



**UNIVERSITY OF PETROLEUM & ENERGY STUDIES
DEHRADUN**

End Semester Examination - April, 2017

Program/Course: B. Tech. Chemical Engineering (RP)

Semester-VIII

Subject: Process Modelling and Simulation

Maximum Marks : 100

Code: CHEG439

Durations : 3 Hrs.

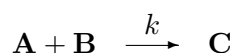
No. of Pages: 2(Two)

Section-A (3x20 = 60 marks)

Answer all **Three** Questions

1. a) A fluid of density, ρ , is flowing through a pipe of diameter, d , with average velocity, v . Express the Reynolds Number, Re , of the Fluid in terms of its dynamic viscosity, μ , the kinematic viscosity, ν , the volumetric flow rate, Q , and the mass flow rate, \dot{m} . (5)

- b) Consider the second order reaction



is being carried out in a batch vessel, where one mole of the reactant **A** and one mole of the reactant **B** react to produce one mole of the product **C** with the reaction rate, r , given by $r = kC_A C_B$, where k is the second order rate constant. The initial concentrations of the **A** and the **B**, are respectively given by C_{A0} and C_{B0} . Prove that the transient concentration, C_C of the product, **C**, is given by (15)

$$C_C = C_{A0} C_{B0} \frac{\exp[(C_{B0} - C_{A0})kt] - 1}{C_{B0} (\exp[(C_{B0} - C_{A0})kt]) - C_{A0}}$$

2. a) Show that (10)

$$\frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} \exp\left[-\frac{x^2}{2}\right] dx = 1$$

Hint: use the relation: $\Gamma(\frac{1}{2}) = \sqrt{\pi}$

- b) Write a brief note on three Laws of Conservation. Write the definitions of the Mass diffusivity, \mathcal{D} , the Kinematic Viscosity, ν , and the Thermal Diffusivity, λ . Write the units of Mass Diffusivity, Kinematic Viscosity and Thermal Diffusivity respectively, in fundamental dimensions. (10)
3. A consecutive first order reaction is occurring in a batch vessel of volume V isothermally, with the following scheme



- Formulate the governing differential equations to determine the C_A , C_B and the C_C for the A, B and C respectively, as function of time. The initial conditions are given by $C_A(0) = C_0$, $C_B(0) = 0$ and $C_C(0) = 0$. (10)
- Solve the equation for C_A , C_B and C_C against time. (10)

Continued in the next page

Section-B (1x40 = 40 marks)

Answer any **one** Questions

4. a) In a Semi-Batch (no out-flow) Vessel, the limiting reactant **A** with inlet concentration, C_{in} (mole/volume) with constant flow rate, α (volume/time), is being dosed in the reactor where the other reactant **B**, is already present in large excess ($N_B(0)$ mole), so that the reaction can be deemed as *pseudo* first order reaction. The initial volume of the reacting mixture is V_0 (volume). The initial concentration of the reactant A, C_{A0} , is zero in the vessel.

– Formulate the governing differential equation to calculate the transient profile of the reactant **A** concentration, C_A . (10)

– Write the assumptions made to formulate the model. (5)

– Solve the equation for C_A . (15)

b) In a double pipe heat exchanger with one dimensional co-current flow, the spatial temperature difference, $\Delta T (= T_h - T_c)$ between the hot and the cold fluid, is given by (10)

$$\Delta T = \Delta T_{in} \exp[-\beta x]$$

where $\Delta T_{in} (= T_{hin} - T_{cin})$ is the difference in temperature at the inlet. The exchanger's total length is L and β is a constant parameter. Calculate the average difference in temperature, $\overline{\Delta T}$ over the length L , where ΔT_{out} represents the difference in temperature at the outlet (at $x = L$). Prove that $\overline{\Delta T}$ is the Logarithmic Mean Temperature Difference (LMTD).

5. a) Solve the following parabolic partial differential equation (30)

$$\frac{\partial C}{\partial t} = \frac{\partial^2 C}{\partial x^2}$$

with initial condition

$$C = 0 \text{ at } t = 0 \text{ for } x > 0$$

and the boundary conditions

$$C = C_0 \text{ at } x = 0 \text{ for } t \geq 0$$

$$C = 0 \text{ for } x \rightarrow \infty \text{ for } t > 0$$

Hint: use the similarity variable $\eta = \frac{x}{2\sqrt{t}}$ to convert the partial differential equation into an ordinary differential equation.

b) A large empty cylindrical tank with volume V and having cross-sectional area A is being filled up with a liquid of constant density, ρ . The input volumetric flow rate of the liquid is fixed at F_{max} . Calculate the time, t_f for filling the tank to its brim. (10)