(1) This is a CLOSED BOOK EXAM. No notes or textbooks permitted.

(2) Candidates may use one of the approved Casio or Sharp calculators.

(3) Answer all questions except where otherwise noted, i.e. in Problems 4 and 5.

(4) Show all calculations.

(5) 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.

(6) The mark distribution is as follows:

Problem 1  (a) 10  (b) 8  (c) 5  (d) 4  (e) 7  Total 34 marks
Problem 2  (a) 3  (b) 4  Total 7 marks
Problem 3  (a) 8  (b) 5  (c) 4  Total 17 marks
Problem 4  Six marks for each part Total 30 marks
Problem 5  Two marks each Total 12 marks

Bonus Question  2 marks
PROBLEM 1
(a) Shown to the right is the flowsheet of the Bell concentrator which operated in central British Columbia from 1972 to 1992. The mill processed 12,000 tonnes/day of ore from an open pit mine to produce a copper concentrate. Identify the unit operations which best fit into the flowsheet at the appropriate locations from A to P. Select the unit operations from the list below:  

(10 Marks)

- thickener
- secondary screen
- scavenger flotation cells
- ball mill
- 1st stage cleaner flotation cells
- tertiary crusher
- hydrocyclones
- regrind ball mill
- dryer
- rougher flotation cells
- 2nd stage cleaner flotation cells
- filter
- secondary crusher
- rod mill

Primary Crusher

Primary Screen

A

B

C

D

E

G

H

F

Regrind Cyclone

J

K

L

M

N

P

3rd Cleaner Flotation Cells

Mill Tailings

Final Concentrate
Problem 1 Continued
(b) If the copper content of the solid streams at the Bell concentrator were:
   Mill feed  0.5% Cu
   Tailings  0.04% Cu
   Concentrate 28.0% Cu
Calculate the tpd of copper concentrate produced.  (8 Marks)

(c) If electrical power was available a 6¢/kw-hr, using Bond's equation and a Work Index of
16, estimate the power cost (in $/day) required for comminution of the Bell ore. List the
assumptions made in your calculation.

Bond's Equation:

\[ W = \frac{10W_i}{\sqrt{P}} - \frac{10W_i}{\sqrt{F}} \]  
(5 Marks)

(d) Assuming that chalcopryte (CuFeS₂, 34.6% Cu, SG 4.2) and siliceous gangue (SG 2.7)
are the only two mineral components present in the ore, calculate the specific gravity of the
copper concentrate.  (4 Marks)

(e) Assuming that the copper concentrate was sold to a smelter according to the following
schedule:
(i) Treatment charge, $100/tonne of concentrate
(ii) pay for 90% of copper at the London Metal Exchange (LME) price
Using the following economic factors, calculate the net operating profit (in $/day) of the
operation (i.e. income minus operating costs)
   Mining cost .......... $4/tonne of ore
   Milling cost .......... $3/tonne of ore
   Freight to Smelter..... $30/tonne
   LME copper price....... $2500/tonne  
(7 Marks)

Problem 2.  (7 marks).
A laboratory flotation test was carried out on a sample of lead/zinc ore. The results were as
follows.

<table>
<thead>
<tr>
<th></th>
<th>Weight g</th>
<th>Pb</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pb Concentrate</td>
<td>40</td>
<td>65</td>
<td>7</td>
</tr>
<tr>
<td>Zn Concentrate</td>
<td>30</td>
<td>4</td>
<td>50</td>
</tr>
<tr>
<td>Tailing</td>
<td>430</td>
<td>0.5</td>
<td>1</td>
</tr>
</tbody>
</table>

(a) What is the calculated assay of the flotation feed i.e. % Pb & % Zn.  (3 Marks)

(b) What is the distribution of lead and zinc to the concentrates and tailings.  (4 Marks)
Problem 3

![Diagram of coal cleaning circuit]

**FIGURE 1. Layout of Coal Cleaning Circuit for Problem 3**

A two-stage automedium (water only) cyclone circuit is used for cleaning 100 tonnes/hour of fine coal as illustrated in Figure 1. The circuit was sampled and the results were as follows:

<table>
<thead>
<tr>
<th></th>
<th>Percent Solids</th>
<th>Percent Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circuit feed</td>
<td>12.5</td>
<td>25</td>
</tr>
<tr>
<td>Primary Cyclone Feed</td>
<td>13.16</td>
<td>25</td>
</tr>
<tr>
<td>Primary Cyclone Overflow (clean coal)</td>
<td>10.00</td>
<td>10</td>
</tr>
<tr>
<td>Primary Cyclone Underflow</td>
<td>25.00</td>
<td>47.5</td>
</tr>
<tr>
<td>Secondary Cyclone Overflow</td>
<td>16.67</td>
<td>25</td>
</tr>
<tr>
<td>Secondary Cyclone Underflow (rejects)</td>
<td>33.33</td>
<td>70</td>
</tr>
</tbody>
</table>

(a) Carry out a material balance and calculate the tonnes/hour of clean coal produced by the circuit. *(8 marks)*

(b) Calculate the tonnes/hour of dilution water added to the sump. *(4 marks)*

(c) Calculate the tonnes/hour of solids in the primary cyclone underflow. *(5 marks)*

4. Explain the similarities and differences between the following terms and explain how they are related to mineral processing. Use sketches in your answers.

**Answer any five (5) (30 marks)**

(i) Coagulation/flocculation
(ii) Jig/shaking table
(iii) Mechanical/column flotation cell
(iv) Frother/collector
(v) Gyratory/cone crusher
(vi) Dense Medium/classification cyclone
(vii) Upstream/downstream tailings dam
(viii) Magnetic/high-tension separator
(ix) $d_{50}/d_{50C}$
Problem 5. Short answer questions. ONLY Answer any six (Total 12 marks)

(a) With regard to tumbling mills, what is the meaning of critical speed.

(b) List two particle size analysis techniques other than sieving.

(c) Gy’s sampling equation is usually written as follows: M= C d^3 /s^2
   Where M is the minimum weight of sample required.
   Define the meanings of d and s.

(d) List two limitations of Stokes Equation (Law)

(e) With the aid of a sketch, explain the concept of contact angle.

(f) What are the two most abundant metals present in the earth’s crust?

(g) The rate of flotation is usually described by the following equation:
\[ R = RI \left[ 1 - \exp(-kt) \right] \]
where R is the cumulative recovery of a given mineral species in time t
Define the meanings of k and RI

(h) List two naturally hydrophobic minerals.

(i) Sketch the structural formula of sodium ethyl xanthate.

Bonus Question

Name two mineral commodities produced in Canada which are not concentrated by froth flotation (2 marks)