NOTES:

(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 Problem 2.
(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) Hand in page six (plot for problem 4) with your examination booklet.
(7) The mark distribution is as follows:

   Problem 1  Total 15 marks
   Problem 2  Five Marks for each part, Total 30 marks
   Problem 3  25 marks
   Problem 4  8 marks
   Problem 5  7 marks
   Problem 6  15 marks
Problem 1. (15 marks)
The following is an excerpt from *Canadian Milling Practice* which describes the grinding circuit of the Key Lake uranium mill in northern Saskatchewan.

**Grinding**
The grinding circuit consists of a 4.42 diam. by 2.0 m long SAG mill in open circuit with a single sizing screen. Screen oversize reports to a 2.7 m diam. by 3.0 m long ball mill. The ball mill operates in closed circuit with two sizing screens. The undersize from all three screens reports to the neutral thickener. The thickened slurry is pumped at a nominal density of 50% solids to four air-agitated storage pachucas in leaching. The average feed rate is 65 t per operating hour. The product size is about 80% passing 300 µm and 45% passing 75µm. The work index of the ore is 23.7 kw-hr/t.

(a) Sketch a flow sheet of the Key Lake grinding circuit.

(b) If electrical power is available a 20¢/Kw-hr, using Bond's equation estimate the power cost (in $/24-hr day) required for comminution of the ore. List the assumptions made in your calculation.
Bond's Equation:

\[ W = \frac{10W_i}{\sqrt{P}} - \frac{10W_i}{\sqrt{F}} \]

(c) Using a grinding ball size of 0.1 m, calculate the percent critical speed if the SAG mill rotates at 13 rpm.

\[ N_c = \frac{42.3}{(D - d)^{0.5}} \text{ rev/min} \]

Problem 2. (30 marks).
Explain the similarities and differences between the following terms as they are applied to mineral processing. Use sketches in your answers. Answer any SIX of the following nine topics.

- Coagulation/flocculation
- Jig/table
- Cateracting/cascading
- Merrill-Crowe/carbon-in-pulp process
- Magnetic/High tension separator
- Mechanical/column flotation
- d_{50}/d_{50c}
- Bulk/reverse flotation
- Gyratory/cone crusher
Problem 3. (25 marks)
A copper flotation circuit is used to concentrate 100 tonnes per hour of ore (valuable mineral is chalcocyste (specific gravity 4.2, containing 34.6 % copper) with a siliceous gangue (specific gravity 2.6). The circuit layout is shown on the sketch below:

![Diagram of flotation circuit](image)

FIGURE 1. Layout of Flotation Circuit for Problem 2

Assume that the circuit was sampled and the results were as follows:

<table>
<thead>
<tr>
<th>Stream</th>
<th>% solids by wt</th>
<th>% Cu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circuit Feed</td>
<td>33.3</td>
<td>0.5</td>
</tr>
<tr>
<td>Rougher concentrate</td>
<td>50</td>
<td>13.89</td>
</tr>
<tr>
<td><strong>Final Concentrate</strong></td>
<td><strong>75</strong></td>
<td><strong>25</strong></td>
</tr>
<tr>
<td>Cleaner Tailings</td>
<td>33.3</td>
<td>5</td>
</tr>
<tr>
<td>Final Tailings</td>
<td>75</td>
<td>0.1016</td>
</tr>
</tbody>
</table>

Using the above data carry out a material balance and calculate the following:

(a) the copper recovery in
    (i) the circuit
    (ii) the cleaners
    (iii) the roughers

(b) the tonnes/hour of dilution water added to the cleaners

(c) the tonnes/hour of final concentrate produced

(d) the tonnes/hour of solids recirculated back to the roughers i.e. the cleaner tailings.

(e) the specific gravity of the final concentrate solids
Problem 4  (8 Marks)

A sieve analysis was carried out on an ore. The results were as follows:

<table>
<thead>
<tr>
<th>Size Fraction</th>
<th>Weight Grams</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ 600 μm</td>
<td>42.2</td>
</tr>
<tr>
<td>-600 + 300 μm</td>
<td>40.0</td>
</tr>
<tr>
<td>-300 + 150 μm</td>
<td>26.4</td>
</tr>
<tr>
<td>-150 + 75 μm</td>
<td>17.4</td>
</tr>
<tr>
<td>- 75 μm</td>
<td>33.9</td>
</tr>
</tbody>
</table>

Using the log-log graph paper provided on page 6, plot the Cumulative Weight Percent Passing versus the Particle Size in microns. From the plot determine:

(a) the 80 % passing size in microns

(b) the estimated percentage of material in the -75+37 micron fraction

Problem 5. (7 marks).

\[ V = \frac{g \, d^2}{18 \, \mu} \left( D_s - D_f \right) \]

(a) Using Stokes' equation (given above) calculate the diameter of a coal particle (Specific gravity 1.4) which would settle in water at the same rate as a 40-micron diameter quartz (Specific gravity 2.65) particle settling in water.

(b) Repeat the calculation in part (a) for both particles settling in air.
Problem 6. Short answer questions

(a) Given the following flotation reagents, classify them according to their function, and for each, give an example of an application:
   - potassium amyl xanthate
   - sodium cyanide
   - methyl isobutyl carbinol
   - copper sulphate

(b) Why is the heap leaching of gold usually more economical than leaching in stirred tanks?

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

(d) Referring to problem 3, assuming you wish to collect samples for copper assays of the final concentrate and final tailings from the circuit. Which should be the larger sample and why?
(e) Referring to Problem 3, if the circuit were operated without the cleaners, would the overall copper recovery increase, decrease or not change?

**Bonus Question (2 marks):**
List two mineral commodities mined in Canada which are not beneficiated using froth flotation.
Figure 2. Size Analysis Graph for Problem 4