National Exams May 2012

09-MMP-A2, Underground Mining Methods & Design

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.

2. This is an CLOSED BOOK EXAM.
   A Casio or Sharp approved calculator is permitted.

3. The candidate is allowed one only 8.5x11 inch reference sheet, hand written both sides.

4 Question 1 and FOUR (4) candidate choice questions constitute a complete exam paper.
Only question 1 and the first four candidate choice questions as they appear in the answer book will be marked.

5 Question 1 is compulsory and has 40 marks. The first four other questions (chosen from questions 2 to 7) as they appear on the candidates exam booklet will be marked for 15 marks each. The total mark is 100.

6 Most questions require an answer in essay format. Neat sketches should be used where and when ever appropriate. Clarity and organization of the answer are important.

You must answer **compulsory Question 1**, parts 1.1 to1.7 inclusive, worth 40 marks total.

Of the remaining 6 questions (2 to 7) you must select four to answer. Any extra questions answered after the four required will not be marked. The four you choose each have 15 marks.

The total marks possible will then be $40 + 4 \times 15 = 40 + 60 = 100$

Question 1 This question (1.1 to 1.7 inclusive) is **compulsory** and worth 40 marks

1.1 With the aid of a neat isometric sketch, show the following mine openings (0.5 marks each)

1.1.1 shaft
1.1.2 cross cut
1.1.3 drift
1.1.4 raise
1.1.5 winze
1,1,6 dip
1.1.7 strike
1.1.8 apparent dip

Show the outline of the ore-body in your neat sketch (1 mark)

Total 5 marks

1.2 Draw sketch sections looking along strike of the following typical cut and fill stopes showing the cycle of operations. (2 marks each)

1.2.1 conventional overhand

1.2.2 underhand

1.2.3 tight

Total 6 marks

1.3 Why would sub-level (sometimes called long-hole) stoping be preferred to cut and fill mining. (2 marks)

Compare the dilution and recovery for both sub-level and cut and fill methods. (3 marks)

Total 5 marks

1.4 With respect to wire ropes for hoisting, what do you understand by the term "6 x 7, 63.5mm FC rope". (2 marks)

Describe shaft conveyance "safety dogs". Can they be used with wire rope guides and why. (3 marks)

What means are available to prevent "overwind" of a shaft conveyance. (2 marks)

Total 7 marks

1.5 Recent changes to the Ontario Mines Regulations specify the minimum volume of air required for each specific diesel engine. What are these regulations/specifications. (4 marks)

What types of approved exhaust scrubbers are available for such engines. (2 marks)

Total 6 marks

1.6 With respect to locked coil hoisting ropes, what do you understand by the terms "Z", "V" and Omega strand. (3 marks)

Why are lubricants used internally in locked coil ropes when manufactured, and what are these lubricants composed of. (3 marks)

Total 6 marks

1.7 During the pre-feasibility stage, a cost estimator has suitable capital cost information for an operation started 5 years ago and operating costs from the same period for another mine. The estimator also has yearly cost indices starting 10 years ago at 100. The index 5 years ago was 107 and the present index is 120.

How can the estimator produce information for present day costs given the indices today and 5 years ago and the costs 5 years ago. If the price of a piece of equipment 5 years ago was $500 thousand/unit what is the estimated price today. (2 marks)

In your reference text "CIM Special Volume 47, CAPCOSTS by A.L. Mular and Poulin, R.", what are the four cost indices described and discuss variations in these indices. (3 marks)

Total 5 marks

Total for **compulsory** Question1 (1.1 to 1.7 inclusive) 40 marks

Of the remaining 6 questions (2 to 7) you must **select four** to answer. Any extra questions answered after the four required will not be marked. The four you choose will each have 15 marks.

Question 2 This is one of four multiple choice questions worth 15 marks. Do not answer this question if it is not one of the four questions you have chosen to answer from questions 2 to 7.

2. Cut and fill mining can be subdivided into 3 types, conventional overhand, underhand and tight.

For each of the 3 types, discuss, compare and contrast

2.1 ore and waste ground conditions (2 marks)

2.2 safety (1 mark)

2.3 necessary equipment assuming mechanised (2 marks)

2.4 operating cost, (2 marks)

2.5 skilled personnel (1 mark)

2.6 value of product mined (1 mark)

2.7 types of fill materials (1 mark)

2.8 strength of fill (including additives) (1 mark)

2.9 methods of placing fill in the stopes (2 marks)

2.10 scheduling a constant production and fill rate (2 marks)

Total 15 marks

Question 3 This is one of four multiple choice questions worth 15 marks. Do not answer this question if it is not one of the four questions you have chosen to answer from questions 2 to 7.

3. There are several versions of the sub-level (sometimes called long-hole) stoping method, Including the following 2 groups (3.1 and 3.2),

Group 3.1
- True sub level
- Transverse stoping
- Longitudinal retreat

Group 3.2
- Avoca
- Eureka
- Viscaria (alimak)
- VCR

Select one sub-level mining method from Group 3.1 and one sub-level mining method from Group 3.2.

Draw neat isometric sketches of your 2 choices. (5 marks)

Show in your sketches the method of sequencing the development, drilling and blasting, back-fill, loading and transportation of mined rock.

Discuss sub-level stoping. Typical headings for this part of the question include access, geology, rock strength, geometry, safety, dimensions (stopes and ore-body), productivity, equipment (drilling, loading and haulage), blasting, filling (tailings fill and additives/alternatives), speed of mining, mine planning and scheduling. (6 marks)

Discuss pillar recovery methods which might be used after the fill has consolidated. (4 marks)

Total 15 marks

Question 4 This is one of four multiple choice questions worth 15 marks. Do not answer this question if it is not one of the four questions you have chosen to answer from questions 2 to 7.

4 Briefly discuss each of the following wire hoist rope types. Include a neat sketch section of each type, describe their applications to hoist drums etc. used in mines. Describe advantages and disadvantages of each type. (3 marks).

- Round strand
- Triangular strand
- Flattened strand
- Half locked coil
- Full locked coil
- Non-rotating rope

Describe and compare the "reliance capel" and "crosby clamp" methods of attaching a hoist rope to the top of a man-cage or skip. (4 marks)

With the aid of sketches, briefly discuss each of the following shaft hoisting systems and their typical applications, advantages and disadvantages. Note whether balanced, the type of rope used, types of guides and tail rope (if required) in each case. (3 marks)

Unbalanced single drum
Balanced single drum
Double drum, one drum clutched
Double drum, both drums clutched
Blair multi-rope hoist
Friction or Koepe hoist

With regard to hoisting wire ropes, what do you understand by the terms "right lay", "ordinary lay" and "langs lay". Using the single drum unbalanced hoisting system as an example, discuss how the hoist drum is designed with respect to the clockwise/counter clockwise "lay" where such wire ropes are used. (2 marks)

Include a diagram showing the rope sitting on the drum such that you can show the strands of wire with respect to the drum. (3 marks)

Total 15 marks

Question 5 This is one of four multiple choice questions worth 15 marks. Do not answer this question if it is not one of the four questions you have chosen to answer from questions 2 to 7.

5. An underground mine proposes to use the following types of equipment underground,

Diesel powered LHD's and low profile haulage trucks

Electrical powered jumbo's and scrapers

Compressed air jacklegs and stopers

Electrically powered primary crusher, ventilation fans, refrigeration system, pumps and lighting

Surface hoist(s) and ventilation fans

How would you estimate the amount of "services" including power, compressed air, fresh air and water, required to operate such a variety of equipment. (5 marks)

Discuss the types/sizes of equipment (both on surface and underground) you might use to provide "services". (5 marks)

The mine may operate for at least 10 years, so given the rate of change in mining technology, and given that power costs are related to peak power consumption, what redundant amounts of "services" would you include in your design and why. (5 marks)

Total 15 marks

Question 6 This is one of four multiple choice questions worth 15 marks. Do not answer this question if it is not one of the four questions you have chosen to answer from questions 2 to 7.

6. A 500 tonne/hr shaft is 425 m deep. It is equipped with a skip of 12 tonnes (empty plus attachments) which carries a 10 tonne load.

You may assume the drum/rope diameter ratio is 108. Wire ropes are available in 47.6, 50.8, 54.0, and 63.5 mm diameters (nominal 1.875, 2.0, 2.125 and 2.25 inch),.

Assume a locked coil rope with a breaking load (tonnes) of 0.07625 times rope diameter squared in mm. (50xdxd long tons where rope diameter is inches), and length (shaft + headframe) = 450m.

The weight of rope (kg/m) is 0.00577 times rope diameter squared in mm. (2.5xdxd lbs/ft where d is rope diameter in inches).

The shaft winds rock for 10 hours per day and there is another skip on another drum returning as the skip referred to in the question is hoisting. Assume that the returning skip has no influence on the HP required for the hoisting skip.

Use 10 seconds decking (loading plus dumping), and 12 seconds acceleration and 12 seconds deceleration time.

Assume linear acceleration and deceleration.
Assume the electrical driving motor has 8 pairs of poles and is attached to the hoist via a gear box.

6.1 what is the rope diameter
6.2 what is the weight of the rope
6.3 what is the drum diameter
6.4 how many winds/hr and what is the cycle time
6.5 neatly draw the velocity (y) versus time (x) diagram

6.6 find the "steady state" hoisting velocity. For this calculation assume linear acceleration and deceleration, and that the velocity is constant.

6.7 what are the maximum revs/min of the hoist drum.
6.8 what is the average linear acceleration
6.9 what is the average angular acceleration of the drum
6.10 what is the motor speed at "steady state"
6.11 what is the gear box ratio required at "steady state"

6.12 what is the maximum static load on the rope
6.13 what is the estimated horse power required at "steady state" (often described as $HP(M)_3$) where (M) refers to metric
6.14 what is the horse power required to accelerate the maximum static load assuming linear acceleration (often described as $HP(M)_1$)
6.15 what is the estimated maximum horsepower HP(M) required

(1 mark each)

Total 15 marks

Question 7 This is one of four multiple choice questions worth 15 marks. Do not answer this question if it is not one of the four questions you have chosen to answer from questions 2 to 7.

7. This question refers to data from the United States and the units are US Imperial and US dollars as of 1989. Answers are expected in US dollars for 1989 in 7.1 and 7.2, and escalated to 2008 US $ in 7.3 for a pre-feasibility study of a 20,000 short ton per day (st/d) block caving mining operation.

7.1 Table 7.1 refers to the capital and operating costs of a shaft to be sunk to a nominal 2000 foot level. What are the shaft capital and operating costs for 1989 based on the Table 7.1 for the 20,000 short ton/day operation. Comment on each of the component values found and the adequacy of the models in each case. (5 marks)

Table 7.1. Underground mine model depth factors for year 1989		
(Capacity range 100 - 40,000 st/d)		
Category	Capital cost, $	Operating cost, $/st
Labor	$+ 75(D)(X)^{0.399}$	+ 2,010/(X)
Equipment	$+ 350(X) + 65(D)(X)^{0.386}$	+0.325(D)/(X)
Steel	$+ 25(D)(X)^{0.373}$	+ 0.00014(D)
Lumber	Nap	Nap
Fuel	Nap	Nap
Lube	$+ 6(D)(X)^{0.342}$	+ 0.090(D)/(X)
Explosives	$+ 5(D)(X)^{0.389}$	Nap
Tires	Nap	Nap
Construction material	$+ 9(D)(X)^{0.522}$	+ 200/(X)
Electricity	$+ 4(D)(X)^{0.230}$	+ 0.0014(D)
Total	$+ 371(X) + 180(D)(X)^{0.404}$	
D = Depth of shaft to bottom of ore body in feet		
NAp = Not Applicable		
X = Capacity of mine in short tons per day		

7.2 The mine will use the block caving method for the material between 1000 and 2000 feet and hoist the rock from the nominal 2000 foot deep shaft described in part 7.1 above. What are the mining (excluding shaft related costs found in 7.1) capital and operating costs for 1989 based on the Table 7.2 for the 20,000 st/d operation. Comment on each of the values found and the adequacy of the models in each case. (5 marks)

Table 7.2 Block caving mine model, base case for year 1989		
(Capacity range 4,000 - 40,000 st/d)		
Category	Capital cost, $	Operating cost, $/st
Labor	$27{,}900(X)^{0.646}$	$60.0(X)^{-0.305}$
Equipment	$25{,}600(X)^{0.812}$	$4.40(X)^{-0.230}$
Steel	$4{,}410(X)^{0.685}$	$0.217(X)^{0.0}$
Lumber	$149(X)^{0.902}$	$0.310(X)^{0.0}$
Fuel	$10.6(X)^{0.897}$	$0.894(X)^{-0.239}$
Lube	$4.54(X)^{0.897}$	$0.545(X)^{-0.253}$
Explosives	$1{,}040(X)^{0.737}$	$0.183(X)^{-0.0}$
Tires	$1.87(X)^{0.946}$	$0.412(X)^{-0.151}$
Construction material	$31{,}100(X)^{0.591}$	$2.83(X)^{-0.182}$
Electricity	$50.4(X)^{0.748}$	$1.36(X)^{-0.060}$
Total	$64{,}800(X)^{0.759}$	$48.4(X)^{-0.217}$
X = Capacity of mine in short tons per day		

7.3 The cost escalation factors for the period 1989 to 2008 are given in Table 7.3. What are the total shaft and total mining capital and operating costs for 2008 for the 2000 ft deep project at the 20,000 st/d capacity. Comment on the adequacy of the cost estimates for 2008. (5 marks)

	7.3 Underground Mine	
Year	Capital Cost Index	Operating Cost Index
1989	95.5	91.1
1990	96.3	93.0
1991	97.1	94.9
1992	97.9	96.8
1993	98.3	98.2
1994	100	100
1995	102.8	102.6
1996	105.1	106.1
1997	106.1	105.9
1998	108.2	109.3
1999	109.3	108.5
2000	111.2	110.4
2001	112.2	115.1
2002	114	115.3
2003	113.8	116.8
2004	115.7	122.8
2005	118.1	126.7
2006	119.6	126.4
2007	123.8	133.9
2008	129.9	141.9

Reference Camm, T.W., SME Transactions, and InfoMine

Total 15 marks.

End of Exam

Marking Scheme

1. 40 marks total (**compulsory** question, parts 1.1 to 1.7 must be attempted)

Only **four** of the remaining "your choice" questions 2 to 7 are to be answered.

2. 15 marks total (1 or 2 marks per section depending on difficulty)
3. 15 marks total (5 marks for neat sketch, then 5 marks per section)
4. 15 marks total (3, 4, 4, 2 and 2 marks per section)
5. 15 marks total (5 marks per section)
6. 15 marks total (1 mark for each stage of the calculations)
7. 15 marks total (5 marks per section)