

National Exams May 2011

09-MMP-A5, Surface 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.
4. Compulsory Question 1 is worth 44 marks. Each optional question is of equal value (14 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 sketches and drawings to illustrate your answers when possible.

Question 1 (44 marks) *You must answer all of this question, parts 1.1 to 1.7 inclusive*

Question 1.1 (6 marks)

answer compulsory

1.1) What do you understand by the terms “utilization” and “availability” with reference to large open pit mining equipment.

A mine loses 2 hours in every 24 hours because of unavoidable shift change, lunch and coffee breaks. It has therefore decided that utilization and availability values should be based on a 22 hour daily maximum.

1.1.a) If a piece of equipment works for 2 periods of 6 hours in a day, what is the availability and utilization.

1.1.b) If a piece of equipment is under repair for 4 hours and idle for the remainder of the day, what is the availability and utilization.

1.1.c) If a piece of equipment works for 20 hours and is under repair for 2 hours, what is the availability and utilization.

(3 marks for 1.1 and 1 mark each for 1.a-1.c)

Question 1.2 (6 marks)

answer compulsory

With regard to the stripping of coal and other products using draglines, describe the following terms using a neat sketch.

- 1.2.a Tub diameter (d)
- 1.2.b Operating Radius (OR)
- 1.2.c Positioning (P)
- 1.2.d Reach Factor (RF)

1.2.e How is the reach factor (RF) affected by the strength and stability of the high-wall when carrying the weight of the working dragline given that the operating radius and tub diameter are fixed.

(1 mark for each of 1.2.a-d and 2 marks for 1.2.e)

Question 1.3 (6 marks)

answer compulsory

1.3.a) Why is “double back up” the preferred loading configuration and draw a neat sketch in plan to show how it has been modified to increase truck/shovel productivity when digging narrow pushbacks. (3 marks)

1.3.b) What is the loader/truck "match factor" and how is it determined? What match factor values are typical for most operating mines. Give an example calculation which shows the size and number of trucks required for optimal truck/shovel operations in small and large open pit mines.

(3 marks)

Question 1.4 (7 marks)

answer compulsory

What do you understand by "Pareto's Curve" when applied to mining costs.

(1 mark)

The operating costs (\$/tonne mined) of an open pit mine can be broken down into the following sub-headings,

- Drill
- Blast
- Load
- Haul
- Other (General & Administration)

What would be representative Canadian/U.S. unit cost values for these sub headings for a conventional open pit moving about 400,000 tonnes/day.

(3 marks)

Using a "Pareto" type analysis, what are the three biggest cost items in each of the above 5 cost centres.

(3 marks)

Question 1.5 (7 marks)

answer compulsory

1.5.a What do you understand by the term "stripping ratio" as applied to mineral deposits which resemble a vertical pipe such as most porphyry copper open pit mines.

(1 mark)

1.5.b These types of open pit mines can be simply operated and their mining scheduled such that the stripping ratio decreases with time. Describe this method with the aid of a neat sketch section showing the schedule of ore and waste mining (say mining periods 1 through 5 with equal ore production/period). What typically happens to the ore grade and stripping ratio in periods 1 to 5. The placement of pit ramps and haul roads can be ignored for this question.

(2 marks)

1.5.c What do you understand by the terms "nested pits" and "push-back" when used in open pit mining.

(1 mark)

1.5.d Draw a neat sketch section using mining periods 1 through 10 (these periods are half those used in (1.5.b) such that the pit starts and ends at the same time) showing how the use and scheduling of practicable push backs can improve the financial results for the mine, especially where capital costs of mill and mine construction etc. are large, and the "time value of money" is significant. Again ramps and roads may be ignored.

(3 marks)

Question 1.6 (6 marks)

answer compulsory

1.6.a Open pit ramp steepness is usually referred to in terms of percent gradient (%). Provide a **dimensioned** neat sketch section of a 10% ramp between two adjacent 15m benches.

Rolling resistance of large off-highway trucks can also be expressed in terms of %. What is the total rolling resistance on the 10% ramp in (1.6.a) if the effective rolling resistance of the truck is 2%, when the truck is travelling;

1.6.b uphill

1.6.c downhill

What are typical approximate % rolling resistance values for the following roadbed materials.

1.6.c Concrete

1.6.d Packed 50 mm gravel at +5 degrees C (summer in Canada)

1.6.e Packed 50mm gravel at -20 degrees C (midwinter in Canada)

1.6.f Loose sand

(six marks total, one per 1.6.a – 1.6.f)

Question 1.7 (6 marks)

answer compulsory

1.7.a What do you understand by the term “water hammer” in the context of open pit mine dewatering.

1.7.b There are two major effects of water hammer in pipes. What are they.

1.7.c What steps can be taken to minimise water hammer

(2 marks per 1.3.a – 1.3.c)

Question 2 (14 marks)

Are you sure you have to answer this question

A dragline is operating in a simple side casting mode.

The overburden material being mined has an angle of repose of 60 degrees, and the depth to the top of the 2 meter thick coal seam is 20 meters. The width of cut is 30 meters and the spoil pile has an angle of repose of 30 degrees and a swell factor of 25 percent. You may assume that the coal will stand vertically.

The dragline has an operating radius of 80 meters, tub diameter of 15 meters, a “positioning factor” of 0.75, a dumping height (stacking height above the bottom of the tub) of 30 meters and a digging depth of 30 meters below tub bottom.

- 2.a) Calculate the important distances and volumes (areas) of the range diagram (4 marks) and draw a **neat** range diagram to scale (3 marks).
- 2.b) Will the dragline be capable of simple side casting to mine the overburden and why. (3 marks)
- 2.c) If the dragline could not complete the removal of the overburden using simple side casting, briefly describe other operating techniques which would allow the coal to be mined. (4 marks)

Question 3 (14 marks)

Are you sure you have to answer this question

In 1980, truck dispatch was developed at the Tyrone mine in New Mexico, and is now an integral part of haulage control and analysis.

- 3.a) Describe a typical installation of that era, and the technological changes that have been made leading to a modern application. (4 marks)
- 3.b) How have mine productivity, maintenance of stripping ratios, grade control and other parameters benefited from this technology. (4 marks)
- 3.c) Discuss the interaction of Best Path, Linear Programming and Dynamic Programming in determining which truck goes where in a large mine with 10 loaders and 60 trucks. (6 marks)

Question 4 (14 marks)

Are you sure you have to answer this question

Four technologies have been applied to improve the efficiency of open pit truck haulage.

- Overhead trolley assist
- Truck Dispatch
- In-pit crushing and conveying
- Direct loading of a short portable conveyor feeding a close-by slurry plant for hydraulic transport

- 4.1) Describe each of the above with the aid of **neat** sketches. Include typical applications, benefits, disadvantages, and effects on mine planning (e.g. location of shovels, push-backs etc.). (5 marks)
- 4.2) Provide some indication of capital and unit operating cost / tonne of these systems. Discuss the implementation of those which have large up-front costs demanding a long pay-back period. (5 marks)
- 4.3) Discuss the future of truck haulage including modifications to truck design, size and fuel. Which practical technologies might replace typical loading and haulage equipment leading to more efficient transfer of material en-route from mine face to mills and processing plants. (4 marks)

Question 5 (14 marks)

Are you sure you have to answer this question

In 1964, Lerchs and Grossmann introduced the first true open pit limit optimizer.

5.1 In the block model of any deposit how is the cash flow of the following calculated

(5.1.a) negative waste blocks (2 marks)

(5.1.b) positive (ore) blocks (2 marks)

Figure 5.2.1 (page 7) shows a simple 2 dimensional section of an open pit being mined with 15 x 15 meter square blocks and a 45 degree wall slope. The cash flow per block is indicated and waste blocks are shown negative. The example is "contrived" to demonstrate the problem.

On the section Figure 5.2.1 (page 7) a pit expansion to the right is indicated as shaded.

5.2.a How many waste and ore blocks are mined and (1 mark)

5.2.b What is the total "cash flow". (1 mark)

5.2.c Is this the "optimal" pit expansion, and if not, what is (8 marks)

Space has been allocated on the figure for calculations and Figure 5.2.a (page 8) is a duplicate in case you need to revise your answer. It is expected that you use the two dimensional Lerchs-Grossmann algorithm to solve problem 5.2.c.

You may use the "floating/moving cone" method if you wish, but you will lose 1/2 your marks in this part of Question 5 (5.2.c) for doing so (maximum 4 marks not 8).

You **must detach the figure(s)** and place them in your exam answer book with your name printed in the space provided on all the figures.

Your Name _____

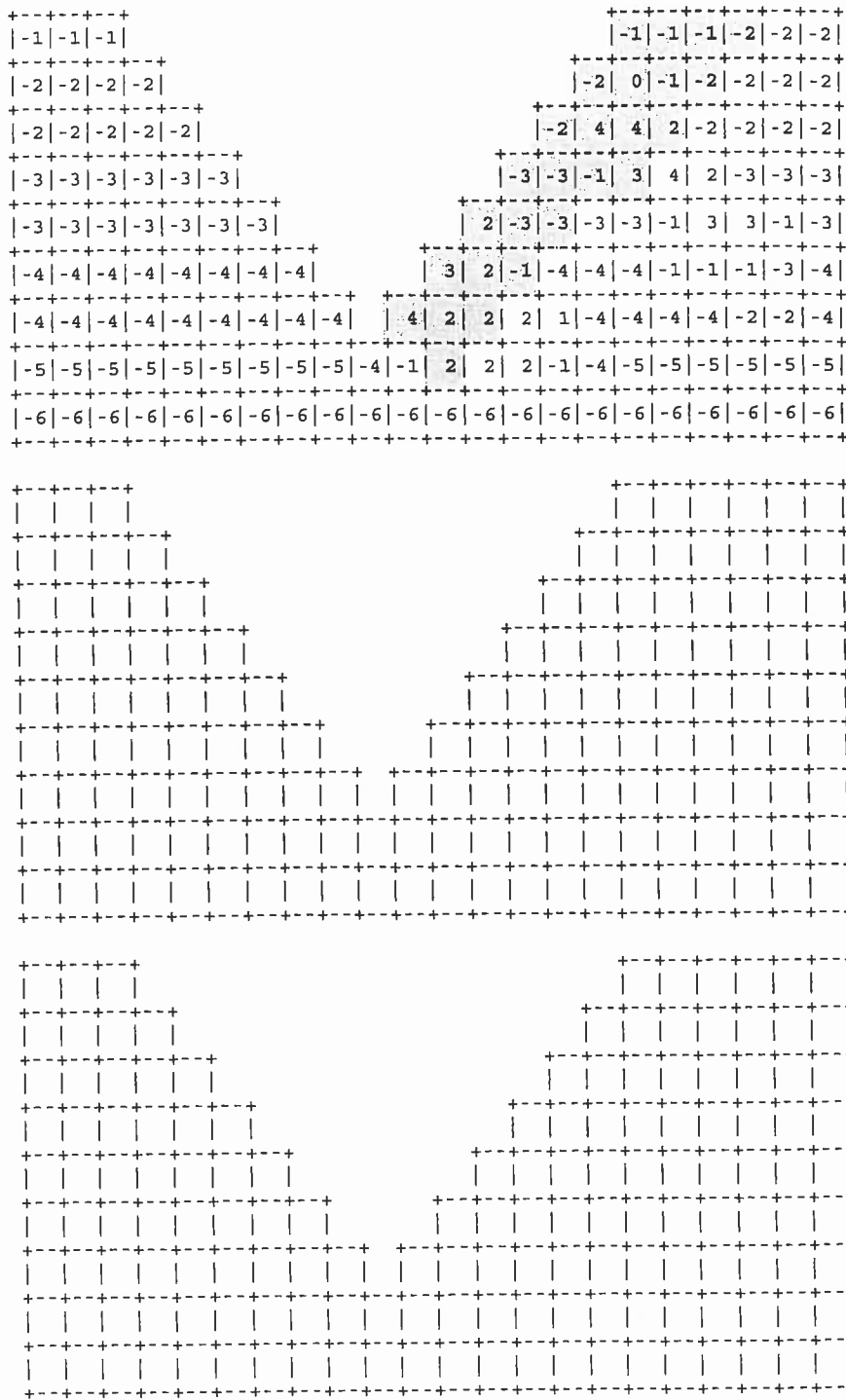


Figure 5.2.1. Top part shows the cash flow for each block on a single two dimensional section for a typical pit expansion. The middle and lower parts of the figure are spaces to calculate the Lerchs-Grossman "optimal" pit expansion. Blocks are 15x15m and wall slope 45 degrees.

Question 6 (14 marks)

Are you sure you have to answer this question

Truck performance can be calculated from manufacturers graphs of velocity (X) in kilometers/hour and force (Y) in kilograms. By using small increments (3 km/hr in this case but usually 0.1 to 1 k/hr), the maximum (ramp gradient plus road resistance) that a stationary truck can start moving up-ramp can be found. The maximum velocity on the ramp and the time taken to achieve that maximum speed can also be found.

The table below shows values for velocity versus force for a typical medium sized diesel electric off-highway truck.

Velocity (km/hr)	Force (1000's kilograms)
0 km/hr	72.6 K kg
5	63.5
10	40.4
15	28.6
20	21.0
25	18.0

The empty truck weighs 123.8 K kg and the load carried is 181.5 K kg, total 305,300 kg.

The truck is sitting idle on a 10% ramp facing uphill and the ramp rolling resistance is 1.5%. It is required to find,

- 6.1 From a stationary position
 - 6.1.a What is the resistive force to moving the truck uphill
 - 6.1.b What is the available propel force
 - 6.1.c What will be the acceleration at the moment of starting to move
 - 6.1.d What will be the time taken to reach 5 km/hr
 - 6.1.e What will be the distance travelled to reach 5 km/hr
 - 6.1.f What will be the average velocity over this stretch of ramp
(6.1.a to f, 1 mark each, total 6 marks)

- 6.2 Re-calculate the values 6.1.a to 6.1.f with the truck starting at 5 km/hr and reaching 10 km/hr.
(2 marks)

The process is repeated at 10, 15, etc km/hr until the truck ceases to accelerate.

Given the limited time in an exam, a simple straight line interpolation between values at the last velocity at which the truck continues to accelerate to the next increment where the truck decelerates must be found.

This will enable estimates of the resistive and propel forces at zero acceleration, the maximum (terminal) velocity, the total distance travelled and total time taken to be reach that "equilibrium" to be found.

- 6.5.a Will the truck start moving up the ramp (1 mark)
- 6.5.b What will be the estimated terminal velocity (1 mark)
- 6.5.c What will be the estimated total time taken to reach terminal velocity (2 marks)
- 6.5.d What will be the estimated total distance travelled to reach terminal velocity (2 marks)

The acceleration due to gravity can be assumed as 9.8 meters / second squared

Some formulae that may or may not be of use

$R = \text{weight} \cdot \text{gradient}$

$F = M \cdot a$

$s = u \cdot t + \frac{1}{2} \cdot a \cdot t^2$

$v = u + a \cdot t$

Question 7 (14 marks)

Are you sure you have to answer this question

Question 7.1 (8 marks)

A mine has chosen to use in-pit pumps in a sinking cut sump to remove water. There are two of the same type of pump available with the characteristic curves shown in Figure 7.1. below. The pumps can be used in high volume (MT) or high head (HT) configuration. The pumps can also be used submersible (with a screen adaptor around the intake) or in series (tandem) with a pipe adaptor at the inlet.

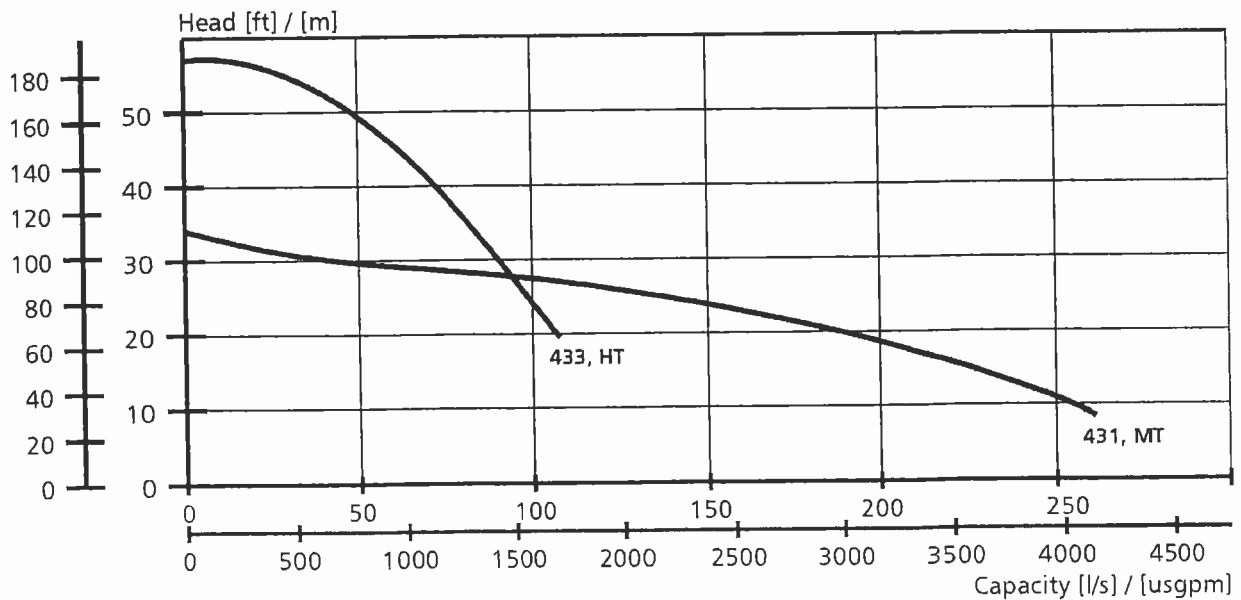


Figure 7.1 Pump characteristics (head and flow rate) for high head (433, HT) and high volume (431, MT) versions.

The mine has to move water from the sinking cut sump at 1650 meters to the pit crest discharge at 1740 meters, a 90 meter lift. The 15 meter benches from 1695 meters and up are accessible for the laying of high density polyethylene pipe, but are not suitable for pump infrastructure such as power lines, generators or for pump etc. maintenance.

The cost of a pipe line buried in the 10% ramp (900+ meters) is regarded as far too expensive and not easily repaired and therefore ignored.

One pump will be placed in the sump (1650m) and run as a submersible unit and the other placed as far as possible up the ramp at the 1695 meter elevation. At this upper pump, a tandem fitting will be coupled directly to the pipeline coming up from the sump. The upper tandem pump must deliver sufficient pressure to discharge water at the pit crest. You may assume that the friction loss in the large diameter polyethylene pipe used is small over a 125 meter length on a 45° pit wall.

- 7.1.a From the graph (Fig. 7.1. page 10) will the high volume pump configuration (431, MT) be used for both pumps. (1 mark)
- 7.1.b What will be the maximum volume of water (liters per second) discharged at the pit crest based on the best pump configurations (HT or MT). (1 mark)
- 7.1.c What will be the inlet and outlet pressures at each of the pumps in meters of water. (3 marks)
- 7.1.d What schedule of pipe will be required at the outlets of the two pumps (2 marks)
- 7.1.e If a check (gate) valve is fitted at the outlet of the top pump to stop water returning to the sump, what modifications will be required. (1 mark)

Assume the water is "clean" and temperature/pressure has no effect on density.

Some conversion factors that may or may not be of use,
1 m water at 8°C is 1.41 psi 1 ft water at 62°F is 0.43 psi 1 psi = 6.9 kPa 1 ft water = 3 kPa

Question 7.2 (6 marks)

An alternative to the pumping system described in 7.1 is a series of deep well pumps around the pit perimeter and possibly on the ramp inside the pit.

From this perspective, discuss

- 7.2.a How the transmissibility and storage constants of the pit wall rocks are found using a graphical solution and experimental wells. (2 marks)
- 7.2.b How the pumps might be laid out in plan and the pump depth determined. (1 mark)
- 7.2.c How the feasibility and cost of such a system might be estimated. (2 marks)
- 7.2.d The operational advantages quantified from a pit operations perspective. (1 mark)

End of the Exam