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1. 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 volumetric flow rate Q through the annulus. (20%)

   (b) The velocity profile of the fluid on the wire after the wire has left the die and the film thickness has reached δ. (15%)

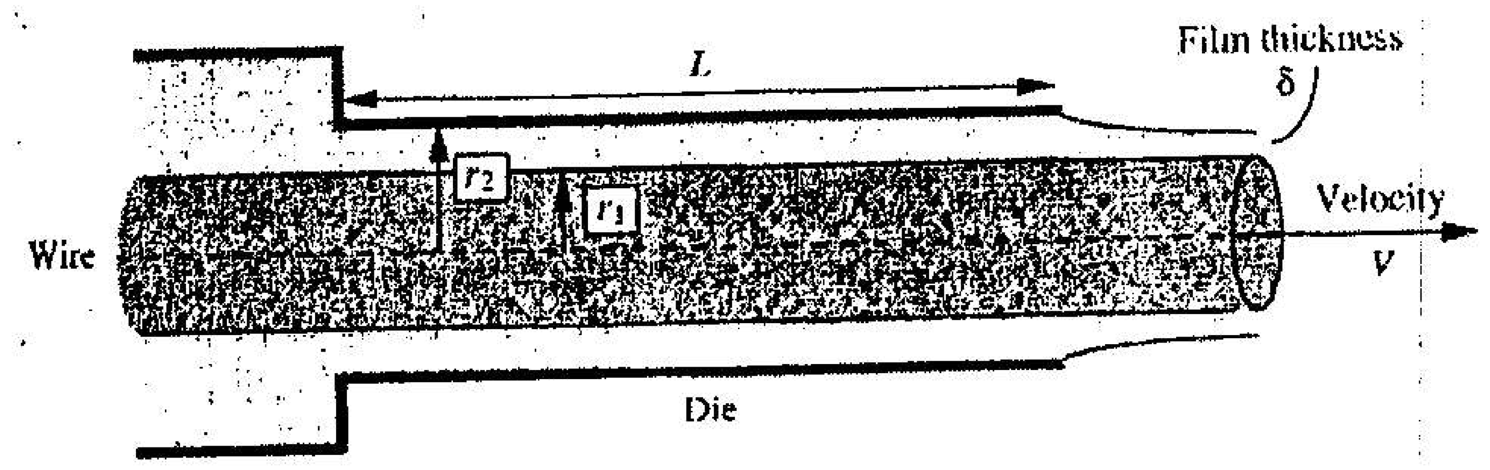

Figure 1

2. Figure 2 shows the gas-phase diffusion in the neighborhood of a catalytic surface. Component A diffuses through a stagnant film of thickness δ to the catalytic surface where it is instantaneously converted to B by the reaction,

$$A \rightarrow 3B$$

   The product B diffuses away from the catalytic surface, back through the stagnant film.

   (a) Evaluate the concentration profile $y_A = f(z)$. (15%)

   (b) Determine the rate at which A enters the gas film if this is a steady-state process. (10%)

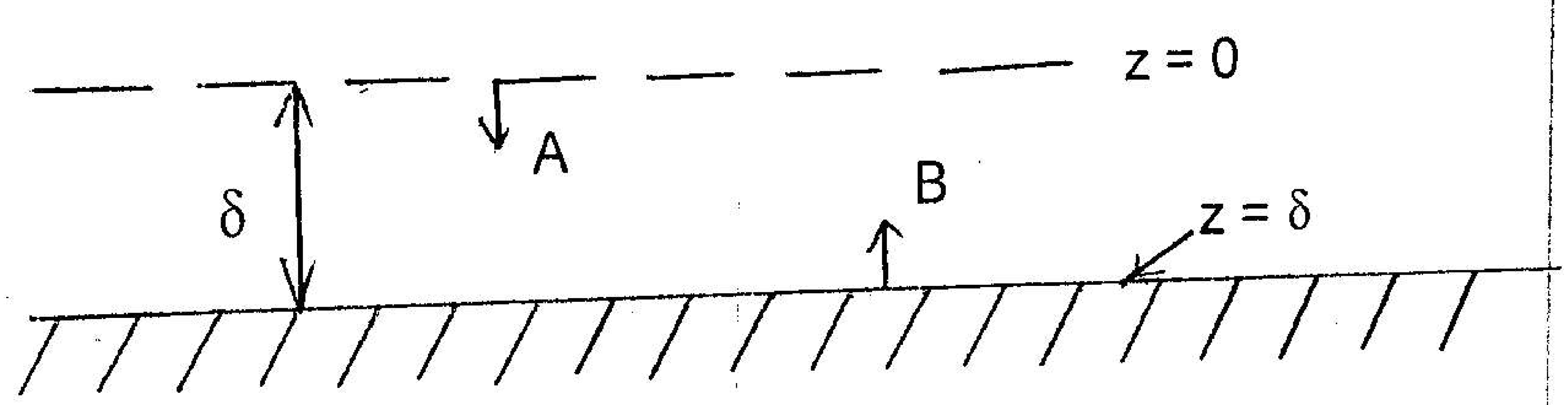

Figure 2

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3. A layer of insulation is installed around the outside of a metal pipe containing saturated steam at temperature Ti. The pipe has a length L and outside radius r_i. Assume that the metal pipe has a high thermal conductivity and therefore, the temperature of the outside wall of the pipe (i.e., $r = r_i$) is at Ti as well. The ambient air temperature is T_0 and the heat transfer coefficient from the pipe is ho. The temperature on the outside surface of the insulation (i.e., $r = r_s$) is Ts. The heat loss from the insulated pipe is proportional to the area and the temperature driving force between the outside surface (As) and the ambient air temperature. As the thickness of the insulation increases, Ts does decrease, but at the same time As increases. Does increasing the thickness of the insulation ($r_s - r_i$) always decrease the heat loss from the cylinder? If not, under what conditions would increase the insulation thickness? Prove your answer. (15%)

4. The explosion in a chemical facility released huge amounts of benzene, the noxious solvent (Component A). Assume the liquid-layer benzene covers an area of water-saturated soil. Setup and simplify the 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%)

5. Determine the steady-state temperatures of two radiation shields placed in the evacuated space between two infinite planes at temperatures of 700 K and 300 K. All the surfaces are diffuse-gray with emissivities of 0.7. (10%)

(命題請用黑色鋼筆、原子筆繕寫或電腦打字；試題字體務求清晰，並一律以正面單頁書寫，背面請勿書寫。)