Exam Date & Time: 06-Jan-2023 (02:30 PM - 05:30 PM)

MANIPAL ACADEMY OF HIGHER EDUCATION

B.TECH MAKE UP EXAMINATIONS, Dec - Jan 2023
V SEM, Chemical Engineering

TRANSPORT PHENOMENA [CHE 3154]

Marks: 50 **Duration: 180 mins.**

A

Answer all the questions.

Instructions to Candidates: Answer ALL questions Missing data may be suitably assumed

1) From the following data, determine the type of fluid that characterizes it.

A)

Shear Stress (N/m^2)	170	24
Shear Rate, (1/s)	1020	64

(2)

B) Write the governing equations for the various laws of transport and explain. (3)

C) Consider a Newtonian fluid at constant density and viscosity is flowing in a cylindrical pipe. By performing a momentum balance on a thin shell, derive an expression for

- the velocity profile and
- maximum velocity

(5)

2) In fully developed laminar flow in a circular pipe, the velocity at a distance of R/2 is measured to be 6 m/s (R: radius of the pipe). Determine the velocity at the centre of the pipe. (2)

A)

B) In a 1 m diameter duct carrying air the velocity profile was found as, u (m/s) = 0.45 – $5r^2$, where r is the radius in m. Determine the volume flow rate of the air and the mean velocity of flow of air. (3)

C) A Newtonian fluid flows down an inclined (Ø = angle of inclination with vertical axis) plane surface in a steady, fully developed laminar film of thickness 'H'. Obtain the expressions for the fluid velocity profile and maximum velocity using Navier-Stokes equations. (5)

3) A) Heat is generated in a radioactive plane wall according to the relationship

$$q_G = q_m \left[1 - \left(\frac{x}{L}\right)\right]$$

where q_G is the volumetric heat generation rate, q_m is a constant and L is the half-thickness of the plate and x is the distance measured from the plate centre line. Develop the equation that expresses the temperature difference between the rod centre line and its surface. (4)

B) Let the thermal conductivity of a certain solid be expressed as a linear function of temperature $k = a+bT$. Find the expression for the heat flow if the solid is in the shape of a cylindrical pipe and heat flow is in the radial direction only (4)

C) Estimate the rate of evaporation of liquid oxygen from a spherical containers of 6 ft inside diameter covered with a 1-ft thick jacket insulation. The following information is available. (2)

- ◦ Temperature at inner surface of insulation: - 183 °C
  - ◦ Temperature at outer surface of insulation: 0 °C
  - ◦ Boiling point of O_2 : - 183 °C
  - ◦ Heat of vaporization of O_2: 1636 cal/mol
  - ◦ Thermal conductivity of insulation at 0 °C : 0.155 W/m K
  - ◦ Thermal conductivity of insulation at - 183 °C : 0.1245 W/m K

4) A) Consider the base plate of a 1200 W household iron that has a thickness of 0.5 cm, base area of 300 cm^2 and thermal conductivity 15 W/m°C. The inner surface of the base plat is subjected to uniform heat flux generated by the resistance heaters inside and the outer surface loses heat to the surroundings at 20 °C by convection. By taking the outside convective heat transfer coefficient as 80 W/m^2 °C, evaluate the temperatures at the inner and the outer surfaces. (2)

B) A heated sphere of diameter D is placed in a large amount of stagnant fluid. Consider the heat conduction in the fluid surrounding the sphere in the absence of convection. The thermal conductivity k of the fluid may be considered constant. The temperature at the sphere surface is T_R and the temperature far away from the sphere is T_a. Set up the differential equation describing the temperature T in the surrounding fluid as a function of r, the distance from the centre of the sphere and determine the temperature profile. (Boundary conditions: @r=R, $T = T_R$ and @ $r = \infty$, $T = T_a$) (3)

C) Using the first order reaction, concentration profile for a spherical catalyst, derive an expression for observed reaction rate with pore diffusion. (5)

5) If Thiele-modulus parameter is given by the following expression,

A)

$$\varphi = \frac{V_p}{S_x} \frac{|-r_A|_{C_{AS}}}{\sqrt{2}} \left\{ \int_0^{C_{AS}} D_{Ae}(-r_A)\,dC_A \right\}^{-1/2}$$

(2)

Derive an expression φ for a flat plate & spherical catalyst, first order reaction.

B) You have a porous particle (8mm) used for a first order reaction with a rate constant of 0.0015 sec^{-1} and an effective diffusivity of 2.1 x 10^{-9} m^2/sec. The concentration of the reactant A at the surface is 3.2 x 10^{-3} kg/m^3. Determine the steady-state substrate concentration as a function of particle radius (Note: Minimum 3 concentrations have to be calculated). (3)

C) A gaseous substrate is consumed by a catalyst at a rate, which is nearly independent of the substrate concentration. Assume that the catalyst is a sphere of radius r, and let k and C_0 be the substrate consumption rate per unit volume and the substrate concentration just inside the catalyst, respectively. Derive an expression for the steady-state substrate concentration profile inside the catalyst, C(r), assuming that the consumption rate is spatially uniform. (5)

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