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1. List four basic models of convective mass transfer coefficients and their relationships with diffusivity D_{AB} (10 %)

2. Figure 1 depicts a wire of radius r_1 that is pulled steadily with velocity V through a horizontal die of length L and internal radius r_2. The wire and die are coaxial, and the space between them is filled with liquid. The pressure at both ends of the die is atmospheric. The wire is coated with the liquid as it leaves the die, and the thicknesses of the coating eventually settles to a uniform value, δ. Neglect end effects and assume that v_z is the only non-zero velocity component.

   Derive expressions for the following questions, assuming the liquid is Newtonian fluid of constant viscosity μ

   (a) The velocity profile within the annular space. (15%)

   (b) The limiting values for volumetric flow rate Q if r_1 approaches zero. (15%)

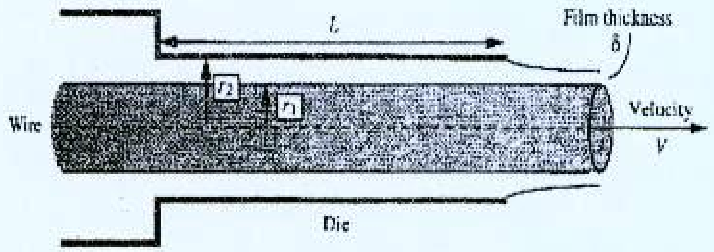

Figure 1

3. An aluminum cube 5 cm on a side is initially at uniform temperature 100°C and is suddenly exposed to room air at 25°C. The convective heat transfer coefficient is 20 W/m^{2}K. Calculate Biot number and the time required for the geometric center temperature to reach 50°C. (15 %)

   Note: Aluminum k=204 W/mK, ρ = 2707 kg/m^3, cp = 896 J/kgK

4. The explosion in a chemical factory released large amounts of benzene, a toxic solvent (Component A). Assume the liquid-layer benzene covers an area of water-saturated soil. Setup and simplify a partial differential equations (in terms $C_A(z,t)$) that could be solved to describe 1 dimensional mass transfer. You don't need to solve, but propose initial and boundary conditions. (15%)

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5. Pyrex glass is almost impermeable to all gases except helium. This fact suggests that a method for separating helium from natural gas could be based on the relative diffusion rates of different contaminants present in natural gas. Suppose a natural gas mixture is contained in a pyrex tube with inner radius R_1 and outer radius R_2 as shown below. At $r = R_1$ we specify a surface flux (a design value for the process),

$$\Psi\Big|_{r=R_1} = -D\left(\frac{dC_{He}}{dr}\right)\Big|_{r=R_1}$$

At $r = R_2$ the helium concentration is $C_{He} = C_2$.

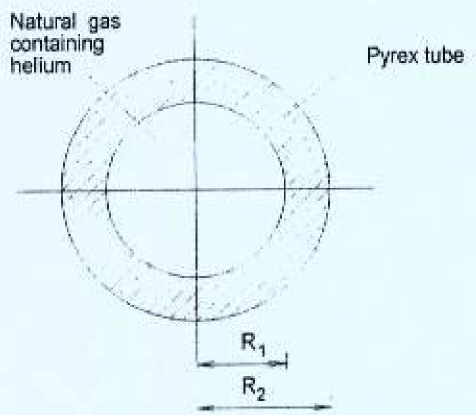

Figure 2

(a)Write the general balance relationship for this problem in terms of the general property ψ and the differential equation arising from this property balance in terms of the helium concentration, C_{He}. (15%)

(b)Based on the boundary conditions given for this problem, find an expression for the concentration profile through pipe wall. (15%)