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 = $1{\cdot}572 \times 10^{-5}$ m^2/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 kmoles/hr by McCabe-Thiele method. Use relative volatility of benzene-toluene = 2·16. Also, calculate the production rates. *15*

(c) Explain the batch sedimentation process showing different zones formed at various stages of settling. *10*

Q3. (a) Explain the working of rotary vacuum drum filter with the help of neat sketch. *10*

(b) Suppose a 3 inch schedule 80 pipe (inside diameter = 73·66 mm; outside diameter = 88·9 mm) having thermal conductivity of 43 $\frac{W}{m°C}$ is covered with 25·4 mm of an insulation having thermal conductivity of 0·06 $\frac{W}{m°C}$. The outside of the insulation is exposed to an environment having heat transfer coefficient of 10 $\frac{W}{m^2°C}$ 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. *15*

(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_2O	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 $\frac{W}{m^2 \, °C}$. 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 $\frac{W}{m^2 \, °C}$? The specific heat of water may be considered as 4179 $\frac{J}{kg°C}$. The relation of effectiveness (ε) and number of transfer units (NTU) may be expressed as $\varepsilon = 1 - \exp[-\text{NTU}]$. *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%. *15*

Given Data :

density of water = $998{\cdot}2\ kg/m^3$

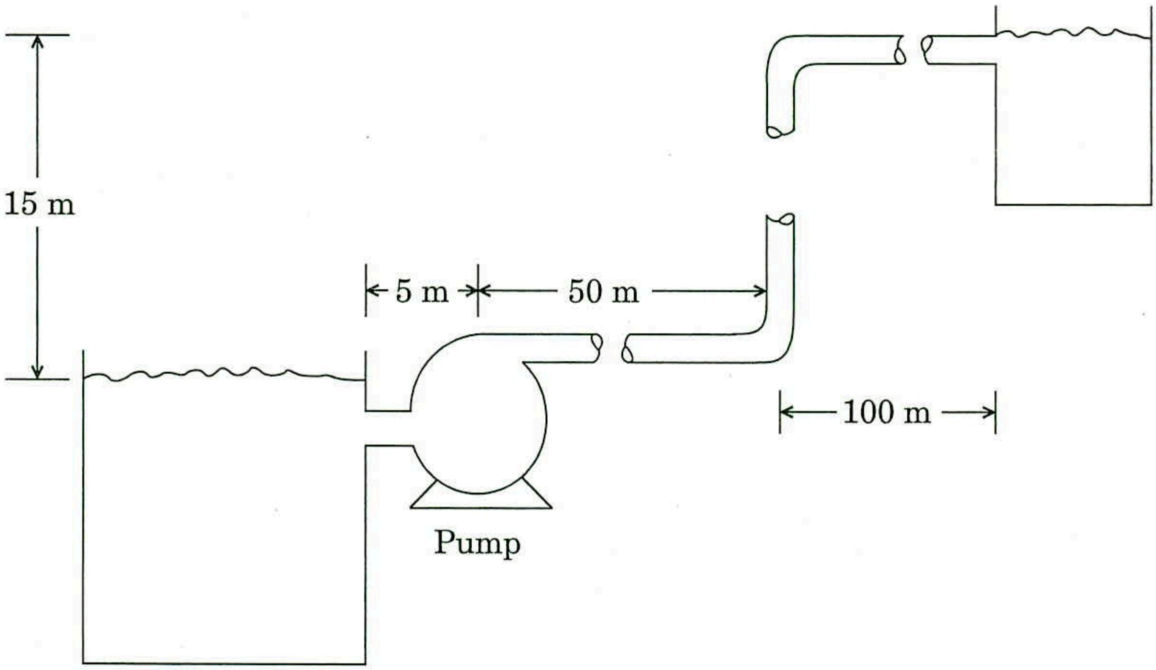
viscosity of water = $1{\cdot}005 \times 10^{-3}$ Pa-s

loss coefficient for elbow = 0·75

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

$$f = 0{\cdot}079\ N_{Re}^{-0{\cdot}25}\ (4000 < N_{Re} < 10^5)$$

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 :

(i) Flux

(ii) Permeability

(iii) Trans-membrane pressure

(iv) Molecular weight cut-off 5

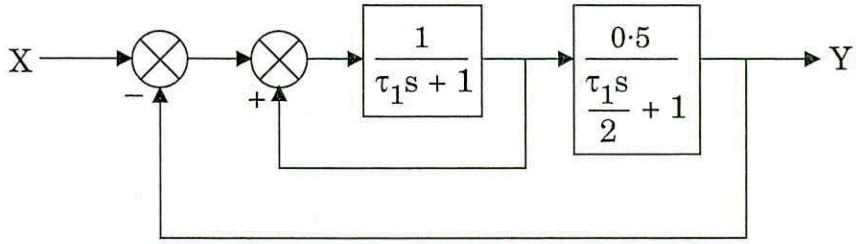
(c) Estimate the thickness of the cylindrical vessel having 1·5 m diameter. The vessel is to operate at a pressure of 15 bar absolute and temperature of 300°C. 5

Given – MOC : Steel (Design stress = 85 N/mm^2); 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 $\frac{Y(s)}{X(s)} = \frac{10}{s^2 + 1{\cdot}6s + 4}$.

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. *15*

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

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

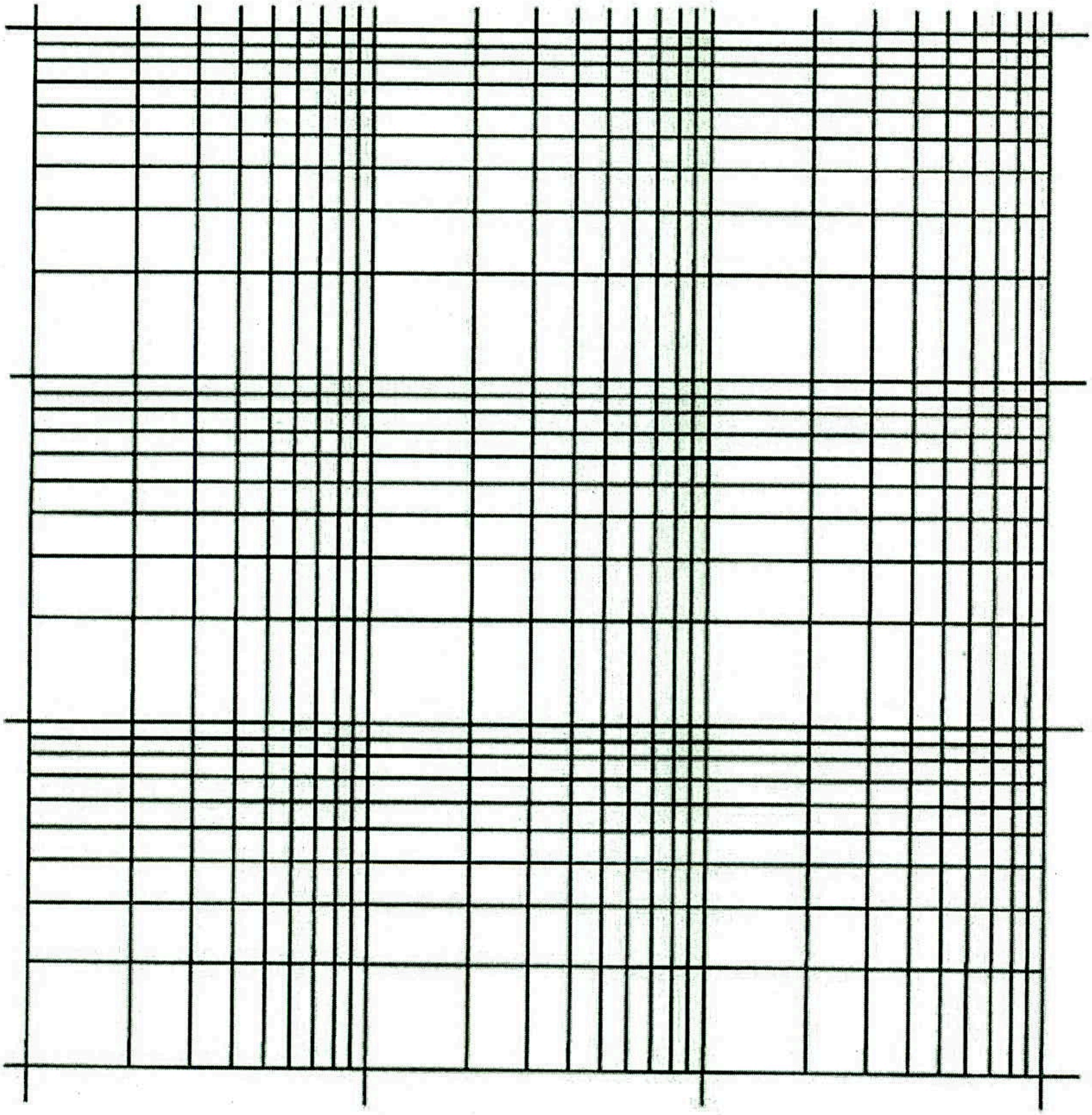
using Routh Array test. *10*

(c) Discuss the different membrane modules used for reverse osmosis. *15*

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