QUESTION 1: COMMINUTION

The milling section of a South African porphyry copper plant has a SAG mill followed by a hydrocyclone and a ball mill. All of the SAG mill product passes through the ball mill before it is pumped to the hydrocyclone.

The hydrocyclone has a 75 micron cutsize. The hydrocyclone underflow is recycled back to the ball mill, and the overflow goes on to flotation.

The plant personnel consider the SAG mill product as consisting of only two particle size classes; that which is finer than 75 microns (10% of the material coming from the SAG mill), and the rest, which is coarser than 75 microns.

Only 70% of all the material that is coarser than 75 microns entering the ball mill is broken to become finer than 75 microns. Of the feed to the hydrocyclone, 25% of the particles finer than 75 microns and 100% of the coarse material (greater than 75 microns) are returned to the ball mill from the hydrocyclone underflow.

The tonnage to the flotation plant is 1000 tonnes per hour.

a) The SAG mill takes a feed from the crushers that is 80% finer than 2.5cm, and produces a product that is 80% finer than 500 microns. The ore has typical hardness. Estimate the power drawn by the SAG mill. (2 marks)
b) If the crushers are improved, and the feed to the SAG mill becomes 80% finer than 1cm, what is the change in the power the SAG mill consumes? Is this significant? (2 marks)
c) Draw the flowsheet, labelling each unit operation and each stream. (3 marks)
d) What are the flow rates of the material finer and coarser than 75 microns, and the total mass flow rate coming out of the ball mill? (6 marks)
e) Estimate the power drawn by the ball mill. (3 marks)

After a few months, the hydrocyclone performance changes and 10% of the coarse material (>75 microns) now goes to flotation.

f) What could have happened to the hydrocyclones over time? (1 mark)
g) Calculate the change in the tonnage passing through the ball mill. (4 marks)
h) Explain why this specific change in the tonnage through the mill happened. (1 mark)
i) How will this affect the power drawn by the ball mill? Why? (3 marks)

QUESTION 2: FROTH FLOTATION

A 500 tph of mined ore contains 0.45 % by weight of valuable mineral (symbol Z), the rest being gangue.

Flotation is performed in a bank of 4 flotation cells.

The cumulative grade-recovery performance after each cell is as shown in the table below:

Cell number	Cumulative Recovery (%)	Cumulative Grade (%)
1	58.5	29.8
2	75.7	28.8
3	84.3	25
4	87.8	15.6

a) Explain the principle of flotation in point form. [4]

b) How many tones of mineral Z enter the plant per hour? [1]

c) Calculate the mass of Z recovered to concentrate in cell 1. [1]

d) For cell 2, calculate the mass of Z recovered to concentrate, the recovery (%) of Z in cell 2, and the concentrate grade (%) from cell 2. [4]

e) Calculate the recovery and grade of the concentrates from cells 3 and 4. [6]

f) Which cell has the lowest recovery? Why do you think this occurs? [3]

g) Which cell produces the lowest grade? Explain why this is so? [3]

h) Give two examples of actions that can be taken to increase the recovery and grade from the flotation plant? [3]

QUESTION 3: HYDROCYCLONES

A hydrocyclone treats 100 tph of solids.
Given the feed particle size and hydrocyclone partition curve data in the table below:

a. Calculate the cumulative coarse product size distribution. [5]

b. Calculate the solids mass flowrate to the coarse product. [2]

c. Calculate the cumulative size distribution of the fine product stream [3]

d. ON THE SAME GRAPH, draw and label the cumulative coarse and fine particle size distributions and the partition curve. Label the axes. HAND IN THE GRAPH [6]

e. Estimating from the graph, how many tonnes/hr of solids finer than 75 microns go to the fine product stream? [2]

f. Estimate the cutsize, and the bypass for the partition curve [2]

Particle size: [μm]	**Feed: % passing size**
300	100.0
150	90.0
75	70.9
38	32.8
19	2.7

Particle size: [μm]	**Partition number:**
212	0.98
106	0.76
53	0.46
27	0.30
13	0.23

g. Calculate both the mass and volume solids concentrations of a solid-water slurry of relative density 1.78. The solids have a relative density of 2.35. (3)

h. Calculate the relative density of a 45% by mass solids and water mixture. The solids have a relative density of 2.55. (2)

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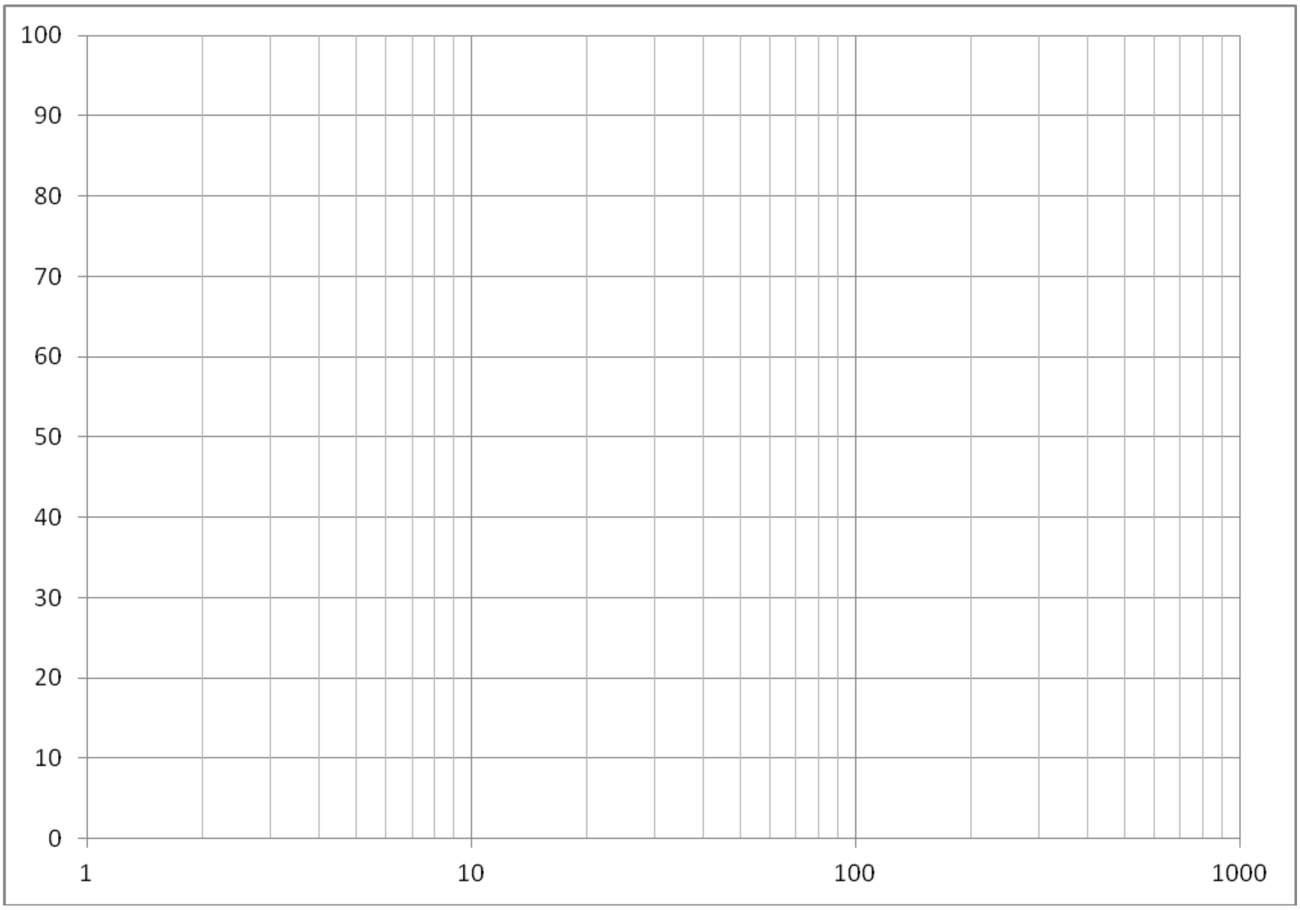

QUESTION 4: HYDROMETALLURGY and SX-EW

The flowrate of PLS into an SX plant is 1500 m^3/h, with a Cu content of 3 kg/m^3 solution. The loaded electrolyte feed to the EW plant has a Cu content of 59.5 kg/m^3 solution, which is reduced to 40 kg/m^3 following the electrowinning stage.

a) Draw the schematic flowsheet of the process and label all streams. (4)

b) The concentration of the raffinate stream is 0.0988 kg/m^3. What is the efficiency of the extraction stage? (1)

c) What is the copper production rate? (2)

d) The loaded organic concentration is 4.2 kg/m^3, and the depleted concentration is 1.588 kg/m^3. What are the required organic flowrate and the ratio of organic to aqueous phase in the extraction stage? (4)

e) What is the volumetric flowrate of the electrolyte to electrowinning? (3)

f) The raffinate is used as lixiviant in the heap leach. The addition rate of lixiviant is 0.01 m^3/h per m^2 heap surface. What is the surface area of the heap? Suggest dimensions for the length and width of the on/off heap. (3)

g) If the height of the heap is 7 m, and the voidage is 0.4, what mass of ore is being leached? (2)

h) The equilibrium data for the extraction and stripping sections is given below. Do a McCabe-Thiele construction to determine the number of stages required in each section. Hand in your construction. (6)

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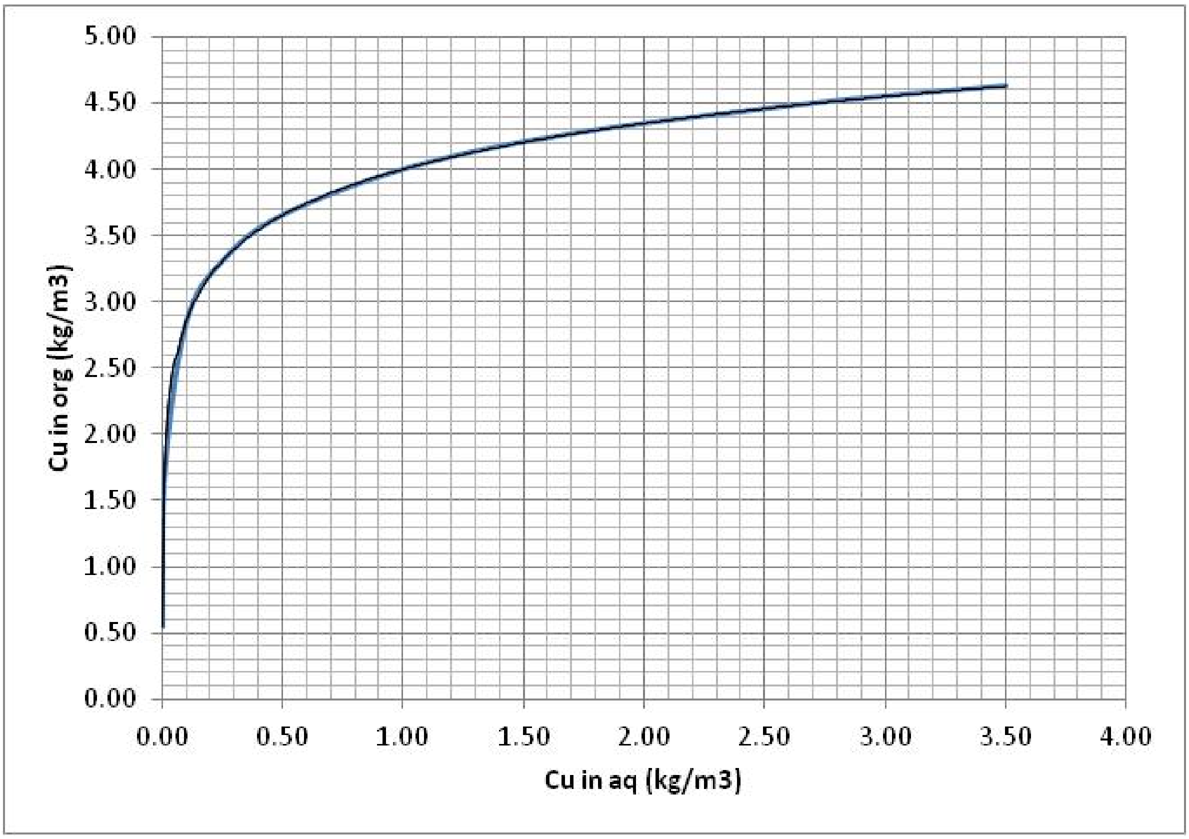

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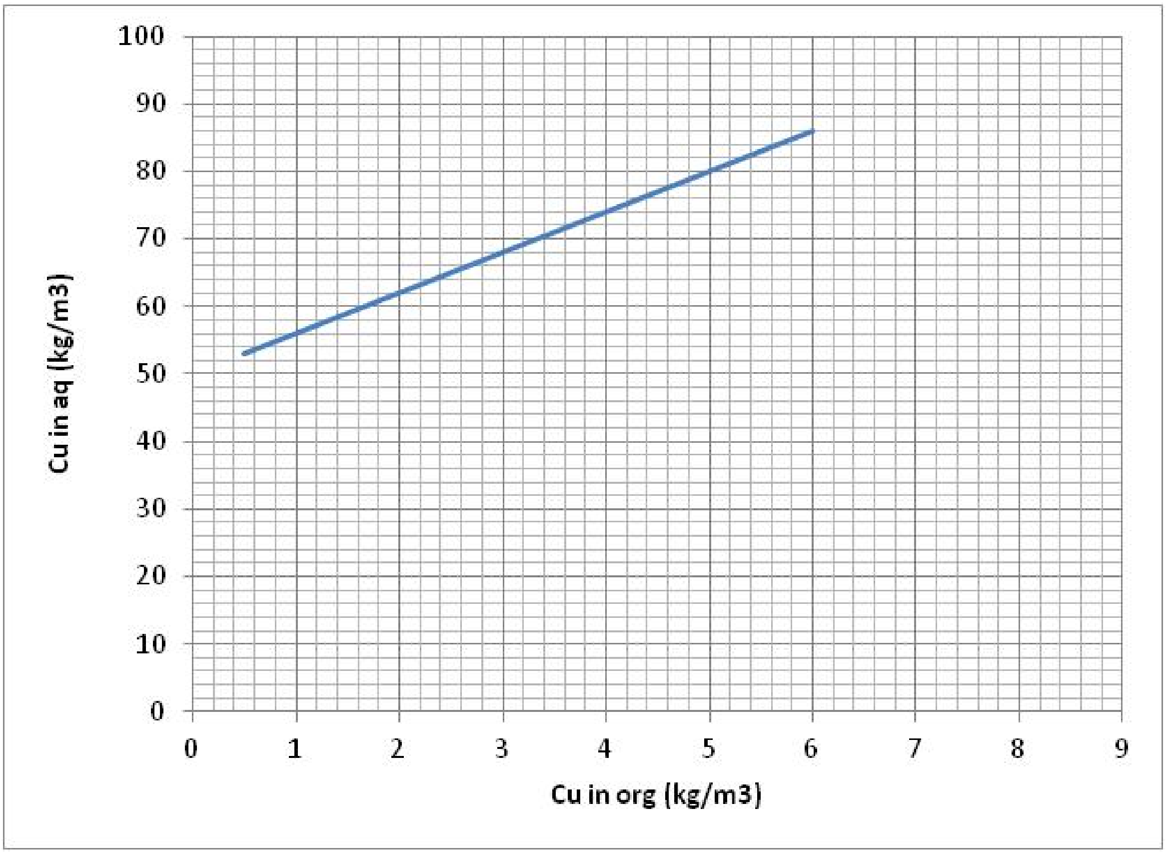
Cu in org (kg/m3)
Cu in aq (kg/m3)



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80
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40
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10
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1
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4
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6
7
8
9
Cu in aq (kg/m3)
Cu in org (kg/m3)