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.

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.

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

SECTION A

Q1. (a) (i) What do you know about nominal diameter and schedule number of pipes ? Explain. *4*

(ii) What is equivalent diameter of a pipe of non-circular cross-section ? *4*

(b) 200 ton/h of rock feed, of which 80% passed through a mesh size of 2·56 mm, were reduced in size such that 80% of the crushed product passed through a mesh size of 1·28 mm. The power consumption was 150 kW. If 200 ton/h of the same material is similarly crushed from a mesh size of 5·1 mm to a mesh size of 2·56 mm, then estimate the power consumption (in kW) using Bond's Law. *8*

(c) A solid loading (dry basis) of 60 kg/m^2 is dried with a constant drying rate of 6 kg/m^{2}h. Consider the falling rate of drying is linear with moisture content. Calculate the drying time (in h) required to reduce an initial moisture content of 26% (wet basis) to a final moisture content of 2% (wet basis). The critical moisture and equilibrium moisture content on dry basis are 0·1 and 0·005 respectively. *8*

(d) In absorption column, mechanical entrainment phenomena occurs. Under what conditions does mechanical entrainment phenomena occur in tray absorption column ? How does it affect the tray efficiency ? *8*

(e) The form is the same for the Nusselt number and the Biot number. How are they different from one another in terms of the variables used and their physical significance ? *8*

Q2. (a) Determine the loss of head due to friction, when water at 18°C flows through a 310 m long galvanized steel pipe of 140 mm diameter at 0·042 m^3/s. Also, calculate the power required for pumping the water to maintain the above flow. *10*

Given data :

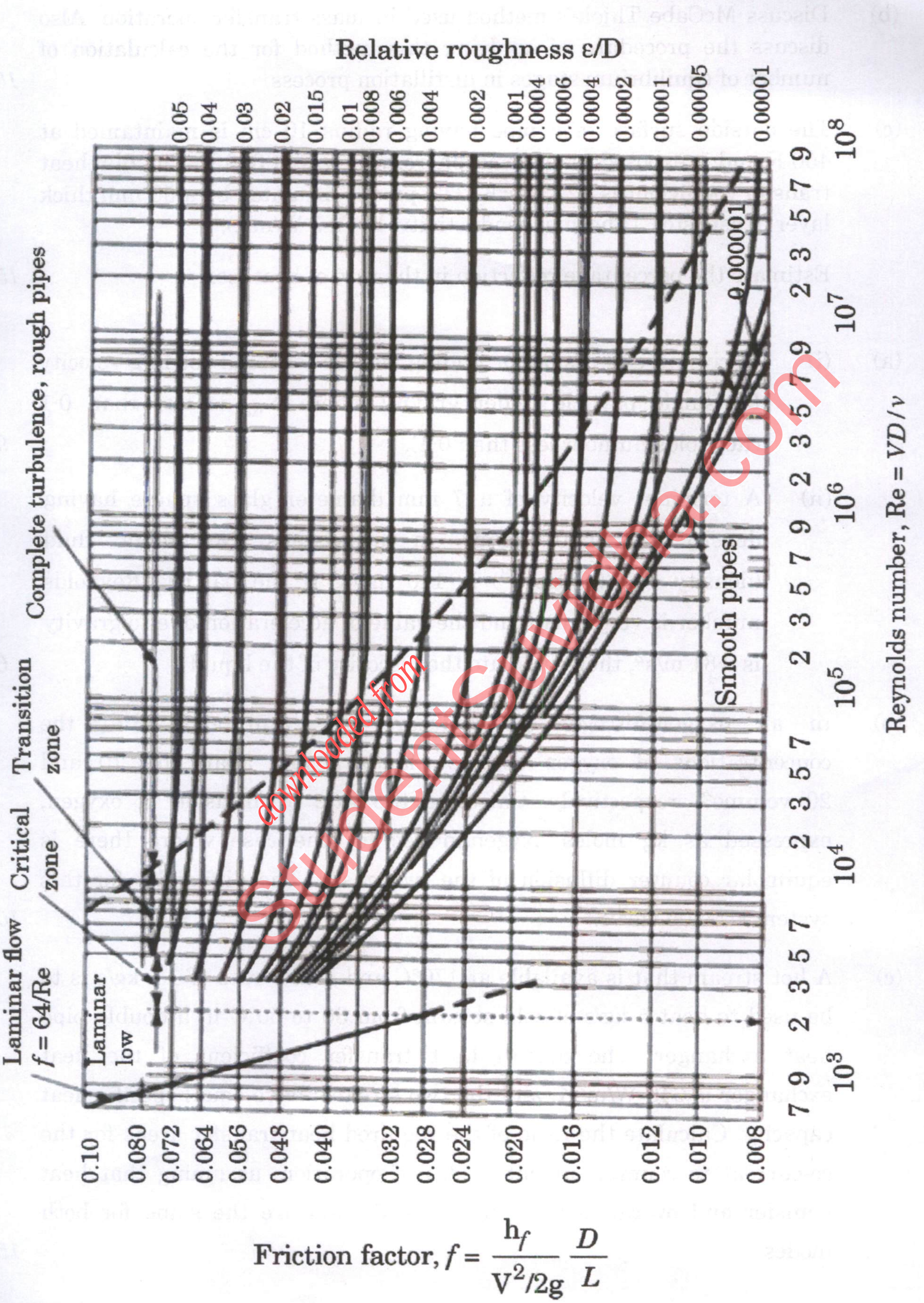
Kinematic viscosity of water at 18°C

$= 1{\cdot}15 \times 10^{-6}$ m^2/s

Average surface roughness of galvanized steel = 0·15 mm

Density of water at 18°C = 1000 kg/m^3

Friction factor vs Reynolds number chart given herewith, may be used.



Friction Factors for pipes (adapted from Trans, ASME, 66, 672, 1944)

(b) Discuss McCabe Thiele's method used in mass transfer operation. Also discuss the procedure of applying this method for the calculation of number of equilibrium stages in distillation process. *15*

(c) The outside surface of a pipe having radius 10 cm is maintained at 450 K and is exposed to an atmosphere, which is at 350 K. The film heat transfer coefficient is 12 W/m^2K. The pipe is insulated by a 50 mm thick layer of asbestos. (Thermal conductivity, k = 0·5 W/mK).

Estimate the percentage reduction in the rate of heat loss. *15*

Q3. (a) (i) Derive an expression for finding out the terminal settling velocity for single particle under gravity where N_{Re} is less than 0·1 (Reynolds number less than 0·1). *9*

(ii) A terminal velocity of a 7 mm diameter glass sphere having density of 2600 kg/m^3 in a viscous Newtonian fluid (density = 1600 kg/m^3) is 110 μm/s. If the particle Reynolds number is very small and the value of acceleration due to gravity is 9·81 m/s^2, then calculate the viscosity of the liquid. *6*

(b) In an oxygen-nitrogen gas mixture at 1 atm and 25°C, the concentrations of oxygen at two planes 3 mm apart are 10 and 20 volume% respectively. Calculate the rate of diffusion of oxygen, expressed as kg moles oxygen/m^2/sec for the case where there is equimolar counter diffusion of the two gases. The diffusivity for this system is 0·206 cm^2/s. *10*

(c) A hot stream that is available at 170°C and a flow rate of 1·5 kg/s is to be used to heat 5 kg/s of cold stream from 30 to 50°C in a double pipe heat exchanger. The overall heat transfer coefficient of the heat exchanger is 640 W/m^2K, and the two streams have equal specific heat capacity. Calculate the ratio of the required heat transfer areas for the co-current to counter-current modes of operation, assuming that heat transfer and overall heat transfer coefficients are the same for both modes. *15*

Q4. (a) A nozzle of 8 cm diameter inclined at an angle of 30° above the horizontal discharges 0·045 m^3 of liquid. Determine the maximum height to which it rises and its horizontal travel at the nozzle level. If the nozzle was inclined at 45°, calculate the corresponding distances. *10*

(b) 20,000 kg/h of a solution containing 20% NaOH, 20% NaCl and 60% water by weight is fed continuously to an evaporator. Water content is reduced in this process and NaCl precipitates as crystals and is removed from the remaining liquor. The concentrated liquor leaving the evaporator contains 70% NaOH, 4% NaCl and 26% water. *15*

Calculate :

(i) kg of water evaporated per hour

(ii) kg of salt precipitated per hour

(iii) kg of concentrated liquor produced per hour

(c) Two infinite parallel plates are kept at temperatures of 900 K and 600 K. Consider the emissivity as 0·7 for the hot plate and 0·5 for the cold plate. Calculate the radiant heat exchange in W/m^2 between these two infinite parallel plates. *15*

(Stefan-Boltzmann's constant = $5{\cdot}669 \times 10^{-8}$ W/m^2K^4)

SECTION B

Q5. (a) Describe the mechanism of the dialysis process used to remove waste materials from human blood. *8*

(b) Describe the significance of the following mechanical properties of any material : *8*

(i) Fatigue

(ii) Creep

(iii) Resilience

(iv) Ductility

(c) Discuss the Bracket or Lug support for vessels. Which type of vessels are suitably supported by these supports ? Explain. *8*

(d) Find the solution to the following Laplace equation : *8*

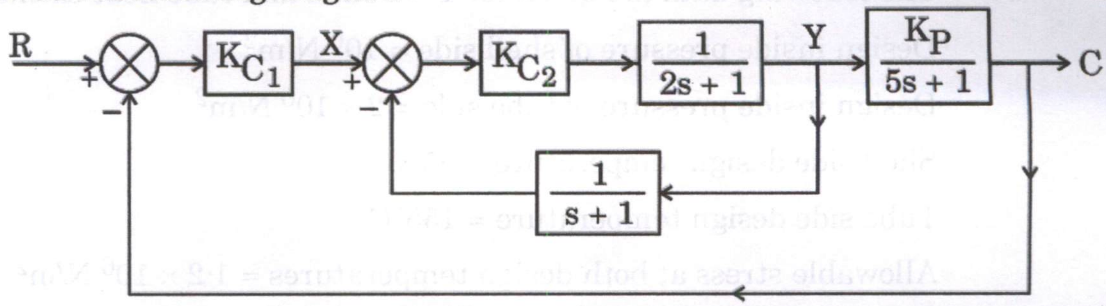
$$F(s) = \frac{s+2}{s(s+1)(s+3)}$$

(e) Define the term "Time constant". A thermometer with a time constant of 0·4 minutes is at a steady state temperature of 40°C. At time t = 0, the thermometer is placed in a bath maintained at 45°C. What will be the temperature read by the thermometer after 0·3 minutes ? *8*

Q6. (a) What is ultrafiltration ? Explain the term 'fouling' in this process and suggest the remedial measures for the same. *15*

(b) Describe common types of formed heads for cylindrical vessels and their usages with suitable sketches. *10*

(c) Given the following diagram : 15



(i) Express the transfer function (C/R) as a ratio of polynomials in terms of 's'.

(ii) Calculate the offset in C due to a unit step change in the reference signal (set point) R.

Q7. (a) (i) Explain the process of molecular distillation. 7

(ii) Enlist the four, most common types of membrane modules in membrane separation. Explain any one of them in detail. 8

(b) Discuss the different types of storage tanks for storing volatile and non-volatile liquids. 15

(c) Draw the response of a second order underdamped system. Also define the terms : 10

(i) Overshoot

(ii) Decay ratio

(iii) Rise time

(iv) Response time

Q8. (a) A dilute solution containing a solute A having concentration 3×10^{-2} kg mol/m^3 is flowing through a membrane of thickness 3×10^{-5} m. The membrane diffusivity of solute and the distribution coefficient are 6×10^{-11} m^2/s and 1·6 respectively. The solute diffuses through the membrane. The concentration of the solute in permeate side is $0{\cdot}6 \times 10^{-2}$ kg mol/m^3. The mass transfer coefficient of feed side is large and can be considered as infinite and permeate side is 2×10^{-5} m/s. Calculate the flux of solute and the concentrations at the membrane interfaces. 15

(b) The following data are given for 1 – 1 shell and tube heat exchanger :

Design inside pressure of shell side = 10^6 N/m^2

Design inside pressure of tube side = 2×10^6 N/m^2

Shell side design temperature = 55°C

Tube side design temperature = 155°C

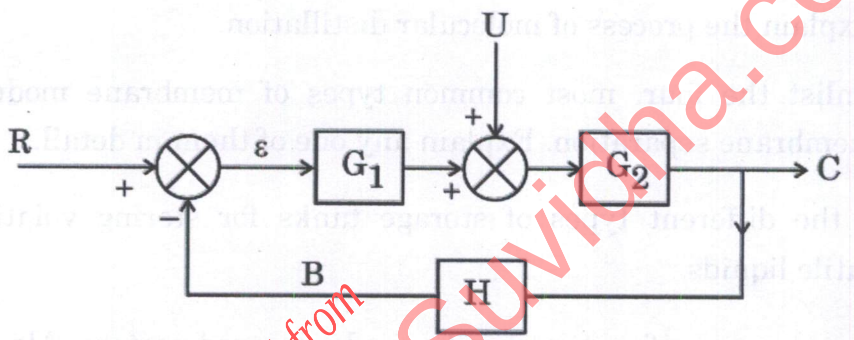
Allowable stress at both design temperatures = $1{\cdot}2 \times 10^6$ N/m^2

Corrosion allowance for shell = 4×10^{-3} m

Joint efficiency = 1; Shell inside diameter = 60 cm

Estimate the shell thickness. 10

(c) Consider the following single loop control system : 15



The transfer functions are :

$$G_1 = 10\,\frac{0{\cdot}5s + 1}{s} \text{ (PI controller)}$$

$$G_2 = \frac{1}{2s + 1} \text{ (Stirred tank)}$$

H = 1 (measuring element without lag)

Find the characteristic equation, its roots and determine whether the system is stable or not.