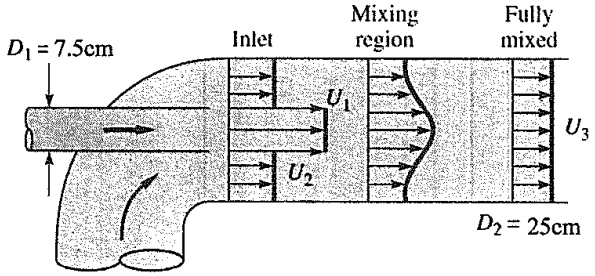
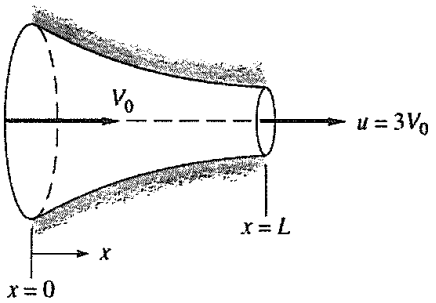
1. (25%) The jet pump injects water at U_1=40 m/s through a 7.5-cm-pipe and entrains a secondary flow of water U_2=3 m/s in the annular region around the small pipe. The two flows become fully mixed downstream, where U_3 is approximately constant. Let p_1 and p_2 =172.4 kPa, and the distance between sections 1 and 3 is 2.032 m. The average wall shear stress between sections 1 and 3 is 335 Pa. Assume that the flow is steady and incompressible. For water, take ρ=998 kg/m^3.
   (a) (5%) Calculate the velocity U_3 (m/s) at section 3.
   (b) (5%) Calculate the momentum change rate (kg·m/s^2) between sections 1 and 3.
   (c) (5%) Calculate the total wall shear force (N) between sections 1 and 3.
   (d) (10%) Calculate the pressure p_3 (kPa) at section 3.



2. (25%) Flow through the converging nozzle can be approximated by the one-dimensional velocity distribution

$$u \approx V_0\left(1+\frac{2x}{L}\right) \quad v \approx 0 \quad w \approx 0$$

   (a) (15%) Find a general expression for the fluid acceleration *du/dt* in the nozzle.
   (b) (10%) For the specific case V_0 =10 ft/s and L=6 in, calculate the fluid acceleration (ft/s^2) at the entrance (5%) and at the exit (5%).



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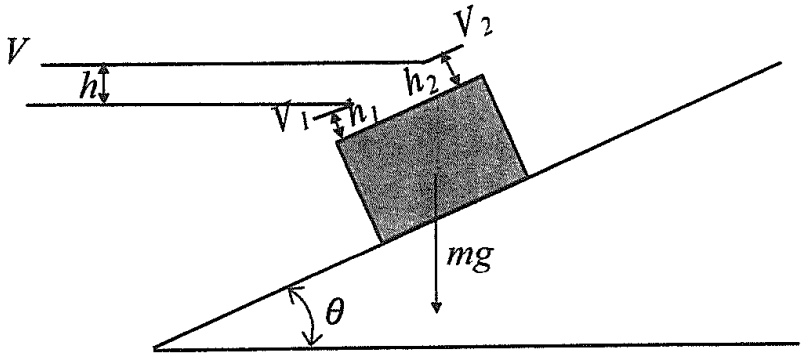
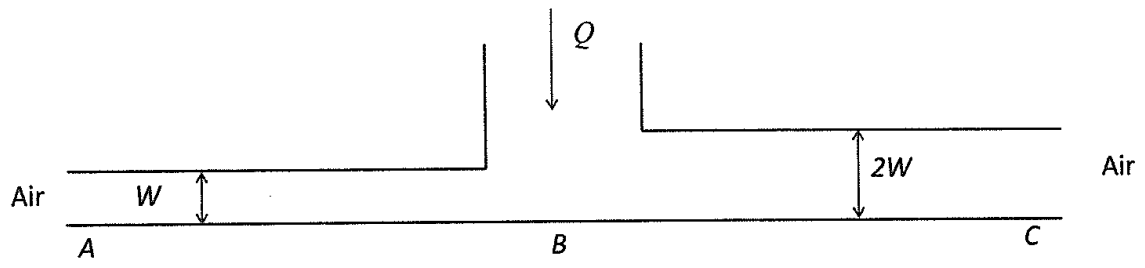
3. (25%) As shown in the figure below, a two-dimensional (2D) water jet with a velocity V and width h is impinging on a block on a sloping wall with an angle of inclination θ such that the block does not move. The weight of the block is mg. Assume that the block is so small that the gravitational force acting on the jet stream and the resulting torque on the block are negligible. Neglect the flow viscosity.
   (1) (10%) What are the velocities at the lower (V_1) and upper (V_2) ends of the jet stream on the block? Explain your answer.
   (2) (5%) If there is no friction between the block and the sloping wall, what are the water depths at the lower (h_1) and upper (h_2) ends of the jet stream on the block?
   (3) (10%) What is your answer in (2) if there is a frictional force with the coefficient of friction μ between the block's bottom and the sloping wall?



4. (25%) As shown in the figure below, a two-dimensional (2D) viscous fluid with the flow rate Q is injected into a 2D T-junction with asymmetric cross-sectional widths, W and $2W$ for the left and right branches, respectively. Both of the two branches have the same length and are opened to the air at the downstream ends. In this figure, points A and C are both far away downstream from the junction B, such that flows are fully developed.
   (1) (5%) What are the velocity profiles looked like at A and C? (You only have to plot schematically. You will be asked to find the mathematical expression later on.)
   (2) (5%) With fluid viscosity μ, write down the momentum equations at points A and C.
   (3) (10%) What is the flow rate ratio between A and C? (Flow rate $= \int_{Area} \boldsymbol{U} \cdot d\boldsymbol{a}$).
   (4) (5%) What are the velocity profiles $u(y)$ at A and C? (Your final answer will contain only Q, W, and y.)



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