Exam Date & Time: 08-Dec-2023 (02:30 PM - 05:30 PM)

MANIPAL ACADEMY OF HIGHER EDUCATION

V SEMESTER B.TECH END SEMESTER EXAMINATIONS, NOV/DEC 2023

TRANSPORT PHENOMENA [CHE 3154]

Marks: 50

Duration: 180 mins.

A

Answer all the questions.

Section Duration: 180 mins

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

1)

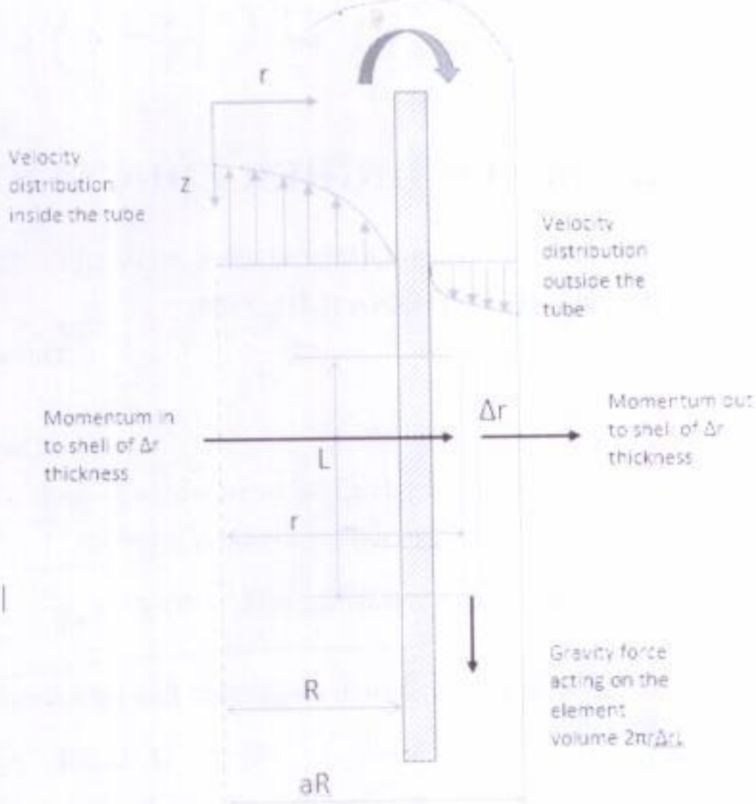
A) The velocity (m/s) profile in a circular pipe of diameter 4 cm is given by $u(r) = 4\,(1 - (r/R)^2)$. Calculate the volumetric flowrate in m^3/s. (2)

B) Develop an expression for the velocity profile from momentum flux for a Bingham fluid flowing through a cylindrical pipe. (3)

C) In a gas absorption experiment a viscous fluid flows upward through a small circular tube and then downward in laminar flow on the outside. Apply momentum balance over a shell of thickness Δr in the film and develop expressions for the following:

- Momentum flux
- Velocity

(5)



2) A) A horizontal annulus, 27 ft in length, has an inner radius of 0.495 in. and an outer radius of 1.1in. A 60% aqueous solution of sucrose is to be pumped through the annulus at 20°C. At this temperature the solution density is 80.3 lb/ft^3 and the viscosity is 136.8 lb/ft h. Calculate the volume flow rate when the pressure difference is 5.39 psi? (2)

B) Consider steady state laminar flow of a Newtonian fluid at constant density and viscosity in a in an annular space between two coaxial cylinders of radii R and kR. Develop an expression for the volumetric flowrate from the velocity profile in the annular space. (3)

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

3) A) A fresh food product is held in cold storage at 278 K. It is packed in a container in the shape of a flat slab with all faces insulated except for the top flat surface which is exposed to the air at 278 K. For estimation purposes the surface temperature will be assumed to be 278 K. The slab is 152.4 mm thick and the exposed surface area is 0.186 (2)

m^2. The density of the foodstuff is 641 kg/m^3. The heat of respiration is 0.07 kJ/ kg h and the thermal conductivity is 0.346 W/m K. Calculate the maximum temperature in the food product at the steady state and the total heat given off in W.

B) Develop an equation for overall heat transfer coefficient for conduction in four-layered cylinders with convection on both sides. (3)

C) Consider a large plane wall of thickness *L*. The wall surface at $x = 0$ is insulated, while the surface at $x = L = 0.05\ m$ *is* maintained at a temperature of $T_o = 30$ °C. The thermal conductivity of the wall, k is constant (30 W/ m K) and the heat is generated in the wall at a rate $q_G = q_m \left[exp\left(-0.5\ \frac{x}{L}\right)\right]$ W/m^3, wherein $q_m = 8\ MW/m^3$. Assuming steady one-dimensional heat transfer. (5)

- Develop a relation for the variation of temperature in the wall by solving the differential equation, and
- Calculate the temperature of the insulated surface of the wall.

4) Using the following temperature profile inside a cylindrical nuclear rod (1 m length, 10 cm diameter; k = 0.6 W/m K), which was cooled at 4 °C.

A) $T = 4 + 0.7\left(1 - \left(\frac{r}{R}\right)^2\right)$

wherein, T is in °C. (2)

Calculate the

- Rate of heat generation in W/m^3 and
- Rate of heat loss from the surface.

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. Apply 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 develop the temperature profile. (Boundary conditions: @r = R, T = T_R and @ r = ∞, T = T_a) (3)

C) Develop an expression for the concentration profile, observed reaction rate with pore diffusion and effectiveness factor for a flat slab catalyst for a first order reaction. (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)

- Develop an expression, φ for a flat slab catalyst for a zero-order reaction.

B) For a porous spherical catalyst particle (1000 μm, diameter) with a rate constant of 6.32 min^{-1} and an effective diffusivity of 3.5 x 10^{-4} cm^2/min, the concentration of the reactant A at the surface is 100 mM. Calculate the concentration of A at 10, 100 200 and 500 μm catalyst diameter. (3)

C) A gaseous substrate is consumed by a catalyst at a rate, which is 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. Develop 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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