# RAMAKRISHNA MISSION VIDYAMANDIRA

(Residential Autonomous College affiliated to University of Calcutta)

**B.A./B.Sc. FIFTH SEMESTER EXAMINATION, FEBRUARY 2022**

**THIRD YEAR [BATCH 2019-22]**

**INDUSTRIAL CHEMISTRY (Honours)**

**Paper : XI [CC11]**

Date : 26/02/2022

Time : 11 am – 1 pm

Full Marks : 50

## Unit-I

Question No. 1 is **compulsory** :

*[Symbols are usual significance]*

1. Answer the correct one [1×6]

a) A copper block and an air mass block having similar dimensions are subjected to symmetrically heat transfer from one face of each block. The outer face of the block will be reaching to the same temperature at a rate

i) Faster in the air block ii) Faster in copper block

iii) Equal in air as well as copper block iv) cannot be predicted

b) A furnace is made of a red brick wall of thickness 0.5 m and conductivity 0.7 W/mK. For the same heat loss and temperature drop, this can be replaced by a layer of diatomite earth of conductivity 0.14 W/mK and thickness

i) 0.05 m ii) 0.1 m iii) 0.2 m iv) 0.5m

c) For fully-developed turbulent flow in a pipe with heating, the Nusselt number, Nu, varies with the Reynolds number, Re and Prandtl number, Pr, as

i) $Re^{0.5}Pr^{0.333}$ ii) $Re^{0.8}Pr^{0.2}$ iii) $Re^{0.8}Pr^{0.4}$ iv) $Re^{0.8}Pr^{0.3}$

d) in a counter flow heat exchanger, the hot fluid is cooled from 110°C to 80°C by a cold fluid which gets heated from 30°C to 60°C. LMTD for the heat exchanger is

i) 20°C ii) 30°C iii) 50°C iv) 80°C

e) The properties of mercury at 300K are: density = 13529 kg/$m^3$; specific heat at constant pressure = 0.1393 kJ/kgK; dynamic viscosity = $0.1523 X 10^{-2}$ N.s/$m^2$ and thermal conductivity = 8.540 W/mK. The Prandlt number of the mercury at 300K is:

i) 0.0248 ii) 2.48 iii) 24.8 iv) 248

f) Upto the critical radius of insulation

i) Added insulation increases heat loss

ii) Added insulation decreases heat loss

iii) Convection heat loss is less than conduction heat loss

iv) Heat flux decreases

Answer **any three** questions of the following: [3×8]

2. a) State and explain Fourier's law of heat conduction.

   b) Write the significance of thermal diffusivity.

   c) An exterior wall of a house may be approximated by a 0.1 m layer of common brick (k=0.7W/mK) followed by a 0.04m layer of gypsum plaster (k=0.48 W/mK). What thickness of loosely packed rock wool insulation (k=0.065 W/mK) should be added to reduce the heat loss or gain through the wall by 80%? [1+2+5]

3. a) Derive an expression for the critical insulation thickness for spherical body.

   b) An aluminium pipe carries steam at 110$^o$C. The pipe (k=185 W/mK) has an inner diameter of 100 mm and outer diameter of 120 mm. The pipe is located in a room where the ambient air temperature is 30$^o$C and the convective heat transfer coefficient between the pipe and air is 15 W/m$^2$K. Determine the heat transfer rate per unit length of pipe.

   To reduce the heat loss from the pipe, it is covered with a 50 mm thick layer of insulation (k=0.2 W/mK). Determine the heat transfer rate per unit length from the insulated pipe. Assume that the convective resistance of the steam is negligible. [3+5]

4. a) Differentiate between free and force convection.

   b) Write the significance of Re and Pr.

   c) A nuclear reactor with its core constructed of parallel vertical plates 2.2 m high and 1.4 m wide has been designed on free convection heating of liquid bismuth. The maximum temperature of the plate surfaces is limited to 960$^o$C while the lowest allowable temperature of bismuth is 340$^o$C. Calculate the maximum possible heat dissipation from both sides of each plate.

   For the convective coefficient, the appropriate correlation is

   $$Nu = 0.13(Gr.\text{Pr})^{0.333}$$

   Where different parameters are evaluated at the mean film temperature.

   The mean film temperature , $T_f = \frac{960+340}{2} = 650^o C$

   The thermo-physical properties of bismuth are

   $\rho = 10^4$ kg/m$^3$; $\mu$=3.12Kg.m/hr; $C_p$=150.7 J/kgK; k=13.02 W/mK [2+2+4]

5. a) What is fouling in heat exchanger?

   b) Derive an expression for logarithmic mean temperature difference (LMTD) in the case of parallel-flow heat exchanger.

   c) The flow rate of hot and cold water streams running through a parallel flow heat exchanger are 0.2 kg/s and 0.5 kg/s respectively. The inlet temperatures on the hot and cold sides are 75$^o$C and 20$^o$C respectively. The exit temperature of hot water is 45$^o$C. If the individual heat transfer coefficients on both sides are 650 W/m$^2$K. Calculate the area of the heat exchanger. [1+3+4]

# Unit-II

Question No. 6 is **compulsory** :

6. What is "minimum fluidization velocity"? Explain in brief. [2]

Answer **any two** questions of the following: [2×9]

7. a) A roll crusher crushes particles of maximum size 2 in. (assume spherical particle). The roll size is 18 in dia and gap between the two rolls is 0.25 in. What is the angle of nip? If the particles get wet, the coefficient of friction decreases by 25%. What will now be the maximum size of particle the crusher will be able to crush? [3]

   b) The following data are available for a particular filtration in a plate and frame filter press for a particular loading (that is concentration of solid particles in slurry: wt of solid/wt of clear liquid)

| t min | Filtrate vol lit | Cake thickness mm |
|---|---|---|
| 0 | 0 | 0 |
| 13.3 | 10 | 5 |
| 104 | 30 | 15 |

Frame size limits the cake thickness to 15 mm.

For another slurry with twice the loading, how long it will take for the frame to fill up with cake.

Note that filtration rate Q (=dV/dt) may, according to Darcy's law, be expressed as

$$Q = \Delta p/(a + b\alpha V),$$

where a and b are constants, $\alpha$ is the solids loading of the slurry, $\Delta p$ is pressure drop maintained constant, and V is the filtrate volume. [3]

   c) A CSTR of volume **V** and volumetric input rate **Q** shows a conversion of 25%. Calculate the relative volume of a plug flow reactor giving the same conversion, assuming 1st order kinetics and same volumetric input rate and no change in volume due to reaction. [3]

8. a) In an Andreasen pipette experiment the tip of the pipette is at a depth of 20 cm from the liquid surface. Samples withdrawn upto 3 hrs show no decrease in concentration, while after 10 hours the sample become clear that contain no solid material. [3]

   What is the maximum and minimum size of particles in the mixture? Assume particle density to be 2.5 g/ml, liquid density 1.0 g/ml, liquid viscosity 1.0 cP. Assume particles to be spherical.

   b) The following data are available for a particular filtration in a plate and frame filter press

| Time min | Filtrate vol lit | Cake thickness mm |
|---|---|---|
| 0 | 0 | 0 |
| 2 | 10 | 5 |
| 6 | 20 | 10 |

If the thickness of the frame be 20 mm (that is maximum possible cake thickness) estimate the time after which the frame will have to be opened to remove the cake. [3]

c) A CSTR with volume **V** and volumetric input rate **Q** produces 75% conversion. Assume first order reaction, input concentration $\mathbf{C_0}$, output concentration $\mathbf{C^*}$.

If the volumetric input rate be changed to **2Q** will how will the conversion change? Obtain a quantitative expression.

How will the conversion change if the reaction be of order 0, all other conditions remaining same. [3]

9. a) Size distribution of a particular sample is as follows:

2 mm dia 30% by wt, 1 mm dia 49% by wt, 0.5 mm dia 20% by wt, 0.2 mm dia 10 % by wt

All particles are of same material. What is the average volume to surface area ratio of this sample. Note that average can be defined in different ways. First state your definition in quantitative terms, showing the expression and then use the expression to get the result. Assume the particles to be spherical. [3]

b) Starting with expression for filtration rate Q (=dV/dt) from Darcy's law

$$Q = \Delta p/(a + b\alpha V),$$

Where a and b are constants, $\alpha$ is the solids loading of the slurry, $\Delta p$ is pressure drop, and V is the filtrate volume

Show that for constant filtration rate, pressure drop must increase linearly with time. [3]

c) There are 3 CSTRs each of volume **V** in series. A solution of reactant with concentration $\mathbf{C_0}$ flows in at a volumetric rate **Q**. The final concentration from the last reactor is $\mathbf{C_3}$.

Show that if a single reactor with volume 3**V** is use instead, the conversion will be lower. Obtain a quantitative relation between $\mathbf{C_3}$ and output concentration $\mathbf{C^*}$ from the single stage CSTR. Assume first order reaction kinetics, rate constant **k** being same in both the cases. [3]

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