National Exams

09-MMP-A2, Underground Mining Methods and 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. One only reference sheet, 8.5 x 11 inch, hand written both sides is allowed in the exam. This is a Closed book exam, therefore only the approved Sharp or Casio type calculators are permitted.

3. Compulsory Question 1 and FOUR (4) other questions constitute a complete exam paper.

   Only question 1 and the first four optional questions as they appear in the answer book will be marked. You must select four questions from the "optional" Questions 2 to 7. Be sure you understand that two of Questions 2 to 7 must not be answered.

4. Compulsory Question 1 is worth 40 marks. Each optional question is of equal value (15 marks). Four optional questions plus Question 1 constitute a complete exam paper.

5. Many questions require an answer in essay format. Clarity and organization of the answer are important. Use neat sketches and drawings to illustrate your answers whenever possible.

Question 1.1 (6 marks)

With regard to mine ventilation circuits;

1.1.1) What is the relationship between total, static, velocity and potential head between two points in a simple ventilation system.

1.1.2) Describe the components of the Atkinson equation for friction loss.

1.1.3) How are Kirchhoff's first and second laws applied to more complex series and parallel airways

(2 marks each)

Question 1.2 (6 marks)

A continuous high-grade hard-rock vein is located 400 metres below surface. Its characteristics are the following:

Dip:	70 degrees
Horizontal width:	4 metres
Quality of footwall and hanging wall:	fair

Which mining methods could be considered for the extraction of this orebody and why?

Question 1.3 (6 marks)

Briefly describe and differentiate between the following underground mining methods;

1.3.1) Sub-level stoping (1 mark)

1.3.2) Longitudinal longhole retreat (1 mark)

1.3.3) True Avoca mining (2 marks)

1.3.4) Eureka mining method. (2 marks)

Sketches are required as part of your answer.

Question 1.4 (6 marks)

In the context of mine cost estimating, what do you understand by the following terms, and describe the function and development of these terms.

1.4.1 The Marshall and Swift Mine/Mill cost index (M&S M/M) (2 marks)

1.4.2 The "six tenths rule" (the rule may also be referenced as the 'two thirds' or 0.7 rule depending on the practitioner) (2 marks)

1.4.3 List the cost centers applicable to mine cost estimation on which such as the Marshall and Swift (and many other) indices for mining are based.

(2 marks)

Question 1.5 (6 marks)

Name three types of mine hoisting ropes in general use in underground mines. Describe each type, and in what context and hoisting method each would be preferred.

Question 1.6 (5 marks)

1.6.1) When designing a head frame, what is the critical design parameter.

(3 marks)

1.6.2) Briefly describe the various types of head frames in common use, and why a particular design might be chosen. (2 marks)

Question 1.7 (5 marks)

With respect to conventional overhand cut-and-fill;

"Uppers" drilling using mechanised or semi-mechanised drill rigs must have sufficient room to work and also a working height which can be easily reached by the drill carriage. There is an optimal working height for scaling and roof bolting from the top of the muck-pile after the roof has been blasted down in preparation for mucking out. Once mucking has been completed, access man-ways and percolation drain ways must be built of timber, steel mesh and fabric (often burlap) to the required height. Circular steel mill hole segments must be installed on top of existing ore-passes and welded in preparation for filling.

Question 1.7 continued

Discuss the importance of the swell factor of broken rock and the elevation of the backfill to the efficiency of the mining method. A sketch section is required.

(5 marks)

Question 2 (15 marks) **Only answer this question if it is one of four chosen from questions 2 to 7**

The top of an orebody is located 500 metres below surface and ends at 900 meters below surface. The orebody consists of a vein dipping 60 degrees with a strike length of one kilometre. Access from surface will be through a shaft. The main levels will be located every 100 meters, with 2 sublevels between each. The ore is to be extracted at a rate of 3000 tonnes per day on three shifts per day for 6 years.

2.1.1) Design the general lines of an ore handling system, proposing the location of the shaft, raises, transport drifts, crosscuts to the raises, transfer raises, and mobile equipment used. (5 marks)

2.1.2) Design the general lines of essential mine services, proposing the location of the clean water, electrical, compressed air, waste water and communications infrastructure. (5 marks)

Question 2 continued

2.1.3) Include the factors you took in consideration in taking your decision. Provide hand-drawn sketches of your layouts to complement your description.

(5 marks)

Question 3 (15 marks) **Only answer this question if it is one of four chosen from questions 2 to 7**

Longitudinal retreat is commonly used to mine the veins with widths less than 4 metres, especially in North-Western Quebec and North-Eastern Ontario. Answer the following questions including sketches where applicable.

3.1) Describe the characteristics of the veins and wall rocks for the application of Avoca. (4 marks)

3.2) Discuss 3.1 in terms of dip, lateral and vertical extent, continuity of the vein and grades, quality of the rock mass of the hanging and footwall and of the ore.

(4 marks)

3.3) Draw and discuss the general sequence of development and production in 3.1.

(4 marks)

3.4) Describe fluctuations in production from individual Avoca stopes and discuss methods of ensuring continuous mill feed. (3 marks)

Question 4 (15 marks) **Only answer this question if it is one of four chosen from questions 2 to 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 4.1 and 4.2, and escalated to 2013 US $ in 4.3 for a pre-feasibility study of a 20,000 short ton per day (st/d) block caving mining operation.

4.1 Table 4.1 below refers to the capital and operating costs of a shaft to be sunk to a nominal 2000 foot level.

What are the ***component*** shaft capital and operating costs for 1989 based on the Table 4.1 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)

4.2 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 4.1 above.

What are the mining (excluding shaft related costs found in (4.1)) capital and operating costs for 2012 based on the Table 4.2 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)

Question 4 continued

Table 4.1. 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	$+ 371(X) + 180(D)(X)^{0.404}$	$2{,}343/(X) + 0.44(D)/(X) + 0.00163(D)$
D = Depth of shaft to bottom of ore body in feet		
NAp = Not Applicable		
X = Capacity of mine in short tons per day		

Table 4.2 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		

4.3 The cost escalation factors for the period 1989 to 2008 are given in Table 4.3. What are the total shaft and total mining capital and operating costs for 2012 for the 2000 ft deep project at the 20,000 st/d capacity. Comment on the adequacy of the cost estimates for 2008, 2009 and 2012. (5 marks)

4.3 Underground Mine					
Year	**Capital Cost Index**	**Operating Cost Index**	**Year**	**Capital Cost Index**	**Operating Cost Index**
1989	95.5	91.1	2001	113.2	112.1
1990	96.3	93	2002	116	114.3
1991	97.1	94.9	2003	118.8	121.8
1992	97.9	96.8	2004	121.7	136.8
1993	98.3	98.2	2005	135.1	146.7
1994	100	100	2006	176.6	167.4
1995	102.8	102.6	2007	210.8	185.9
1996	105.1	106.1	2008	245.9	199.9
1997	106.1	105.9	2009	228	187.2
1998	108.2	109.3	2010	227.5	191.4
1999	109.3	108.5	2011	240	201.5
2000	111.2	110.4	2012	256.8	210.8

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

Camm, Thomas W., (1991), Simplified cost models for prefeasibility mineral evaluations:
In U.S. Bureau of Mines Information Circular 9298 (pp.35).
Mining Engineering (SME), June 1994 (pp.4)
SME Pre-print 93-85 (pp.9)

Reference IHS Indexes
In http://www.ihs.com/info/cera/ihsindexes/index.aspx

Question 5 (15 marks) **Only answer this question if it is one of four chosen from questions 2 to 7**

5.1) You are in the pre-feasibility stage of designing a head-frame;

5.1.1) What do you understand by the term "fleet angle". (1 mark)

5.1.2) What criteria are used to determine the sheave wheel diameter. (1 mark)

5.1.3) What is the basis for determining the rope diameter. (1 mark)

5.2) In regard to hoist ropes;

5.2.1) Discuss the testing of hoist ropes. (1 mark)

5.2.2) Discuss the safety of hoist ropes. (1 mark)

5.2.3) With respect to locked coil hoisting ropes, what do you understand by the terms "Z", "V" and Omega strand. (2 marks)

5.2.4) Why are lubricants used internally in locked coil ropes when manufactured, and what are these lubricants composed of. (2 marks)

5.3) A deep mine is accessed through a circular five-compartment vertical shaft. The skipping system is composed of one hoist controlling two skips, and is designed to hoist muck from two distinct production levels. A cage with counterweight is used to move the workers and materials to many levels. Answer the following questions.

Question 5 continued

5.3.1) Which hoisting systems could be used for the cage and counterweight? Briefly describe them. Which system would you choose and why? (3 marks)

5.3.2) What hoisting system is most likely to be used for skipping? Describe the system and be very specific about the design. Justify why you chose this hoist.

(3 marks)

Question 6 (15 marks) **Only answer this question if it is one of four chosen from questions 2 to 7**

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 (nominal) 47.6, 50.8, 54.0, and 63.5 mm diameters (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.

Question 6 continued

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

Question 6 continued

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)

Question 7 (15 marks) **Only answer this question if it is one of four chosen from questions 2 to 7**

7.1) The ‘Cut and Fill’ stoping method can be broadly subdivided as ‘overhand’ versus ‘underhand’, and as ‘open’ versus ‘tight’. What do you understand by these statements.

(2 marks)

Question 7 continued

7.2) What are the two major mine products used for fill. (2 marks)

7.3) Comment on the use of cement and other binders as fill components. Using neat sketches, show, with two examples, where and why high early strength fill is necessary for the success of the cut-and-fill method. (2 marks)

7.4) Discuss the cycle of operations in mechanised overhand cut and fill stoping. (2 marks)

7.5) Compare 'captive' cut and fill where the equipment can be shared between a few stopes (2 to 4), with the use of ramps joining all stopes in a particular mining sector. (2 marks)

7.6) Why has the use of 'captive' cut and fill decreased substantially in favour of methods with ramp access. (2 marks)

7.7) There are more and less expensive mining methods than cut-and-fill. Discuss the role of rock strength in;

7.7.1) Choosing cut-and-fill mining (1 mark)

7.7.2) Choosing a variation of standard cut and fill mining (2 marks)

End of Exam