FS – 11 / 15-16

Chemical Engineering

Paper – I

Time : 3 hours

Full Marks : 200

The figures in the right-hand margin indicate marks.

*Candidates should attempt Q. No. 1 from Section – A and Q. No. 5 from Section – B which are compulsory and any **three** of the remaining questions, selecting at least **one** from each Section.*

SECTION – A

1. Answer the following questions : 10×4 = 40

(a) Explain, with example, the shear stress and shear rate behaviour of pseudoplastic. Bingham-plastic and Dilatants fluid. How apparent viscosity of these fluids depends on shear rate ? What do you mean by Eddy viscosity ?

(b) State Fick's first and second law of diffusion. Explain the mechanism of turbulent mass

transfer with the help of boundary layer diagram. What are the factors on which mass transfer coefficient depends ? What do you mean by critical and equilibrium moisture content ? Explain it from drying characteristics curve.

(c) Define the minimum fluidization velocity for a gas-solid system. Explain how a fluidized bed is characterized. State Rittinger's law and how it is used to calculate energy consumption. What do you mean by free settling velocity of particle ? Which is the most important factor which influences the settling velocity ?

(d) Explain Fourier law of heat conduction. Where and why LMTD correction factor is needed for design of heat exchanger ? Define steam economy. Define emissivity and absorptivity of a grey body. What is the physical significance of Nusselt Number ?

2. (a) Water is flowing in a circular pipe of radius rw with a following velocity profile approximated by a parabola as $V = Vmax [1 - 0.4 (r/rW)^2]$ in turbulent flow condition,

where V = velocity of water at any position 'r' in m/s and Vmax = Maximum velocity at the centre of the pipe. Find out the kinetic energy correction factor, "a". 20

(b) What is relative volatility ? For a binary system show how minimum number of theoretical stages are calculated. 20

3. (a) A hot oil from a distillation column is flowing through a pipeline of 100 mm ID at 78°C at the rate of 30 m^3/min. The oil is to be cooled by using cold water at 27°C with the help of concentric pipe of diameter 150 mm ID. The water passes through the annulus of concentric tube at the rate of 120 kg/min. The density of the Oil and Water are 880 kg/m^3 and 990 kg/m^3. The viscosity of oil is 1.2 cP. Calculate the Reynolds number for the water flow and oil flow through the pipes. Describe the pattern of flow as laminar or turbulent. If the Reynolds number is 1500 for oil, what is the flow rate in kg/hr through the annulus pipe ? 25

(b) A standard cast iron pipe of ID = 5 cm and OD = 5.5 cm is insulated with 85% magnesium insulation (K = 0.02 W/m°C). The temperature at the interface between the pipe and the insulation is 300°C. The allowable heat loss through the pipe is 600 W/m length of pipe and for safety the temperature of the outside surface of the insulation must not exceed 100°C. Calculate : Minimum thickness of insulation required and the temperature of inside surface of the pipe assuming K = 20 W/m°C. 15

4. (a) Ammonia gas is diffusing at a constant rate through a layer of stagnant air 2 mm thick. Conditions are such that the gas contains 50 per cent by volume ammonia at one boundary of the stagnant layer. The ammonia diffusing to the other boundary is quickly absorbed and the concentration is negligible, at that plane. The temperature is 295 K and the pressure atmospheric, and under these conditions the diffusivity of ammonia in air is

1.8×10^{-5} m^2/s. Estimate the rate of diffusion of ammonia through the layer. 20

(b) The rate of flow of water in a 150 mm diameter pipe is measured with a Venturi-meter with a 50 mm diameter throat. When the pressure drop over the converging section is 121 mm of water, the mass flow rate of water is 2.91 kg/s. Calculate the coefficient of discharge for the Venturi-meter. If the flow rate of water changes and corresponding pressure drop across the manometer indicates 160 mm of water in the converging section, what will be the flow rate of water ? 20

SECTION – B

5. Answer the following questions : $10 \times 4 = 40$

(a) Explain the working principle of electro-dialysis. What is the difference between reverse osmosis and osmosis ? What are the preferable properties of supercritical fluids ? How molecular weight cut-off is decided in membrane separation ?

(b) Explain, with example, the working principle of a manipulated variable system. Derive an expression for transfer function for any liquid-level system. Prepare a block diagram of a chemical reactor control system of your choice.

(c) How operating velocity is calculated for a distillation column design ? What do you mean by economic pipe diameter and how is it calculated ? How supports for vertical vessel and horizontal vessel are selected ? What is Break even point ?

(d) Explain the design procedure of an elliptical head. What are the criteria for selecting ion-exchanged resigns ? State the various PID controllers used in industry. What is the difference between analog and digital output of a signal ?

6. A SS pressure vessel operating at internal pressure on 0.4 N/mm^2 of shell internal diameter 1200 mm, permissible stress at 150°C is 130 N/mm^2. The head used for design is flanged shallow dished type with external diameter of

1200 mm, crown radius 1200 mm and knuckle radius of 72 mm. In additional data required if any may be assumed suitably with justification. Calculate : 40

(a) Thickness of pressure vessel

(b) Total stress in longitudinal and axial directions

(c) Thickness of head

7. A lipid solution from a manufacturing process plant is ultrafiltered in 0.06 M NaCl solution with mass transfer coefficient 4×10^{-5} m/s. Filtration is gel layer controlled with gel a concentration of 120 kg/m^3 and feed concentration 2 kg/m^3. Charge on lipid is 4e and radius is 6 nm. 40

(a) What is permeate flux ?

(b) If 600 V/m external electric field is applied, what is permeate flux ?

8. A step change of magnitude of 4 is introduced into a system having the transfer function : 40

$$\frac{Y(s)}{X(s)} = \frac{10}{s^2 + 1.6s + 4}$$

Calculate :

(a) Percent overshoot

(b) Rise time

(c) Maximum value of Y(t)

(d) Ultimate value of Y(t)

(e) Period of oscillation