National Exams December 2018

09-MMP-A4, Mine Valuation and Mineral Resource Estimation

3 hours duration

FORMAT:

A Casio or Sharp approved calculator is permitted; Closed Book, but one aid sheet written on both sides containing notes and formulae is permitted.

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 not an open 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.

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.

6. Always use large (½ page or larger) neat sketches and drawings to illustrate your answers. This is important in obtaining good marks.

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Suggested Timing: 30 minutes to read the exam and consider answers. Allow an hour for Question 1. Choose 3 of 5 multiple choice questions. Three multiple choice questions chosen from the five (Q 2 to 6), should take 30 minutes per question, 1.5 hours in all. Total 3 hours.

Question 1, 40% or about 1 hour total, 5 marks/section.

(Note, each of the 8 parts of this question carries 5 marks and should be answered in 7 to 8 minutes; also note that the time you should allocate to each mark is about 1.5 minutes).

1.1 Aspects of geological conditions and control relating to mineral resource estimation

Using (a) a deep narrow copper, tin or gold vein and (b) an extensive porphyry copper or epithermal gold deposit as examples, briefly describe how the geological conditions and controls affect how the respective mineral resources might be estimated.

Large neat clear diagrams (not thumbnail sketches) are expected here and throughout the exam.

1.2 Principles of mineral resource estimation using conventional and geostatistical methods

Historically, 1.2.1) the method of sections, 1.2.2) method of polygons and 1.2.3) inverse distance squared mineral estimation methods have been used to estimate the grade of orebodies. Discuss how each method progressed from "manual estimation" to the use of calculators and eventually computers in the estimation process. Describe the types of orebodies each is applied to. Very briefly detail how geostatistical techniques would be applied to supplant these conventional methods.

1.3 Ultimate Value of Mined Materials

To potential buyers, sellers and the stock market, what factors determine the value of a mineral resource. Using copper as an example, outline the supply and demand settings determining "market conditions".

What are the prices of the following products as given by say "Metals Week" and more reputable news print, or the BNN and similar media ***sometime on the week before this examination***. Answers are expected in US$, the customary currency of such products, and per pound, troy ounce or barrel are commonly used. You may use metric units if you prefer. Answers +/- 20% of actual will receive half marks, and +/- 10% full marks.

1.3.1. copper 1.3.2 zinc 1.3.3 oil

What do you understand by the terms "producer price and discounted price" and how does the application of such prices affect mine profitability over time.

1.4 Capital and operating cost estimation

From visits to and analyzing costs at various mines, T.A. O'Hara has produced a simplified method of estimating capital costs over a range of deposit sizes. The same mathematical formulation is used for cost estimation of cost components and total cost in each case.

Describe this formulation.

O'Hara also developed an empirical 'mine life' rule used frequently in economic analysis of potential, and operating, ventures in the minerals industry. What is the 'rule', and discuss its accuracy when compared to studies involving the 'time value of money'.

1.5 Net Smelter Return and similar measures of viability

Describe each of the following as related to the economics of a mine, emphasizing and comparing the value to a holder of such an interest in a mining venture.

1.5.1 Net Smelter Return, NSR
1.5.2 Net Smelter Value, NSV
1.5.3 Net Profit Interest, NPI

1.6 Estimation of revenue including smelter contracts

The revenue from Copper mining is relatively difficult to estimate, and even more complex when small amounts of other products are involved. Discuss the smelter contract and its component parts for a one product (copper) operation including estimates of the "realized" (or "street") revenue as a percentage of the published metal price. Describe a smelter contract involving copper plus several other included (in the concentrate as shipped) and separated components.

Give examples of such products which make up often significant revenues for a copper mine. and the costs included in a typical smelter contract.

1.7 Taxation, cash flow, sensitivity and risk analyses

What do you understand by the term 'cash flow' in the mining context. What factors affect the risks and sensitivities of the components of cash flow.

One such risk is taxation. Compare the tax rules of relatively stable countries (e.g. Canada, Australia) with unstable regimes in emerging economies (e.g. South America, Africa). What rates or return would you use in the two cases when developing a mine feasibility, and over what time frame.

Discuss how the application of 'incremental financial analysis' can result in more profitable mining operations. Include in your discussion the application at (a) the feasibility study of a mineral resource and (b) an operating mine.

1.8 Extraction variables including cut-off grade

The 'cut-off grade' is typically applied at the 'rock face', but this restriction does not include the changes to profitability of changes to, for example, crushing and grinding, float cells and means of transporting concentrates. Discuss how other extraction variables affect the cut-off at the rock face.

Define 1.8.1) cut-off grade, 1.8.2) marginal cut-off grade and 1.8.3) cut-off grade yielding sufficient funds to cover only the sum of mine operations, and 1.8.4) the sum of (1.8.3) plus debts, smelter and distribution, taxes and shareholder equity.

Questions 2 to 6, select 3 out of 5, 20% each and suggested 30 minutes each

Question 2

Two non-ferrous metallic mineral deposit types made up a significant part of the value of Canada's production.

- Volcanic (volcanogenic) Massive Sulfide (VMS) (e.g. Bathurst, NB)
- Sedimentary Exhalative (SEDEX) (e.g. Sullivan, BC)

2.1 Describe, with the aid of neat full-page sketches/sections (not thumbnails), the geologic settings and ore deposit models of these types of deposit.

Discuss the differences between VMS and SEDEX deposits, and the host rocks containing them. Include some description of the role of oceans and other brine rich sediments in the differentiation of the two deposit types.

Specify the constituent economic minerals, and the products produced for shipment to smelters. Also discuss the alteration minerals expected.

2.2 Describe typical mining methods and operating costs as applicable to the Canadian mining industry for the two types of deposit.

Part 2.1 12 marks, part 2.2 8 marks

Question 3

Note that for the rest of this exam paper, and in your answer book, the term "variogram" is taken to mean "semi-variogram" as these terms are used interchangeably in practice

3.1 Provide a sketch section and describe a typical "porphyry" deposit of the type found in the Canadian Cordillera. (2 marks)

Your description should include very brief (less than 50 words or 5 lines) of the following;

3.1.1 Tectonic Setting
3.1.2 Host (and associated) rock types
3.1.3 Alteration Mineralogy
3.1.4 Associated economic minerals

(1 mark each, total 4)

Such deposits as (3.1) usually have good descriptive variograms which are best described by a "nested spherical" model

A typical nested spherical semi-variogram (the more usual term "variogram" will be used interchangeably in this exam) consists of a nugget and two structures.

3.2.1 Make a half or full page diagram to scale showing the individual structures and sum of structures of the following "nested" variogram as X (distance) versus Y, gamma (γ) values;

Nugget		0.1		
Structure (1)	Sill	0.5	Range	100m
Structure (2)	Sill	0.4	Range	500m

(2 marks)

Calculate the gamma (γ) variogram value at distances of;

3.2.1.a)	0 meters	(1 mark)
3.2.1.b)	50 meters	(2 marks)
3.2.1.c)	250 meters	(2 marks)
3.2.1.d)	1000 meters	(1 mark)

Indicate the answers on your diagram and use this graph to check your answers.

(1 mark, total 7 marks)

3.3) Describe how variograms can be used to define trends in ore-bodies. In this regard, and with the aid of neat sketches, describe/explain the following,

3.3.1 tolerance (included angle)
3.3.2 band width
3.3.3 anisotropy
3.3.4 Why the variogram at "azimuth 90, dip 0" is the same as "azimuth 270, dip 0".
3.3.5 Why the variogram at "azimuth 90, dip 45" is not necessarily the same as "azimuth 270, dip 45".

(1 mark each, total 5 marks)

Question 4

A porphyry copper ore-body is located in central British Columbia and typically contains amounts of lead slightly less than the grade of molybdenum.

The copper concentrate could be sent to smelters in eastern Canada or to ports on the eastern Pacific coast. Transporting concentrates from the mine to the smelter can incur substantial costs.

4.1 Use a diagram to help describe the various modes of transportation employed in getting concentrate from mine site to smelter destinations in both eastern Canada and the Pacific rim. Include some estimates of costs and justify a choice of either destination. (2 marks)

4.2 As an analyst, describe a typical smelter contract for the copper concentrate. Include items such as;

4.2.1 concentate content
4.2.2 treatment charge
4.2.3 treatment losses
4.2.4 refining charge
4.2.5 metal price
4.2.6 charges and deductions
4.2.7 what effect the lead will have on revenue
4.2.8 how gold and silver will be accounted for
4.2.9 stoppages in the process
4.2.10 shipment and discharge conditions
4.2.11 environmental concerns
4.2.12 minimum payable
4.2.13 deductions
4.2.14 price escalation and participation
4.2.15 impurities
4.2.16 splitting limits and umpires

(half mark each, total 8 marks)

4.3) Despite the molybdenum grade being typically about a quarter that of the copper in the ore, why does molybdenum provide almost as much revenue as copper in some typical porphyry copper deposits. (1 mark)

4.4) What do you understand by the terms (a) NSV (Net Smelter Value) and (b) NSR (Net Smelter Return), and define and differentiate between them. How does the mining engineer use such values. (3 marks)

4.5 Evaluate a porphyry copper deposit with an ore grade of 0.7% Cu. Assume that the Mo, Au or Ag grades, common in this type of deposit, are so low that these metals are not paid for in the concentrate.

For the calculation of revenues certain assumptions are made

- 90% recovery
- 25% concentrate grade
- freight cost US$60/short ton
- treatment charge US$255/tonne
- treatment losses of 1 unit
- refining charge USc24/lb paid Cu (24 cents/lb for each lb paid for)
- metal price 2.75US$/lb

4.5.1 What is the recovered ore grade %Cu
4.5.2 What is the gross value of the concentrate US$/short ton
4.5.3 What is the refining charge (paid metal content)
4.5.4 What is the Net Smelter Return of the mine (in US$/short ton of concentrate)
4.5.5 What are the short tons of ore per short ton of concentrate (concentration factor)
4.5.6 What is the Net Smelter Return of the ore (in US$/short ton of ore)

(1 mark each, total 6 marks)

Question 5

5.1) Discuss the situation where two adjacent deposits (a) and (b) have the following general values. Deposit (a), high grade and large grade variance due to lack of drill data, and deposit (b), medium grade but low grade variance due to its selection as the deposit where drilling was concentrated. (3 marks)

5.2) In the early 1970's McKelvey produced a box diagram relating "Increasing degree of feasibility of recovery" to "Increasing degree of geological assurance" for the US Geological Survey. Make a sketch of the McKelvey diagram including the various classifications of mineral resources and reserves within it. Describe what the diagram represents and what can be learned from it. (7 marks)

A very few fraudulent "reserves" have been produced for mineral occurrences over the last few decades, and have resulted in stricter regulations in Australasia, Canada, Europe, South Africa, the United Kingdom, the United States and other jurisdictions. Perhaps one of the best known is the Canadian "National Instrument 43-101".

5.3 In the context of NI 43-101 (or similar), discuss the following (a short 50 ~ word or 5 lines for each is sufficient) in terms of what it represents and why it is a part of the NI 43-101 process.

5.3.1 Mineral inventory
5.3.2 Data verification
5.3.3 Mineral resource
5.3.4 Ore reserve
5.3.5 Measured, indicated and inferred
5.3.6 Qualified Person "QP"
5.3.7 Technical report
5.3.8 System for Electronic Document Analysis and Retrieval (SEDAR)
5.3.9 Producing issuer
5.3.10 "Independence"

(1 mark each, total 10 marks)

Question 6

6.1 What do you understand by the following,

6.1.1 Internal Rate of Return (IRR)
6.1.2 Net Present Value (NPV)
6.1.3 Present value factors
6.1.4 Cumulative present value factors
6.1.5 Profitability Index

(1 mark each, total 5 marks)

A mining corporation has two junior part interest potential investments available to it both with 5 year lives, but different after tax cash flows and terminal values. The alternatives 6A and 6B are as follows:

Alternative 6A

Investment cost $80,000,000 ($80 million)
Net cash inflow share from operations

Year 1	50 million
Year 2	30 million
Year 3	20 million
Year 4	10 million
Year 5	7 million
Terminal value share at end year 5	5 million

Alternative 6B

Investment cost $80,000,000 ($80 million)
Net cash inflow share from operations

Year 1	28 million
Year 2	28 million
Year 3	28 million
Year 4	28 million
Year 5	28 million
Terminal value share at end year 5	10 million

The company has set 15% as the minimum acceptable internal rate of return.

Two test alternatives have been run at 5% and 50% in order to find the internal rate of return (IRR %) producing zero NPV (net present values) ($). Note that interpolation of the results does not provide the correct IRR as the IRR/NPV curve for a zero NPV does not approximate a straight line for large differences in the trial rates of returns.

You may assume that between adjacent 5% units of interest rate, changes in the present value are linear, but not the larger adjacent units as in the trial where the difference is (50-5) or 45%, far in excess of the 5% units (the assumed curvature is approximated by the straight line between 5% intervals, but not larger units such as 45%).

Table 6 provides present value factors for 1 to 10 years from 5 to 50 %, at 5% intervals, and similar cumulative present value factors. The curve between adjacent 5% interest rates is well approximated by a straight line for calculation purposes.

Table 6

Present Value Factors

time years	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
1	0.9524	0.9091	0.8696	0.8333	0.8000	0.7692	0.7407	0.7143	0.6897	0.6667
2	0.9070	0.8264	0.7561	0.6944	0.6400	0.5917	0.5487	0.5102	0.4756	0.4444
3	0.8638	0.7513	0.6575	0.5787	0.5120	0.4552	0.4064	0.3644	0.3280	0.2963
4	0.8227	0.6830	0.5718	0.4823	0.4096	0.3501	0.3011	0.2603	0.2262	0.1975
5	0.7835	0.6209	0.4972	0.4019	0.3277	0.2693	0.2230	0.1859	0.1560	0.1317
6	0.7462	0.5645	0.4323	0.3349	0.2621	0.2072	0.1652	0.1328	0.1076	0.0878
7	0.7107	0.5132	0.3759	0.2791	0.2097	0.1594	0.1224	0.0949	0.0742	0.0585
8	0.6768	0.4665	0.3269	0.2326	0.1678	0.1226	0.0906	0.0678	0.0512	0.0390
9	0.6446	0.4241	0.2843	0.1938	0.1342	0.0943	0.0671	0.0484	0.0353	0.0260
10	0.6139	0.3855	0.2472	0.1615	0.1074	0.0725	0.0497	0.0346	0.0243	0.0173

(Interest Rate)

Cumulative Present Value Factors

time years	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
1	0.952	0.909	0.870	0.833	0.800	0.769	0.741	0.714	0.690	0.667
2	1.859	1.736	1.626	1.528	1.440	1.361	1.289	1.224	1.165	1.111
3	2.723	2.487	2.283	2.106	1.952	1.816	1.696	1.589	1.493	1.407
4	3.546	3.170	2.855	2.589	2.362	2.166	1.997	1.849	1.720	1.605
5	4.329	3.791	3.352	2.991	2.689	2.436	2.220	2.035	1.876	1.737
6	5.076	4.355	3.784	3.326	2.951	2.643	2.385	2.168	1.983	1.824
7	5.786	4.868	4.160	3.605	3.161	2.802	2.508	2.263	2.057	1.883
8	6.463	5.335	4.487	3.837	3.329	2.925	2.598	2.331	2.109	1.922
9	7.108	5.759	4.772	4.031	3.463	3.019	2.665	2.379	2.144	1.948
10	7.722	6.145	5.019	4.192	3.571	3.092	2.715	2.414	2.168	1.965

(Interest Rate)

The calculations for the 5% and 50% trial, following the format given by Edge and Irvine, are as follows,

Try 5 and 50 % for alternative 6A to find IRR

	Amount	At 5% PV factor	PV	At 50% PV factor	PV
Investment now	80M	1.0	-80.0M	1.0	-80.0M
Net cash inflows	50	0.9524	47.6	0.6667	33.3
	30	0.9070	27.2	0.4444	13.3
	20	0.8634	17.3	0.2963	5.9
	10	0.8227	8.2	0.1975	2.0
	7	0.7835	5.5	0.1317	0.9
Terminal value At end of year 5	5	0.7835	3.9	0.1317	0.7
Net present value			+29.7M		-23.9M

6.2 From the above 5% and 50% trial, and using the data in alternatives 6A and 6B, estimate (interpolate) the internal rate of return (%) producing zero NPV (net present values, $). Recognize that the assumed straight line is a curve, and the answer is not correct, but does provide a starting point to quickly estimate the true value. (2 marks)

6.3 From the data in the above (Alternatives 6A and 6B) and Table 6, estimate the IRR (internal rate of return %) producing zero NPV (net present values $). Be sure to use adjacent 5% interest units provided Table 6. The format used in the above 5 and 50% trial is suggested for your calculations if you wish to use it, *i.e. try Y% and (Y% +/- 5%) until an adjacent set of rates (%) spans zero NPV, and then interpolate the IRR.*

Which alternative is the best, 6 A or B based on the best IRR (internal rate of return %).
(5 marks)

6.4 Make a sketch graph of Internal Rate of Return (IRR % as X) versus Net Present value (NPV $ as Y) including the 5 and 50 % trial given above, and comment on the curvature. (1 mark)

6.5 Using the minimum acceptable rate of return set by the company (15%), what are the (net) present values ($) of alternatives 6A and 6B, and which is best, 6 A or B, based on the NPV's calculated. (3 marks)

6.6 Calculate the profitability indexes for alternatives 6A and 6B, and discuss your choice of which of the two alternatives (6A and 6B) you prefer and why. (2 marks)

6.7 In the question example case of alternatives 6A and 6B, lives are similar. Does this negate the reason for calculating the more complex and time consuming IRR alternative in favour of NPV at the 15% corporate IRR. (1 mark)

6.8 Discuss the IRR and NPV alternatives in assessing profitability when projects have different lives, capital costs or corporate IRR's. When project lives, capital costs or rates of return differ between projects, how would this affect the optimal rate of return and/or present value and how would the results affect the eventual investment decision. (1 mark)

End of Exam