Closed book exam, a Casio or Sharp approved calculator is permitted plus one aid sheet 81/2 " x 11" written on both sides.

NOTES ON CHOICES OF QUESTIONS, 2/3 and 4/5/6:

In summary you may not answer all three Questions 4, 5 and 6 as your choice of three of five optional questions from Questions 2 to 6. You must include either or both of Questions 2 and 3.

1. Compulsory Question 1 is worth 40 marks. Each optional question 2 to 6 is of equal value (20 marks). Three valid optional questions plus Question 1 constitute a complete exam paper. Your choice of Question 2 and 3 (group 2/3) and of Questions 4, 5 and 6 (group 4/5/6) must follow the special rules which you **must comply with**.

2. You must answer compulsory Question 1. Compulsory Question 1 and THREE (3) other questions **which follow the group rules** for Questions 2/3 and Questions 4/5/6 constitute a complete exam paper.

3. You must only answer 3 questions from Questions 2 to 6, noting that Questions 2 and 3 form a special group 2/3, and Questions 4, 5 and 6 form another special group, 4/5/6. Only the first 3 questions as they appear in the exam booklet will be marked provided they **adhere to the group rules** governing answer groups 2/3 and 4/5/6. The first and subsequent selections which do not follow the rules will not be marked.

4. You **may** answer **both** Questions **2 and 3** as part of your 3 choice questions, or choose **either** Question **2 or 3**.

5. You may answer **one or two** questions in the group **4/5/6**, but **no more than two.**

6. Within the rules 4 and 5 above, you must answer 3 optional questions.

7. Examples of acceptable selections include; Questions 3, 5 and 6 **or** 2, 3 and 4.

8. An example of the **unacceptable** selection is; Questions 4, 5 and 6.

09-MMP-A2 Underground Mining Methods and Design (December 2015)

Question 1 is compulsory, consists of six sections and carries 40 marks.

The remaining optional choice questions are divided into two groups, questions 2 and 3 (group 2/3) and questions 4, 5 and 6 (group 4/5/6).

You may answer **one or both** optional questions from **group 2/3**. **(one or both)**

You may answer **one or two** optional questions from **group 4/5/6**. **(one or two)**

You must choose a maximum of 3 of these optional group questions which carry 20 marks each. Be sure to answer only **three** of the optional questions **2 to 6** and **follow** the **group rules**. The maximum mark will be (40 + 3 X 20) = 100.

If group rules are broken, the **first** and **subsequent questions** to break the rules will **not be marked**. Only the **first three** of the **eligible optional choice** questions **(2 to 6)** will be marked in the order they appear in the answer book

Compulsory Question 1 (40 marks) **you must answer all 6 parts of Question 1**

1.1 dilution & recovery (7 marks)	1.2 power & services (7 marks)	1.3 capital & operating costs (6 marks)
1.4 mine scheduling (7 marks)	1.5 block caving (7 marks)	1.6 rock haulage (6 marks)

Compulsory Question 1 (40 marks)

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

Question 1.1 (7 marks) *answer compulsory*

With reference to underground mines, what do you understand by the terms 'dilution' and 'recovery', and are the values related. Describe mining methods that minimize dilution and maximise recovery.

Question 1.2 (7 marks) *answer compulsory*

Describe the means of providing and moving electrical power to underground mining equipment and services. Describe such services. One such service is dewatering. Describe typical pumps and pumping systems used to dewater mines, including the handling of water and slimes from hydraulic fill.

Question 1.3 (6 marks) *answer compulsory*

Underground mine production equipment must be purchased and maintained. Give examples of capital and operating costs of such equipment that you are familiar with.

Question 1.4 (7 marks) *answer compulsory*

Prior to the commencement of production stoping, development headings must be completed. Describe the timelines of such infrastructure for a typical mine.

When stoping commences, a schedule of production must be produced. What are the essential aspects of such a schedule, and your answer should explore essential items beyond the location and timing of primary stope production.

Question 1 continued ***Compulsory Question***

Question 1.5 (7 marks) ***answer compulsory***

The block caving method has the potential for having mining production costs in line with those of open pits. Discuss the application of block caving in achieving this.

What are the advantages and disadvantages of block caving as a mining method and give examples from operating and completed mining operations

Question 1.6 (6 marks) ***answer compulsory***

The transportation of ore from the production draw point or chute is an essential item in mine planning and development. Describe with examples, the application of scoop-trams, trucks, conveyors and gravity in moving ore to the shaft loading pocket used at many mines.

Question 2 (20 marks) **One of Three Optional Questions to be Selected**

One Group 2/3 Question, one or two of which can be Selected

2.1.2 Discuss large mine-wide ventilation fans, including their performance characteristics. Sketch and describe the means of heating the mine air in a typical northern Canadian operation using such fans. (4 marks)

2.1.1 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. (3 marks)

Question 2 continued **One Group 2/3 Question, one or two of which can be Selected**

2.1.3 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

2.1.3.1 Equivalent resistance R_{eq}
2.1.3.2 Head loss of the parallel airways Hl
2.1.3.3 Quantity of air flowing in each airway Q_1 to Q_4.
2.1.3.4 The sum of airflows Q (the sum Q_1 to Q_4)

(2 marks each, except 2.1.3.4, 1 mark, total 7 marks)

2.2 A mine has a single fan with a static head H_S of 500 Pa (2 in H_2O) and a total head H_1 of 750 Pa (3 in H_2O) at a quantity of 190 m^3/s (400,000 cfm);

2.2.1 Determine the static and total heads at an air quantity of 375 m^3/s (800,000 cfm).

2.2.2 Draw a ***neat*** mine characteristic curves graph (X quantities (m^3/s or cfm)) versus (Y heads (in H_2O or Pa)). The X axis should span 0 to 400 m^3/s (0 to 800,000 cfm) and Y 0 to 3000 Pa (0-12 in).

2.2.3 From your graph at 285 m^3/s (600,000 cfm) what are the H_S and H_1 values.

(2 marks each, total 6 marks)

Question 3 (20 marks) One of Three Optional Questions to be Selected

One Group 2/3 Question, one or two of which can be Selected

3.1 Neat diagrams are expected for question 3 part 1, and may be supplemented with a sentence or paragraph explanation.

3.1.1 Describe the various types of automatic dumping skips.

3.1.2 There are two methods of preventing skips from 'over-winding'. What is over-winding and what are the prevention methods.

3.1.3 What do you understand by a locked coil rope and describe 2 types. How is the rope examined for defects after installation.

3.1.4 In reference to electrical driving motors, what are 'pairs of poles', and what would be the advantages of having 8 pairs of poles on AC and DC motors.

(1 mark each except 3.1.4 carries 2 marks, total 5 marks)

3.2 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 in 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).

Question 3 continued **One Group 2/3 Question, one or two of which can be Selected**

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.

3.2.1 what is the required rope diameter

3.2.2 what is the weight of the rope

3.2.3 what is the drum diameter

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

3.2.5 neatly draw the velocity (y) versus time (x) diagram for the skip

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

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

3.2.8 what is the average linear acceleration

3.2.9 what is the average angular acceleration of the drum

Question 3 continued **One Group 2/3 Question, one or two of which can be Selected**

3.2.10 what is the motor speed at "steady state"

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

3.2.12 what is the maximum static load on the rope

3.2.13 what is the estimated horse power required at "steady state" (often described as $HP(M)_3$) where (M) refers to metric)

3.2.14 what is the horse power required to accelerate the maximum static load assuming linear acceleration (often described as $HP(M)_1$)

3.2.15 what is the estimated maximum horsepower HP(M) required

(1 mark each, total 15 marks)

Question 4 (20 marks) **One of Three Optional Questions to be Selected**

One of the Group 4/5/6 Questions, maximum two of which can be Selected

4.1.1 The 'Cut and Fill' stoping method can be broadly subdivided as 'overhand' versus 'underhand', and as 'open' versus 'tight'. What do you understand by this statement.

(2 marks)

4.1.2 What are the two major products used for fill (>80% +/-), and comment on the use of additives (<5% +/-) as fill components. Using neat sketches, show with two examples where and why high early strength fill is necessary for the success of the overhand fill method. (3 marks)

4.1.3 Discuss the cycle of operations in mechanised cut and fill stoping. (3 marks)

Question 4 continued One of Group 4/5/6 Questions, **maximum two** of which can be Selected

4.1.4 Compare 'captive' cut and fill, where (a) the equipment can be shared between a very few stopes, with (b) the use of ramps in a particular mining sector. Why has the use of 'captive' cut and fill decreased substantially in favour of methods with ramp access.

(2 marks)

4.2 An ore zone in an underground mine is being considered for production. The zone comprises a narrow vein of average width of 1 meter and is very rich. The use of "ramp-in-vein" cut and fill mining is being considered as the mining method. In order to improve the extraction and recovery, resuing will be used to limit ore vein dilution.

4.2.1 In the context of underground mining what is "resuing". Provide suitable sketches and describe how the economics of the ore zone will be improved with the use of this technique. (2 marks)

4.2.2 With the aid of sketches, describe the general mining sequence of ramp-in-vein cut and fill mining. (2 marks)

4.2.3 When using the "ramp-in-vein" cut and fill method coupled with resuing, what types of drilling, loading and haulage equipment would be used in typical stopes and describe how the equipment is positioned with respect to the vein (4 marks)

4.2.4 Again, with neat sketches, describe how cemented fill might be placed in the stope and how the use of fill might be avoided. (2 marks)

Question 5 (20 marks) **One of Three Optional Questions to be Selected**

One of Group 4/5/6 Questions, maximum two of which can be Selected

The longhole stoping method and variations are the primary methods of underground mining in Canada

5.1 Draw a neat sketch diagram and use it to describe the development and production cycle of operations utilizing the longhole stoping method of mining. (1 mark)

Clearly describe and show examples of the following in your sketch,

- Geology, orebody shape, size and orientation
- Host and ore rock properties
- Development size, amount, cost and time taken to start extraction
- Ground support
- Mining sequence and mill feed rate
- Number and skills of mining personnel
- Types and numbers of mechanized equipment
- Cost of mining
- Mine life
- Mining rate
- Dilution and recovery
- Methods and costs of any pillar recovery
- Post mining stabilization

Your answer may be in table format if you feel this makes your answers more understandable.

(1 mark each, total 13 marks)

Question 5 continued One of Group 4/5/6 Questions, **maximum two** of which can be Selected

5.2 "Modifications" to longhole stoping include

5.2.1 Avoca (longitudinal retreat)

5.2.2 Viscaria (Alimak)

5.2.3 VCR (vertical crater retreat)

Compare and contrast modifications 5.2.1, 2 and 3 and draw sketches showing each of these as an aid to your answer. Compare and contrast each of 5.2.1, 2 and 3 with conventional longhole stoping.

(2 marks each, total 6 marks)

Question 6 (20 marks) **One of Three Optional Questions to be Selected**

One of Group 4/5/6 Questions, maximum two of which can be Selected

In the case of only vertical crater retreat, use sketches and/or descriptions to explain the following;

6.1.1 Initial cross-cuts and drifts from the shaft.

6.1.2 Initial stope access.

6.1.3 Starter stope.

6.1.4 Stope at the peak of production.

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

6.1.6 The sequence of mining a set of stopes.

6.1.7 Pillar reclamation and mining.

6.1.8 'Permanent' stabilization of the mined out area.

(1 mark each, total 8 marks)

Question 6 continued One of Group 4/5/6 Questions, **maximum two** of which can be Selected

Special emphasis should be made of the "raise", "slot" and "stope" used in 6.1.2 and 6.1.3 above in your answer. (3 marks)

6.2.1 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.

6.2.2 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 to avoid "frozen" rock.

6.2.3 Describe at least three ore loading methods/machines used in VCR and discuss how appropriate ventilation can be provided to these methods/machines. What advantages do the ore loading methods/machines provide, and what disadvantages.

(3 marks each, total 9 marks)

End of Exam