THE UNIVERSITY OF ZAMBIA
SCHOOL OF MINES
2007 FIRST SEMESTER EXAMINATIONS

1.	GG	202	Physical geology
2.	GG	205	Principles of geology I
3.	GG	305	Principles of geology II
4.	GG	312	Petrology II – Practical
5.	GG	322	Stratigraphy and remote sensing paper I – theory
6.	GG	335	Structural geology paper II – practical
7.	GG	402	Geology of Zambia
8.	GG	412	Metamorphic petrology I (theory)
9.	GG	442	Economic geology of metalliferous ore deposits (paper II)
10.	GG	472	Applied geochemistry (paper I theory)
11.	GG	542	Economic geology of non-metallic deposits (paper I theory)
12.	GG	572	Hydrogeology
13.	MG	319	Computer technology I
14.	MI	455	Operations research
15.	MI	515	Rock mechanics (Paper I)
16.	MI	535	Coal mining methods
17.	MI	562	Investment analysis
18.	MI	595	Mineral production control
19.	MM	205	Introduction to metallurgy and mineral processing paper I theory
20.	MM	332	Chemical thermodynamics II
21.	MM	412	Mineral processing II
22.	MM	442	Hydrometallurgy
23.	MM	452	Process control and instrumentation
24.	MM	542	Fuels, finances and refractories
25.	MM	552	Process design
26.	MM	562	Foundry

THE UNIVERSITY OF ZAMBIA
SCHOOL OF MINES
GEOLOGY DEPARTMENT
UNIVERSITY EXAMINATIONS – FEBRUARY 2007

GG 202 – PHYSICAL GEOLOGY

TIME: THREE HOURS
ANSWER: **ALL** QUESTIONS FROM **SECTION A,** AND ANY **FOUR** QUESTIONS FROM **SECTION B**. ALL QUESTIONS IN SECTION B CARRY EQUAL MARKS

SECTION A: MULTIPLE CHOICE

1. Porosity is_____
   a) the percentage of a rock's volume that is empty space; **b)** the capacity of a rock to transmit water; **c)** the ability of sediment to retard water; **d)** None of these
2. The total area drained by a river and its tributaries is called the _____
   b) hydrologic cycle; **b)** headwaters; **c)** divide; **d)** drainage basin
3. Which rock type would make the best aquifer? _____
   a) shale; **b)** unfractured granite; **c)** sandstone; **d)** All of them
4. Which of the following statements about groundwater is **FALSE**? _____
   a) the steeper the water table, the faster the groundwater will flow.
   b) groundwater moves from where the water table is high to where the water table is low.
   c) the higher the permeability of an aquifer, the slower the groundwater will flow.
   d) gravity drives the flow of groundwater.
5. Water soluble (dissolved) contaminants in groundwater will _____
   a) sink to the bottom of the aquifer system; **b)** travel against (upstream of) the regional groundwater flow direction; **c)** float on top of the water table; **d)** travel with the regional groundwater flow direction
7. A river's velocity is _____ on the outside of a meander curve compared to the inside.
   a) higher; **b)** lower; **c)** equal; **d)** None of these
8. A measure of a material's ability to transmit water through interconnected pore spaces _____
   a) porosity; **b)** aquifer; **c)** permeability; **d)** aquitard
9. A deep bedrock aquifer *sandwiched* between two impermeable layers is called a(n) _____
   a) confined aquifer; **b)** unconfined aquifer; **c)** perched aquifer
10. Gravel-sized particles are more likely to be transported in a stream's _____
    a) bed load; **b)** suspended load; **c)** dissolved load; **d)** all of the choices before
11. Excessive pumping of groundwater can cause _____
    a) land subsidence; **b)** reversal of groundwater flow direction; **c)** salt water intrusion; **c)** all of the choices before
12. The process by which sand is moved parallel to shore when waves strike at an angle is called _
    a) winter storm response; **b)** longshore transport; **c)** beach erosion; **d)** tidal flow
13. Hydraulic action, abrasion, and dissolution are all examples of stream _____
    a) erosion; **b)** transportation; **c)** deposition; **d)** All of these.
14. Mass wasting is _____
    a) a collective term for all processes that modify Earth's surface; **b)** downslope movement of material under the influence of gravity; **c)** transport of rock and soil by wind and water; **d)** the decomposition of rocks under the influence of gravity

15. Which of the following will promote mass wasting? _____
a) removal of anchoring vegetation; **b)** earthquake vibrations; **c)** over-saturation with water; **d)** over steepening a slope; **e)** all of the previous choices

SECTION B: ESSAY – TYPE QUESTIONS

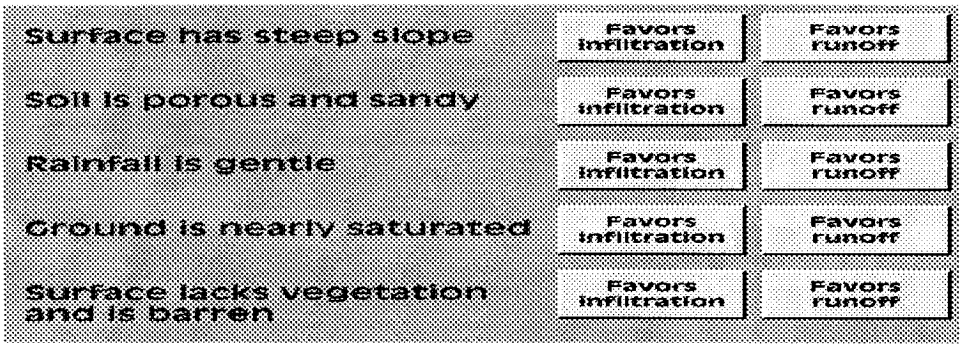
1. a) What is plate tectonics?
b) Describe the three types of plate boundaries.
c) What happens at each of these plate boundaries?
d) At one of these plate boundaries, **three** types of collisions occur. Describe
i) The types of collisions
ii) The major features produced by each type of collision.

2. a) Describe **three** ways in which streams carry their sediment load.
b) What is stream discharge?
c) Suppose a stream is 35 m wide and 4.5 m deep. Water in this stream flows at a rate of 6 m/second. Determine the discharge for this stream.
d) Describe **three** types of drainage patterns and what can be inferred from them
e) Describe the following
i) Stream competence
ii) Stream capacity
iii) Alluvial fan
iv) Delta

3. a) List **four** characteristics of deserts
b) Describe **three** different types of dunes.
c) Under what conditions does each type of dune form?
d) Describe **two** conditions for wind erosion.
e) Describe **two** types of wind erosion.
f) What factors affect how wind carries its load?

4. a) What is an earthquake?
b) What causes earthquakes and where do they occur?
c) Describe the three types of waves generated by earthquakes with respect to their speed and level of destruction.
d) How do seismologists locate an earthquake's epicentre?

5. a) Describe four components of the hydrologic cycle.
b) Using some component(s) of the hydrologic cycle, describe a situation that would lead to frequent flooding as experienced in Lusaka after a heavy down-pour.
c) Describe the difference between porosity and permeability. Explain whether or not soil/rock can be porous but NOT permeable.
d) Explain two factors that would lead to a decline in the groundwater table.
e) Many factors influence the proportion of water from a rainfall episode that soaks in or runs off the land surface. Indicate with a tick, whether each of the situations below favours greater infiltration or greater runoff.



END OF EXAMINATION.

GOOD LUCK!

THE UNIVERSITY OF ZAMBIA
SCHOOL OF MINES
GEOLOGY DEPARTMENT
UNIVERSITY EXAMINATIONS – FEBRUARY 2007

GG 205 PRINCIPLES OF GEOLOGY I
PAPER I – THEORY

TIME: THREE HOURS

INSTRUCTIONS: Answer question number one and any other three questions. All the questions carry equal marks. Use diagrams and equations wherever it is necessary.

---

1. Describe the structure and the composition of the earth.
2. Discuss the origin of the solar system and the chemical elements.
3. Write brief notes on the geological time scale.
4. Discuss the mineral resources of Zambia and their role in economic development.
5. Write some notes on the following:
   (a) Classification of minerals.
   (b) Seven crystal systems.
   (c) Crystal structures of rock forming silicate minerals.
6. Describe the formation and classification of either igneous or sedimentary rocks.
7. Describe the major processes through which mineral deposits are formed.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF MINES
GEOLOGY DEPARTMENT
UNIVERSITY EXAMINATIONS – FEBRUARY 2007

GG 205 PRINCIPLES OF GEOLOGY I
PAPER I – THEORY

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END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF MINES
GEOLOGY DEPARTMENT
UNIVERSITY EXAMINATIONS – FEBRUARY 2007

GG 205 PRINCIPLES OF GEOLOGY I
PAPER I – THEORY

TIME: THREE HOURS

INSTRUCTIONS: Answer question number one and any other three questions. All the questions carry equal marks. Use diagrams and equations wherever it is necessary.

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END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

SCHOOL OF MINES

UNIVERSITY EXAMINATIONS – FEBRUARY 2007

GG 305 PRINCIPLES OF GEOLOGY II

PAPER I – THEORY

TIME: THREE HOURS

INSTRUCTIONS: Answer question number one and any other three questions. All the questions carry equal marks. Use diagrams and equations wherever it is necessary.

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1. Describe the processes that lead to the formation of either early magmatic mineral deposits or hydrothermal deposits.

2. Describe the major methods that are used in either geophysical or geochemical exploration for base metal sulfide deposits.

3. Write short notes on the following:

   (a) Ductile and brittle deformation of rock units.

   (b) Primary and tectonic structures.

   (c) Classification of faults and folds.

4. Discuss the importance of geological mapping in engineering operations that involve large scale excavation of rock units.

5. Discuss the economic importance of the following stratigraphic units.

   (a) Karoo super group

   (b) Katanga super group

   (c) Recent alluvial deposits

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF MINES
GEOLOGY DEPARTMENT
UNIVERSITY EXAMINATIONS – FEBRUARY 2007

GG312 11 PETROLOGY
PRACTICAL

TIME : THREE HOURS

ANSWER: ALL QUESTIONS

Q1 Describe in details the hand specimens 1,2,3,4,5,& 6 and name the rock.

Q2 Study thin sections A,B,C,D,E,&F, with rgard to the following:

(a) mineralogy
(b) Texture
(c) Name the rock

END OF EXAM

THE UNIVERSITY OF ZAMBIA
SCHOOL OF MINES
GEOLOGY DEPARTMENT
UNIVERSITY EXAMINATIONS - FEBRUARY 2007

GG322 STRATIGRAPHY AND REMOTE SENSING

THEORY

PAPER I

TIME: THREE HOURS

ANSWER: ANY FIVE QUESTIONS. ALL QUESTIONS CARRY EQUAL MARKS. USE SKETCHES WHERE POSSIBLE FOR A FULL MARK

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1. Differentiate between the following terms:
   (a) Biofacies and Lithofacies
   (b) Stratigraphy and Lithostratigraphy
   (c) Principle of Original Continuity and Principle of Original Horizontality
   (d) Hiatus and Diastem
   (e) Disconformity and Paraconformity

2. (a) With a NEAT sketch illustrate the Electromagnetic spectrum, indicating the various blinds and windows, and the location of the various sensor systems.
   (b) List the advantages for having a Polar Orbiting Earth Resources satellites.

3. (a) Describe the Law of the Correlation or Succession of facies. Use diagrams to illustrate your explanations.
   (b) Outline the five main categories of evidence of life in the Precambian.

4. (a) Outline the 5 main activities recognized in early trace fossil studies as responsible for forming most trace fossils
   (b) (i) What are the differences between Relative and Absolute Ages.
   (ii) Describe two methods used in Radiometric Dating indicating their limitations

5. (a) The fossils contained in sedimentary rocks are used as tools in Biostratigraphy. Outline five (5) uses of fossils in Biostratigraphy.
   (b) Charles Darwin (1859) provided a key with his explanation of organic evolution -- the origin of species by natural selection. Outline Darwin's observations (Hint: He observed 4 things)
   (c) Differentiate between Landsat Thematic Mapper (TM) and SPOT Satellites

6. (a) What name is given to the surface that separates unconformable strata?

(b) Physical correlation makes use of a wide variety of properties and techniques, many of which have little or no time-significance. List these properties and techniques.
(c) Stratigraphic information can be organized, displayed and communicated to fellow geologists and the public in various ways. Outline how this information can be organized, displayed and communicated (Hint – 4 ways)

7. Write short notes on the following:
   (a) Transgression and Regression.
   (b) Sequence Stratigraphy
   (c) Value of Remote Sensing
   (d) Normalized Difference Vegetation Index (NDVI)

END OF EXAMINATION

GOOD LUCK

THE UNIVERSITY OF ZAMBIA
SCHOOL OF MINES
GEOLOGY DEPARTMENT
UNIVERSITY EXAMINATIONS – FEBRUARY 2007

GG 335 - STRUCTURAL GEOLOGY
PAPER II - PRACTICAL

TIME: THREE HOURS

ANSWER: ALL QUESTIONS
WORK AS NEATLY AS POSSIBLE

PART A (40 %)

On Map 1 a thin limestone bed with attitude N090E/20N crops out at X at an altitude of 2050 m. Draw the complete outcrop of this limestone bed on the map and make a cross section X - Y

PART B (60 %)

Study the Geological Map shown below on Map 2 carefully. The rocks of the area are known to be Devonian and Cambrian series of beds.

(a) Mark the plane of unconformity with a heavy line.
(b) What is the attitude of the Devonian series of beds.
(c) What is the attitude of the Cambrian series of beds.
(d) Draw a section to natural scale from R to S.
(e) Give a brief description of the geological history of the area.

Additional Optional

END OF EXAMINATION

UNIVERSITY OF ZAMBIA
SCHOOL OF MINES
GEOLOGY DEPARTMENT
UNIVERSITY EXAMINATIONS - FEBRUARY 2007

GG402: GEOLOGY OF ZAMBIA

TIME: 3 HOURS

INSTRUCTIONS: ANSWER QUESTION 1 AND ANY OTHER THREE **SKETCHES AND DIAGRAMS ARE IMPORTANT FOR A FULL MARK**

---

1. Draw a NEAT sketch map of Zambia and on it, indicate and name the following:

   (a) Cratons
   (b) Ancient Metamorphic Belts that have shaped the Zambian Geology during the Pre-Cambrian
   (c) The Karoo and Kalahari Basins **40 marks**

2. (a) Define the Zambezi Belt and the Mozambique Belt.
   (b) With brief descriptions fill-in the Table below. Restrict your answer to Zambian parts of the belts.

	Zambezi Belt	Mozambique Belt
Age		
Major Rock Types		
Structural Trend		
Tectonic Setting		
Depositional Environment		
Economic Potential		

20 marks

3. Write short notes on the following Ubendian Belt and Irumide Belt using the following headings:
   (i) Age
   (ii) Major Rock Types
   (iii) Occurrence in Zambia
   (iv) Structural Trend
   (v) Tectonic Setting
   (vi) Economic Potential

20 marks

4. (i) What is the Lufilian Arc famous for in Zambia?
   (ii) Discuss the evidence for existence of the Lufilian Arc on the Zambian and DRC Copperbelt?
   (ii) Outline the regional setting, and tectonism that affected the Lufilian Arc.

20 marks

5. In form of a Table outline the Stratigraphy of the Karoo Supergroup in Zambia. In addition, in a separate column, for each formation indicate the following:

   (i) depositional environment
   (ii) tectonic setting
   (iii) economic potential

20marks

6. Discuss how the Copperbelt stratigraphy has evolved over the years starting with that given in Mendlesohn's edited book on Geology of Northern Rhodesian Copperbelt, 1961.

20 marks

END OF EXAMINATION

GOOD LUCK

UNIVERSITY OF ZAMBIA
SCHOOL OF MINES
GEOLOGY DEPARTMENT
UNIVERSITY EXAMINATIONS - FEBRUARY 2007

GG402: GEOLOGY OF ZAMBIA

TIME: 3 HOURS

INSTRUCTIONS: ANSWER QUESTION 1 AND ANY OTHER THREE **SKETCHES AND DIAGRAMS ARE IMPORTANT FOR A FULL MARK**

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20 marks

END OF EXAMINATION

GOOD LUCK

UNIVERSITY OF ZAMBIA
SCHOOL OF MINES
GEOLOGY DEPARTMENT
UNIVERSITY EXAMINATIONS – FEBRUARY 2007

GG 412 METAMORPHC I PETROLOGY
PAPER II PRACTICAL

TIME: Three Hours

ANSWER: All questions

Illustrate your answers with sketches, figures etc where possible

---

Q1 Identify and discuss the mineralogy and texture of thin section **A&B** and name the rocks accordingly

Q2. Give a complete petrography description of this sections **C&D**, emphasize on the following:-

(a) Mineralogy
(b) Texture
(c) Metamorphic grade
(d) Name the rock

Q3. Study the three thin section drawings in Fig. 1 which show three garnet schists, each having a rather different history from the others. Assuming that the foliation in each rock is due to directed stress causing recrystallization of clay minerals into micas, describe the textures in the three cases.

END OF EXAM

UNIVERSITY OF ZAMBIA
SCHOOL OF MINES
GEOLOGY DEPARTMENT
UNIVERSITY EXAMINATIONS – FEBRUARY 2007

GG 412 METAMORPHC I PETROLOGY
PAPER II PRACTICAL

TIME: Three Hours

ANSWER: All questions

Illustrate your answers with sketches, figures etc where possible

---

Q1 Identify and discuss the mineralogy and texture of thin section **A&B** and name the rocks accordingly

Q2. Give a complete petrography description of this sections **C&D**, emphasize on the following:-

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END OF EXAM

UNIVERSITY OF ZAMBIA
SCHOOL OF MINES
GEOLOGY DEPARTMENT
UNIVERSITY EXAMINATIONS – FEBRUARY 2007

GG 442 ECONOMIC GEOLOGY OF METALLIFEROUS ORES
PAPER II - PRACTICAL

TIME: 3 Hours

INSTRUCTIONS: ANSWER ALL QUESTIONS. USE ILLUSTRATIONS AND DIAGRAMS

Q1. Study the given polished section. The polished section is mounted with five ore mineral samples.

Describe the numbered ore mineral specimens individually by use of the ore microscope. Use the numbering provided on the section. Pay attention to following properties:

i. Colour
ii. Anisotropy
iii. Internal reflections
iv. Fabric
v. Ore genesis
vi. Name the mineral and give its chemical formula

END OF EXAM

THE UNIVERSITY OF ZAMBIA
SCHOOL OF MINES
GEOLOGY DEPARTMENT
UNIVERSITY EXAMINATIONS – FEBRUARY 2007

GG 472 APPLIED GEOCHEMISTRY
PAPER I - THEORY

TIME: THREE HOURS

INSTRUCTIONS: Answer question 1 and any other three questions. All the questions carry equal marks. Use diagrams and equations wherever it is necessary.

---

1. Use the thermodynamic data given in Table 1 and Figure 1 to answer the following questions.

   (a) Construct an Eh-pH diagram for the system Fe-O-H at STP. Assume that the dominant Fe phase is $Fe(OH)_3$ and that the activity of dissolved Fe is 10^{-6}.

   (b) Discuss briefly the role of Eh and pH in the development of oxide deposits of Fe and Mn in the secondary geochemical environment.

   Table 1 Thermodynamic data for selected species

Species	ΔG_f^0 (kcal/mole)
H^+ (aq)	0
OH^- (aq)	0
H_2 (g)	0
O_2 (g)	0
H_2O (l)	-56.69
Fe^{2+} (aq)	-18.86
Fe^{3+} (aq)	-1.12
$Fe(OH)_3$ (c)	-166.47
$Fe(OH)_2$ (c)	-116.30

2. Discuss the role of surface geochemical processes in the development of deposits of bauxite and uranium.

3. The composition of the Munali Gabbro and its weathering product is given in Table 2. Discuss the processes which have led to the formation of the gossan.

Fig. 1 Eh-pH diagram for the system Mn-O-H

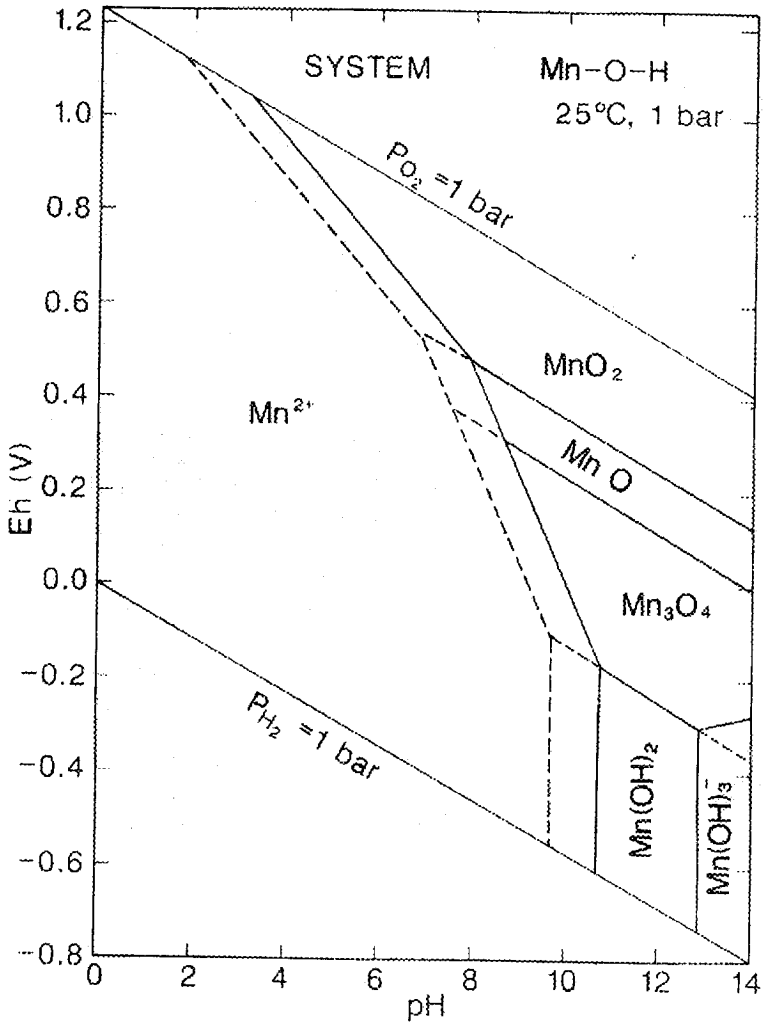

Table 2

Oxide	Gabbro	Gossan
SiO_2	49.84	6.24
TiO_2	0.86	0.14
Al_2O_3	15.29	0.73
Fe_2O_3	2.11	88.48
FeO	9.14	0.95
MnO	0.18	0.01
MgO	7.62	0.23
CaO	11.34	0.15
Na_2O	2.64	0.12
K_2O	0.24	0.04
Ni	1.2	0.54
S	1.5	0.02
Cu	0.4	0.18
H_2O	0.78	3.05

Additional information:

Mineralogical composition of Munali Gabbro
Olivine, pyroxene, calcic plagioclase, pentlandite, pyrite, magnetite and chalcopyrite.

4. Discuss the secondary dispersion patterns that are associated with copper deposits in the Zambian copperbelt.

5. Discuss the major factors that control the aqueous mobility of Al, Na, Cu, Mn, S and Pb in the secondary environment.

6. Describe the procedures that you would use for partial and total extraction of heavy metals in contaminated top soils.

==========END OF EXAMINATION==========

THE UNIVERSITY OF ZAMBIA
SCHOOL OF MINES
UNIVERSITY EXAMINATIONS – FEBRUARY 2007
GG542 Geology of Non-metallic Mineral Deposit
Theory

TIME: 3 hours
ANSWER: Any **Four** Questions
All questions carry equal marks

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1. Outline in detail the main stages of an industrial mineral operation explaining why it is essential to follow such a sequence.

2. (a) Give a classification of industrial raw materials by their end use.
   (b) What category of end use are gemstones classified as? Explain why they are classified as such.

3. For the following resources: cement, copper, sand and gravel, describe each with respect to the following parameters:

   (i) Intrinsic value
   (ii) Place value
   (iii) Formation process for raw materials
   (iv) Land demand
   (v) Processing

4. (a) Discuss the nature of the Zambian gemstone industry outlining its major problems and what are the possible solutions
   (b) Describe the geological occurrence of the emerald deposits of Ndola Rural

5. (a) What is the major difference between a metallic and non metallic mineral deposit

   (b) Discuss the technical characteristics that are of importance in assessing a rock formation for use as dimension stone.

(6) As a geologist you have been assigned to investigate a clay resource in Western Province. The extent of the area is 400,000 m^2 and the thickness of the clay is 20m. If the resource were converted into a small brickworks, using these clay reserves and assuming that the clay has an average density of 1600kg/m^3, that the weight of an average unfired brick is about 4kg and an annual output of the Mongu works is 16 million bricks, answer the following

(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 Mongu works?

END OF EXAMINATION

UNIVERSITY OF ZAMBIA
SCHOOL OF MINES
GEOLOGY DEPARTMENT
UNIVERSITY EXAMINATIONS – FEBRUARY 2007

GG 572 – HYDROGEOLOGY

TIME: THREE (3) HOURS

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

---

1. (a) Show, in form of Flow Chart, the distribution of precipitation input

   (b) Describe Thiessen's Method of determining areal rainfall average. State the limitations of the Method.

25 marks

2. Given Penman Equation:

$$ET = \frac{\Delta H + 0.27\,E}{\Delta + 0.27} \qquad (A)$$

where $E = 0.35\,(e_a - e_d)\,(1 + 0.0098\,u_2)$ (B)

and $H = R\,(1 - r)\,(0.18 = 0.55\,S) - B\,(0.56 - 0.092\,e_d^{0.5})\,(0.10 + 0.90S)$ (C)

Answer the following:

(a) Explain all terms and units in Equations (A), (B) and (C)

(b) Using Penman Method, estimate ET, given the following data (without units, except for u_2):

(i) $\Delta = 1.0$
(ii) $e_a = 17.53$
(iii) e_d = 31.83 multiplied by a relative humidity of 40%
(iv) $u_2 = 3.2$ K ph
(v) $R = 16.5$

(vi) $\Upsilon = 0.07$
(vii) $S = 0.75$
(viii) $B = 17.01$

25 marks

3. (a) Compare and contrast Intrinsic Permeability of a rock or soil with Hydraulic Conductivity.
Is Transmissivity related to any of the two; if so, how?

(b) Describe how a constant Head Permeameter is used to determine hydraulic conductivity of sandy materials.

25 marks

4. Given the equation:

$$\nabla^2 h = \frac{S}{T} \frac{\partial h}{\partial t}$$

(a) reduce the equation to describe the relation between head, h, as a function of unidirectional flow in the x-direction, for steady state conditions, in a confined aquifer of uniform thickness.

(b) Do the same for the similar flow situation in an unconfined (phreatic) aquifer.

25 marks

5. Between November and December, 2006, UNZA experienced water supply problems, both in quantity and quality.

(a) explain what problems these were

(b) what was the impact of microbiological parameters on the water quality?

(c) What measures were put in place to solve the problem?

25 marks

6. Describe the Cooper-Jacob Method of obtaining T and S from the non equilibrium equation.

25 marks

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

SCHOOL OF MINES

UNIVERSITY EXAMINATIONS – FEBRUARY/MARCH 2007

MG 319 – COMPUTER TECHNIQUES I

TIME: THREE HOURS

ANSWER ANY FIVE QUESTIONS

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1. (a) Convert these HEX numbers to decimal; BD, 4A9, 7CF and 2E.

   (b) What is 111001001_2 in octal and HEX?

2. Show the outputs of the following two codes or programmes, explaining the shortfalls or limitations if any;

Code 1	Code 2

x = 2;
y = 3;
if (x > 2)
if (y > 2)
{
int z = x + y;
System.out.println("z is " +z);
}
else
System.out.println("x is " +x);
	x = 3
	y = 2
	if (x > 2)
	{
	if (y > 2)
	{
	int z = x + y;
	System.out.println("z is " +z);
	}
	}
	else
	System.out.println("x is " +x);

3. (a) There are generally two ways may you write, compile and execute programmes on your computer; from the command prompt window and the Integrated Development Environment (IDE) in the case of Java programming. Describe briefly the steps you have to do in order to work from (i) the command prompt and (ii) setting up of JCreator.

   Assume that you have all the necessary tools of Java in a special folder named j2sdk1.4.2_03 as well the JCreator executable file.

   (b) For programmes or codes requiring input from the keyboard, what should you do in order to make this work from the command prompt.

4. When the operating system Windows 3.1 was released in 1992, it was said that its capability included the following;

(i) TrueType scalable font support
(ii) Multimedia and networking capability
(iii) Application reboot capability
(iv) Better inter-application protection and better error diagnostics

Write brief notes on all four of the above statements.

5. The release of Windows Vista in January 2007, an operating system as an up grade (or successor) of Windows XP, was received with mixed feelings. Some of the comments included the following;

(i) No need to rush or switch over as there is particularly no compelling reason to do so
(ii) Has enhanced graphics and systems performance capabilities
(iii) Has six editions unlike XP's two and Vista Ultimate includes everything
(iv) Hardware requirements for Windows Vista should not be taken lightly
(v) Windows Vista installation requires an always on internet connection

Write brief notes on all five of the above statements.

6. Write out a procedure or algorithm to add marks obtained in a computing course and display results of;

(i) Class average or mean
(ii) Highest and lowest scores
(iii) Student name and mark

Make use also of standard flowchart symbols to show your work. Choose your own number of students and other attributes necessary.

END OF EXAMINATION IN MG 319

UNIVERSITY OF ZAMBIA
SCHOOL OF MINES
MINING ENGINEERING DEPARTMENT
SECOND SEMESTER EXAMINATIONS – FEBRUARY 2007

MI 455 - OPERATIONS RESEARCH

TIME: THREE (03) HRS **FULL MARKS: 100**
INSTRUCTIONS: ANSWER FIVE (05) QUESTIONS
NORMAL DISTRIBUTION TABLES TO BE PROVIDED

1. (a) How are multiple optimal solutions identified in Graphical Method? **[2 marks]**

   (b) Write short notes on the following;

   (i) Objective function **[2 marks]**
   (ii) Model constraints **[2 marks]**
   (iii) Decision variables **[2 marks]**

   (c) Describe the steps followed in formulating a linear programming model. **[3 marks]**

   (d) A mining company produces two mineral products, Copper and Cobalt, which have profits of $9 and $7 per tonne respectively. Each mineral product must be processed on two assembly lines, where the required production times are as follows.

Product	**Hr/Unit**	
	Line 1	**Line 2**
Copper	12	4
Cobalt	4	8
Total hours	60	40

   (i) Formulate a linear programming model to determine the optimal product mix that will maximize profit. **[2 marks]**
   (ii) Solve the problem using Simplex Method. **[7 marks]**

2. (a) What is project crashing and what is its purpose in network analysis? **[3 marks]**

   (b) What is the critical path and what is its importance in project planning? Discuss the various methods of determining the critical path in Network Analysis. **[3 marks]**

   (c) The following are details for the times required for the maintenance of a mining shovel.

Activity	Description	Times [hours]		
		Most Optimistic	Most Likely	Most Pessimistic
A	Move shovel from face	4	6	8
B	Service electrical parts	8	12	16
C	Service mechanical parts	6	10	12
D	Perform test run	6	10	12
E	Prepare new face	3	5	6
F	Move shovel to new face	2	4	8

Assume that the maintenance of the mechanical and electrical parts can be performed simultaneously. Also assume that the preparation of the new face can only start when the servicing of the electrical parts has been completed, since the maintenance and installation of the power supply at the face is done by the same team of electricians.

(i) Draw a PERT network for the maintenance work **[5 marks]**
(ii) Find the critical path. **[3 marks]**
(iii) What is the probability of completing the project within 35 hours? **[3 marks]**
(iv) If you had to estimate a time for project completion, and wanted to be 95% confident of completion by this time, what would be your estimate? **[3 marks]**

3. (a) (i) Give two main characteristics of the Assignment Method. **[2 marks]**

(ii) In an underground mine operations at Monks Mining Plc of Zambia, four Jackhammers are to be used to drill four ends. The table below shows the four ends that must be driven and the Jackhammers that must be assigned to these ends. The matrix entries represent costs (in dollars) of drilling the end for that particular jackhammers.

Table showing ends to be driven, the Jackhammers to be assigned to these ends and the cost of drilling an end;

Jackhammer / Ends	1	2	3	4
2310 Tip Cross-cut	600	500	700	400
2350 Drilling drive	500	800	300	800
2350 Vent Raise	600	300	400	700
2350 Haulage	1000	800	700	400

(i) If you are the Mine Captain of this area, what assignment would you adopt in order to ensure that all 4 ends are completed at minimum cost? **[6 marks]**

(ii) What is the total cost of the assignment? **[2 marks]**

(b) A copper mining company in Zambia transports copper cathodes from its three plants to three destinations. The supply capacities of the three plants, the demand requirements at the three destinations, and the transportation costs per ton are as follows;

Plants	Destinations			Supply (Tons)
	A	B	C	
1	8	5	6	120
2	15	10	12	80
3	3	9	10	80
Demand (Tons)	150	70	60	280

(i) Determine the initial solution to this problem using the minimum cell cost method. **[2 marks]**

(ii) Solve the problem using the stepping-stone method. **[8 marks]**

4. (a) (i) Discuss at least five (4) applications of queuing theory in mining. **[4 marks]**

(ii) Briefly discuss the four characteristics that define a queuing system? **[4 marks]**

(iii) How can the result of queuing analysis be used by a decision maker for making decisions? **[2 marks]**

(b) An underground pump station has currently a single pump machine on which underground loaders come to refuel. Over the course of a working day, the loaders come to refuel at random times and arrive at the rate of one every ten minutes. The rate at which the pump can be used is randomly distributed but does approximate a Poisson distribution with a mean rate of eight per hour. A loader driver is paid at the rate of $5 per hour. Determines;

(i) The percentage of time that the pump is idle. **[2 marks]**

(ii) The average length of the queue. **[2 marks]**

(iii) The average time which a loader spends in the queue after arriving for service. **[2 marks]**

(iv) The average time which a loader spends in the system after arriving for service. **[2 marks]**

(v) The average cost per job as a result of the loader waiting in the queue. **[2 marks]**

5. (a) Explain the following terms as applied in Dynamic Programming;

(i) Transition function **[2 marks]**

(ii) Recursive return function **[2 marks]**

(b) Discuss the simplifying assumptions of the Economic Order Quantity (EOQ) Model? **[2 marks]**

(c) Mining Spare Parts Limited is a world wide discount mining store that sells Jack Hammers. The annual demand for Jack Hammer is 4000. The cost per order from the manufacturer is $800. The carrying cost is $60 per Jack Hammer per year. The store has an inventory policy that allows shortages. The shortage cost per Jack Hammer is estimated at $80. Determine the following;

(i)	Optimal order size	**[2 marks]**
(ii)	Maximum shortage level	**[2 marks]**
(iii)	Maximum total annual inventory cost	**[2 marks]**
(iv)	Maximum inventory level	**[2 marks]**
(v)	Number of orders per year	**[1 marks]**
(vi)	Time between orders	**[1 marks]**
(vii)	Time during which there is inventory on hand	**[2 marks]**
(viii)	Time during which there is a shortage	**[2 marks]**

6. (a) Several decision making criterion have been developed to aid managers of business firms in making decisions. The following are some of the criterion used in decision making process. Explain how these decision criterion are applied in decision making process;

(i)	Maximin	**[2 marks]**
(ii)	Minimax regret	**[2 marks]**
(iii)	Equal likelihood	**[1 marks]**

(b) A small-scale miner in Ndola Rural Mining area found out that he can mine three minerals on his three mining licence areas: Emerald, Aquamarine and Garnet. The return from each mineral will be determined by the prevailing mineral market conditions in Zambia. The profit the miner will realise from each mineral given the two possible market conditions (good or poor) is shown in the following payoff table. Determine best mineral to mine using the following decision criteria.

Mineral	**Market Conditions**	
	Good	**Poor**
Emerald	35,000	8,000
Aquamarine	18,000	12,000
Garnet	22,000	20,000

(i)	Maximan	**[3 marks]**
(ii)	Maximin	**[3 marks]**
(iii)	Minimax regret	**[3 marks]**
(iv)	Hurwitz ($\alpha = 0.3$)	**[3 marks]**
(iii)	Equal likelihood	**[3 marks]**

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
SCHOOL OF MINES
MINING ENGINEERING DEPARTMENT
SECOND SEMESTER EXAMINATIONS – FEBRUARY 2007

MI 515 ROCK MECHANICS II

TIME: 3 Hours **FULL MARKS:** 100

INSTRUCTIONS: Answer **question 1** and any other five; total questions to be answered, **six**.

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1. The following questions are designed to explore your general knowledge of geotechnical engineering. Each question is worth the marks indicated and only a brief (but accurate) explanation or justification of your answer is requested.

   (a) What is the definition of soil **(2 marks)**

   (b) Is the axial stress σ_1 in the triaxial test equal to the applied piston load L divided by the cross sectional area A i.e. is $\sigma_1 = L/A$ **(3 marks)**

   (c) What tests are primarily used for soils classification in the laboratory? **(3 marks)**

   (d) Can the dry unit weight of a soil be correctly calculated from the specific gravity of the solids and porosity of the soil; in the form $\gamma_d = Gs(1-n)$? **(3 marks)**

   (e) Is the strength of the soil greatest when it is partially saturated or completely saturated? **(3 marks)**

   (f) Why are piezometers considered to be the most important item of field instrumentation in the construction of earth works? **(3 marks)**

   (g) Does the hydraulic gradient at a point in a given flow net in a homogenous saturated soil depend on the permeability of the soil? **(3 marks)**

2. A laboratory constant head permeability test is shown in diagram 1. The sample area A is $80cm^2$.

   (a) If the quantity of flow through the sample is given as 4×10^{-6} m^3/sec., calculate the coefficient of permeability K. **(8 marks)**

   (b) Calculate the effective vertical stress in the soil just above the filter as $\sigma_v^1 = \sigma_v - u$, and as $\sigma_v^1 = z\gamma^1 + iz\gamma_w$
   If these are not numerically identical, explain why? **(8 marks)**

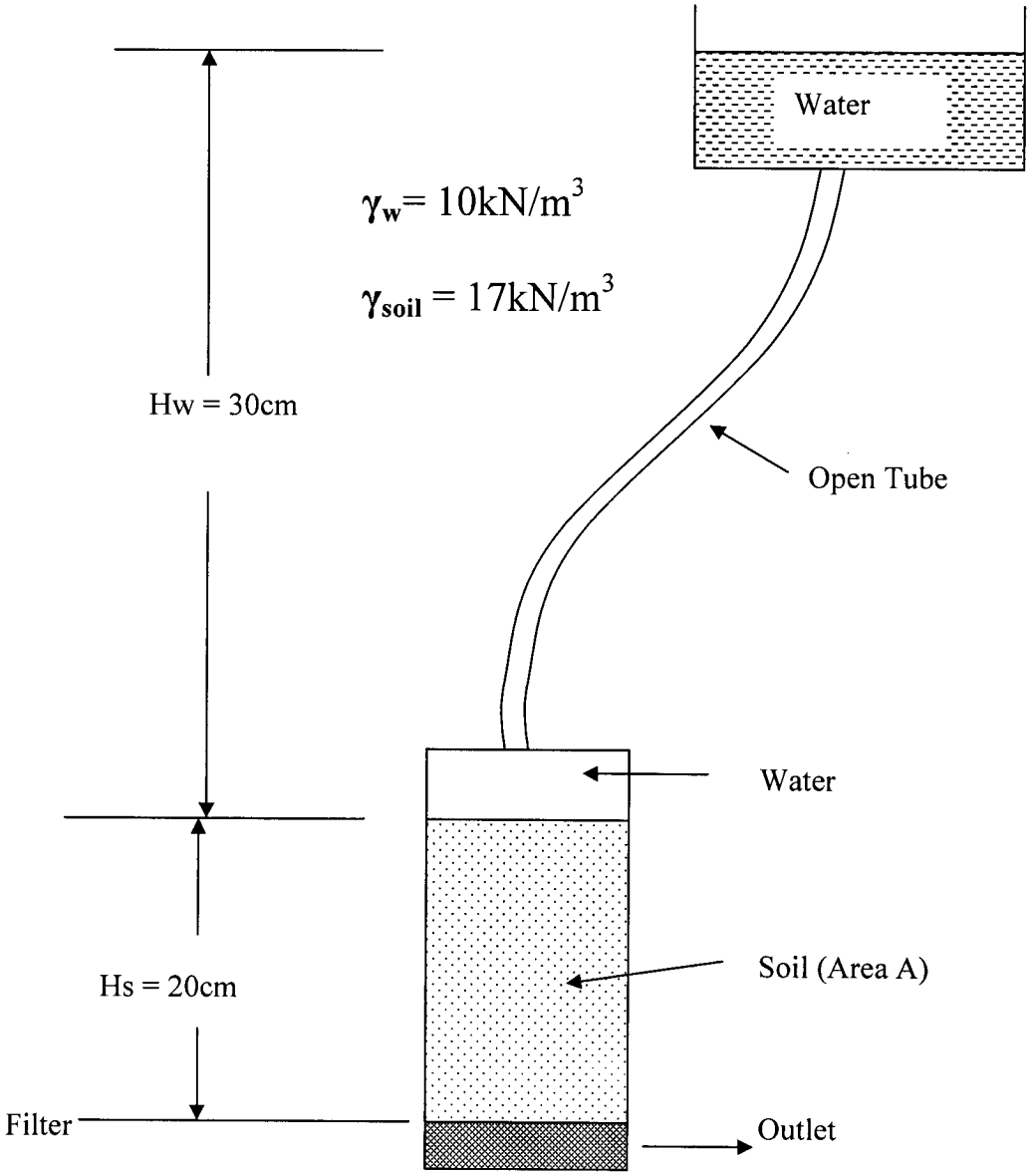


DIAGRAM 1 - FOR QUESTION 2

3. A sample of clay soil was obtained from a natural slope. The clay has:

I_p = 30
W_l = 50
I_l = 1.10 and
G_s = 2.70

A carefully trimmed test specimen of 400cm^3 volume had a mass of 680g.

(a) Is the clay of low, medium or high plasticity?
(b) What symbol (s) would you use to classify the soil?
(c) What is the natural water content of the clay?
(d) Calculate the void ratio of the in-situ clay assuming $S_r = 100\%$.
(e) Calculate the void ratio of the test specimen and compare this value to that calculated in (d).
(f) Is the clay saturated in the slope?
(g) Can the test specimen be considered undisturbed? **(16 marks)**

4. (a) Write the important parameters to be considered in the design of mine pillars. **(8 marks)**

(b) A flat orebody at a depth of 250m below ground surface is planned for extraction using 6.0m room spans, and pillars 7.0m square in plan. The thickness of the ore deposit is 3.5m but mining has to be done leaving 0.5m in the roof due to weak rock in the roof. The unit weight of the overburden rock is $25kN/m^3$

Determine the factor of safety (F.S.) against compressive failure of pillars and comment on the stability of the pillar. If the F.S. is inadequate, suggest the possible options (and then the best) to achieve the F.S. to a safe list. **(8 marks)**

5. (a) Rock bolts/dowels when used underground have different supporting actions to that of conventional type of support. Describe with the help of diagrams principle of support of rock strata using bolts/dowels.

How can the effectiveness of bolts/dowels be checked? **(8 marks)**

(b) A section of a hillock to be stabilized using steel bolts. The number of bolts to be used for this purpose is 30. Calculate the safety factor (SF) from the specifications given below:

- Area of rock block (wedged shape, base 25m top 20m) = $500m^2$
- Average thickness = 14m
- Average density of rock block = $24kNm^{-3}$
- Cohesive strength of the sliding surface (c) = 0.051 MPa
- Dip of sliding surface (Ψ) = 47°
- Frictional angle of the sliding surface (ϕ) = 22°
- Angle between the plunge of the bolt and normal to the sliding surface = 68°
- Tension recommended on each bolt = 100t

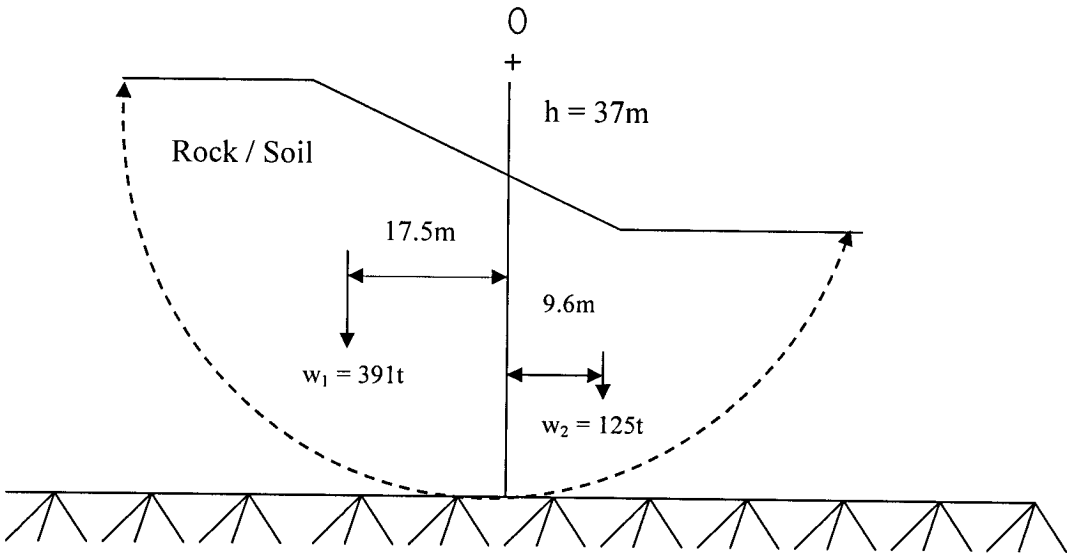
Show the design pattern of the bolts to be installed in the hillock. **(8 marks)**

6. (a) Discuss the modes of failure of slopes in case of open cut mining pit consists of weathered, weak rock and soil. How can such failures be controlled? **(8 marks)**

(b) An open pit bank consisting of soil and weakened rock has been analyzed by slip circle technique and expected to have base failure. Calculate the factor of safety (a) during the dry condition and (b) during the rainy season when soil is saturated.

Rock soil property and the dimensions of the bank is given below:

- Rock-soil specific weight = $16.8kNm^{-3}$
- Rock-soil cohesion = 5.36kPa
- Rock-soil internal friction angle = 15°
- Pit slope = 32°
- Bank height = 24m
- Depth rock ledge = 36m



Comment on the stability of slope. **(8 marks)**

7. (a) The nature of subsidence due to mining of bedded deposit (e.g. coal) varies drastically to that of metalliferous vein deposits (e.g. copper, iron, etc). Describe with the help of diagrams the kind of subsidence you would expect from the above two cases. **(6 marks)**

(b) (i) List the factors that are responsible for subsidence due to mining and suggest the measures that can be taken underground to minimize such subsidence. **(6 marks)**

(ii) A stratified mineral deposit of 3.0m thickness lying at a depth of 300m is being mined out. The width of excavation is 430m. How far will the surface from the centre of excavation be affected if the angle of draw is 27°. Draw a neat diagram and show all the given values and calculated ones on the diagram. **(4 marks)**

Q8. (a) Explain clearly what is meant by stress concentration factor (SCF) and its significance in mining. What are the main parameters on which its value depends? **(8 marks)**

(b) An opening of rectangular shape 2.5m high and 7.5m wide, in a biaxial stress field $\left(K = \frac{\vartheta}{1-\vartheta}\right)$ is at a depth of 1 200m. The uniaxial compressive strength and tensile strength of the rock in which opening exists are 150MPa and 15MPa. The values of SCF at top = +0.3 and at corner = -3.1.

Given the unit weight of overlying rock is $27kNm^{-3}$, comment on the stability of the opening. **(8 marks)**

THE UNIVERSITY OF ZAMBIA
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MINING ENGINEERING DEPARTMENT
SECOND SEMESTER EXAMINATIONS, FEBRUARY 2007
MI 535 COAL MINING METHODS

TIME: 3 HOURS **FULL MARKS:** 100

INSTRUCTIONS

- Answer questions 1 and 6 and any other four. Total questions to be answered are six (06).
- Neatly drawn diagrams will be credited.

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1. **(a)** Considering the requirements of Coal Mining Regulations, state what is meant by 'adequate ventilation'. How can you ensure that the mine section of which you are the in-charge is having adequate ventilation? **(08 marks)**

(b) As per Coal Mine Regulations, certain preventive measures are recommended against the danger from (i) methane gas (ii) coal dust and (iii) water inundation in underground coal mine.

Discuss these preventive measures using diagrams where necessary. **(12 marks)**

2. **(a)** Explain what is meant by 'rank' of coal? List the factors which contribute to the rank of coal. State whether rank of coal can be improved by washing? **(08 marks)**

(b) Discuss briefly, giving reasons, the geological information you would like to obtain prior to mining a coal deposit. (Just listing of factors will not be considered as complete answer) **(07 marks)**

3. **(a)** Although longwall mining is a popular method for mining coal world-wide, there are situations in which room and pillar mining is recommended. Give clearly the reasons for it. **(04 marks)**

State the factors on which the size of the pillars in room and pillar mining and length of a coal face in longwall mining depends? **(04 marks)**

(b) A coal scan 3.0 m thick, over a plan area of 250 x 250 m, at a depth of 350 m to be mined by room and pillar mining. Calculate the size of the pillars of square shape fifteen (15) in number, so that they remain stable during mining. Given the strength of coal pillars equal to 15 MPa. Take average density of overlying rock is 25 kNm^{-3} and safety factor of pillars = 1.2. **(05 marks)**

What will be the effect on the size of pillars if safety factor is increased from 1.2 to 1.5? **(02 marks)**

4. **(a)** A coal deposit 3.5 m thick at a depth of 650 m to be mined. The coal is highly prone to spontaneous combustion. There is a dirt band about 0.5 m thickness in the coal scan. Describe a suitable method for mining such deposit. The Coal Company of such deposit does not want to spend money on salvage of equipment and on pack walls. **(08 marks)**

(b) Calculate the annual production and suggest possible OMS you would expect from a longwall face of which details are given below:

- Length of the longwall face = 160 m
- Thickness of coal seam = 3.5 m; but 0.5 m is supposed to be left on the top of the coal seam since the immediate roof is shale.
- Web of shearer = 1.0 m
- Average Speed of shearer = 8.0 m/min
- Number of coaling shift/day = 3
- Length of shift = 8 hours but coaling time is 60% only
- Take specific gravity of coal = 1.5
- Working days/year = 280 days

Calculation for OMS must be shown. **(07 marks)**

5. **(a)** What are the general considerations that govern the layout in horizon mining? **(08 marks)**

(b) A coal seam dipping at 27 degrees to be mined using the horizon method of mining. Draw a suitable layout, both in plan and section showing the method of mining for such a deposit. **(07 marks)**

6. (i) Write short notes on the TEN STEPS in the development of a Surface Coal Mine. **(05 marks)**

(ii) With the aid of corresponding and neat illustrations, state and describe the various methods of opening-up and development of a large scale Surface Coal Mine. **(05 marks)**

(iii) Calculate and comment on the Economic or Ultimate Pit, given the following data:

- Recoverable value = US $ 25.00/tonne
- Minimum profit = US $ 6.00/tonne
- Stripping cost = US $ 0.35/m^3
- Production cost (exclusive of Stripping) = US $ 10.00/tonne

(10 points)

7. Write short notes on Surface Coal Mining Equipment under the following sub-headings:

(i). Types of Surface Coal Mining Systems **(03 marks)**

(ii). Performance estimation for Surface Coal Mining Systems **(03 marks)**

(iii). Comparison of the merits and demerits of continuous Surface Coal Mining systems vis a vis dragline, stripping shovels and shovel/truck systems **(06 marks)**

(iv). Factors affecting Bucket Wheel Excavator (BWE) performance **(03 marks)**

****** END OF EXAM ******

THE UNIVERSITY OF ZAMBIA
SCHOOL OF MINES
SECOND SEMESTER EXAMINATIONS - 2007

MI 562 – INVESTMENT ANALYSIS

TIME: **THREE HOURS**
INSTRUCTIONS: **ANSWER ANY 4 QUESTIONS**

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1. A project with an initial investment of $200,000 and a life of 8 years requires an additional expenditure of $140,000 at the end of the fifth year. A salvage value of $10,000 is realizable at the end of the project life. Project annual cash flows are expected to be $50,000 during the second to end of fifth year and thereafter rise to $100,000 till the end of its life.

   Assuming a discount rate of 10%, determine:

   a) The Net present value of the project **[5 marks]**
   b) The Present value ratio **[5 marks]**
   c) The payback period of the project **[5 marks]**
   d) The equivalent annual value **[5 marks]**
   e) Comment on the project's profitability **[5 marks]**

2. a) With a help of a diagram, define the optimum economic life of a piece of equipment. **[5 marks]**
   b) What are the causes depreciation? [10 marks]
   c) Discuss the major risks associated with new mineral investments. **[10 marks]**

3. a) Define the term "Balance Sheet" **[5 marks]**
   b) What types of assets would you classify as fixed assets and why? **[5 marks]**
   c) What is an income statement? **[5 marks]**
   d) Mineral Resources Plc had recorded the following accounting entries:

Notes payable	$ 200,000
Accounts payable	1,144,942
Prepaid expenses	155,035
Salaries and wages accrued	163,045
Cash	816,800
Inventories	6,849,403

Taxes payable	87,525
Dividends payable	246,240
Accounts Receivable	2,605,701
Notes receivable	662,761
Retained earnings	5,772,782
Total Stockholders' Equity	8,272,782

From the above relevant entries, determine the company's working capital and what does it indicate? **[10 marks]**

4. The initial cost for a newly acquired workshop crane is K4 billion. It has a five-year expected depreciable life. The salvage value at the end of five years will be K1.2 billion.

   a) Taking into account the salvage value, determine using the straight line depreciation:

      i) The accumulated depreciation at end of 4 years. **[5 marks]**
      ii) The book value at end of 3 years. **[5 marks]**

   b) If the sum-of-digits depreciation is applied, determine:

      i) The accumulated depreciation at the end of year 5. **[5 marks]**
      ii) What rate of depreciation is charged at the end of year 2? **[5 marks]**

   c) If the declining-balance method was applied, what constant rate is applied to the book value for each depreciation period? **[5 marks]**

5. i) In the Stock Exchange, what is meant by "primary offering of stock"? And what is "secondary offering"? **[5 marks]**
   ii) Discuss how a new mining venture may use the stock exchange to raise funds. **[10 marks]**
   iii) Discuss how best a high risk small-scale gemstone mining venture can be financed. **[10 marks]**

6. A Systems Project Manager has established that there are three variables with the following probability estimates of levels of activity for the future:

Sales Quantity (Q)	Probability p(Q)	Sales price Per unit	Probability p(P)	Total operating costs (OC)	Probability p(OC)
10,000	0.2	$20	0.1	$200,000	0.2
15,000	0.3	25	0.2	250,000	0.3
20,000	0.4	30	0.3	300,000	0.4
25,000	0.1	40	0.3	400,000	0.1
		50	0.1		

i) Determine the expected value of each of the above variables. **[5 marks]**

ii) What is the expected value of the net profit? **[5 marks]**

iii) Using Monte Carlo simulation technique and the following table below of random numbers, determine the expected net profit and its associated standard deviation from 10 simulations. Why does this result differ from the one obtained in (ii) above? **[15 marks]**

Table of Random Numbers

Sales Quantity Random numbers	**Sales price Random numbers**	**Total cost Random numbers**
0.798	0.690	0.504
0.496	0.053	0.211
0.176	0.569	0.304
0.383	0.067	0.601
0.591	0.942	0.118
0.776	0.583	0.013
0.529	0.597	0.223
0.477	0.545	0.334
0.180	0.009	0.743
0.910	0.132	0.261

END OF EXAMINATION AND GOOD LUCK

UNIVERSITY OF ZAMBIA
SCHOOL OF MINES
MINING ENGINEERING DEPARTMENT
SECOND SEMESTER EXAMINATIONS, FEBRUARY 2007

MI 595 – MINERAL PRODUCTION CONTROL

INSTRUCTIONS : Answer 5 questions only. **Full Marks:** 100
Questions 4 and 5 are compulsory

TIME: 3 hours

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1. Develop a production plan for an Iron ore deposit mine with the following conditions:-
Mining method to be used – Sublevel caving
The iron content is 47% and the mine is to supply a palletizing plant with annual capacity of 3.2 mil t/a. The simplified ore-body is 1000 m long and 100 wide. Each slice is 10 m high, and there are 10 m between cross cuts, each of which has an area of 20 m^2. The density of the ore is 3.5 t/m^3. The spacing between rings is 2 m and the extraction is 100 %.The Iron Content is 65 % in the pellets and 5% in the tailings. The hypothetical parameters of the ore-body are shown in figure 1.

[20 Marks]

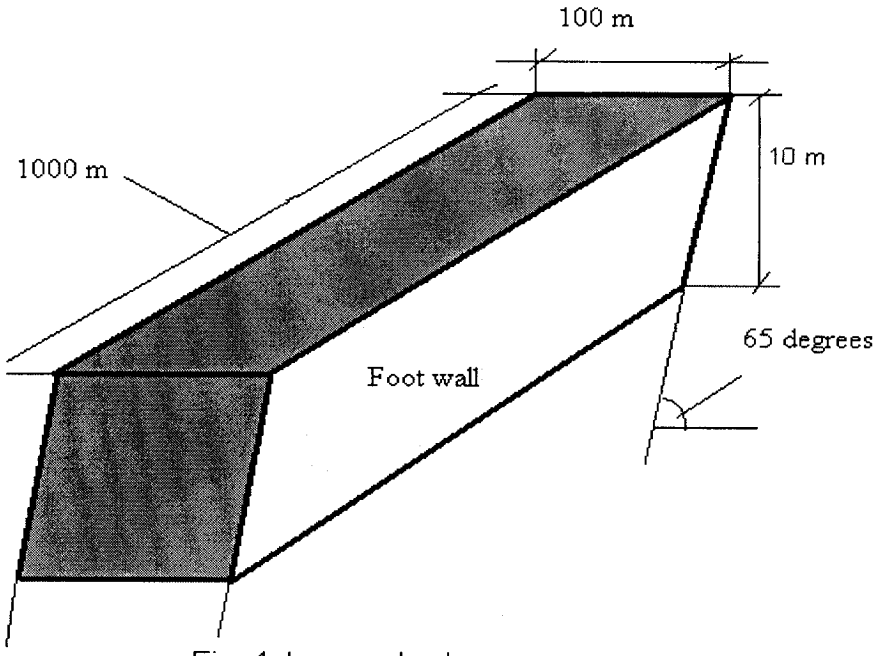


Fig. 1. Iron ore-body

2. Fig.2 shows a vertical ore body divided into eight equal blocks each containing 400 tonnes of ore. In order to mine the ore, the corresponding diamond shaped blocks have to be stripped. Each diamond shaped block contains 300 tonnes of waste rock.

If ore is worth $2.5 per tonne after all mining and processing costs have been paid, and if waste costs $1.00 per tonne to remove, calculate Tonnages and values for possible pit outlines and plot this information on the graph paper. What is the optimum pit?

[20 Marks]

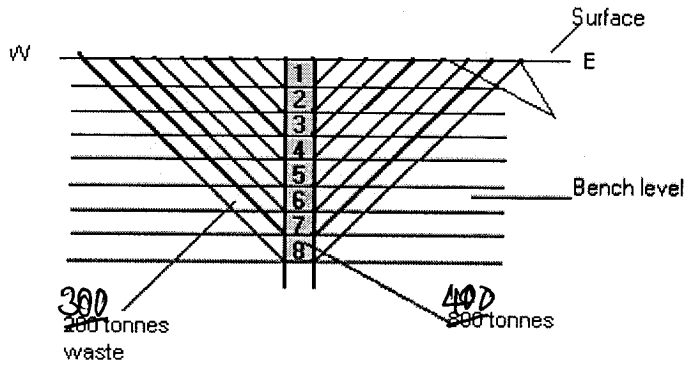


Fig 2. Idealised open pit mine

3. Table 1, shows raw data in terms of tonnages and grades from two loading pockets: levels 600 and 875 m at Mufurila mine. The mill tonnage is 208, 896 tonnes and the grade is 1.64 %:

a) Calculate the reconciled tonnages and grades at the loading pockets of the two levels.

[10 Marks]

b) Briefly state some of the factors in the mine, that may be subjected to investigation if there are large discrepancies in tonnages and grades recorded at loading points and the mill such as, the loading pockets in the mine recording low tonnages and high grades while the mill is recording high tonnages and low grades?

[10 Marks]

Table 1. Raw data for Mufurila Mine loading pockets

FROM	**EXTRACTION**	**TO**	**RAW**	**RAW**
LEVEL	POINT	TIP	TONNES	GRADES %
600	Loading Pocket		99,020	1.55
875	Loading Pocket	Tip	105, 904	1.65
Total			204,928	1.60

4. Compute a production plan for mining a portion of a block in sublevel open stopping with the following conditions:

- Rock strength coefficient f=8;
- Density of ore ρ=3.5 t/m$^{3;}$
- Width of slice to be broken B, is equal to thickness of ore-body. B= 10 m
- Height of Sublevel h=20 m;
- Type of blast holes – fans
- Drilling equipment – Simba – 22; Productivity of equipment PE= 120 m/shift
- Cross section area of Drill drift A=10.24 m^2
- Diameter of blast hole d=77 mm;
- Type of explosive – ANFO;
- Amount of explosives per 1m of blast hole U= 3.50 kg;
- Powder factor q=0.167 kg/t
- Charging coefficient, 0.7
- Recovery co-efficient, R= 0.95
- Dilution coefficient D=0.10
- Productivity of pneumatic charging machine, PE_1 = 1150 kg/shift

In computing the production plan, follow the following sequence:

I. Determine the Burden and spacing; **[2 Marks]**
II. Graphically, locate fan blast holes **[2 Marks]**
III. Generate table and determine total length of holes and amount of explosives; **[5 Marks]**
IV. Determine the Ore- mass, tonnes **[3 Marks]**
V. Calculate actual powder factor **[1 Marks]**
VI. Total length of holes per 1000 tonnes of broken ore and amount of ore broken per meter of blast hole, per 1000 tonnes **[3 Marks]**
VII. Hours spent on drilling **[2 Marks]**
VIII. Hours spent on charging slice **[2 Marks]**

5. Using the data generated in question 4 and hauling distances in figure 3:

a) Calculate the amount of ore tipped per hour using two loaders (LHDs) given the following parameters:

- Bucket pay load carried per cycle: LHD type1, L = 12 Tonnes; LHD type 2, L= 8.5 Ton
- Fixed Cycle time in minutes: LDH type 1, t= 0.80 minutes; LHD type 2, t=0.85, minutes;
- Number of operating minutes per hour (accounting for unavoidable delays):
- LDH type 1, $\mathbf{T_h}$ = 50 minutes; LDH type 2, $\mathbf{T_h}$ = 45 minutes

[10 Marks]

b) Suggest various ways of improving LHDs' productivity in the Mine.

[10 Marks]

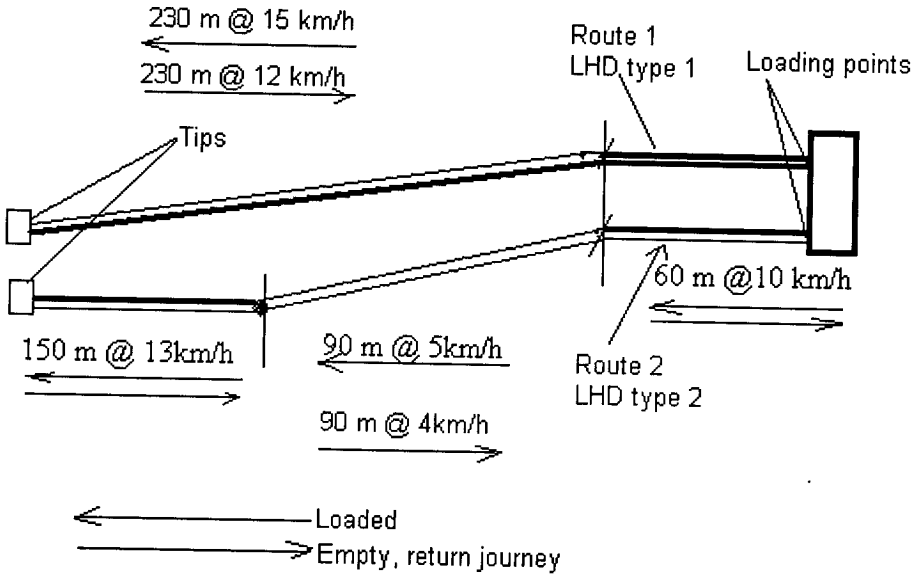


Figure 3 . Hauling distances for two LHDs

6. Figure 4 shows a plan of stope preparation for sublevel open stopping, while table 2 shows the corresponding work schedule.

a) Draw a network analysis and determine the critical path **[10 Marks]**
b) Generate a table and calculate earliest expected and latest allowable times for completion of events.

[10 Marks]

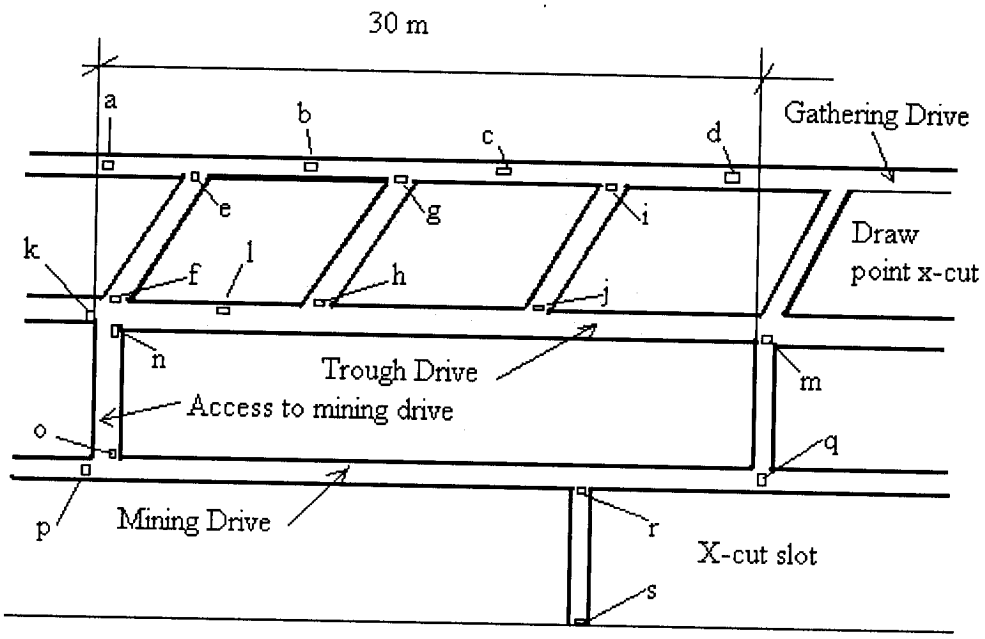


Figure 4. Stope preparation

Table 2. Stope preparation and activity schedule

ACTIVITY	DEVELOPMENT, m	ESTIMATED DAYS FOR COMPLETION
a) Development of gathering drive from point **a** to **b**	10	7
b) Development of trough drive from **k** to **l**	10	7
c) Development of draw cross cut from point **e** to **f.**	18	13
d) Development of gathering drive from point **b** to **c**	10	7
e) Development of draw point cross cut from point **g** to **h.**	18	13
g) Development of gathering drive from point **c** to **d**	10	7
h) Development of draw point cross cut from point **l** to **j**	18	13
i) Development of trough drive from point **l** to **m**	20	14
j) Development of slot cross from point **r** to **s**	14	10
k) Development of access to mining drive from point **n** to **o**	13	9
Development of slot raise	17	21

THE UNIVERSITY OF ZAMBIA
UNIVERSITY EXAMINATIONS – FEBRUARY 2007

MM 205
INTRODUCTION TO METALLURGY AND MINERAL PROCESSING
THEORY: PAPER I

TIME: Three hours

INSTRUCTIONS: Answer any two questions from section A, and any four questions from section B.

Answer Sections A and B in separate answer books.

SECTION A: Introduction to Geology

Question 1

a) What is crystallography?

b) Discussion the seven crystal systems that all crystal forms may be placed in.

c) Define the following terms
   a. Plane of symmetry
   b. Axis of symmetry
   c. Centre of symmetry

[20%]

Question 2

Describe the eight (8) important mineral groups, giving at least two (2) mineral examples in each group with their chemical formula.

[20%]

Question 3

Describe the internal structure of the earth with emphasis on chemical composition, specific gravities, pressure and temperature conditions.

[20%]

Question 4

a) What are the three (3) main rock classifications?
b) How do igneous rocks form?
c) Classify igneous rocks based on composition and mode of occurrence

[20%]

SECTION B: Mineral Processing and Extractive Metallurgy

Question 1

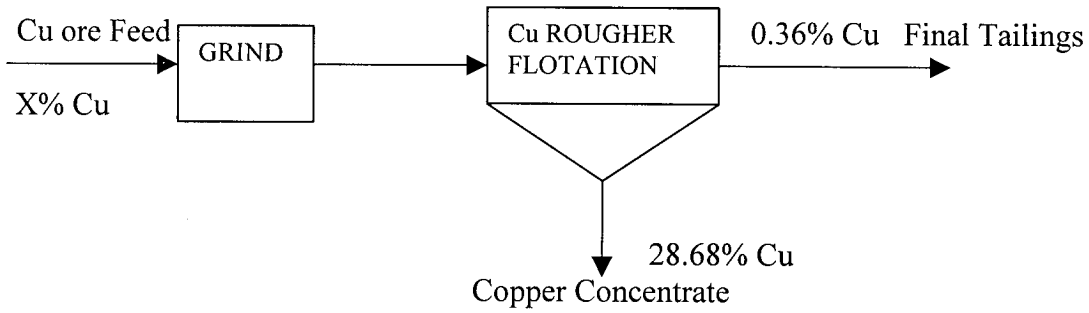
State what you understand by the following terms as used in Metallurgy:

- Mineral
- Ore
- Roasting
- Resources
- Leaching
- Matte
- Recyclable metalliferous resources
- Comminution
- Refractory minerals
- Base metals

[15%]

Question 2

A copper sulphide ore is treated in a rougher flotation circuit to produce a copper concentrate as shown in the diagram below. The average grades of the feed and products of this circuit are as indicated.



(i) If the recovery of copper from feed to concentrate is 80.32 %, what is the grade of the feed? **[3%]**

(ii) What is the ratio of concentration into the copper rougher concentrate? **[2%]**

(iii) What is the enrichment ratio in the copper rougher concentrate? **[3%]**

(iv) If the mass flowrate of the rougher tailings is 333 t/h (dry solids), what are the mass flowrate of the copper ore feed and the copper concentrate? **[4%]**

(v) How much copper will there be in the copper concentrate in one eight-hour shift? **[3%]**

[15%]

Question 3

(a) What is (are) the common principles in the following three hydrometallurgical processes.

- cementation
- hydrogen reduction
- electrowinning **[3%]**

(b) What metals can be recovered by cementation? **[2%]**

(c) What makes it possible to recover zinc from an aqueous solution of its ions by electrowinning? **[3%]**

(d) What do you consider to be essential difference(s) between electrowinning and electrorefining? **[2%]**

(e) Salt (NaCl) is a common additive in a copper refining tank house. What is its purpose? **[2%]**

(f) What do you understand by "liberator cells" in an electrorefining? **[3%]**

[15%]

Question 4

(a) Give a short description of the 'underground' mining method. Illustrate with a rough sketch. **[4%]**

(b) Give three examples of mining methods with self-supporting openings and also three examples of mining methods requiring fabricated supports. **[4.5%]**

(c) What are the main three functions of the air that is drawn from surface through underground mine workings? **[1.5]**

(d) Name three underground mining methods used for steeply dipping ore deposits and briefly state the main differences between them. **[4%]**

(e) What do you understand by 'solution mining'? **[1%]**

[15%]

Question 5

(a) Why do chemical analyses alone provide insufficient information on the economic potential of a mineral deposit? **[2%]**

(b) What pretreatment must any ore undergo before its mineral constituents can be separated from each other? **[1%]**

(c) Why are processes, such as crushing and grinding usually carried out in stages? **[2%]**

(d) Draw a rough flowsheet for a theoretical froth flotation circuit, showing a 'roughing' stage, a 'scavenging' stage and a 'cleaning' stage.

Indicate the main process streams with arrows and give the name of the feed or product that forms each of these streams. **[4%]**

(e) What is the main consideration during 'scavenging' and what is the main consideration during 'cleaning'? **[2%]**

(f) What do you understand by 'middlings' in a mineral separation process? **[2%]**

(g) In the flowsheet, drawn under 4 (d), indicate where middlings are likely to be recovered and show the most logical further treatment route for such middlings. Explain in a few words. **[2%]**

[15%]

Question 6

(a) What do you understand by a copper 'matte'?

What is its approximate chemical composition? **[3%]**

(b) During copper matte smelting, some magnetite is usually formed. Why is this a problem? **[2%]**

(c) How can the formation of magnetite be minimised? **[2%]**

(d) What do you understand by 'converting' in the pyrometallurgical production of copper? **[1%]**

(e) Name the type of converter most commonly used in the copper industry and illustrate its operation with rough sketches. **[2%]**

Give the main chemical reactions that take place. **[2%]**

(f) Why is the product of copper converting usually fire-refined before it is cast into anodes for electrolytic refining? **[3%]**

[15%]

END OF MM205 EXAMINATION
GOOD LUCK!

THE UNIVERSITY OF ZAMBIA
SCHOOL OF MINES

MM 332 - CHEMICAL THERMODYNAMICS II

UNIVERSITY EXAMINATIONS

SECOND SEMESTER 2006-7

FEBRUARY 2007

TIME ALLOWED: THREE HOURS

ANSWER FIVE(5) OUT OF SIX (6) QUESTIONS But remember, all questions carry equal MARKS.

---

1. Kubaschewski and Alcock reported the data for relative integral molar enthalph and entroph for bismuch-thallium liquid solutions at 623° K. Derive from the data the value of the relative integral Gibbs energies for the liquid solutions at 623° K.

(a) Obtain the relative molar Gibbs energies for bismuch and tallium at N_{Ti} = 0.2 and 0.6. Calculate the activities of bismuch and tallium at these two compositions.**(14)**

N_{Ti}	H^M (J/mol)	S^M (J/mol.°K)
0.0	0.0	0.0
0.1	-1113	2.70
0.2	-2063	4.14
0.3	-2887	5.06
0.4	-3703	5.40
0.5	-4268	5.48
0.6	-4561	5.31
0.7	-4289	4.85
0.8	-3452	3.98
0.9	-2008	2.59
1.0	0.0	0.0

(b) Calculate G^{ex} at N_{Ti} = 0.2 and 0.6. **(6)**

2. (a) Derive the expression for the lowering of the freezing point of a water, due

to the addition of a small amount of salt, a non-volatile solute. Assume that, there is no solid - solid solubility, and that water and salt are components A and B forming a binary solution at room temperature. **(12)**

(b) The activity coefficient of chromium in iron at infinite dilution relative to pure solid chromium as the standard state is unity. Calculate the change in the Gibbs energy when solid chromium is dissolved in iron so as to form an infinitely dilute, weight percent solution of chromium in liquid iron at 2073 K from the following data:

Heat of fusion of Chromium L_f = 5,000 cal/mol (20,920 J/mol)
Melting point of Chromium T_ff = 1830° C
Atomic weights of Fe and Cr are 55.85 and 52 respectively.
R =8.31 J/mol.K **(8)**

3. (a) Explain the differences between ideal, real and regular solutions. **(4)**
   (b) For an ideal solution derive ΔV mix, Δ H mix, ΔS mix and ΔG mix. **(6)**
   (c) A solute obeys the following relation in dilute solutions; $f_B = kN_B^{\frac{3}{2}}$

   Where N_B is the mole fraction of the solute. Derive the expression for the fugacity of the solvent f_A. Assume a binary solution. **(10)**

4. The Henrian activity coefficient Υ^{o}_{Al} for Aluminium in liquid iron-Aluminium alloys is reported to be 0.063 at 1600°C. Calculate the standard Gibbs energy change of formation of $Al_2O_3(s)$ at 1600° C for each of the following four standard states for Al:
   a) $2Al(l, pure) + 3/2O_2(g) = Al_2O_3(s)$ **(5)**
   b) $2Al(l, h) + 3/2O_2(g) = Al_2O_3(s)$ **(5)**
   c) $2Al(l, wt) + 3/2O_2(g) = Al_2O_3(s)$ **(5)**
   d) $2Al(l, at) + 3/2O_2(g) = Al_2O_3(s)$ **(5)**

$\Delta G^{o} = -1{,}682{,}927 + 323.239T$ J/mol.

Molecular weights if Al and Iron are 26.98 and 55.85 respectively.

5. The emf of the cell $Cd(l) \mid Cd^{2+}$ [in melt] $\mid$ Cd – Pb (l, $X_{Cd} = 0.128$) is found to be 37.14 mV at 500°C. The temperature coefficient of the cell emf is 99.1μ~~m~~V/°K

a. Find the G^{M}_{Cd} (= G_{Cd} - G^{0}_{Cd}), H^{M}_{Cd} (= H_{Cd} - H^{0}_{Cd}), H and S^{M}_{Cd} (= S_{Cd} - S^{0}_{Cd}) at 500°C **(6)**

b. Determine the value of a_{Cd} in the alloy, relative to pure liquid Cd as the standard state. **(2)**

c. Calculate the vapour pressure over the Cd – Pb alloy given that the vapour pressure of pure liquid Cd is 13.5 Torr at 500^0C and ascertain whether the Cd – Pb system at $X_{Cd} = 0.128$ exhibit a positive or negative deviation from Raoult's law. **(4)**

d. In electrolysis of primary products, the amount of material W in grams produce in passing a current of I amperes in a period of t seconds for a substance with atomic weight A and valence n is given by

$W = ItA/nF$

An important parameter of this process is the so called current efficiency which is defined as the percentage of the total quantity of electricity passing through the cell that is actually utilized in the production of the electrolyte. This is designed as CE = Actual weight of material produced divided by the theoretical amounts estimated. In the industrial production of Aluminum using the Hall-Heroult cell working at 40,000 amps, 275 kg of pure Aluminum is produced per day. Calculate the Current Efficiency CE. The Molecular Weight of Aluminum is 26.98 **(8)**
Dissolved of aluminum ionizes according as $\mathbf{2Al_2O_3 \Leftrightarrow 2\ Al^{3+} + 2\ AlO^{-3}}$
And hence n = 3. F = 96,487 Coulombs/g.mole (J/V.gmole)

6..a. Discuss the role of following on the velocity of a chemical reaction.

i. The nature of reactants and products **(2)**

ii. Temperature of the reaction **(3)**

iii. Concentration of both reactants and products **(3)**

iv. Presence of catalysts **(2)**

b. Explain in detail, how the **collision theory** differs from the **theory of absolute rates. (6)**

c. The concentration of Sulphur in pig iron after desulphurisation with basic slag at 1470^0C at various intervals of time is a follows below as :

Time [Min]	0	9	20	40	64
Concs of Sulphur Kg/m^2	87.1	57.4	30.2	10.0	2.75

Show that the desulphurisation is a first order reaction and determine the half life for this process.**(4)**

END OF EXAMINATION, GOOD LUCK.

THE UNIVERSITY OF ZAMBIA
SCHOOL OF MINES
UNIVERSITY EXAMINATIONS – FEBRUARY/MARCH 2007

MM 412 – MINERAL PROCESSING II

Answer *question 6* and any *other four*. **Time: 3 hours**

Question 1

State briefly what you understand by the following terms, used in mineral processing:

- the wash ratio in filter cake washing
- surfactant
- pulp dilution
- differential flotation
- solids-handling capacity of the thickener
- surface active agent
- magnetic susceptibility
- electrical double-layer
- micelles
- physical adsorption

[20 %]

Question 2

(a) Explain briefly, but clearly, why heavy medium separation in a gravitational vessel can be used only to separate relatively large particles, or minerals with a large difference in density, even though in theory any particle with a density larger than the medium density should sink, and any particle with a density lower than the medium should float. **[3%]**

(b) What are the main factors determining whether the feed particle is rejected, held in the bed, or passed down through in jigging? **[4%]**

(c) Outline the usual sequence of operation in the heavy media separation process. **[3%]**

(d) What are the main requirements for a medium to be used in heavy media separation?

Explain your answer briefly, but clearly. **[4%]**

(e) Draw a simplified flowsheet of a heavy media separation plant, using a cone separator and ferrosilicon as medium, and show how the medium is recovered.

Explain your flowsheet in a few words. **[6 %]**

[20 %]

Question 3

(a) It is given that a complex sulphide ore contains pyrite, galena, sphalerite, bornite and chalcopyrite, and that its treatment by froth flotation yields three concentrates: a lead concentrate, a zinc concentrate and a copper concentrate.

The main reagents used in this flotation process are:

- copper sulphate
- lime
- sodium cyanide

- sodium di-chromate
- sodium iso-propyl xanthate
- tri-ethoxy butane

(i) State briefly what the function would be of each of the above reagents in this flotation process. **[6%]**

(ii) Draw a simplified flowsheet for this flotation process, showing its main stages, and indicate in the flowsheet where you would add each of the above reagents (some reagents may be added at more than one addition point).

Indicate the principal mineral composition of each of the products, obtained with this flowsheet. **[4%]**

(b) Describe the up stream method of tailings-dam construction with the aid of a clearly labelled diagram. Outline the advantages and disadvantage of this method. **[7%]**

What are the most serious problems associated with the disposal of tailings and how are they minimised? **[3%]**

[20 %]

Question 4

(a) Give an equation that expresses the 'area principle' in sedimentation, state what the symbols used in this expression represent, and explain this principle in a few a words. **[3.5%]**

(b) Which operations and what equipment used in mineral processing are based upon this area principle? **[2%]**

(c) The main design parameters of a gravity thickener are its surface area and its depth. What quality is controlled by the surface area and what quality the depth controls? Explain your answers briefly. **[3%]**

(d) What are the functions of the rakes in a gravity thickener? What circumstances would necessitate raising of the rakes? **[2%]**

(e) What circumstances would necessitate re-circulation of the thickener underflow? Explain briefly for each case why this re-circulation is necessary. **[2%]**

(f) Describe briefly and in simple terms the differences between 'coagulation' and 'flocculation'. **[3%]**

(g) Discuss, very briefly the effects of (i) solid concentration (ii) pulp temperature and (iii) flocculant doserate, upon coagulation and flocculation. **[4.5%]**

[20 %]

Question 5

(a) Briefly state the differences between diamagnetic, paramagnetic and ferromagnetic substances. **[3%]**

Illustrate with rough graphs of the intensity of magnetisation against the applied magnetic field for these three groups of substances. **[2%]**

What can you say about the magnetic susceptibility for these three groups of substances?

(b) What factors limit in practice the intensity of the applied magnetic field? **[3%]**

(c) Because of these limitations, what else is done in industrial practice to obtain a high magnetic force on the particles to be separated? **[2%]**

(d) Give a brief discussion on the separation of minerals by electrostatic separation and by electrodynamic (high-tension) separation.

Briefly describe the basic principles involved and the main types of equipment in use. Illustrate with rough diagrams. **[5%]**

(e) What is the characteristic difference in the size distribution in the products obtained by these two types of equipment? Explain briefly but clearly. **[3%]**

(f) Name two typical 'conducting' minerals and two 'non-conducting' minerals that are commonly separated by high-tension separation. **[2%]**

[20%]

Question 6

(a) Briefly describe the steps, necessary for the attachment and adhesion of solid particles to air bubbles in a mineral pulp. **[3%]**

(b) Describe the concepts of a 'disjoining pressure', of a 'critical film thickness' and of an 'induction time' in flotation. **[3%]**

(c) What is the effect of the adsorption of a suitable collector upon the critical film thickness and the induction time? **[2%]**

(d) A zinc-lead sulphide ore, assaying 12.6 % PbS and 17.4 % ZnS, is treated by flotation.

With the assumption that the only minerals in the ore are galena, sphalerite and silicate gangue, calculate:

(i) the theoretically possible recoveries of galena and of sphalerite after two minutes flotation; **[3%]**

(ii) the theoretical concentrate grade of galena and sphalerite (% PbS and % ZnS) after two minutes flotation. **[6%]**

(iii) the amount (in grams) of the silicate gangue contained in the concentrate after two minutes of flotation. **[3%]**

The specific rates of flotation under the conditions chosen were found to be:

galena	0.6 min^{-1}
sphalerite	0.1 min^{-1}
water	0.05 min^{-1}
silicates	0.02 min^{-1}

You may assume flotation to be first-order and these flotation rates to remain constant during the flotation times considered. You may also assume all the gn and sl to be floatable under the conditions chosen.

- END OF MM 412 EXAMINATION –
GOOD LUCK !

THE UNIVERSITY OF ZAMBIA
SCHOOL OF MINES
UNIVERSITY EXAMINATIONS – FEBRUARY/MARCH 2007

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- END OF MM 412 EXAMINATION –
GOOD LUCK !

THE UNIVERSITY OF ZAMBIA
UNIVERSITY EXAMINATIONS - SECOND SEMESTER, 2006-7
FEBRUARY 2007
MM 442
HYDROMETALLURGY

ANSWER: ALL QUESTIONS.
TIME: THREE HOURS. THE CREDIT FOR A FULL ANSWER IS SHOWN IN BRACKETS BESIDE EACH QUESTION.

1(a) How do leaching reactions that are classified as "chemical dissolution" differ from those in the category of "oxidative dissolution"? Explain for each category by considering the dilute sulphuric acid leaching of any copper mineral of your choice.(5%)

b(i) What is the general name for aluminium ores? Give the name and chemical formula of each principal aluminium mineral in such ores. (3%)

(ii) Draw a clearly labelled material-flow diagram for the Bayer process. (4%)

(iii) What is the objective of each processing step of the Bayer process? Outline what is involved in each step, giving the relevant chemical reactions where necessary.(10%)

(iv) What is the final product of the Bayer process and what is such a product used for?(3%)

2(a) Which type of refractory gold ores would be assisted by microbial leaching prior to cyanidation and how would such facilitation occur? (5%)

(b) Account for how the aurocyanide complex ion, $Au(CN)_2^-$, is adsorbed on activated carbon in gold ore processing. (8%)

(c) In a pilot plant study of gold adsorption, a 90 ppm Au pregnant solution is passed through a 10 m^3 fixed bed of activated carbon.. The treated exit solution, which comes out at the rate of 5 m^3/hr, is recycled to the leaching stage. The results of sampling the column exit solution at different times are shown below.

Time (hr)	1	2	3	4	5	6	7	8	9	10
Au tenor (ppm)	0	0	0	0	1	2	11	18	27	55

(i) Plot the instantaneous Au concentration in the column exit stream as a function of the bed volumes of cumulative solution that will have left the column at the time of sampling. (4%)

(ii) With the aid of the plotted graph, estimate the amount of gold (in kg) adsorbed on the carbon column at the time that the exit solution will have had 40 ppm Au. (8%)

3(a) For each of the diagrams cited below, explain how the diagram is determined and used: (8%)

(i) A pH isotherm in solvent extraction.
(ii) An ion exchange elution curve.

(b) A solution obtained from a typical agitation leaching operation contains 2.51 g/l Cu at a pH of 1.9. Portions of this solution are equilibrated with different volumes of LIX 984 dissolved in a suitable diluent. Data obtained pertaining to these equilibrium experiments is shown below.

Phase ratio (V_O/V_A)	10/1	5/1	2/1	1/1	1/2	1/5	1/10
g/l Cu in extract	1.42	1.63	2.34	3.15	3.50	3.59	3.69
g/l Cu in raffinate	0.056	0.070	0.18	0.68	1.41	2.08	2.31

(i) Construct an equilibrium extraction isotherm for LIX 984 using the data given. (4%)

A continuous counter-current operation is to be used for extracting copper from a solution with 2.51 g/l Cu, and it is anticipated that the stripped organic with LIX 984 entering extraction will be completely barren. Answer the following, assuming an organic to aqueous volumetric flow rate ratio of 0.7;

(ii) What will be the copper content of the loaded organic? (4%)

(iii) Predict the number of useful stages which will be required for such an operation assuming 100% stage efficiency. (6%)

(iv) Explain why the areas of the stages in your McCabe-Thiele diagram are not equal. (3%)

4(a) It is desired to recover copper by cementation from spent electrolyte that is due to be discarded because of a high build-up of impurities. Iron powder is added to achieve this. If the final Fe^{2+} concentration in the de-copperized spent electrolyte is 50 g/l, what is the copper concentration (in g/l) of the disposable electrolyte after cementation? Take the electrolyte temperature as 35 °C and assume ionic activities are equal to molar concentrations. State any other assumptions made in your calculation. (8%)

Data: Atomic weights: Fe = 55.8; Cu=63.5. Universal gas constant, R = 8.314 J/deg/mol. F=96500 C/mol.

$Cu^{2+} + 2e^- = Cu$ $\quad E^\circ = 0.337$ V

$Fe^{2+} + 2e^- = Fe$ $\quad E° = - 0.440$ V

(b) In carrying out cementation of copper on iron, a higher amount of iron than stoichiometrically required is used. Explain why. (4%)

(c) What advantages does "periodic current reversal" offer and what problems does it overcome when used in copper electrometallurgy? Explain whether the technique can be used for copper electrowinning. (5%)

(d) Cathode starting sheets each with a submerged cross section of 95 cm X 95 cm are used in a zinc electrowinning tankhouse in which the potential drop between anodes and cathodes is maintained at 3.5 V. The average current density used is 220 A/m^2. At a current efficiency of 92%, calculate the time (in hours) required to deposit 10 kg of zinc per starting sheet placed between two anodes. (7%)

Data: Relative atomic weight of Zn = 65.4; F = 96500 C/mol

END OF EXAMINATION.

MM 442 - HYDROMETALLURGY

COURSE CONTENTS

Leaching:

of metals, metal oxides, and metal sulphides. Leachants. Chemical, oxidative, and reductive dissolution. Leaching involving complex ion formation. Heap, vat, agitation, and pressure leaching.

Solid-liquid separation.

Filtration and clarification.

Solution purification and concentration and reclamation of metals from waste liquors.

Adsorption on activated carbon (AC): Preparation of AC, uses. Sorption, stripping, and regeneration of spent AC.

Ion exchange: Cation and anion exchangers. Uses. Sorption and elution. Resin poisoning.

Solvent extraction: Extractants and diluents. Extraction and stripping. Mixer-settler units. Applications.

Crystallization: Evaporative, high temperature-high pressure processes, by cooling. supersaturated solutions and seeding. Effect of organic liquids. Fractional crystallization.

Chemical precipitation: Thermodynamics and common ion effect. Metal hydroxide, sulphide, carbonate, and phosphate precipitation.

Cementation: Applications, thermodynamics. Methods.

Gaseous reduction, Applications and thermodynamics.

Electrowinning: Faraday's laws, current efficiency. Electrodes, electrolytes, and electrode processes. Theoretical cell voltage, overvoltages, and applied cell voltage. Energy efficiency. Relationship between applied cell voltage, current density, and deposit quality. Behaviour of electrolyte impurities. Electrolyte additives.

Product recovery from solution:

Crystallization, chemical precipitation, cementation, gaseous reduction, and electrowinning.

Electrorefining

Electrodes, electrolytes, electrode reactions, theoretical and applied cell voltage. Electrolyte additives. Behaviour of impurities. Electrolyte purification. Anode slimes. Anode bags. Diaphragms.

Applications

Typical flow-sheets for hydrometallurgical extraction of: copper, cobalt, nickel, zinc, aluminium (Bayer process), gold, and uranium.

Prescribed reading

Jackson, E. Hydrometallurgical Extraction and Reclamation. Ellis Horward, Chichester (1986).

THE UNIVERSITY OF ZAMBIA
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UNIVERSITY EXAMINATION - FEBRUARY 2007
MM 452
PROCESS CONTROL AND INSTRUMENTATION

Time : **THREE** hours
Answer: **FIVE** questions
Additional information is provided with the question paper

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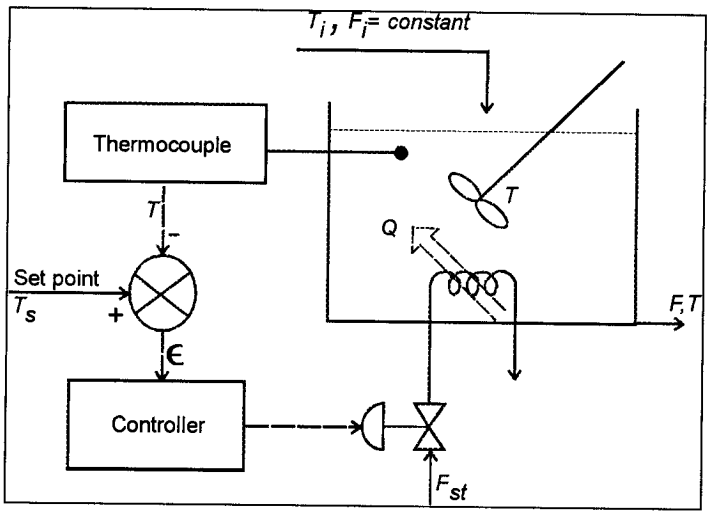
1. (a) The student-teacher learning process is inherently a feedback process intended to reduce the system error to a minimum. The desired output is the knowledge being studied and the student may be considered the process. Construct a feedback block diagram model of the learning process and identify each block and the corresponding input and output variables.

(5 marks)

(b) The diagram below is a control and instrumentation diagram for a stirred-tank heater:



Discuss, ***with reasons where applicable,*** the heater system in the context of control as follows:

(i) Identify the control objective;
(ii) Identify input variables and classify as manipulated or disturbance;
(iii) Identify output variables and classify these as measured or unmeasured;
(iv) Should the control system fail open or fail closed? For the strategy you have chosen, is the valve gain positive or negative? Why?
(v) Discuss safety and economic considerations;
(vi) Draw a control block diagram for the feedback system.
(vii) Briefly, comment on the possibility using feedforward control in this process.

(15 marks)

2. (a) An isothermal, first-order, liquid-phase, irreversible reaction is conducted in a constant volume batch reactor:

$$A \xrightarrow{k} B$$

The initial concentration of reactant A is c_{A0}. The specific reaction rate k decreases with time because of catalyst degradation as $k = k_0 e^{-\alpha t}$.
Derive a mathematical model for this process and find $c_A(t)$. **Also**, show that in the limit as $\alpha \to 0$, $c_A(t) = c_{A0} e^{-k_0 t}$ **and** that in the limit as $\alpha \to \infty$, $c_A = c_{A0}$.

(8 marks)

(b)An isothermal, first-order, liquid-phase, irreversible reaction is conducted in a continuous flow stirred tank reactor. The modelling equations are:

$$\frac{dV}{dt} = F_i - F$$

$$\frac{d(c_A V)}{dt} = c_{Ai}F_i - c_A F - kc_A V$$

(i) Determine the number of degrees of freedom for this system.

(2 marks)

(ii) Find the number of control objectives you can specify.

(3 marks)

(iii) Consider steady state inlet and outlet flow rates of F_s = 2 litre/min, a liquid volume V_s = 2 litre, k = 1 min^{-1}, c_{Ais} = 2 moles/litre and c_{As} = 1 mole/litre. Suppose there is a step inlet concentration change in A from 2 moles/litre to 3.0 moles/litre. Determine the vessel concentration of A after 0.5 minute and 1 minute. **Also**, determine the new steady state concentration of A.

(7 marks)

3. (a) What are state variables and state equations? Describe what they are used for.

(5 marks)

(b) You are given a system with the transfer function

$$\frac{y(s)}{f(s)} = \frac{T_1 s + 1}{T_2 s + 1}$$

If $T_1/T_2 = 5$ and if f(t) is a unit step function

(i) Find y(t).

(6 marks)

(ii) Calculate y(t) for the following values of t/T_2 : 0; 0.5; 1.0.

(4 marks)

(iii) Determine the numerical values of minimum, maximum and ultimate values that may occur during the dynamic and static response. Check these values using the initial value and final value theorems.

(5 marks)

4. (a) Given that

$$y(s) = \frac{e^{-10s}}{s(5s+1)}$$

Determine y(t) at t = 15.

(5 marks)

(b) A tank having a cross-sectional area of 0.2 m^2 is operating at a steady state with an inlet flow rate of 10^{-3} m^3/s. Between liquid heads h of 0.3m and 0.09m the flow head characteristics are given by the equation:

$$F_o = 0.002h + 0.0006$$

where F_o is the outlet volumetric flow rate.

(i) Calculate the initial steady state level.

(2 marks)

(ii) Determine the transfer function relating liquid level to inflow ($H(s)/F_i'(s)$) and the transfer function relating outflow to inflow ($F'(s)/F_i'(s)$).

(8marks)

(iii) If the inflow increases from 10^{-3} to $1.1x10^{-3}$ m^3/s according to a step change, calculate the liquid level 200s after the change has occurred.

(5 marks)

5. (a) A second order process with one pole at the origin has the transfer function

$$\frac{y(s)}{f(s)} = G(s) = \frac{3}{s(s+1)}$$

Find the output as a function of time for a unit step change. What is the ultimate value?

(5 marks)

(b) For the following second order process with numerator dynamics, solve for the time domain output response to a unit step input change in temperature:

$$\frac{T'(s)}{T_i'(s)} = \frac{(20s+1)}{(3s+1)(15s+1)}$$

In this case, T'(t) is the deviation in temperature in ^0C.

(i) Find T'(t).

(7 marks)

(ii) Determine the ultimate value of T'(t) and check with the final value theorem.

(5 marks)

(iii) What is the maximum value of T'(t)?

(3 marks)

6. Process liquid is continuously fed into a perfectly mixed tank in which it is heated by a steam coil. Feed rate m_{is} is 22,700 kg/h of material of constant density ρ of 800 kg/m^3 and heat capacity of 2.1 kJ/kg.^0C. Holdup in the tank M_s is constant at 1820 kg. Inlet feed temperature T_i is 27^0C.

Steam is added at a rate of S kg/h that heats the process liquid up to T. At the initial steady state the temperature in the tank is 90^0C. The latent heat of vaporisation λ_v of the steam is 2100 kJ/kg.

(a) Derive a mathematical model of the system and prove that the process temperature is described dynamically by

$$\tau\frac{dT}{dt} + T = K_1T_i + K_2S$$

where $\tau = M_s/m_{is}$ $\quad K_1 = 1$ $\quad K_2 = \lambda_v/c_Pm_{is}$

(8 marks)

(b) Solve for the steady state value of steam flow S_s.

(3marks)

(c)Suppose a proportional feedback controller is used to adjust steam flow rate such that $S=S_s+K_c$ (90-T). Solve analytically for the dynamic change in T(t) for a step change in inlet feed temperature from 27 ^{0}C to 10 ^{0}C. What will the final values of T and S be at the new steady state for a K_c of 80 kg/h.^{0}C?

(9 marks)

END OF EXAMINATION IN MM452

Additional information to assist the students in this examination is found below.

Table of Laplace Transforms

f(t)	f(s)	f(t)	f(s)
u(t)	$\frac{1}{s}$	tu(t)	$\frac{1}{s^2}$
$t^n u(t)$	$\frac{n!}{s^{n+1}}$	$e^{-at}u(t)$	$\frac{1}{s+a}$
$t^n e^{-at}u(t)$	$\frac{n!}{(s+a)^{n+1}}$	sin kt u(t)	$\frac{k}{s^2+k^2}$
cos kt u(t)	$\frac{s}{s^2+k^2}$	cosh kt u(t)	$\frac{s}{s^2-k^2}$
sinh kt u(t)	$\frac{k}{s^2-k^2}$		

Inversion by partial fractions

METHOD 1

Suppose $L\{x(t)\} = x(s) = \frac{F(s)}{(s+k_1+jk_2)(s+k_1-jk_2)}$

where F(s) is some real function of s.

Let the function x(s) after partial fraction expansion become

$$x(s) = F_1(s) + \left(\frac{a_1 + jb_1}{s + k_1 + jk_2} + \frac{a_1 - jb_1}{s + k_1 - jk_2} \right)$$

where a_1 and b_1 are constants evaluated in the partial fraction expansion and $F_1(s)$ is a series of fractions arising from F(s).

Then the inverse transform arising from the complex root reduces to

$$2e^{-k_1 t}\,(a_1 \cos k_2 t + b_1 \sin k_2 t)$$

METHOD 2

Suppose x(s) after partial fraction expansion becomes

$$x(s) = F_1(s) + \frac{Bs + C}{(s+a)^2 + k^2}$$

Then

$$x(s) = F_1(s) + B\frac{s+a}{(s+a)^2 + k^2} + \left(\frac{C - aB}{k}\right)\frac{k}{(s+a)^2 + k^2}$$

The inverse transform arising from the above becomes

$$x(t) = F_1(t) + Be^{-at}\cos kt + \left(\frac{C - aB}{k}\right)e^{-at}\sin kt$$

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UNIVERSITY EXAMINATION – FEBRUARY 2007

MM 542

FUELS, FURNACES AND REFRACTORIES

TIME: THREE HOURS

Answer: ALL QUESTIONS

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1. (a) Write short notes on classification of fuels. (6 marks)

(b) Distinguish between **rank** and **grade** of coal (2 marks)

(c) Name **two** purposes for which the storage procedures of coal are designed. (2 marks)

(d) How can coal be stored safely? (4 marks)

(e) Briefly describe the coking process in coke ovens. (6 marks)

2. (a) Define calorific value of a fuel. [2 marks]

(b) A fuel gas containing 22.4% CO, 12.6% CO_2 and 65% N_2 by volume is burned with the theoretically required amount of air in a furnace designed to heat solids. The gases enter the furnace at 250° C and leave it at 700° C and 1 atm.

Calculate
(i) the adiabatic flame temperature and [10 marks]
(ii) the quantity of heat supplied to the solids in the furnace, in joules per cubic meter of exhaust gases. [6 marks]

(c) State three assumptions for these calculations [2 marks]

Use the following data:

$(\Delta H^{\circ}_{298})_{CO}$ = -110,530 J/mol
$(\Delta H^{\circ}_{298})_{CO2}$ = -393,770 J/mol

Heat - capacity data (in J/g. mole. °K):

$C_{P,CO2} = 44.17 + (9.04 \times 10^{-3}T) - (8.54 \times 10^{5} /T^{2})$

$C_{P,CO} = 28.43 + (4.10 \times 10^{-3}T) - (0.46 \times 10^{5} /T^{2})$

$C_{P,N2} = 27.88 + (4.27 \times 10^{-3}T)$

$C_{P,O2} = 29.98 + (4.19 \times 10^{-3}T) - (1.674 \times 10^{5} /T^{2})$

3. (a) Give a brief description of the following furnaces:

(i) Hearth furnaces [2 marks]

(ii) Shaft furnaces [2 marks]

(iii) Converters [2 marks]

(b) In the selection of refractories, some of the most important properties of refractory materials generally considered are:

(i) Refractoriness
(ii) Spalling resistance
(iii) Slag resistance

Briefly describe the determination of these properties. [9 marks]

(c) Outline the standard route followed in the manufacture of refractories and show sketches of the firing furnaces used. [5 marks]

4. (a) Describe the manufacture of Carbon bricks under the following headings:

(i) Sources of raw materials (4%)
(ii) Manufacture (5%)
(iii) Applications (2%)

(b) How do insulation materials derive their low thermal conductivity? (5%)

(c) Outline **four** examples of insulation raw materials (4%)

5. (a) Describe the slip casting method in the manufacture of refractories. [3 marks]

(b) Name **three** advantages of slip casting [3 marks]

(c) Distinguish between zircon and zirconia [2 marks]

(d) Describe the manufacture of zircon and zirconia ware under the following heading:

(i) Raw materials [2 marks]
(ii) Manufacture (Pressing and Firing) [3 marks]
(iii) Applications [1 mark]

(e) Describe the manufacture of silicon carbide and its applications. [6 marks]

END OF EXAMINATION IN MM 542.

THE UNIVERSITY OF ZAMBIA
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UNIVERSITY EXAMINATION – FEBRUARY 2007
MM 552
PROCESS DESIGN

Time : **THREE** hours
Answer: **FIVE** questions
All questions carry equal marks

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1. (a) Suggest how the following set of equations may be solved:

$$f_1(x_1, x_4) = 0$$
$$f_2(x_1, x_2, x_3) = 0$$
$$f_3(x_4) = 0$$
$$f_4(x_3, x_4) = 0$$

(5 marks)

(b) Distinguish between external and internal constraints in process design. Give one example of each.

(3 marks)

(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 melting, 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		30	
Alloy B	83.5	15		1.5
Alloy C	69	1		30
Pure Cu	100			

(12 marks)

2. (a) Deduce the number of degrees of freedom (design variables) in the design of a partial condenser and indicate how these may be utilised.

(5 marks)

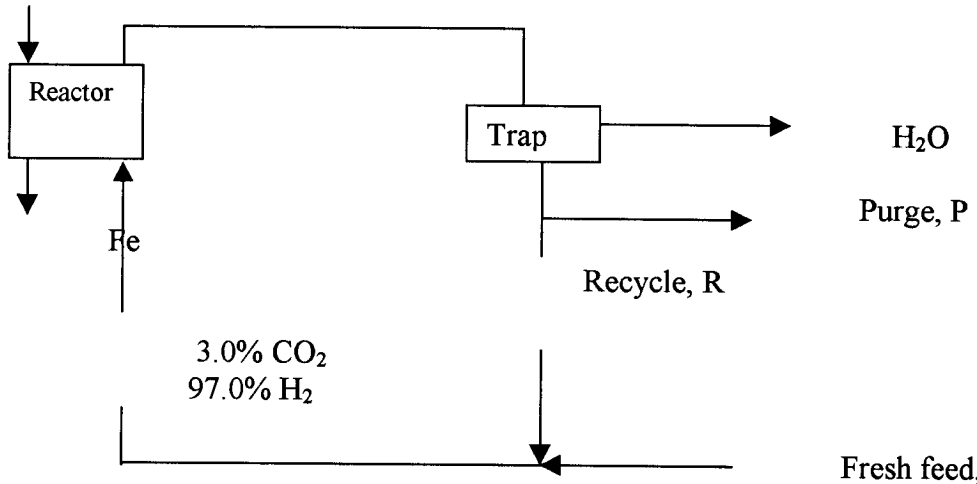
(b) The plant in the attached flow sheet employs H_2 to reduce 2500 kg/h of Fe_2O_3 according to

$$Fe_2O_3 + 3\ H_2 \rightarrow 3H_2O + 2Fe$$

The hydrogen in the recycle is mixed with the hydrogen in the fresh feed before entering the reactor. The purge stream, P, is bled off to prevent CO_2 buildup in excess of 36 mass % CO_2 at the inlet. The ratio of R to the fresh feed gas is 4:1. Calculate the amount and composition of the purge stream.

Atomic masses: Fe, 55.85; O, 16: H, 1; C, 12.

2500 kg Fe_2O_3 /h



(15 marks)

3. (a) A gas mixture containing 10% CO_2, 6% H_2O, 15% O_2 and 69% N_2 is to be cooled from 1650^0C (3000^0F) to 650^0C (1200^0F). How much heat must be removed from 100 moles of the mixture?

(8 marks)

(b) Hot gases leaving a gas recovery unit at a rate of 1600 moles/min at 200^0C (392^0F) and 1 atm pressure are passed through a heat recovery train. The gases contain 80% CO_2 and 20% H_2O. They leave the heat recovery train at 25^0C and essentially the same pressure. Since there has been some condensation, the gases now contain only 4% H_2O. Calculate the amount of heat removed in MJ per minute if the heat of vaporization of steam at 25^0C is 2.45 MJ/kg?

Use the heat capacity data in the given figure. Remember 1 cal = 4.187 J.

(12 marks)

4. (a) Briefly discuss the discounted-cash-flow rate of return measure of profitability.

(5 marks)

(b) Derive the relationship between the uniform periodic payment, R, made during **n** discrete periods and the present worth, P, of the ordinary annuity at an interest rate **i**.

(5 marks)

(c) An engineer in charge of the design of a plant must choose either a batch or a continuous system. The batch system offers a lower initial outlay but, owing to high labour requirements, exhibits a higher operating cost. The cash flows (***in millions of Kwacha***) relevant to this problem have been estimated as follows:

System	Year/Years		Discounted-cash-flow rate of return
	zero	One to ten	
Batch system	-200	56	25%
Continuous system	-300	76.5	22%

Calculate the net present worth at 10%. Check the values of the discounted-cash-flow rate of return. If the company requires a minimum rate of return of 10%, which system should be chosen?

(10 marks)

5. (a) A heat exchanger is to be designed to cool 8.7 kg/s of ethyl alcohol solution [c_{ph} = 3.84 kJ/(kg. ^{0}C). This is to be done from 75^{0}C to 45^{0}C with cooling water [c_{pc} = 4.18 kJ/(kg. ^{0}C) entering the tube side at 15^{0}C with a flow rate of 9.6 kg/s. The overall heat transfer coefficient based on the outer tube surface is U_o = 500 W/(m^2. ^{0}C). Calculate the heat transfer area for a counterflow arrangement.

(10 marks)

(b) Steam at atmospheric pressure enters the shell of a surface condenser in which the water flows through a bundle of tubes of diameter 30 mm at the rate of 0.06 kg/s. The inlet and outlet temperatures of water are 20^{0}C and 75^{0}C, respectively. The condensation of steam takes place on the outside surface of the tubes. If the overall heat transfer coefficient is 250 W/m^2 ^{0}C, using the NTU method, calculate: (i) the effectiveness of the heat exchanger, (ii) the length of tube.

(10 marks)

6. An experimental filter press having an area of 0.0414 m^2 was used to filter a slurry at a constant pressure of 267 kPa. The filtration equation obtained was

$$\frac{t}{V} = 10.25 \times 10^6 V + 3.4 \times 10^3$$

where t is in seconds and V in m^3.

(a) Calculate the values of K_1 and K_2 giving the appropriate SI units.

(10 marks)

(b) If the same slurry and conditions are used in a leaf press having an area of 6.97 m^2, how long will it take to obtain 1.00 m^3 of filtrate?

(5 marks)

(c) Suppose the filtration is run at a constant rate of 0.0001 m^3/s, calculate the time it takes for the pressure to reach 10 bar.

(5 marks)

Please note: $P = (K_1 V + K_2)q$

where $K_1 = \dfrac{s\rho\mu\alpha_{av}}{(1-ms)A^2}$ and $K_2 = \dfrac{R_m \mu}{A}$

END OF EXAMINATION IN MM 552

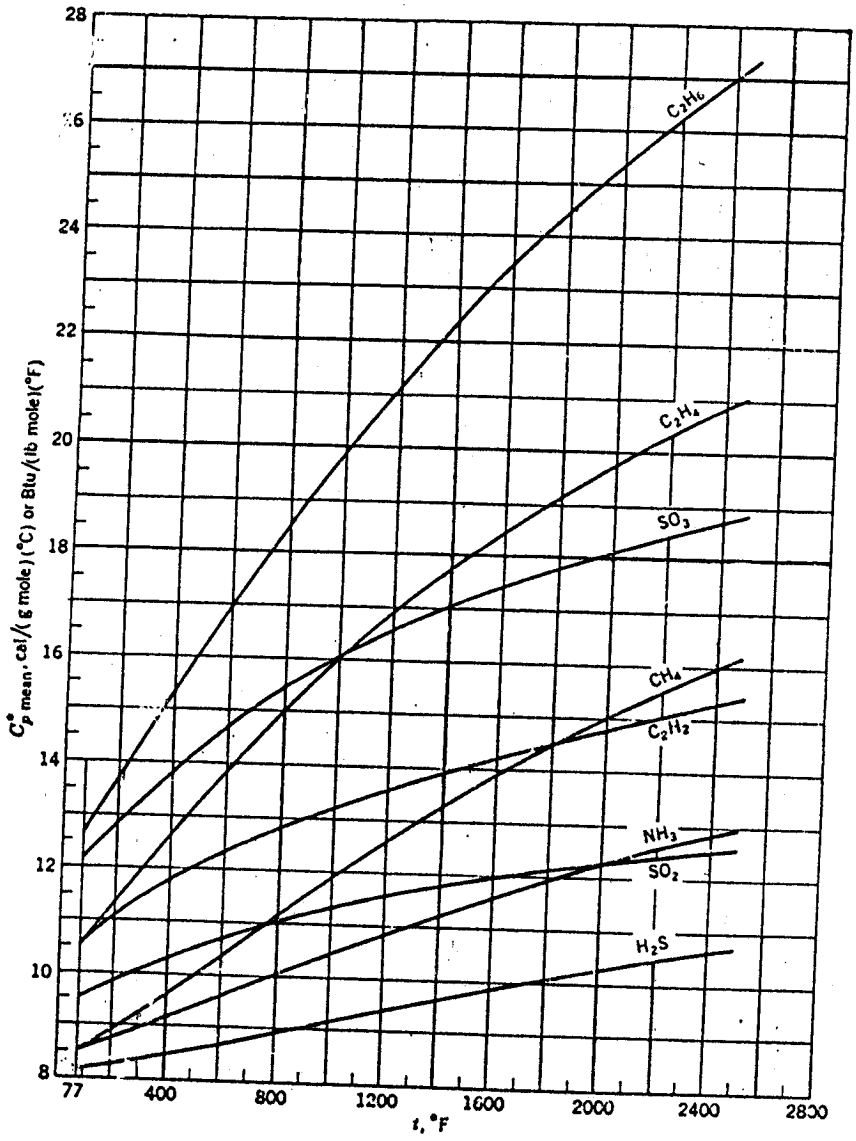


Figure 10–1 Mean molar heat capacities of gases in the ideal state. Base temperature, 77°F. *Based mainly on data from D. D. Wagman (ed.)*, Selected Values of Chemical Thermodynamic Properties, *Natl. Bur. Stand. Circ.* 500, 1952. *From J. M. Smith and H. C. Van Ness,* Introduction to Chemical Engineering Thermodynamics, Second Edition. *Copyright 1959 McGraw-Hill Book Co. Reprinted by permission.*

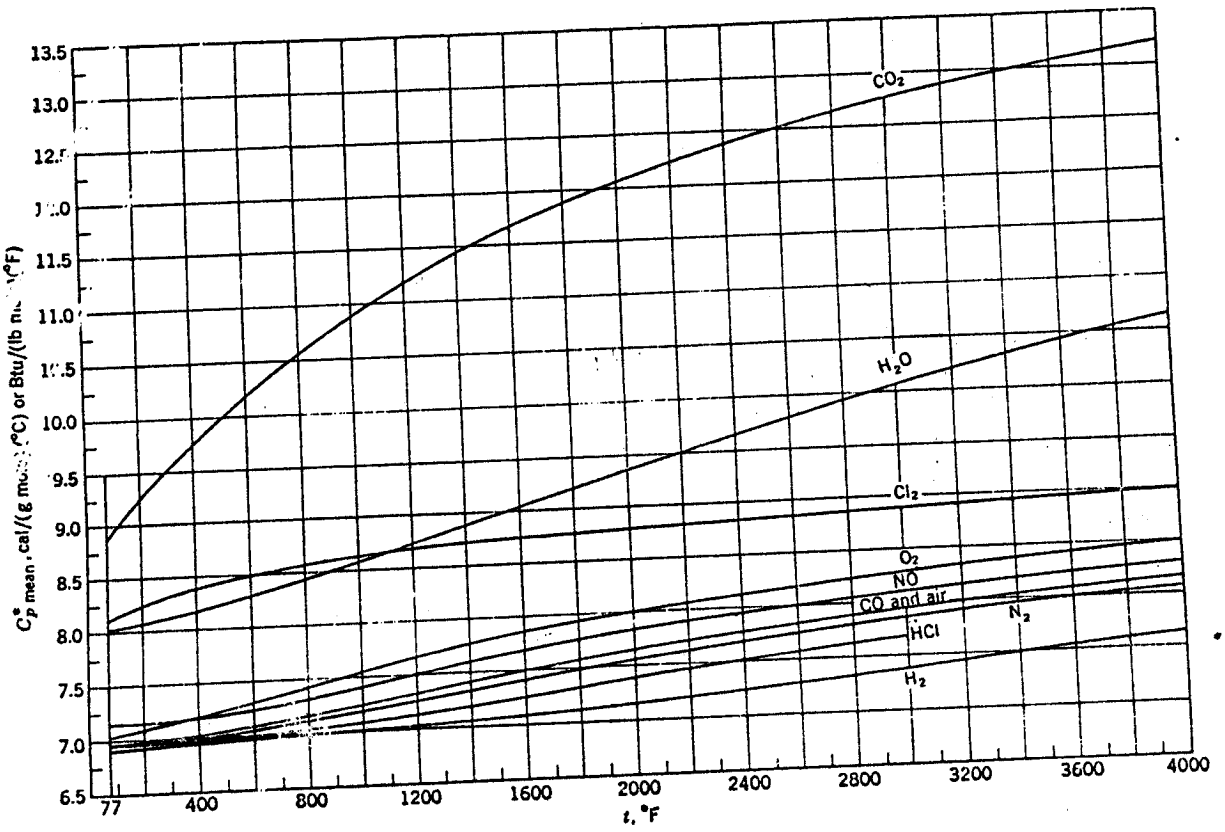


Figure 10–2 Mean molar heat capacities of gases in the ideal-gas state. Base temperature, 77°F. *Based mainly on data from D. D. Wagman (ed.)*, Selected Values of Chemical Thermodynamic Properties, *Natl. Bur. Stand. Circ.* 500, 1952. *From J. M. Smith and H. C. Van Ness,* Introduction to Chemical Engineering Thermodynamics, Second Edition. *Copyright 1959 McGraw-Hill Book Co. Reprinted by permission.*

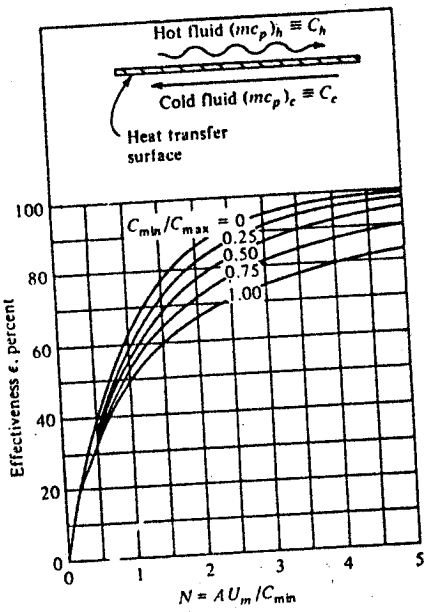


Figure 11-18 Effectiveness for a counterflow heat exchanger. (*From Kays and London* [*10*].)

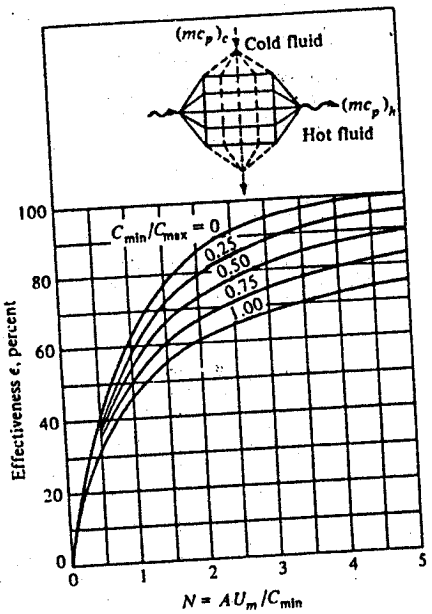


Figure 11-19 Effectiveness for a cross-flow heat exchanger, both fluids unmixed. (*From Kays and London* [*10*].)

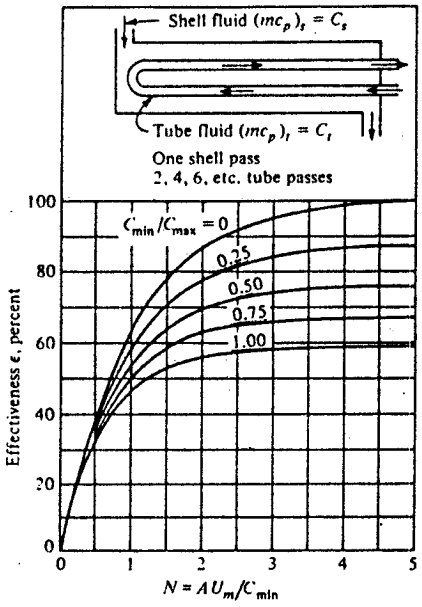


Figure 11-20 Effectiveness for a single shell pass heat exchanger with two, four, six, etc. tube passes. (*From Kays and London* [*10*].)

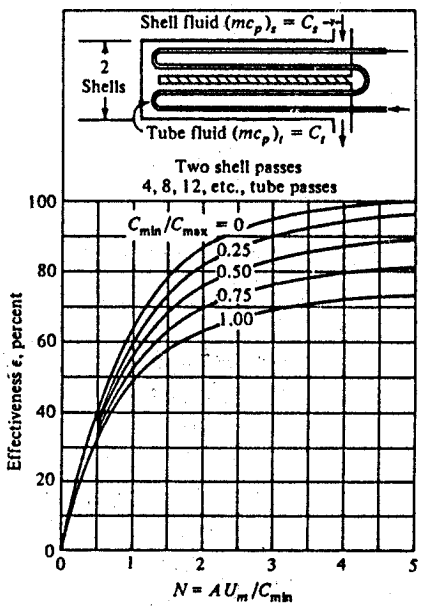


Figure 11-21 Effectiveness of a two shell pass heat exchanger with four, eight, twelve, etc. tube passes. (*From Kays and London* [*10*].)

THE UNIVERSITY OF ZAMBIA

SCHOOL OF MINES

UNIVERSITY EXAMINATIONS – FEBRUARY/MARCH 2007

MM 562 – FOUNDRY

TIME: THREE HOURS

ANSWER ANY FIVE QUESTIONS

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1. A cylindrical riser with diameter-to-length ratio = 1.0 is to be designed for a sand casting mould. The casting is illustrated in Figure 1 below in which the units are in cm. If K=19.5 min/cm^2 in Chvorinov's Rule, determine the dimensions of the riser (i.e. length, L and diameter, D) so that the riser will take 0.5 minute longer to freeze than the casting itself.

   Assume the total area and volume of the casting are 203.4 cm^2 and 62.0 cm^3 respectively.

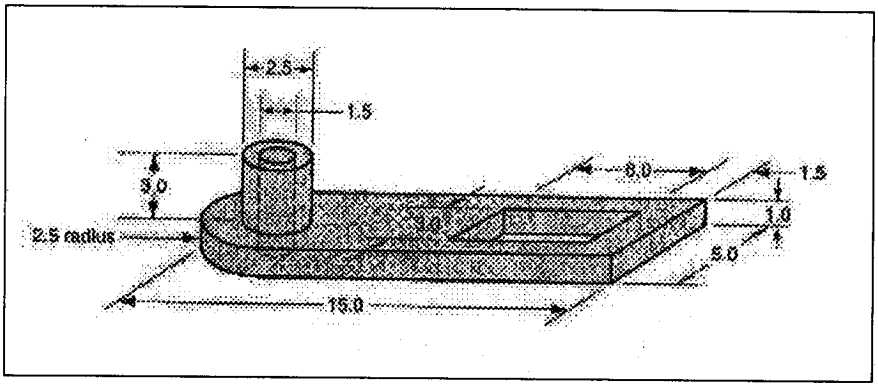

Figure 1

2. (a) Explain why sand testing in a production foundry should be an integral part of the production process in relation to any two of its important properties. Describe how your chosen properties may impact on one another in producing a sound casting.

   (b) Discuss the limiting factors in the choice of pattern materials for a production run. Why is softwood often a material of choice for pattern making in sand casting?

3. (a) Calculate the iron balance (% Fe yield) for a cupola melt of cast iron given the following selected data:

(i) Input

Material	Pig A	Pig B	Scrap	Steel	FeMn	Coke
	298.4	99.5	398.0	199.0	3.58	132.5
% Fe	92.0	93.2	93.8	99.2	50.0	1.0

(ii) Output

Material	Cast iron	Slag
Wt.% (kg/ton of cast iron)	1000.0	68.0
% Fe	93.4	2.25

(b) Although the theoretical heat content of an aluminium alloy at 750° C is 1.05 MJ/kg, in practice it takes 8.2 m^3 of natural gas of net calorific value of 36.5 MJ/m^3 to melt 100 kg of an alloy in a crucible furnace and 55.6 kWh (200 MJ) to effect melting in an induction furnace.

Explain these results and comment upon their significance.

4. For a simple top gated casting, calculate the flow rate at an intermediate point situated 0.45 m from the surface in the downsprue given that the total height, h_t, is 1.20 m and the diameter at the sprue outlet is 35 mm (where the velocity is a function of the total potential energy).

From information above, calculate the mould filling time as well as its solidification time, t_s, with mould capacity of 1,200 cm^3 (assume cubic shape) and that the value of K is 180 secs/cm.

5. (a) Explain the factors that are responsible for the varying crystal structure in an ordinary ingot. What is constitutional (or compositional) super-cooling?

(b) Discuss the variables responsible for the critical free energy changes, ΔG^*, in both homogeneous and heterogeneous nucleations given that;

$$\Delta G^* = \frac{16 \pi \gamma^3 T_m^2}{3L^2 \Delta T^2}$$

6. (a) Using a single phase binary alloy model, show how solute segregation influences the process of solidification in a case of no solid diffusion and limited liquid mixing. Explain initial solid composition, kC_o, and the subsequent solid and solute variations.

(b) What commercial application or use may the occurrence above be used for?

END OF EXAMINATION IN MM 562

THE UNIVERSITY OF ZAMBIA

SCHOOL OF MINES

UNIVERSITY EXAMINATIONS – FEBRUARY/MARCH 2007

MM 562 – FOUNDRY

TIME: THREE HOURS

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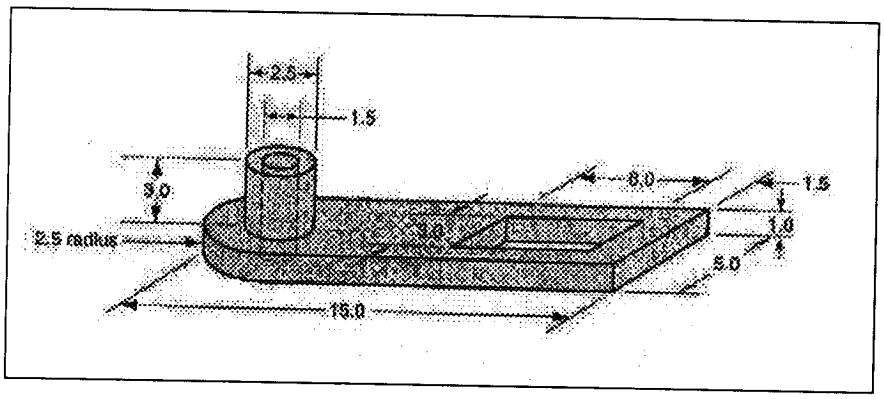

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