

CHEMICAL ENGINEERING

Paper – I

Time Allowed : **Three Hours**

Maximum Marks : **200**

Question Paper Specific Instructions

Please read each of the following instructions carefully before attempting questions :

*There are **EIGHT** questions in all, out of which **FIVE** are to be attempted.*

*Questions no. 1 and 5 are **compulsory**. Out of the remaining **SIX** questions, **THREE** are to be attempted selecting at least **ONE** question from each of the two Sections A and B.*

Attempts of questions shall be counted in sequential order. Unless struck off, attempt of a question shall be counted even if attempted partly. Any page or portion of the page left blank in the Question-cum-Answer Booklet must be clearly struck off.

All questions carry equal marks. The number of marks carried by a question/part is indicated against it.

*Answers must be written in **ENGLISH** only.*

Unless otherwise mentioned, symbols and notations have their usual standard meanings.

Assume suitable data, if necessary, and indicate the same clearly.

Neat sketches may be drawn, wherever required.

SECTION A

- Q1.** (a) State Fick's first law of diffusion. Prove that $D_{AB} = D_{BA}$. 5
- (b) Calculate the critical speed of a ball mill, 1200 mm in diameter, charged with 75 mm balls. 5
- (c) Air at 300 K and 1.0 atm pressure flows over a flat plate at a speed of 3.0 m/sec. Find out whether the flow would be laminar or turbulent at a distance of 40 cm from the leading edge of the plate. Consider momentum diffusivity of air as $= 1.572 \times 10^{-5} \text{ m}^2/\text{s}$. 5
- (d) Give the selection criteria of choosing the solvent in gas absorption column. 5
- (e) A solution of organic colloids; 10,000 kg/hr is to be concentrated from 15% to 50% solids in a vertical tube evaporator by supplying heat of 4.624 MW. The saturated steam is available at 0.8 atm absolute pressure, latent heat = 2272.62 J/kg. Calculate the economy for the evaporator. 5
- (f) Draw and explain the characteristic curves for centrifugal pump. 5
- (g) The x-directed momentum transfer equation for constant density and viscosity is given by
- $$\rho \left(\frac{\partial v_x}{\partial t} + v_x \frac{\partial v_x}{\partial x} + v_y \frac{\partial v_x}{\partial y} + v_z \frac{\partial v_x}{\partial z} \right) = - \frac{\partial p}{\partial x} + \mu \left[\frac{\partial^2 v_x}{\partial x^2} + \frac{\partial^2 v_x}{\partial y^2} + \frac{\partial^2 v_x}{\partial z^2} \right] + \rho g_x.$$
- Write the assumptions of creeping flow and inviscid flow. Also reduce the above expression for both types of flows. 5
- (h) For fluid allocation in a shell and tube heat exchanger, discuss the general design criteria considering corrosion, fouling, fluid temperature and operating pressure. 5

Q2. (a) Differentiate between the following :

- (i) Dropwise condensation and Film condensation
- (ii) Space and Surface resistance
- (iii) Forced and Free convection
- (iv) Black body and Grey body
- (v) Conduction and Convection

15

(b) A liquid mixture of benzene and toluene containing 50 mole percent benzene is to be separated in a distillation column to achieve 98 mole percent benzene in distillate and 2 mole percent benzene in residue. The feed is a saturated liquid. If the reflux ratio of 4.0 is to be used, find the number of theoretical plates needed for a feed rate of 100 kmol/hr by McCabe-Thiele method. Use relative volatility of benzene-toluene = 2.16. Also, calculate the production rates.

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(c) Explain the batch sedimentation process showing different zones formed at various stages of settling.

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Q3. (a) Explain the working of rotary vacuum drum filter with the help of neat sketch.

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(b) Suppose a 3 inch schedule 80 pipe (inside diameter = 73.66 mm; outside diameter = 88.9 mm) having thermal conductivity of $43 \frac{\text{W}}{\text{m}^\circ\text{C}}$ is covered with 25.4 mm of an insulation having thermal conductivity of $0.06 \frac{\text{W}}{\text{m}^\circ\text{C}}$. The outside of the insulation is exposed to an environment having heat transfer coefficient of $10 \frac{\text{W}}{\text{m}^2\text{C}}$ and temperature is 20°C . The temperature of the inside surface of the pipe is 250°C . Calculate the overall thermal resistance and heat loss for unit length of the pipe with insulation.

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- (c) Oxalic acid is to be crystallized from a saturated aqueous solution initially at 80°C. To what temperature does the solution have to be cooled to crystallize 95% of the oxalic acid as the dihydrate? 15.

Solubility data vs Temperature of oxalic acid

Temp °C	0	10	20	40	60	80
Solubility c gms/100 gmol H ₂ O	3.5	6	9.5	21.6	44.3	84.4

- Q4.** (a) Explain briefly the following terms : 10

- (i) Relative humidity
- (ii) Adiabatic saturation temperature
- (iii) Wet bulb temperature
- (iv) Equilibrium moisture content
- (v) HETP

- (b) A shell and tube heat exchanger with one shell pass and two tube passes is used to heat 5 kg/s of water from 30°C to 80°C. The water flows in the tubes and condensing steam at 1 atm is used in the shell side. Calculate the area of the heat exchanger, if overall heat transfer coefficient is $900 \frac{\text{W}}{\text{m}^2\text{°C}}$. Suppose, this same heat exchanger is used with entering water at 30°C, but with a water flow rate of 1.3 kg/s. What would be the exit water temperature under these conditions, if overall heat transfer coefficient is $700 \frac{\text{W}}{\text{m}^2\text{°C}}$? The specific heat of water may be considered as $4179 \frac{\text{J}}{\text{kg}\text{°C}}$. The relation of effectiveness (ϵ) and number of transfer units (NTU) may be expressed as $\epsilon = 1 - \exp[-\text{NTU}]$. 15

- (c) Water at 20°C is being pumped from a tank to an elevated tank at the rate of 5 litre/s through a 4 inch schedule 40 pipe (Inside Diameter = 0.1023 m) as shown in the figure below. Calculate the power required for the pump considering pump efficiency as 65%.

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Given Data :

density of water = 998.2 kg/m³

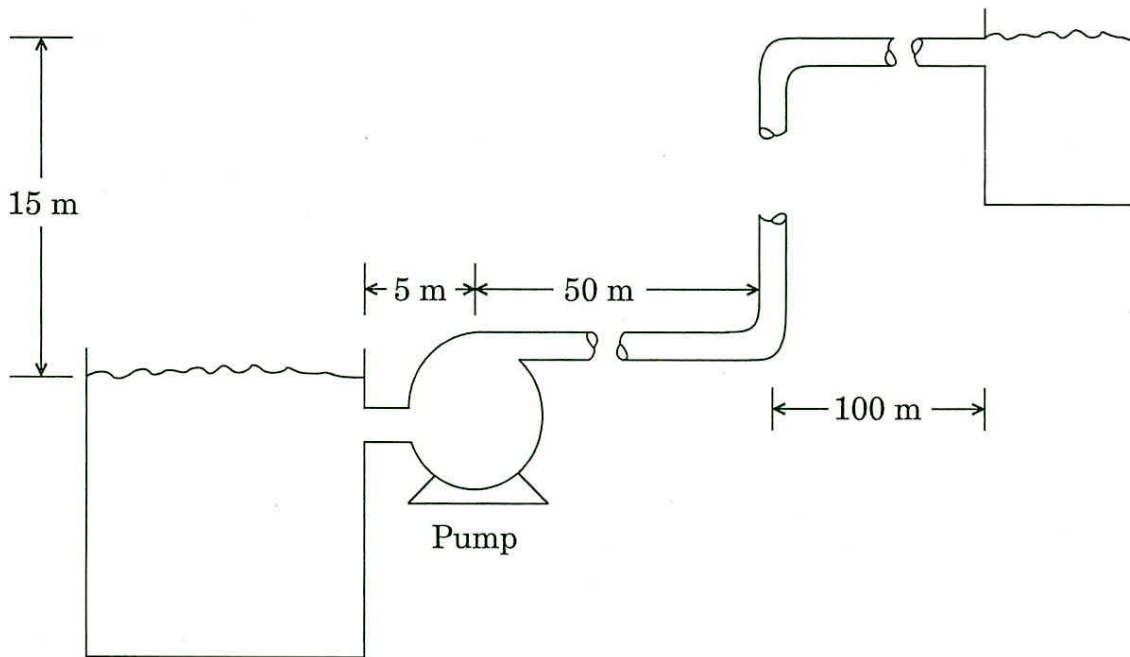
viscosity of water = 1.005 × 10⁻³ Pa-s

loss coefficient for elbow = 0.75

friction factor (f) = $\frac{16}{\text{Reynolds number } (N_{\text{Re}})}$ (Laminar flow)

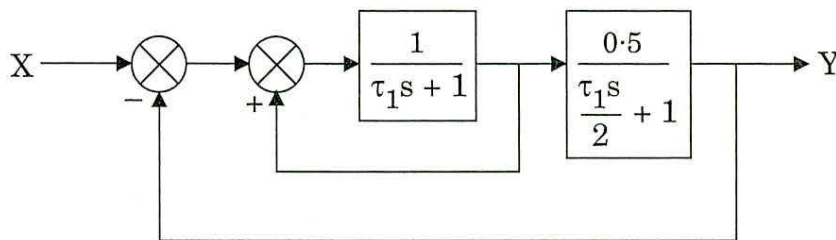
f = 0.079 N_{Re}^{-0.25} (4000 < N_{Re} < 10⁵)

Neglect contraction and expansion losses.



SECTION B

- Q5. (a) List the important characteristics to be considered while selecting a material of construction. 5
- (b) Define the following : 5
- (i) Flux
 - (ii) Permeability
 - (iii) Trans-membrane pressure
 - (iv) Molecular weight cut-off
- (c) Estimate the thickness of the cylindrical vessel having 1.5 m diameter. The vessel is to operate at a pressure of 15 bar absolute and temperature of 300°C. 5
- Given – MOC : Steel (Design stress = 85 N/mm²); A corrosion allowance of 3 mm and Joint efficiency (J) = 1.0.
- (d) What are Horton spheres ? Give its applications. 5
- (e) Define controller's gain, K_c and discuss the effect of value of K_c on the offset. 5
- (f) Find the transfer function $Y(s)/X(s)$ of the system shown in the figure. 5



- (g) List the devices used for high temperature measurement in industry giving their applications. 5

- (h) A step change of magnitude 40 is introduced into a system having transfer function $\frac{Y(s)}{X(s)} = \frac{10}{s^2 + 1.6s + 4}$.

Determine :

5

- (i) Overshoot
- (ii) Maximum value of $y(t)$
- (iii) Ultimate value of $y(t)$

- Q6.** (a) Discuss the algorithm for the design of a skirt support for a tall vertical vessel.

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- (b) Find the value of K_c for a stable system having the characteristic equation

$$s^3 + 6s^2 + 12s + 6(1 + K_c) = 0$$

using Routh Array test.

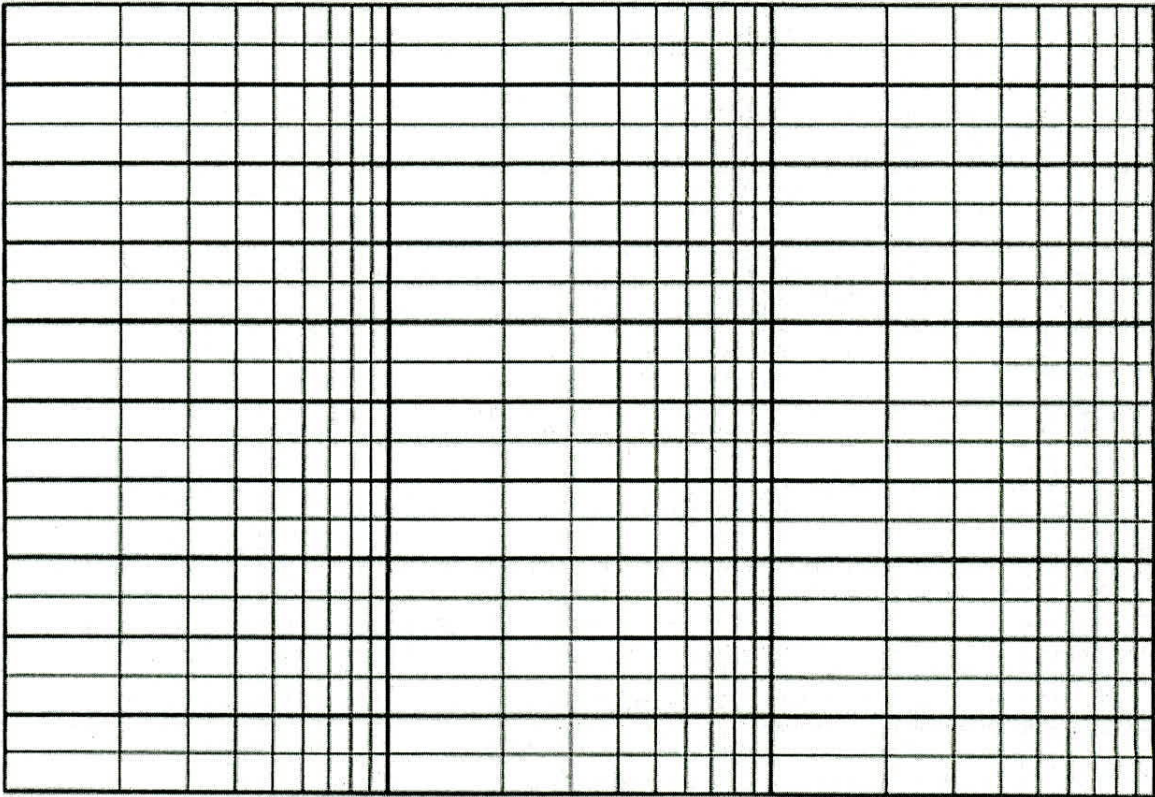
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- (c) Discuss the different membrane modules used for reverse osmosis.

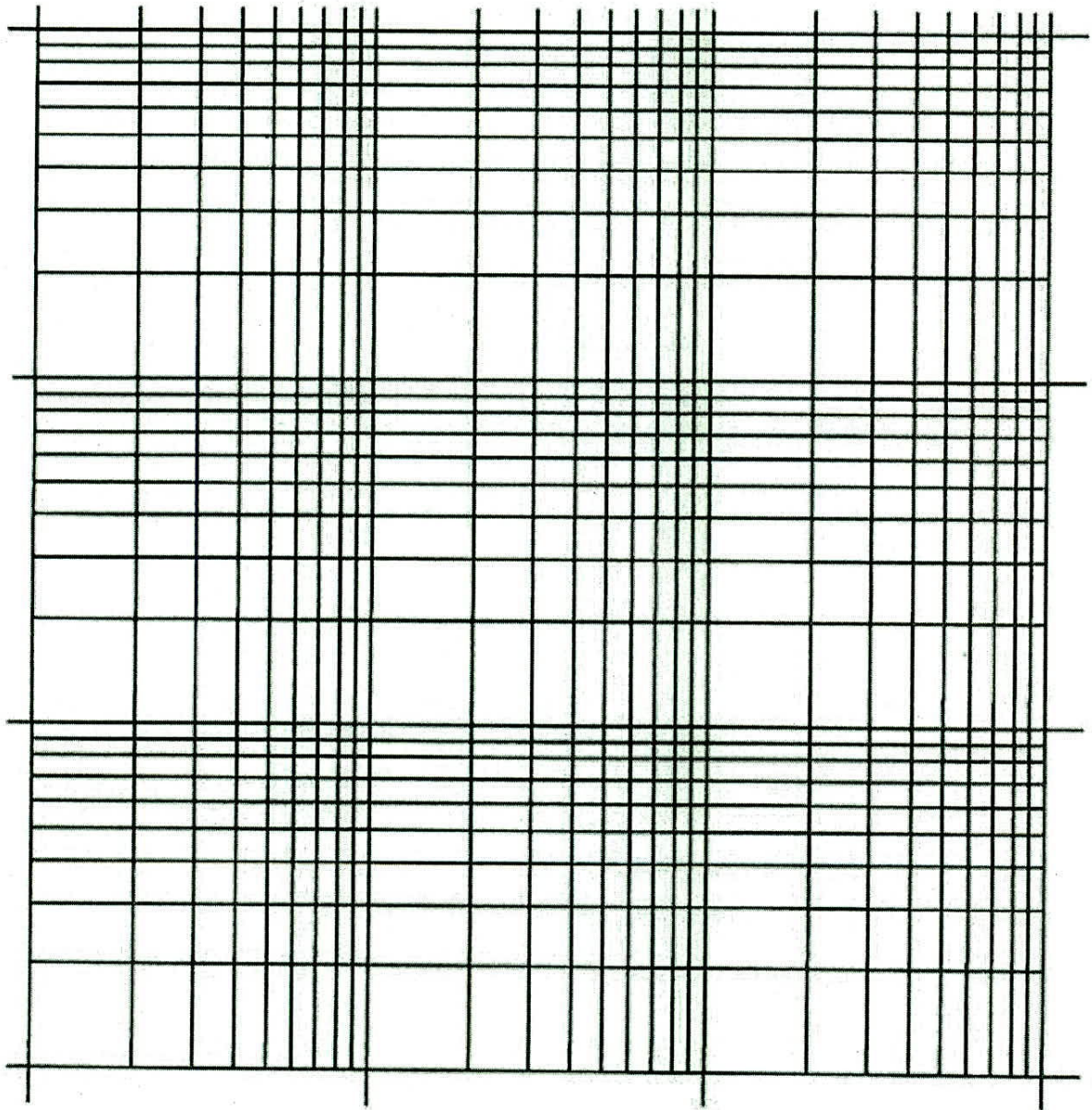
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Q7. (a) Construct the Bode plot for the system having $G(s) = \frac{1}{(s+1)(s+5)}$. 20

Semi log graph paper



Log log graph paper



- (b) What are the advantages of supercritical fluid separation technique ?
List four applications for the same. 10
- (c) List the different types of closures used for vessels under internal pressure. Draw neat sketches of the same. On what factors does the choice of closure depend ? 10

- Q8.** (a) Describe the working of Bourdon tube pressure gauge with the help of a neat diagram. 10
- (b) Explain the principles of ion-exchange method and its application to water softening process. 15
- (c) Answer the following in brief : 15
- (i) What are the various losses encountered while storing volatile liquids ?
 - (ii) What are wind girders ? Why are they provided ?
 - (iii) What is reinforcement ? Why is it provided ?