

**B.E. CHEMICAL ENGINEERING SECOND YEAR SECOND SEMESTER  
EXAMINATION 2023**

**MECHANICAL OPERATIONS**

Time: Three hours

Full marks 100

(50 marks for each Part)

**Use Separate Answer Script for each Part.**

**PART I (50 Marks)**

Answer any two (2) questions

Assume any missing data

1. a) Differentiate jaw crusher and gyratory crusher based on following points: principal type of force for crushing, capacity, maintenance cost.  
b) Show that the shaft power required in an "agitator tank", P

$$P \propto \rho_f \cdot N^3 \cdot D_a^5$$

where,  $\rho_f$ : density of fluid; N: speed of rotation;  $D_a$ : diameter of impeller

- c) Why and how filter aid is used in a batch or continuous filtration operation?  
d) **Choose** a suitable type of pump and **justify** for the following purposes:  
i) for chemical dosing application  
ii) for extremely variable flow rate applications  
iii) for liquids with entrained gas up to 50% (by volume)  
iv) for pumping corrosive liquids

**3+7+5+10**

2. a) A mixture of silica & galena solid particles having a size range of  $5.21 \times 10^{-6} \text{m}$  to  $2.5 \times 10^{-5} \text{m}$  is to be separated by hydraulic classification using free settling conditions in water at 293.2 K temperature. The specific gravity of silica is 2.65 and that of galena is 7.5. Calculate the size range of various fractions obtained in the settling. If the settling is in the laminar region, the drag coefficient will be reasonably close to that for spheres.

b) A material is crushed in a Blake jaw crusher such that the average size of the particle is reduced from 50 mm to 10 mm, with the consumption of energy of 13.0 kW/(kg/s). What will be the consumption of energy to crush the same material of average size 75 mm to average size of 25 mm:

- i) assuming Rittinger's law applies;

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- ii) assuming Kick's law applies?
- iii) Which of these results would be regarded as being more reliable and why?
- c) Cyclones have proved to be very useful to separate solids from gases if particles are more than 5  $\mu\text{m}$ . Discuss why?
- d) A pair of rolls is to take a feed equivalent to spheres of 3 cm of diameter and crush them to spheres having 1 cm diameter. If the coefficient of friction is 0.29, what would be the diameter of rolls?

10+8+5+2

3. a) A centrifugal pump is situated 12.5 m vertically above the surface of liquid toluene in a tank which is open to atmosphere and at 30<sup>0</sup> C. Show that even if primed, the pump could not lift liquid toluene from the tank under this condition.

If the minimum NPSH of the pump is 0.65 m of water under this condition and inside pipe diameter is 2.3 cm, calculate

- i) the maximum height at which the pump could be located above the toluene surface to deliver the liquid at 0.002 m<sup>3</sup>/sec after priming, without risk of cavitation and if the suction pipe just dipped into the toluene in the tank. The pipe may be considered smooth.
- ii) The maximum delivery rate after priming which could be obtained without the risk of cavitation if the pump were located 9 m above the liquid surface with suction pipe just dipping into the liquid (friction factor has same value as in section i).

Saturated vapour pressure of toluene at 30<sup>0</sup> C: 4.535 kPa

Density of toluene at 30<sup>0</sup> C: 867 kg/m<sup>3</sup>, Viscosity of toluene at 30<sup>0</sup> C: 5.26 x 10<sup>-4</sup> kg/m-s

Density of water: 867 kg/m<sup>3</sup>

For turbulent flow in smooth pipe,  $f = 0.0390 \times N_{Re}^{-0.25}$

**OR**

A quartz mixture having the following screen analysis is screened through a standard 12 mesh Tyler screen.

Mesh	DP (mm)	Feed	Overflow	Underflow
4	4.699	0	0	
6	3.327	0.025	0.071	
8	2.362	0.15	0.43	0

10	1.651	0.47	0.85	0.195
14	1.168	0.73	0.97	0.58
20	0.833	0.885	0.99	0.83
28	0.589	0.94	1	0.91
35	0.417	0.96		0.94
65	0.208	0.98		0.975
Pan		1		1

Calculate the mass ratio of overflow and underflow of the feed and the overall effectiveness of the screen.

b) In plate & frame filter press operation, rate of through washing would be one-quarter of simple washing rate. Explain why?

c) Discuss the effect of transport solid flux and settling solid flux in designing the diameter of a continuous thickener.

d) Discuss the advantages and disadvantages of surface-velocity classifier.

10+5+5+5

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**PART II**

Answer any five questions

Assume any data missing

1. Show that Effectiveness of screen  $E = \frac{(X_F - X_B)(X_D - X_F)X_D(1 - X_B)}{(X_D - X_B)^2 \cdot X_F \cdot (1 - X_F)}$  using usual notations. 10
2. Calculate the specific surface in  $\text{cm}^2/\text{gm}$  of pyrite having screen analysis given below. Sp. gravity of Pyrite is 5. 10

Mesh	% Retained	Size (cm)
3/4	0	0.4699
4/6	8.8	0.3327
6/8	12.2	0.2362
8/10	18.0	0.1651
10/14	23.6	0.1168
14/20	19.4	0.0833
20/28	18.0	0.0589
	100.0%	

3. Rock whose average particle size 25mm is crushed to a product, whose average particle diameter is 6 mm at a rate of 10 tones/hr . At this rate the mill takes 18 kW. It requires 0.5 kW to run the mill empty. What will be the power consumption if the same feed is crushed to a particle diameter to 10 mm? Assume Rittinger's Law.
4. Show that  $C_0 Z_0 = C_i Z_i$  using Kynch theory of sedimentation.

5. A settling test conducted in a 40 cm. high cylindrical jar gave the following data

Interface height, cm.	40	20	16	14	12	9.5
Settling time in minute	0	5	7.5	8.0	10	25

The initial concentration of solids was 3000 mg/litre. Determine the thickeners area if an underflow concentration of 20,000 mg/litre is desired. The sludge is to be settled in Continuous flow unit operated at a rate of  $0.33 \text{ m}^3/\text{sec}$ . 10

6. A pump draws a solution of specific gravity 1.84 from a storage tank of large section through 8 cm id pipe. The velocity in the suction pipe is 1m/s. The pump discharges through 5cm id pipe to an overhead tank. The end of discharge line is 15m above the level of solution in the tank. Friction loss in the entire system may be taken as 3m of solution. What pressure must the pump developed and what is theoretical HP required doing this pumping. 10

7. Ruth and Kempe reported the results of laboratory filtration tests on a precipitate of  $\text{CaCO}_3$  suspended in water. A specially designed Plate and Frame Press with a single frame was used. The frame had a filtering area of  $0.283 \text{ ft}^2$  and thickness of 1.18inch. All tests were conducted at  $66^\circ\text{F}$  and  $\Delta P=40 \text{ psi}$ =constant with a slurry containing 0.0723 weight fraction  $\text{CaCO}_3$ . The density of the dried cake was  $100\text{lb}/\text{ft}^3$ . The test results for one run are given below

Vol of filtrate(lit)	0.2	0.4	0.6	0.8	1	1.2	1.4	1.6	1.8	2	2.2	2.4	2.6	2.8
Time (S)	1.8	4.2	7.5	11.2	15.4	20.5	26.7	33.4	41	48.8	57.7	67.2	77.3	88.7

Determine the filtrate volume equivalent in resistance to the filter medium and piping ( $V_e$ ), the specific cake resistance, and cake porosity and the cake specific surface taking sp.gr. 2.93. 10