be used for the storage of liquid nitrogen at 77°K in an area where the relative humidity of the air surrounding the sphere will be 80% at 305 K. What thickness of insulation, k = 0.02 W/m.K, will be necessary to prevent condensation in the insulation surface? The heat transfer coefficient at the insulation surface may be taken as 12 W/m^2.K and the ambient temperature is 310K.

7. Ammonia gas (A) is diffusing through N_2 (B) under steady-state conditions with N_2 nondiffusing since it is insoluble in one boundary. The total pressure is 1.013×10^5 Pa and the temperature is 298K. The partial pressure of NH_3 at one point is 1.333×10^4 Pa and at the other point 20 mm away it is 6.666×10^3 Pa. The D_{AB} for the mixture at 1.013×10^5 Pa and 298K is 2.30×10^{-5} m^2/s. The gas constant R is 8314 m^3.Pa/kmol.K.

(a) Calculate the flux of NH_3 in kmol/s.m^2
(b) Do the same as (a) but assume that N_2 also diffuses. In which case is the flux greater?

END OF EXAMINATION IN MM451

THE UNIVERSITY OF ZAMBIA
SCHOOL OF MINES

SECOND SEMESTER EXAMINATIONS - SEPTEMBER 1998

MM 452

PROCESS CONTROL AND INSTRUMENTATION

Time: THREE HOURS

Answer: FIVE QUESTIONS

ALL QUESTIONS CARRY EQUAL MARKS

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1. (a) A thermometer having a time constant of 1 min is initially at 50°C. It is immersed in a bath maintained at 100°C at t=0. Determine the temperature reading at t=1.2 min.

   (b) In part (a), if at t=1.5 min, the thermometer is removed from the bath and put in a bath at 75°C, determine the maximum temperature indicated by the thermometer. Determine the indicated temperature at t=20 min.

   (c) Determine Y(5) if $Y(s) = \dfrac{e^{-3s}}{s(7s+1)}$

2. A two-tank noninteracting liquid level system is operating at steady state when a unit step change is made in the flow rate to tank 1. The transient response is critically damped, and it takes 1 min for the change in level of the second tank to reach 50 percent of its total change.

   If the ratio of the cross-sectional areas of the tanks is $A_1/A_2 = 2$, calculate the ratio R_1/R_2 assuming linear valves. Show that the time constant for each tank is 0.6 min. How long does it take for the change in level in the first tank to reach 90 percent of its total change?

   $$\frac{H_2(s)}{Q(s)} = \frac{R_2}{(\tau_1 s+1)(\tau_2 s+1)}$$

3. The two-tank heating process shown in the given figure consists of two identical well-stirred tanks in series. A flow of heat can enter tank 2. At time t=o, the flow rate of heat to tank 2 suddenly increases according to a step function to 1000 kJ/min, and the temperature of the inlet water T_i drops from 25°C to 20°C according to a step function. These changes in heat flow and inlet water temperature occur simultaneously.

(a) Develop a block diagram that relates the outlet temperature of tank 2 to the inlet temperature to tank 1 and the flow of heat to tank 2.

(b) Obtain an expression for $T_2'(s)$ where T_2' is the deviation in the temperature of tank 2.

(c) Determine $T_2(\infty)$.

The following data apply:

w = 110 kg/min

holdup volume in each tank V = 0.15 m^3
density of fluid ρ = 800 kg/m^3
heat capacity of fluid C_p= 4.0 kJ/(kg) (°C)

4. (a) A proportional controller is used to control liquid level within the range 1.85 m to 2.25 m. It is found that after adjustment the controller output current changes by 0.8 ma for a 0.01 m variation in level with desired value held constant. If a variation in current from 4 ma to 20 ma moves the control valve from fully open to fully closed, determine the proportional gain and proportional band.

(b) Water is pumped from a tank at atmospheric pressure through a heat exchanger and a control valve into a process vessel held at 7.03 kg_f/cm^2 gauge pressure. The system is designed for a maximum flow rate of 90.84 m^3/h. At this maximum flow rate, the pressure drop across the heat exchanger is 3.515 kg_f/cm^2. A centrifugal pump is used with a performance curve that can be approximated by the relationship

$$\Delta P_p = 13.942 - 1.986 \times 10^{-4} Q^2$$

where

ΔP_p = pump head in kg_f/cm^2
Q = flow rate in m^3/h

Calculate the fraction that the control valve is open when the throughout is reduced to 45.42 m^3/h for a linear valve and an equal percentage valve of equal size with α = 50 by pinching down on each type of control valve.

5. A PD controller is used in a control system having a first order process and a first order measurement lag, both with unity steadystate gain. Assume a unit step change in setpoint.

(a) Find expressions for ς and τ for the closed-loop response.

(b) If τ_I = 1 min, τ_m = 10 sec, show that ς = 0.7 for the two cases: (i) τ_D=0, K_c=3.15; (ii) τ_D=3 sec, K_c=5.25. Convert time units to minutes.

(c) Compare the offset and period realised in both cases in part (b), and comment on the advantage of adding the derivative mode.

6. (a) A control system has the following characteristic equation:

$$s^4 + 4s^3 + 6s^2 + 4s + (1 + K) = 0$$

Determine the value of K above which the system is unstable. Also, calculate the values of the imaginary roots on the imaginary axis and the corresponding remaining two roots.

(b) A closed loop control system has the following transfer functions:

$$G_c = K_c \; ; \; G_2 = \frac{2}{(s+1)^3} \; ; \; H=1.$$

Find the value of K_c for which the system is on the verge of stability.

7. A three-mode controller (PID) has constants K_p = 3, K_D = 2s, K_I = 2.1s^{-1} and P(0) = 35%. Determine the controller output P for the following error:

0 - 2 s : ε_p = 1%
2 - 4 s : ε_p = -t + 3%
>4 s : ε_p = 0 %

Calculate the controller output for t = 1s, 3s and greater than 4s (beyond which time the error has become zero).

END OF EXAMINATION IN MM 452

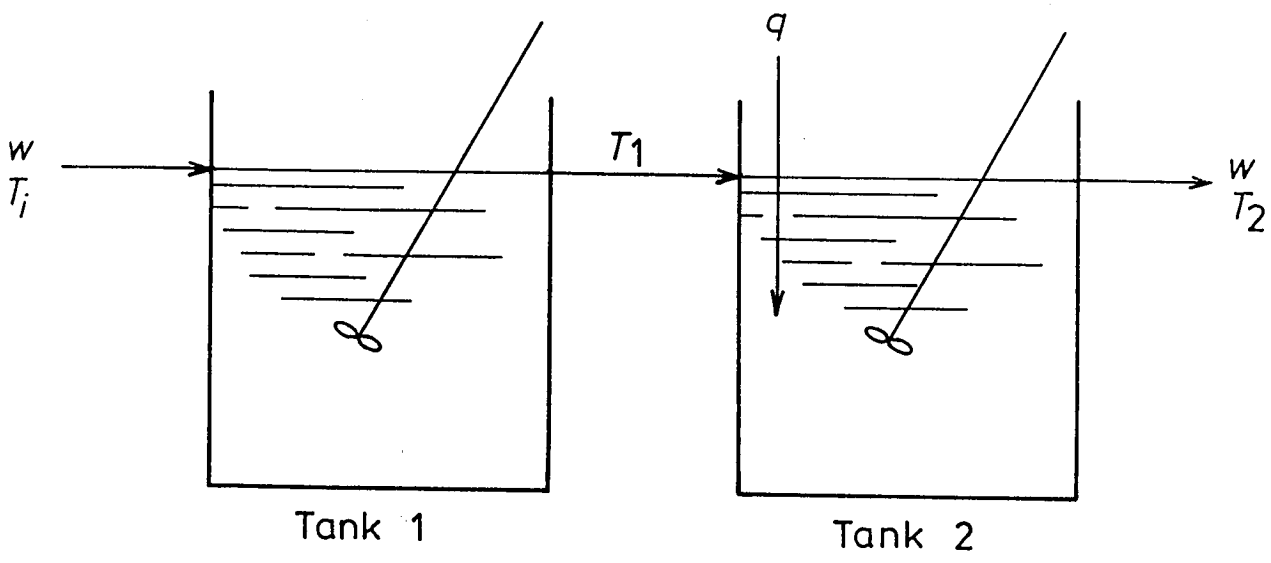

DIAGRAM FOR QUESTION 3

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS – FIRST SEMESTER, JANUARY 2001

MM 481: FERROUS METALLURGY

TIME: THREE HOURS

ANSWER: ALL QUESTIONS (FIVE)

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1. Describe the main operating parts of the Blast Furnace showing how the design of the hearth, bosh and stack correspond to their function. (6%)

(a) With the aid of a sketch, describe the COREX Process of iron production. What are the **two** most important advantages of the COREX process over the Blast Furnace hot metal production. (6%)

(b) Give **four** requirements for a good coke for Blast Furnace operation. (4%)

(c) Draw a sketch of the Blast Furnace showing the **five** internal zones and describe the function of each zone. (4%)

2.

(a) In Direct Reduction of iron ores, if the energy has to be used wisely, some way of reconciling the conflicting requirements of reduction and heating the charge has to be found. Describe **two** designs that exist for the process to solve this problem. (5%)

(b) Where does the sulphur in the hot metal originate from and how is it removed? (2%)

The desulphurisation reaction may be represented as:

$$FeS + CaO \rightarrow CaS + Fe + CO$$

Give **three** reasons why this reaction is said to be inefficient. (3%)

(c) External desulphurisation of hot metal is possible before the steelmaking plant. Describe **four** factors that affect the efficiency of desulphurisation. (4%)

(d) Desulphurisation by magnesium presents problems in steelmaking due to its high reactivity. Describe **three** ways of controlling these problems. (6%)

3.

(a) Write the formular for calculating the productivity of a sintering machine, describe the symbols and their units. (3%)

(b) A pig iron Blast Furnace Plant produces 5,000 tonnes Pig Iron (PI) per working day consuming 1.5 tonnes sinter per tonne PI produced. Eight per cent of sinter delivered to the Blast Furnace is returned back after sieving in the Blast Furnace charging section. Within the sintering plant 5 sintering strands each of 175 m^2 surface area are present. Only 4 of them are in operation at a time. If the sintering plant operates 20 hours per working day, calculate:

(i) the productivity of each sintering machine per day (3%)
(ii) the length of the sintering strand used in this plant (7%)

If sinter charged to the Blast Furnace shop, while being transported from the mixing department uses concave belt conveyors inclining by 20^o and of 1.2 m width, moving with a speed of 1.5 m/s. 9% of mixed charge is lost as dust before the sintering band and the bulk density of mixed charge is 1.8 t/m^3.

Calculate:

(iii) the number of belt conveyors required (7%)

Productivity factor = 60%
Bulk density of sinter = 1.5 t/m^3
Height of material in pallet = 350 mm
Speed of sintering strand = 2m/min
Constant for 20^o inclination, K = 0.81
Productivity of concave conveyor:

$$P = K * 280 * B^2 * W * V \quad (t/hr)$$

4.

(a) The Top Blown Basic Oxygen Steelmaking Process replaced the Bessemer and Open Hearth processes in the early 1950s. Give **seven** reasons why this was so. (7%)

(b) What prompted the re-introduction of the Bottom Blown Steelmaking Process in 1967? (3%)

(c) Dephosphorisation has been found to be better in the Q-BOP than in the BOP. Why? (2%)

(d) What is the influence of **carbon** and **hydrogen** on steel properties? (5%)

(e) Write short notes on manganese distribution in steelmaking.(3%)

5.

(a) For ingot moulds, why is it possible to use cast iron with a melting point much lower than that of steel? (2%)

(b) Distinguish between Basket and Bottom pouring. (4%)

(c) What is the advantage of Bottom pouring? (1%)

(d) Why is it necessary to protect steel from re-oxidation during casting and how is this done? (2%)

(e) Give a general description of a continuous casting plant. (6%)

(f) Describe the progress of solidification in the mould during continuous casting. (5%)

END OF EXAMINATION IN MM 481

THE UNIVERSITY OF ZAMBIA
SCHOOL OF MINES
MM515

Special Topics in Mineral Processing

Time: Three hours
Answer: Five questions

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1. 0.561g of a coal powder absorbed with the following amounts of nitrogen, n at 195°C and various pressures, P

n (milli moles)	0.439	0.534	0.623	0.693	0.754	0.84
p, (Cm, Hg)	2.5	6.30	11.4	16.5	20.8	25.8

   (a) Calculate the specific surface area of the powder using the BET equation

   (b) The surface area of the powder as measured by election microscopy was $60m^2g$! What can you say abut the internalmorphology of the powder?

   BET Equation can be written as:-

$$\frac{P}{V(P_o - P)} = \frac{1}{V_m C} + \frac{C-1}{V_m C}\left(\frac{P}{P_o}\right)$$

   The cross sectional area of a nitrogen molecule is 16.2×10^{-20} m^2.

2. Study the attached flowsheet of the treatment of a pegmatite ore containing quartz, feldspar, mica andiron oxide. The intermediate flotation stage in (a) may be replaced by the outlined in (b). For the given combination of reagents in both (a) and (b) predict what minerals you would expect in the concentrates 1 to 3 and in the tailings.

   Discuss initially the role of each reagent, outlining the theoretical basis for the separation you have predicted. The iep values for the minerals occur at pH values of 1.5, 2.8, 2.8 and 6.2 for mica, quartz, feldspar and hematite respectively.

3. A quantity of ore containing chalcopyrite ($CuFeS_2$) is going to be used in flotation studies. The total amount of material available is 20 kg. to determine the assay of the ore, 200 g is carefully removed and reduced to 100% passing 75 μm before extracting a 2 g sub-sample on which chemical analysis is to be performed. The ore is found to be 3.41% Cu.

Determine to the 95% confidence limit the combined error zero. The largest piece in the ore is 6.35mm and the richest piece is visually estimated to be containing 75% chalcopyrite. The density of the mineral and gangue are 4.2 and 2.7 g/m^3 respectively. The shape and size factors are 05. and 0.25 respectively.

4. (a) What do you understand by "particle size distribution functions" and what is their significance in practice? Give the general equation of these functions and define all the parameters.

(b) Mention the two commonly used function and define the ... meaning of all symbols. Show how meaningful interpretation can be made to check whether a set of data confirm a given function.

(c) Can you show how the two equation may be seen to be almost the same

(d) A particle distribution of an ore is known to follow the G.S function with 90% and 50% of the particles being less than 1mm and 0.5mm respectively. What is the weight % between 10μm and 20μm?

5. Two parallel ball mill-hydrocyclone circuits treating the same ore are used in an experiment to discover a way of increasing the fineness of grind. alterations are made to the operating parameters of one circuit leaving the other unchanged and the final product from each circuit (cyclone overflow) monitored in terms of % passing 76 μm. The results for nine (9) consecutive shifts were:-

Shift	Circuit 1,%	Circuit 2, %
1	36.8	38.2
2	31.4	31.0
3	29.8	33.6
4	35.2	42.1
5	40.6	45.6
6	36.1	34.3
7	30.5	30.1
8	28.2	32.6
9	32.6	33.2

(a) Does the modified circuit give a finer grind?

(c) What conclusion would have been reached if the test had been terminated after 6 shifts?

6. (a) "Only regular geometrical shapes can have their sizes conveniently quantified". Discuss the implications of this statement with regards to:-

(i) the various definitions of "size".

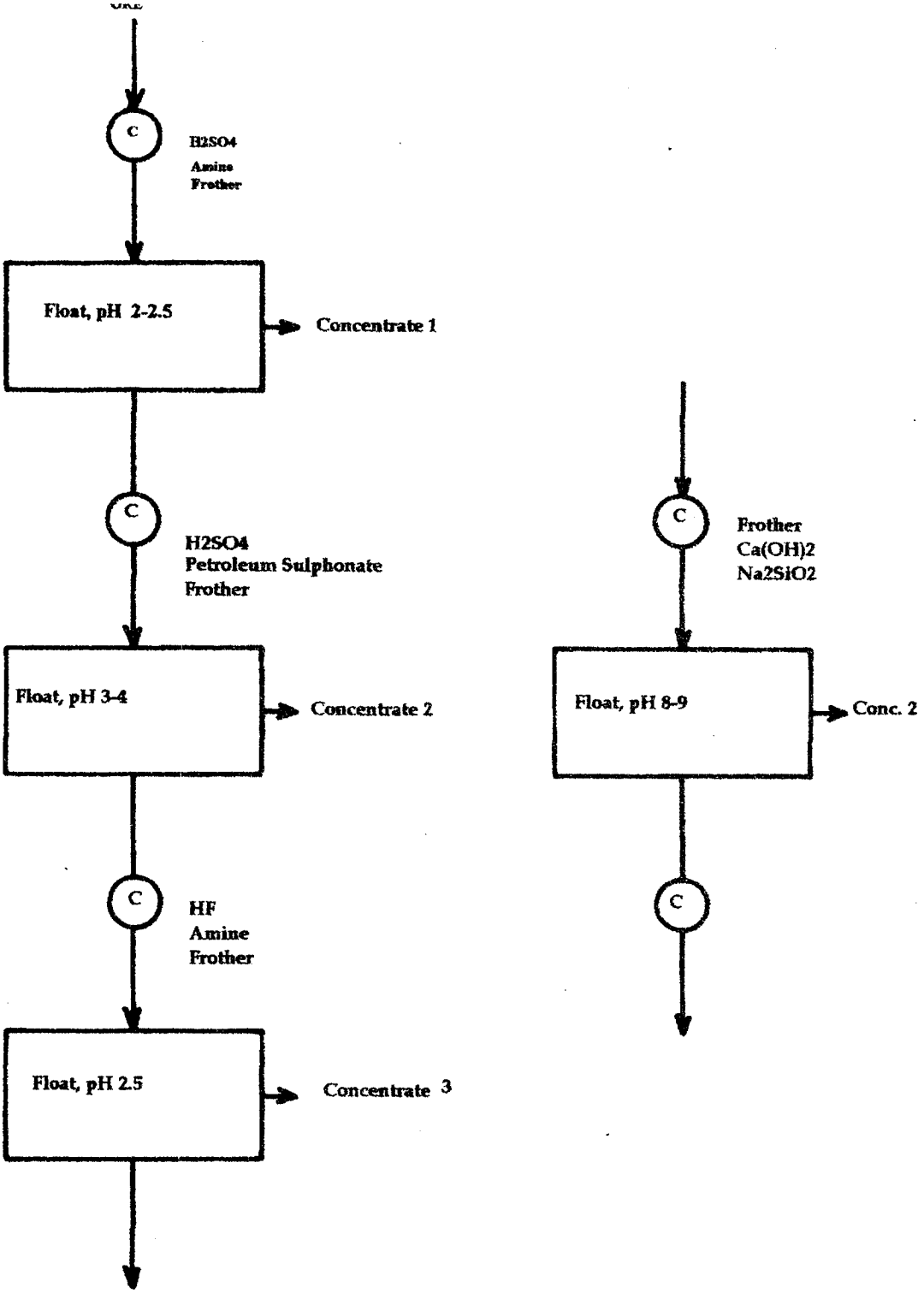
(ii) application of these definitions of size.

(b) Discuss the principle involved in incremental methods and show how the data obtained may be useful

(c) Describe the Andreasen pipette and the interpretation/calculation of results

(iii) What are the main disadvantages of this apparatus.

END OF MM515 EXAMINATION 96/97/98


C
H2SO4
Amine
Frother
Float, pH 2-2.5
Concentrate 1
C
H2SO4
Petroleum Sulphonate
Frother
Float, pH 3-4
Concentrate 2
C
HF
Amine
Frother
Float, pH 2.5
Concentrate 3
C
Frother
Ca(OH)2
Na2SiO2
Float, pH 8-9
Conc. 2
C

The p.d.f. of a t-distribution with ν d.f. is given by

$$f(t) = \frac{(1+t^2/\nu)^{-\frac{1}{2}(\nu+1)}\Gamma[\frac{1}{2}(\nu+1)]}{\sqrt{(\pi\nu)}\Gamma(\frac{1}{2}\nu)} \qquad (-\infty \leqslant t \leqslant +\infty).$$

The distribution is symmetric about $t = 0$. Its mean and variance are 0 and $\nu/(\nu-2)$ respectively. It tends to the standard normal distribution as $\nu \to \infty$. Percentage points are given in Table 2, Appendix B.

The F-distribution

If X_1, X_2 are independent χ^2 random variables with ν_1, ν_2 d.f. respectively, then the random variable

$$F = \frac{X_1/\nu_1}{X_2/\nu_2}$$

is said to have an F-distribution with ν_1 and ν_2 d.f. respectively.

This distribution is useful in a number of situations including the following: two random samples, size n_1 and n_2 respectively, are taken from a normal distribution, mean μ and variance σ^2. The two sample variances, s_1^2, and s_2^2, are calculated in the usual way. Then the sampling distribution of $(n_1-1)s_1^2/\sigma^2$ is χ^2 with (n_1-1) d.f., and the sampling distribution of $(n_2-1)s_2^2/\sigma^2$ is χ^2 with (n_2-1) d.f. Thus the statistic

$$F = \frac{\dfrac{(n_1-1)s_1^2/\sigma^2}{n_1-1}}{\dfrac{(n_2-1)s_2^2/\sigma^2}{n_2-1}} = \frac{s_1^2}{s_2^2}$$

has an F-distribution with (n_1-1) and (n_2-1) d.f.

The mean of the F-distribution is equal to $\nu_2/(\nu_2-2)$ for $\nu_2 > 2$. Thus the mean is very close to one for fairly large values of ν_2, and the distribution is always skewed to the right. Upper percentage points of the distribution are given in Table 4, Appendix B. Lower percentage points can be found using the equation

$$F_{1-\alpha,\nu_1,\nu_2} = \frac{1}{F_{\alpha,\nu_2,\nu_1}}.$$

Appendix B **Statistical tables**

Table 1 Areas under the normal curve

	·00	·01	·02	·03	·04	·05	·06	·07	·08	·09
0·0	·5000	·5040	·5080	·5120	·5160	·5199	·5239	·5279	·5319	·5359
·1	·5398	·5438	·5478	·5517	·5557	·5596	·5636	·5675	·5714	·5753
·2	·5793	·5832	·5871	·5910	·5948	·5987	·6026	·6064	·6103	·6141
·3	·6179	·6217	·6255	·6293	·6331	·6368	·6406	·6443	·6480	·6517
·4	·6554	·6591	·6628	·6664	·6700	·6736	·6772	·6808	·6844	·6879
·5	·6915	·6950	·6985	·7019	·7054	·7088	·7123	·7157	·7190	·7224
·6	·7257	·7291	·7324	·7357	·7389	·7422	·7454	·7486	·7517	·7549
·7	·7580	·7611	·7642	·7673	·7703	·7734	·7764	·7793	·7823	·7852
·8	·7881	·7910	·7939	·7967	·7995	·8023	·8051	·8078	·8106	·8133
·9	·8159	·8186	·8212	·8238	·8264	·8289	·8315	·8340	·8365	·8389
1·0	·8413	·8438	·8461	·8485	·8508	·8531	·8554	·8577	·8599	·8621
1·1	·8643	·8665	·8686	·8708	·8729	·8749	·8770	·8790	·8810	·8830
1·2	·8849	·8869	·8888	·8906	·8925	·8943	·8962	·8980	·8997	·9015
1·3	·9032	·9049	·9066	·9082	·9099	·9115	·9131	·9147	·9162	·9177
1·4	·9192	·9207	·9222	·9236	·9251	·9265	·9279	·9292	·9306	·9319
1·5	·9332	·9345	·9357	·9370	·9382	·9394	·9406	·9416	·9429	·9441
1·6	·9452	·9463	·9474	·9484	·9495	·9505	·9515	·9525	·9535	·9545
1·7	·9554	·9564	·9573	·9582	·9591	·9599	·9608	·9616	·9625	·9633
1·8	·9641	·9648	·9656	·9664	·9671	·9678	·9686	·9693	·9699	·9706
1·9	·9713	·9719	·9726	·9732	·9738	·9744	·9750	·9756	·9761	·9767
2·0	·9772	·9778	·9783	·9788	·9793	·9798	·9803	·9808	·9812	·9817
2·1	·9821	·9826	·9830	·9834	·9838	·9842	·9846	·9850	·9854	·9857
2·2	·9861	·9864	·9868	·9871	·9875	·9878	·9881	·9884	·9887	·9890
2·3	·9893	·9896	·9898	·9901	·9904	·9906	·9909	·9911	·9913	·9916
2·4	·9918	·9920	·9922	·9924	·9927	·9929	·9930	·9932	·9934	·9936
2·5	·9938	·9940	·9941	·9943	·9945	·9946	·9948	·9949	·9951	·9952
2·6	·9953	·9955	·9956	·9957	·9959	·9960	·9961	·9962	·9963	·9964
2·7	·9965	·9966	·9967	·9968	·9969	·9970	·9971	·9972	·9973	·9974
2·8	·9974	·9975	·9976	·9977	·9977	·9978	·9979	·9979	·9980	·9981
2·9	·9981	·9982	·9982	·9983	·9984	·9984	·9985	·9985	·9986	·9986
3·0	·9986	·9987	·9987	·9988	·9988	·9989	·9989	·9989	·9990	·9990
3·1	·9990	·9991	·9991	·9991	·9992	·9992	·9992	·9992	·9993	·9993
3·2	·9993	·9993	·9994	·9994	·9994	·9994	·9994	·9995	·9995	·9995
3·3	·9995	·9995	·9995	·9996	·9996	·9996	·9996	·9996	·9996	·9996
3·4	·9997	·9997	·9997	·9997	·9997	·9997	·9997	·9997	·9997	·9998
3·5	·9998	·9998	·9998	·9998	·9998	·9998	·9998	·9998	·9998	·9998
3·6	·9998	·9998	·9998	·9999	·9999	·9999	·9999	·9999	·9999	·9999

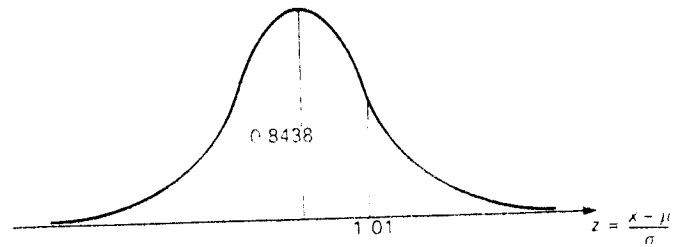


Table 2 Percentage points of Student's t-distribution

a	·10	·05	·025	·01	·005	·001
ν						
1	3·078	6·314	12·706	31·821	63·657	318·310
2	1·886	2·920	4·303	6·965	9·925	22·327
3	1·638	2·353	3·182	4·541	5·841	10·215
4	1·533	2·132	2·776	3·747	4·604	7·173
5	1·476	2·015	2·571	3·365	4·032	5·893
6	1·440	1·943	2·447	3·143	3·707	5·208
7	1·415	1·895	2·365	2·998	3·499	4·785
8	1·397	1·860	2·306	2·896	3·355	4·501
9	1·383	1·833	2·262	2·821	3·250	4·297
10	1·372	1·812	2·228	2·764	3·169	4·144
11	1·363	1·796	2·201	2·718	3·106	4·025
12	1·356	1·782	2·179	2·681	3·055	3·930
13	1·350	1·771	2·160	2·650	3·012	3·852
14	1·345	1·761	2·145	2·624	2·977	3·787
15	1·341	1·753	2·131	2·602	2·947	3·733
16	1·337	1·746	2·120	2·583	2·921	3·686
17	1·333	1·740	2·110	2·567	2·898	3·646
18	1·330	1·734	2·101	2·552	2·878	3·610
19	1·328	1·729	2·093	2·539	2·861	3·579
20	1·325	1·725	2·086	2·528	2·845	3·552
21	1·323	1·721	2·080	2·518	2·831	3·527
22	1·321	1·717	2·074	2·508	2·819	3·505
23	1·319	1·714	2·069	2·500	2·807	3·485
24	1·318	1·711	2·064	2·492	2·797	3·467
25	1·316	1·708	2·060	2·485	2·787	3·450
26	1·315	1·706	2·056	2·479	2·779	3·435
27	1·314	1·703	2·052	2·473	2·771	3·421
28	1·313	1·701	2·048	2·467	2·763	3·408
29	1·311	1·699	2·045	2·462	2·756	3·396
30	1·310	1·697	2·042	2·457	2·750	3·385
40	1·303	1·684	2·021	2·423	2·704	3·307
60	1·296	1·671	2·000	2·390	2·660	3·232
120	1·289	1·658	1·980	2·358	2·617	3·160
∞	1·282	1·645	1·960	2·326	2·576	3·090

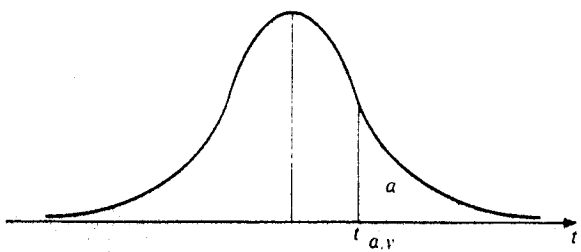
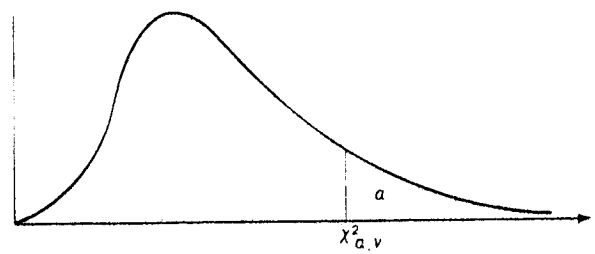


Table 3 Percentage points of the χ^2 distribution

a	·995	·99	·975	·95	·50	·20	·10	·05	·025	·01	·005
ν											
1	0·000	0·0002	0·001	0·0039	0·45	1·64	2·71	3·84	5·02	6·63	7·88
2	0·010	0·020	0·051	0·103	1·39	3·22	4·61	5·99	7·38	9·21	10·60
3	0·072	0·115	0·216	0·352	2·37	4·64	6·25	7·81	9·35	11·34	12·84
4	0·207	0·30	0·484	0·71	3·36	5·99	7·78	9·49	11·14	13·28	14·86
5	0·412	0·55	0·831	1·15	4·35	7·29	9·24	11·07	12·83	15·09	16·75
6	0·676	0·87	1·24	1·64	5·35	8·56	10·64	12·59	14·45	16·81	18·55
7	0·989	1·24	1·69	2·17	6·35	9·80	12·02	14·07	16·01	18·48	20·28
8	1·34	1·65	2·18	2·73	7·34	11·03	13·36	15·51	17·53	20·09	21·95
9	1·73	2·09	2·70	3·33	8·34	12·24	14·68	16·92	19·02	21·67	23·59
10	2·16	2·56	3·25	3·94	9·34	13·44	15·99	18·31	20·48	23·21	25·19
11	2·60	3·05	3·82	4·57	10·34	14·63	17·28	19·68	21·92	24·72	26·76
12	3·07	3·57	4·40	5·23	11·34	15·81	18·55	21·03	23·34	26·22	28·30
13	3·57	4·11	5·01	5·89	12·34	16·98	19·81	22·36	24·74	27·69	29·82
14	4·07	4·66	5·63	6·57	13·34	18·15	21·06	23·68	26·12	29·14	31·32
15	4·60	5·23	6·26	7·26	14·34	19·31	22·31	25·00	27·49	30·58	32·80
16	5·14	5·81	6·91	7·96	15·34	20·47	23·54	26·30	28·85	32·00	34·27
17	5·70	6·41	7·56	8·67	16·34	21·61	24·77	27·59	30·19	33·41	35·72
18	6·26	7·02	8·23	9·39	17·34	22·76	25·99	28·87	31·53	34·81	37·16
19	6·84	7·63	8·91	10·12	18·34	23·90	27·20	30·14	32·85	36·19	38·58
20	7·43	8·26	9·59	10·85	19·34	25·04	28·41	31·41	34·17	37·57	40·00
21	8·03	8·90	10·28	11·59	20·34	26·17	29·62	32·67	35·48	38·93	41·40
22	8·64	9·54	10·98	12·34	21·34	27·30	30·81	33·92	36·78	40·29	42·80
23	9·26	10·20	11·69	13·09	23·34	28·43	32·01	35·17	38·08	41·64	44·18
24	9·89	10·86	12·40	13·85	23·34	29·55	33·20	36·42	39·36	42·98	45·56
25	10·52	11·52	13·12	14·61	24·34	30·68	34·38	37·65	40·65	44·31	46·93
26	11·16	12·20	13·84	15·38	25·34	31·79	35·56	38·89	41·92	45·64	48·29
27	11·81	12·88	14·57	16·15	26·34	32·91	36·74	40·11	43·19	46·96	49·64
28	12·46	13·57	15·31	16·93	27·34	34·03	37·92	41·34	44·46	48·28	50·99
29	13·12	14·26	16·05	17·71	28·34	35·14	39·09	42·56	45·72	49·59	52·34
30	13·79	14·95	16·79	18·49	29·34	36·25	40·26	43·77	46·98	50·89	53·67
40	20·71	22·16	24·43	26·51	39·34	47·27	51·81	55·76	59·34	63·69	66·77
50	27·99	29·71	32·36	34·76	49·33	58·16	63·17	67·50	71·41	76·15	79·49
60	35·53	37·48	40·48	43·19	59·33	68·97	74·40	79·08	83·30	88·38	91·95
70	43·28	45·44	48·76	51·74	69·33	79·71	85·53	90·53	95·02	100·43	104·2
80	51·17	53·54	57·15	60·39	79·33	90·41	96·58	101·88	106·63	112·33	116·3
90	59·20	61·75	65·65	69·13	89·33	101·05	107·57	113·15	118·14	124·12	128·3
100	67·33	70·06	74·22	77·93	99·33	111·67	118·50	124·34	129·56	135·81	140·2



THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - JANUARY 2001

MM 525

MECHANICAL METALLURGY

TIME: THREE HOURS
ANSWER: ANY FIVE QUESTIONS

1.0 A two stage deep drawing operation is used to produce a cup like product from a sheet of aluminium, 1.45 mm thick, and whose initial diameter is 280 mm. Strains of 0.20 and 0.25 are applied in succession on the aluminium material with a yield stress of 190 N/mm^2.

(a) Calculate the drawing load at each of the two stages assuming frictional effects are ignored.

(b) What precautions are taken prior to the deep drawing operation and what would happen if the blank holder load were absent during drawing?

(c) Explain the difference between deep drawing and pressing.

2.0 Write some brief notes on any two tube making processes and citing economic considerations. In each case show the arrangement of the basic equipment employed.

What are the defects likely to occur on a tube during a severe piercing operation?

3.0

(a) Explain why the maximum reduction of the wire during drawing is dependent on the initial flow stress of the material being deformed. Use the limiting drawing ratio criterion in your answer.

(b) Show using a suitable illustration how the total energy required to cause deformation , W_T, is influenced by the semi-die angle . What are the other factors on which W_T is dependent?

4.0

(a) The variation of the rolling load under conditions of sticking friction may be shown by the following expression, $P/2k = (-x)/h + C$, for the conditions that $x = L/2$ and $P = 1.15\sigma_0$ and where;

L = arc of contact between rolls and work piece whose maximum value is $\sqrt{R.\Delta h}$ and

h = mean thickness of the workpiece.

Determine the simplified forms of P_{max} and P_{mean}.

(b) A piece of steel with initial thickness of 7.5 mm is given a reduction of 0.8 mm under conditions of sliding friction with a μ value of 0.16. If the yield stress of the metal is 310.4 N/mm^2 and roll diameters are 520 mm;

(i) What is the rolling stress used?

(ii) Briefly explain how coefficient of friction, roll flattening and the use of front and back tensions affect rolling pressure.

5.0 Tensile loads of 56.8 kN and 91.5 kN acting in two directions are applied on a metal cube with a side measuring 36.6 mm. The critical shear yield stress of the metal is 159.4 N/mm^2.

(a) Estimate the load that must be applied to cause yielding according to Tresca's criterion. If the above were that of compression, what would be the magnitude of the load ?

(b) For a chosen parameter and some selected values, show that true strain is a more convenient way of expressing deformation in metal forming than the use of engineering strain.

6.0 Discuss how the grain size of a material influences its forming behaviour in terms of temperature of working and degree of annealing.

How does the amount of reduction in cold working affect a material's mechanical properties?

End of Examination

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - FEBRUARY/MARCH, 1998

SPECIAL TOPICS IN EXTRACTIVE METALLURGY

MM545

TIME: Three hours

Attempt: Five Questions; Question (5) is compulsory

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1. What is scrap? What is the importance of metal recycling? Describe the methods of recycling copper, gold and lead in the relevant industries.

2. (a) Originally copper solvent extraction, SX was envisaged only as a way to recover copper form low-grade copper dump Leach solutions. Describe the state of the art of copper SX as it is now.

   (b) By the use of the predominance area diagram for the system Cu-Fe-S-O-SiO_2, describe the physico-chemical principles of matte smelting and converting . Describe in detail the occurrence of copper losses in reverberatory and converter slags. How do temperature, matte grade and chemical composition of slags affect the copper losses?

3. (a) Important developments in pyrometallurgy have only taken place in the last forty five years. What reasons can you give to account for this accelerated development.

   (b) Write short but clear notes on the following processes:

   (i) Mitsubishi continuous smelting process
   (ii) Vanyukov furnace
   (iii) Inco oxygen smelting process
   (iv) Queneau - Schumann - Lurgi (Q S L) process

4. What is Aus-melt technology? What are the advantages of this new technology over the convertional methods/processes. For what types of ores can it be used? Describe hypothetically (with neat sketches) the furnaces and possible flowsheets for smelting of zinc-and copper-zinc concentrates. Has this new technology any relevance to the Zambian copperbelt industry?

5. (a) Convert the following parameters into numerical values for their equivalent blast furnace model variables.

Operating parameter		Model Variable
(i)	Ore charge: Hematite	$(O/Fe)^x$
(ii)	Blast: 1200 Nm^3 dry air per tonne of product Fe	n_O^B
(iii)	Pig iron: 5% C	$(C/Fe)^m$
(iv)	Total carbon in charge: 460kg dry coke (90%C) and 50kg oil (85%C) per tonne of Fe	$n_C^i = n_C^o$
(v)	Active carbon from (iii) and (iv)	n_C^A
(vi)	Carbon in top gas (from (v)	n_C^g
(vii)	Top gas composition: 23.9 val.%CO, 20.5% Co_2 and 55.6 % N_2	$(O/C)^g$
(viii)	Quantity of CO and CO_2 in the top gas from (vi) and (vii)	$n_{CO}^g, n_{CO_2}^g$

(b) The heat demand, D of a hematite - charged blast furnace is 560,000kJ per kg mole of product Fe. The total carbon in the charge is 600 kg per tonne of product Fe. The pig iron product contains 5%C. Calculate:

(i) The volume of blast air (Nm^3 per tonne Fe) which is required to keep this furnace operating at a steady state;

(ii) Composition of the top gas

(iii) Enthalpy equation for wustite reduction zone - WRC is complicated by the term:

$$\frac{1}{2} H^{\circ}_{1200.\,O_2} \left\{1.3n_c^A - n_o^B - 1.06\right\}$$

Can you make a general statement about this term based upon the following equation:

$$n_O^B + 1.06 = 1.3n_C^A$$

Draw the operating lines from the data calculated in 5 (a) and (b).

6. (a) By means of flowsheets describe the production of H_2SO_4 and elemental sulphur from the smelter gases. What reasons dictate their recovery?

(b) Describe how the following gas cleaning equipments operate:

(i) Settling chambers
(ii) Cyclones
(iii) Electrostatic precipitators and
(iv) Scrubbers

Show the limits of particle sizes in which these equipments work.

END OF EXAMINATION
MM545

UNIVERSITY OF ZAMBIA

SCHOOL OF MINES

SECOND SEMESTER EXAMINATIONS - SEPTEMBER 1998

MM 552: PROCESS DESIGN

TIME: THREE HOURS

ANSWER: FIVE QUESTIONS

ALL QUESTIONS CARRY EQUAL MARKS

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1. Fuel oil ($C_{18}H_{36}$) is burned in 40% excess dry air. The products of combustion are dried to remove all the water. analysis of the flue gas shows a ratio of CO_2 to CO of 2, on a molar basis. Determine the flue gas composition in mole percent and the volumetric flow rate (m^3/h) at 150°C and 124 kPa after drying if 2300 kg/h of fuel oil are burned.

   The gas constant R = 8.314 J/(mol)(K)
   Atomic weights: C, 12; H, 1; N, 14; 0,16

2. (a) Suggest how the following sets of equations may be solved:

   (i)
   $$f_1(x_2) = 0$$
   $$f_2(x_1, x_2, x_3) = 0$$
   $$f_3(x_2, x_3) = 0$$

   (ii)
   $$f_1(x_1, x_3) = 0$$
   $$f_2(x_1, x_2, x_3) = 0$$
   $$f_3(x_1, x_4) = 0$$
   $$f_4(x_1, x_3, x_4) = 0$$

   (b) A Cu-5% Sn - 10% Bi - 5% Zn alloy is to be melted. If there is a 10% loss of Zn from the charge during smelting, and the following alloys are available, how many kg of each alloy would you charge to make 100 kg of alloy?

	% Cu	% Sn	% Zn	% Bi
Alloy A	70.0		30.0	
Alloy B	83.5	15.0		1.5
Alloy C	69.0	1.0		30.0
Pure Cu	100.0			

3. A reduction process requires a feed of C, O_2 and MO and produces liquid M and a gas phase containing CO and CO_2. For thermodynamic reasons, the ratio of CO to CO_2 in the product gas is desired to be K.

(a) Determine the number of design variables a designer must specify.

(b) If the mass of metal produced is 1000 kg, the atomic mass of M is 60, and the weight of CO, W_{CO}, is 50 kg, set up the equations that must be solved to find the weight of C(W_C), the weight of O_2 (W_{O2}) and the weight of CO_2 (W_{CO2}) in the input and output streams. Show how the equations can be solved.

4. (a) At 600°C the vapour pressure of pure liquid Zn is 10 mm Hg and of pure liquid Cd is 100 mm Hg. For an alloy containing 70 atomic percent Zn, calculate the dewpoint and bubblepoint pressures assuming the Zn - Cd alloy forms an ideal solution. Also, obtain the compositions of the corresponding conjugate phases.

(b) Hot gases leaving a CO_2 recovery unit at a rate of 57 m^3/min at 170°C and 760 mm Hg pressure are passed through a heat recovery train. The gases contain 86 mole percent CO_2 and 14 mole percent H_2O. They leave the unit at 25°C and essentially the same pressure. Since there has been some condensation, the gases now contain only 3.15 mole percent H_2O. Calculate the amount of heat in kilojoules (kJ) which must be removed per minute if the heat of vaporisation of H_2O at 25°C is 2000 kJ/kg. Consider the condensation process as an exothermic reaction.

Heat capacity data:

Compound	Cp (J/(mol)(k))
CO_2	46.8
H_2O	36.6

5. (a) Briefly describe three different interpretations of depreciation.

(b) Derive the relationship for the present value of an annuity P in terms of the equal annual payments R, interest rate i and the number of discrete interest periods n.

(c) An engineer in charge of the design of a plant must choose either a batch or continuous system. The batch system offers a lower initial outlay but, owing to high labour requirements, exhibits a higher operating cost. The cash flows relevant to this problem have been estimated as follows (in thousands of Kwacha):

	Year		Discounted - cash - flow rate of return	Net present worth at 10%
	0	1 - 10		
Batch system	-40 000	11 200	25%	28 800
Continuous system	-60 000	15 300	22%	34 000

Check the values given for the discounted-cash-flow rate of return and net present worth. Suppose the company requires a minimum rate of return of 10%, determine which system should be chosen.

6. A shell-and-tube heat exchanger is used for preheating the feed to a reactor. The liquid of specific heat 4.0 kJ/(kg) (K) and specific gravity 1.1 passes through the inside of the tubes and is heated by steam condensing at 395 K on the outside. The exchanger heats liquid at 295 K to an outlet temperature of 375 K when the flowrate is 1.75×10^{-4} m^3/s and to 370 K when the flowrate is 3.25×10^{-4} m^3/s. Calculate the heat transfer area and the value of the overall heat transfer coefficient when the flow is 1.75×10^{-4} m^3/s.

Assume that the film heat transfer coefficient for the liquid in the tubes is proportional to the 0.8 power of the velocity, that the transfer coefficient for the condensing steam remains constant at 3.4 $kW/(m^2)(K)$, and that the resistance of the tube wall and scale can be neglected.

7. (a) Explain the significance of the specific speed of a centrifugal pump.

(b) A pump is designed to be driven at 600 rev/min and to operate at maximum efficiency when delivering 24 m^3/min of water against a head of 20m. Calculate the specific speed.

(c) A pump, built for the operating conditions in part (b) has a measured maximum overall efficiency of 70%. The same pump is now required to deliver water at 30m head. At what speed should the pump be driven if it is to operate at maximum efficiency? What will be the new rate of delivery and the power required?

$$N_s = \frac{N\,Q^{1/2}}{(h)^{3/4}}$$

Density of water = 1000 kg/m^3

$g = 9.81$ m/s^2

END OF EXAMINATION IN MM 552

THE UNIVERSITY OF ZAMBIA
SCHOOL OF MINES

SECOND SEMESTER EXAMINATIONS - AUGUST/SEPTEMBER 1998.

MM562 - FOUNDRY

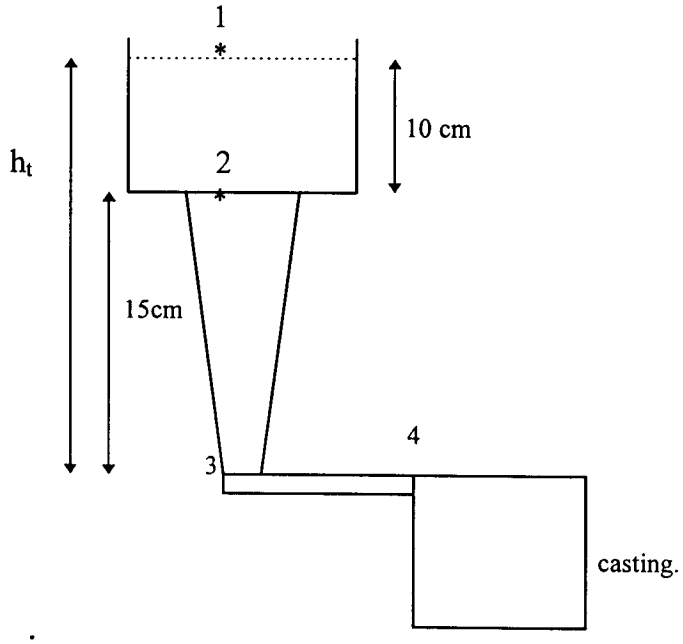
TIME: 3 HOURS
ANSWER: Any five and all questions carry equal marks.

1.0 Aspiration of unwanted gases into the metal stream during casting is avoided by obeying certain conditions in the design of the gating systems. Metal flow in the downsprue is thus governed by

$$R = \frac{\sqrt{h_c}}{\sqrt{h_t}} = \frac{V_2}{V_3} = \frac{A_3}{A_2}$$

(a) What is the major assumption made in the above derivation?

(b) Evaluate the main dimensions of a gating system for top pouring an aluminium alloy if sprue entrance to ingate ratio is 1 : 0.6 in order to avoid aspiration. The weight of the casting is 45 kg with a density of 2.6 $kg.m^{-3}$ and was poured in 50 (fifty) minutes.



(c) Why is it undesirable to hold metal in the casting furnace longer than is necessary and how is the yield of the final product determined from above.

2.0 (a) What are the main considerations in selecting a metallurgical furnace? Discuss your answer with reference to the use of the following types; crucible (fuel fired or resistance heating), cupola and induction furnaces.

(b) Explain how the casting properties of alloys can be related to their equilibrium diagrams. What is fluidity (fluidity index) of an alloy and how is this affected by the superheat of molten metal.

(c) Explain briefly how feeder head geometries have evolved. How are extended bar or plate castings successfully fed?

3.0 Define the term "cast iron" and distinguish it from steel. Write brief notes on any two of the following;

(i) Grey cast iron
(ii) White cast iron
(iii) Ductile iron
(iv) Malleable iron

4.0 (a) What would you say are some of the major differences between a directly cast component and a powder metallurgy produced component?

(b) The sintering process can be monitored by one or a combination of the following parameters; neck growth, densification of the compact, shrinkage, reduction in surface area, increase in toughness and higher ultimate tensile strength. For any two of the mentioned parameters, describe how you would measure them and therefore determine the progress of sintering.

5.0 The concept of contact (wetting) angle is widely applied in the treatment of nucleation of solids from liquid metal in contact with a mould. Determine the equilibrium of forces in interfacial energies at play in this regard with clear illustrations.

(a) Show that the critical radius, $r^* = \frac{2\gamma}{\Delta G_v}$, required for stable growth is a function of the interfacial energy and where γ is one such interfacial energy criterion and ΔG_v is the volume free energy change in forming the solid.

(b) The relation $\Delta G^*_{het.} = \Delta G^*_{hom.} f(\varnothing)$ suggests that the critical free energy change during heterogeneous nucleation is lower than that required in homogeneous nucleation for a given set of solidification conditions. Explain why this is so and include the role of undercooling.

where $f(\varnothing)$ is a shape factor and is less than unity.

6.0 The study of the development of dendritic morphology during solidification is simplified by consideration of a planar solid/liquid interface advancing into the liquid phase. When a protrusion forms on the interface;

(i) What conditions make its growth stable?

(ii) How would you explain the situation in (I) above in terms of the radius of curvature of the protrusion and the associated interfacial Gibbs free energy, $\Delta G_\gamma = \frac{2\gamma . V_m}{r}$

where V_m and r are the molar volume and radius of the protrusion.

(b) Pure metal and alloy solidification processes present major differences in the way they occur. State two of these differences and indicate any known commercial exploitation (use) of any one of them during manufacture or production of engineering components.

End of examination.