National Exams May 2015

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 THREE (3) other questions constitute a complete exam paper.
   Only question 1 and the first three optional questions as they appear in the answer book will be marked. You must select four questions from the "optional" Questions 2 to 6.

4. Compulsory Question 1 is worth 40 marks. Each optional question is of equal value (20 marks). Three 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 large neat sketches and drawings to illustrate your answers when possible.

6. Make sure your diagrams etc. are at least half a page and clearly legible. Thumbnail sketches are not acceptable.

Compulsory Question 1 (40 marks)

You must answer **all** *of this question, parts 1.1 to 1.6 inclusive*

Question 1.1 (6 marks) ***answer compulsory***

Mine Support

Describe and compare, with examples of usage, the following support systems;

1.1.1 Common anchor threaded roof bolt.

1.1.2 Split set bolt.

1.1.3 Cable bolts. (2 marks each, 6 marks)

Question 1.2 (6 marks) ***answer compulsory***

1.2 Mining Methods

1.2.1 Room and Pillar Mining

Discuss the geology, geometry and rock strength issues applicable to room and pillar mining. (3 marks)

1.2.2 Vertical Crater Retreat (VCR)

Discuss the geology, geometry and rock strength issues applicable to the vertical crater retreat mining method. (3 marks)

Question 1.3 (7 marks) *answer compulsory*

1.3 General mine ventilation question. (7 marks)

Describe methods for measuring air velocity in underground mines when the air velocity is;

1.3.1 Slow moving; e.g. a depleted and closed off area of the mine.
1.3.2 Moderate velocity; e.g. supplying air to a working stope.

1.3.3 High velocity; e.g. at a large (say 2m diam.) fan underground with closed ventilation doors.

In hot, deep, underground mines;

1.3.4.1 How is the water content of mine air measured, and why is the water content so important.

1.3.4.2 In order to improve employee productivity in 1.3.4.1, briefly describe any infrastructure typically used.

Question 1.4 (7 marks) *_answer compulsory*

1.4 General mine hoist question.

1.4.1 When choosing a type of hoisting rope, what are the two most important rope properties.

1.4.2 What is the most important factor in selecting the size of a hoisting rope.

1.4.3 Why is the ratio “hoist drum diameter to rope diameter” important, and what are typical values.

1.4.4 In shaft hoisting what do you understand by the term ‘overwind’.

1.4.5 Three methods can be used to prevent overwind. What are they and briefly describe how they achieve their objective.

(1.4.4, 1 mark; remainder 1.5 marks each. 7 marks total)

Question 1.5 (6 marks) *answer compulsory*

1.5 Costs

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

1.5.1 The Marshall and Swift Mine/Mill cost index (M&S M/M)

1.5.2 The "six tenths rule" (the rule may also be referenced as the 2/3 or 0.7 rule depending on the practitioner)

1.5.3 The "O'Hara Method" from the CIM Bulletin, February 1980.

(2 marks each)

Question 1.6 (8 marks) *answer compulsory*

1.6 Haulage of rock to surface

There are many practical methods of moving rock (ore and waste) from underground workings.

With the aid of neat sketches (½ page minimum), very describe four (4) of the many methods which you might consider, including typical "tonnes per day" capacity ranges.

(2 marks per method, 4 methods)

This is one of three optional questions worth 20 marks each. Do not answer this question if it is not one of the three questions you have chosen to answer from questions 2 to 6.

Question 2

2.1 Draw a neat sketch diagram and use it to describe the development and production cycle of operations of "conventional" room and pillar mining in hard rock.

2.2 Where the "ore" is soft, continuous mining machinery can be applied. Compare and contrast "conventional" hard rock and "continuous" soft ore room and pillar operations with respect to "services", ventilation and roof support.

2.3 In the mining of thick seams (greater than 6 m high), a technique sometimes referred to as "stope-and-pillar" mining can be used. Describe how this method differs from the methods in 2.0 and 2.1 above.

2.4 In the late 1960's, Gaspe Copper utilized horizontal and vertical drill jumbo's, small cable shovels (2-3 m3 bucket) and 30 tonne trucks in their underground operations. What advantages did the choice of such equipment provide to Gaspe, and what disadvantages.

(5 marks each, 2.1 through 2.4)

Question 3

This is one of three optional questions worth 20 marks each. Do not answer this question if it is not one of the three questions you have chosen to answer from questions 2 to 6.

Diagrams and Sketches must be at least ½ page and clear to the examiner.

3.1 Draw a neat sketch diagram and use it to describe the development and production cycle of operations utilizing the vertical crater retreat (VCR) method of mining. Clearly show examples of the following in your sketch, "raise", "slot" and "stope"

3.2 In VCR, the term "crater" is used with reference to the work of C.W. Livingston. Describe how the drilling, explosive loading and blasting cycle in practical VCR mining is amended to approximate the "spherical charge" typical of crater blasting. Discuss the types of drill used, how explosives are loaded, how the blast pattern is initiated, and how the blast pattern is delayed to avoid "frozen" rock.

3.3 Describe at least three ore loading machines used in VCR and discuss how appropriate ventilation can be provided to these machines. What advantages does the choice of such equipment provide to your choices, and what disadvantages.

3.4 With the aid of a further sketch, show how low cement ratio tailings fill can be used to improve ore recovery and reduce dilution in VCR mining.

(5 marks each, 3.1 through 3.4)

Question 4

This is one of three optional questions worth 20 marks each. Do not answer this question if it is not one of the three questions you have chosen to answer from questions 2 to 6.

What are Kirchhof's first and second laws, and what is Atkinson's equation. How are these used in the design of mine ventilation systems.

Four airways have been designed in parallel with a total of 47.19 m3/s (100,000 cfm) of air flowing through them.

The resistances of the airways are as follows;

Airway Number	Resistance R $N.s^2/m^8$	(imperial R x 10^{10}) ($in.min^2/ft^6$)
1	2.627	(23.50)
2	0.151	(1.35)
3	0.349	(3.12)
4	0.397	(3.55)

Calculate

4.1	Equivalent resistance R_{eq}
4.2	Head loss of the parallel airways H_l
4.3	Quantity of air flowing in each airway Q_1 to Q_4.
4.4	The sum of airflows Q (sum Q_1 to Q_4)

(5 marks each, 4.1 through 4.4)

Question 5

This is one of three optional questions worth 20 marks each. Do not answer this question if it is not one of the three questions you have chosen to answer from questions 2 to 6.

This question refers to data from the United States (Camm, T.W. (USBM),1989) and the units are US Imperial and US dollars as of 1989. Answers are expected in US dollars for 1989 in 5.1 and 5.2, and escalated to 2008 US $ in 5.3 for a pre-feasibility study of a 20,000 short ton per day (st/d) block caving mining operation.

5.1 Table 5.1 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 5.1 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. (6 marks)

Table 5.1. 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		

5.2 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 5.1 above. What are the mining (excluding shaft related costs found in 5.1) capital and operating costs for 1989 based on the Table 5.2 for the 20,000 st/d operation. Comment on each of the values found and the adequacy of the models in each case. (7 marks)

Question 5 continued

Table 5.2 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		

5.3 The cost escalation factors for the period 1989 to 2008 are given in Table 5.3. 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. (7 marks)

	5.3 Underground Mine	
Year	**Capital Cost Index**	**Operating Cost Index**
1989	95.5	91.1

Question 5 continued

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

Question 5 continued

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

Question 6

This is one of three optional questions worth 20 marks each. Do not answer this question if it is not one of the three questions you have chosen to answer from questions 2 to 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's. (50xdxd long tons where rope diameter d is in inches) , and length (shaft + head-frame) = 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. (1.5 marks each unless noted)

6.01 what is the rope diameter (1 mark)

6.02 what is the weight of the rope (1 mark)

6.03 what is the drum diameter

6.04 how many winds/hr and what is the cycle time

6.05 neatly draw the velocity (y) versus time (x) diagram (neatly on at least ½ page) (1 mark)

Question 6 continued

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

6.07 what are the maximum revs/min of the hoist drum.

6.08 what is the average linear acceleration

6.09 what is the average angular acceleration of the drum

6.10 what is the motor speed at "steady state" (1 mark)

6.11 what is the gear box ratio required at "steady state"

6.12 what is the maximum static load on the rope (1 mark)

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

(6.01, 6.02, 6.05, 6.10, 6.12, 1 mark each, remainder 1.5 marks each)

Total 20 marks

End of Exam