National Exams December 2019

18-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 three questions from the "optional" Questions 2 to 6. Be sure you understand that two of Questions 2 to 6 must NOT be answered.

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 sketches and drawings to illustrate your answers whenever possible.

   Note that "large neat sketches" are required for all answers where appropriate. "Thumbnails", lack of clarity, and messy, ill thought out drawings will receive 0 (zero) marks. This applies to all your answers throughout your answer booklet.

Question 1 (40 marks) *You must answer all of this question, parts 1.1 to 1.5 inclusive*

Note that, in general, at the start of each question in the exam, a brief example section of the syllabus being examined is given in ***bold italics***

Question 1.1 (8 marks) *answer compulsory*

A general question on ***haulage systems*** of rock to surface in underground mines.

There are many practical methods of moving rock (ore and waste) from underground workings to surface or to sub-surface infrastructures.

1.1.1 With the aid of large neat sketches, very briefly describe at least 4 methods which you might consider for the task,

1.1.2 What are typical "tonnes per day" capacity ranges for each of the 4 methods, and with the aid of large neat sketches, show and describe in each of the cases a typical application.
(4 marks for each subsection 1.1.1 and 2)

Note that "large neat sketches" are required for all answers where appropriate. "Thumbnails", lack of clarity, and messy, ill thought out drawings will receive 0 (zero) marks. This applies to all your answers throughout your answer booklet.

Question 1.2 (8 marks) *answer compulsory*

A general mine ***hoists*** question

1 mark each sub section unless otherwise noted.

1.2.1 When choosing a type of hoisting rope, what are the two most important rope properties.
(2 marks)

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

1.2.3 Why is the ratio "hoist drum diameter to rope diameter" important, and what are typical values.

1.2.4 In shaft hoisting what do you understand by the term "overwind".

1.2.5 Three methods can be used to prevent overwind. What are they and briefly describe how they achieve their objective. (3 marks total)

(1 mark each except 1.2.1 (2 marks) and 1.2.5 (3 marks), total 8 marks)

Question 1.3 (8 marks) ***answer compulsory***

A general question on ***Requirements for development*** involving rock bolting and ***support***.

1.3.1 Describe the mechanism of how rock bolts work in ensuring rock falls will be minimized.

Under what geological structures will roof bolts have no effect in securing the roof.
(4 marks total)

1.3.2 Compare, with (a) examples of design/usage/application, and (b) the support mechanism, the following support systems;

1.3.2.1 Common anchor/head threaded roof bolt.
1.3.2.2 Split set bolt.
1.3.2.3 Resin rock bolts
1.3.2.4 Cable bolts.

(1 mark each, total 4 marks)

Question 1.4 (8 marks) ***answer compulsory***

A general mine ***ventilation*** question.

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

1.4.1 Minimal, slow moving; e.g. a depleted and closed off area of the mine.

1.4.2 Moderate velocity; e.g. supplying air to a working stope.

1.4.3 High velocity; e.g. at a large (say 2m diam.) fan underground with closed adjacent ventilation doors supplying air to many workings.
(1 mark each, except 1.4.1 with 2 marks)

1.4.4 In hot, deep, underground mines;

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

1.4.4.2 In order to improve employee productivity, what infrastructure might typically be applied, and how.
(2 marks each)

Question 1.5 (8 marks) *answer compulsory*

A general question on ***Capital and operating cost estimation*** applications in the mining industry.

1.5.1 What do you understand by the "six tenths rule" (the rule may also be referenced as the 'two thirds' or 0.7 rule depending on the practitioner), and where and how is it applied in underground mine costing. (2 marks)

1.5.2 What do you understand by the Marshall and Swift Mine/Mill cost index (M&S M/M). List other example indices. (2 marks)

1.5.3 List the cost centers on which the Marshall and Swift (and many other) indices are based. Provide examples of the importance of the centers on costs and mine viability studies. (3 marks)

1.5.4 You have been asked by your supervisor to provide some "quick fix" capital cost estimates for the underground section of a mine. Who would you communicate with to provide a quick estimate (+/- 25%) within a day. (1 mark)

You must now answer 3 (three) of the following 5 (five) Optional Questions, Questions 2 to 6.

Question 2 (20 marks) **One of Five Optional Questions, *Select Three***

Syllabus, ***Capital and operating cost estimation associated with underground mining activities.***

2.1.1 What do you understand by cost estimation methods. (1 mark)

2.1.2 What is Hugh Taylors rule and how is it used in overall cost estimation in underground mines. (2 marks)

Examples of cost estimation include the "O'Hara Capital Cost Estimation Method" as published in the Canadian Institute of Mining Bulletin, February,1980, further described by Mular and Poulin in "CapCost, CIM Special Volume 17, 1998" and elsewhere in SME, USBM and other publications.

2.2 Working today as a capital cost estimator, how would you convert 1980 and 1998 costs to present day (2019) estimates. _(2 marks)

2.3 For the purposes of this exam question, T is the tonnes/day hoisted (ore only T = 1500 metric tons/day) and W the stope width, W = 10 m.

Question 2 continued

The following are formulae for estimating the fixed capital costs of an underground mine. The formulae used are based in Mular and Poulins work and USBM studies. The use of "C" for the cost of various items indicated by a subscript such as $_5$ (five) where C_5 is the cost of underground mining equipment, follow the CapCost and USBM conventions.

If you make an obvious, substantial and extremely large error in an estimated value, choose a more logical answer in subsequent calculations and ***be sure to indicate this in your exam booklet***.

2.3.1 Find the total cost of a mine compressor plant by first estimating 'Q' the m3/sec required; (powers 0.16, 0.8 and 0.7)

Compressed air required in m³/sec $Q = 0.0957 \times T^{0.16}$ (2 marks)

Cost of compressor equipment $C_{11} = \$\ 369938 \times Q^{0.8}$ _(1 mark)

Cost of compressor installation $C_{12} = \$\ 81382 \times Q^{0.7}$ _(1 mark)

Total compressor plant cost $C_1 = C_{11} + C_{12}$ (1 mark)

Comment on the values of Q which might be expected in a broad selection of underground mines, and how well the total cost C_1 estimates the cost of compressor plants. (2 marks)

2.3.2 The costs of underground mining equipment and an underground maintenance facility are given by the following formulae. Calculate C_2, C_5 and C_6 using the formulae provided.

2.3.2.1 The cost of mine development C_2 is given by $37033 \times T \times W^{-0.8}$ where T is the metric tons/day hoisted (ore only T = 1500 metric tons/day) and W the stope width, (W = 10 m).

Find C_2. (2 marks)

2.3.2.2 The cost of underground equipment and an underground maintenance facility are as follows. According to the formulae presented below, what are these costs.

C_5 Cost of Underground Mining Equipment
$C_5 = 27963 \times W^{-0.3} \times T^{0.8}$ (powers -0.3 & 0.8)

C_6 Cost of Underground Maintenance Facility
$C_6 = 31915 \times T^{0.5}$ (power 0.5)

(total 2 marks)

Question 2 continued

Electrical Power, Water, General Plant Services, Access, Town-site and Housing *C_3 and C_4* are dependent on location, the milling complex, and fly in-out, town-site or established nearby towns.

Also dependent on location, etc., are the costs of surface plant services C_7, feasibility and design C_8, supervision and camp C_9 and administration and accounting etc. C_{10}.

These values are consequently estimated during milling/processing infrastructure cost estimations and are to be ignored when estimating underground infrastructure costs for the purposes of this exam. ***No calculation or estimate for C_3 and C_4 and C_7 to C_{10} are required.***

2.3.3 What is the total fixed cost {not including milling/processing and items C_3, C_4 and C_7 to C_{10}) (1 mark)

2.3.4 Comment on the reliability and applicability of this methodology for finding fixed costs of an underground mine. (3 marks)

Question 3 (20 marks) **One of Five Optional Questions, *Select Three***

Syllabus, ***Design of ventilation facilities***

In describing mine ventilation systems, 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. (6 marks)

Four airways have been designed in parallel with a total of 47.19 m^3/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

3.1 Equivalent resistance R_{eq}
3.2 Head loss of the parallel airways Hl
3.3 Quantity of air flowing in each airway Q_1 to Q_4.
3.4 The sum of airflows Q (the sum Q_1 to Q_4)

(4 marks each except 3.4 which carries 2 marks)

Question 4 (20 marks) **One of Five Optional Questions, *Select Three***

Syllabus, ***"room and pillar" and "vertical crater retreat" mining methods.***

4.1 Discuss and compare the geology, geometry and rock strength issues applicable to room and pillar mining and vertical crater retreat (VCR) mining.

(1 mark)

4.2 Draw neat sketch diagrams and use these to describe and compare the (a) development and (b) the production cycle of operations of "conventional" room and pillar versus vertical crater retreat (VCR). in hard rock. Clearly show examples of any drifts, cross-cuts, raises, slots and exploratory openings in your sketches. Indicate how these lead to the production stopes in your answers to sections 4.2.1 to 4.2.8 below.

The answers must include both sketches and descriptions as applicable. Note that "large neat sketches" are required for all answers where appropriate. "Thumbnails", lack of clarity, and messy, ill thought out drawings will receive 0 (zero) marks.

4.2.1 Initial cross-cuts and drifts from the shaft

4.2.2 Initial stope access.

4.2.3 Starter stope

4.2.4 Stope(s) at the peak of production

4.2.5 Support for stability and how this might be designed, including ore losses both permanent and temporary.

4.2.6 The sequence of mining a set of stopes.

4.2.7 Pillar reclamation and mining.

4.2.8 "Permanent" stabilization of the mined out area

(1 mark each, total 8 marks)

4.3 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 in the following 4.3.1 and 2.

(1 mark each, total 2 marks)

4.2.1 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 conventional room-and-pillar methods. Use deposits utilizing huge stopes and mining equipment used in surface mining at the time (e.g. Gaspe, QC, underground 1960's) to explain your answer.

(1.5 marks)

Question 4 continued

4.2.2 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, avoiding “frozen” rock. (1.5 marks)

4.3 Describe a modern ore loading method/machine used in 4.3.1 VCR and in 4.3.2 room-and-pillar mining. Discuss how appropriate services (ventilation, power, compressed air and water) can be provided to these methods/machines. What advantages do the ore loading methods/machines provide, and what disadvantages. (2 marks)

4.4 Given that hoisting and processing costs, grades and recoveries are essentially the same, compare the following for room-and-pillar and VCR mining methods,

4.4.1 productivity (tons per employee shift)

4.4.2 mining equipment capital costs

4.4.3 rate of mining (tons per month)

4.4.4 support and auxiliary costs

(1 mark each total 4 marks)

Question 5 (20 marks) **One of Five Optional Questions, *Select Three***

Syllabus, ***Requirements for development and services including: shafts and hoists***

Using a simple friction hoist with the hoist sheave at the top of a tall vertical building of reinforced concrete centered over the shaft as an example;

5.1 What do you understand by the term “hoist duty cycle” and what hoist selection parameters are defined by such a duty cycle. An orderly flow and very brief explanation of the parameters is expected as an answer. (5 marks)

5.2 What do you understand by the term “hoist motor power requirements" and how are the differing power requirements for DC and AC systems obtained. Again, an orderly flow and very brief explanation of the parameters is expected as an answer. (5 marks)

A simple head-frame mounted, balanced friction-sheave hoist has the following operating conditions.

Shift time	7.2 hours
Shifts/day	3
Skip capacity	11 metric tons (12.12 short tons)
Cycle time (1 complete trip)	85 sec/skip

Question 5 continued

5.3 What is the daily production (4 marks)

5.4 What is the approximate energy consumption per skip hoisted given;

average power consumed	730 kW	(975 hp)
hoist efficiency	85%	
acceleration time	6.5 sec	
constant velocity time	63.5 sec.	

(6 marks)

Question 6 (20 marks) **One of Five Optional Questions, *<u>Select Three</u>***

Syllabus, ***Underground design including haulage systems. Development and services including shafts, hoists, ramp and multi-level access design.***

A mining company is reviewing two commonly used methods of moving rock from an underground mineral deposit, and has limited its choices to two alternatives, "skip and vertical shaft", and "truck and incline".

6.1 Describe the fundamentals of each system, including a neat sketch for each case. (5 marks)

In making their choice, the company requires two sets of costs in each case, i.e. capital and operating. The deposit geometry and associated material (depth, size of ore-body, rock strength) are also considerations.

6.2 Prepare a "spread sheet" type design report for the company which details the component inputs to (6.2.1) capital and (6.2.2) operating costs for skip/shaft and truck/incline operations. The "spread sheet" must discuss variable deposit size/geometry, rock strength and production capacity such that the company can make informed and accurate decisions regarding typical deposits in its business portfolio.

Break down 6.2.1 and 2 into component parts and estimate approximate costs (10 marks)

6.3 Draw conclusions as to which conditions favor one material handling method or the other (skip/shaft or truck/incline). Under what circumstances could each method be used effectively to advantage over the other. (5 marks)

End of Exam