系所組別： 機械工程學系甲組
考試科目： 流體力學
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1. (50 pts) A boat propelled by a water jet is shown in Figure A. Dimensions of the boat are also shown in the figure. The boat is travelling with a constant speed V. Dimensions of the propulsion system are shown in Figure B. The propulsion system consists of a pump and a round pipe. Water is pumped into the propulsion system vertically, and horizontally exits the propulsion system through the pipe.

Figure A

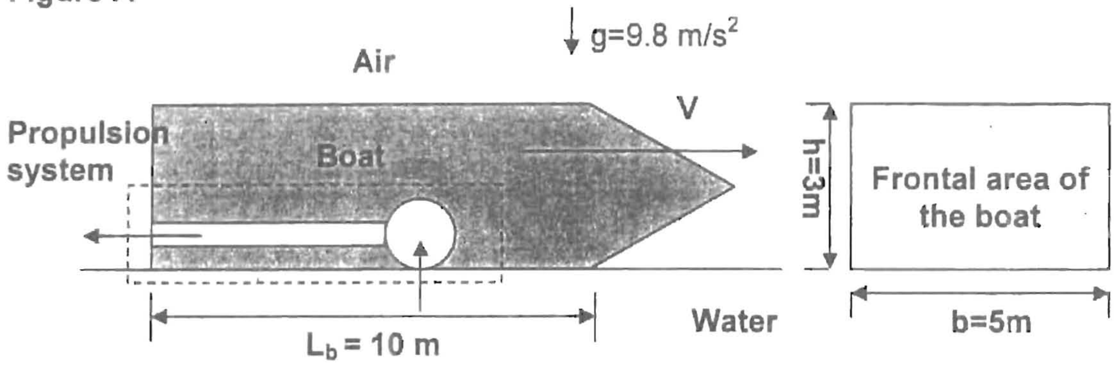
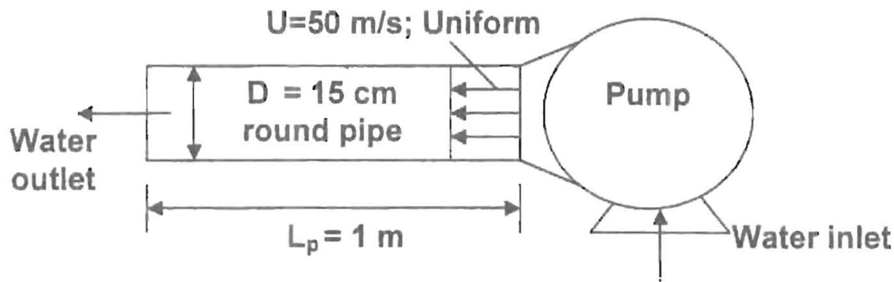


Figure B



Drag coefficients for flow over a smooth plate can be calculated using the following equations:

Laminar: $C_D = \dfrac{1.328}{\mathrm{Re}_L^{1/2}}$

Transitional ($5\times10^5 < \mathrm{Re}_L < 8\times10^7$): $C_D = \dfrac{0.031}{\mathrm{Re}_L^{1/7}} - \dfrac{1440}{\mathrm{Re}_L}$

Turbulent: $C_D = \dfrac{0.031}{\mathrm{Re}_L^{1/7}}$

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Boundary layer thicknesses for laminar and turbulent flows can be calculated by the following correlations:

Laminar: $\frac{\delta}{x} = \frac{5}{\sqrt{\mathrm{Re}_x}}$

Turbulent: $\frac{\delta}{x} = \frac{0.16}{\mathrm{Re}_x^{1/7}}$

Densities of air and water are 1.2 kg/m^3 and 1000 kg/m^3, respectively. Kinematic viscosity of water is 1.3×10^{-6} m^2/s.

i) A Pitot tube attached to a U-tube manometer is installed on the boat to monitor the traveling velocity of the boat, V. The density of the manometer fluid is ρ_m. Derive a correlation between V and ρ_m List all assumptions/approximations for the correlation.

ii) If water enters the propulsion system pipe with a uniform velocity U=50 m/s, assuming constant free stream velocity flat plate boundary layer in the pipe, calculate the boundary layer thickness at the exit of the pipe.

iii) Can the flow in the pipe at the exit be considered as fully developed?

iv) What is the power loss in meters in the pipe, assuming constant free stream velocity flat plate boundary layer on a smooth surface?

v) Since boundary layer is thin compared to the pipe diameter, the velocity at the exit of the pipe could be consider uniform with a velocity equal to the average velocity. Using this assumption and calculating the drag exerted by water and air on the boat. Drag coefficient based on frontal area of the boat is C_D=0.4. Assume the bottom of the boat is smooth and flat with length 10 m and width 5 m.

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2. A cylindrical can with one end open is observed to be floating on a liquid of density ρ with the open end down. The can has weight W, internal cross-sectional area A, and is supported by the air trapped in it. Moreover, as shown in Fig. P2, the can floats out of the fluid a distance h. If the trapped air is assumed to follow Boyle's law, that is, its pressure times volume is a constant, determine the force, F, necessary just to submerge the can. **(15 pts)**

Note: The thickness of the wall is assumed to be zero, and the hydrostatic pressure due to the atmosphere may be neglected. Also, the distances x_1 and x_2 shown in Fig. P2 may be used as auxiliary quantities, but they should not appear in the final answer.

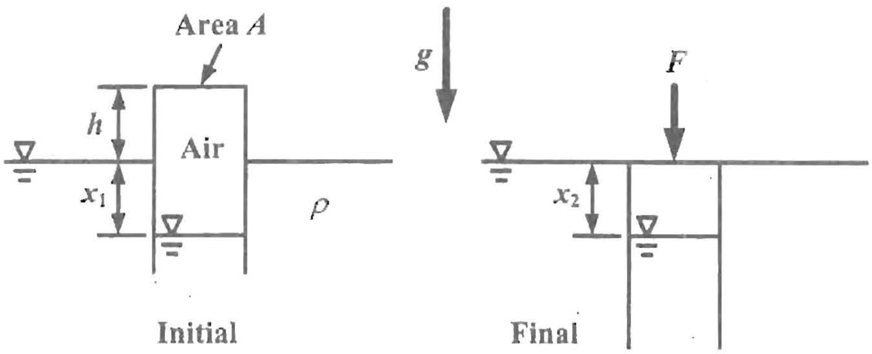

Fig. P2

3. (a) By solving the Navier–Stokes equations with suitable boundary conditions, derive the *Hagen–Poiseuille law* that relates the volumetric flowrate and pressure drop of a steady incompressible flow between two fixed parallel plates. Define your variables and parameters clearly. **(10 pts)**

(b) Now, a massive, precisely machined, 6-ft-diameter granite sphere rests upon a 4-ft-diameter cylindrical pedestal as shown in Fig. P3. When the pump is turned on and the water pressure within the pedestal reaches 8 psi, the sphere rises off the pedestal, creating a 0.005-in. gap through which the water flows. The sphere can then be rotated about any axis with minimal friction. Estimate the pump flowrate, Q_0, required to accomplish this. **Hint:** Use Hagen–Poiseuille law. Also, for water, take density $\rho = 1.94$ slugs/ft^2 and viscosity $\mu = 2.34 \times 10^{-5}$ lb·s/ft^2. **(10 pts)**

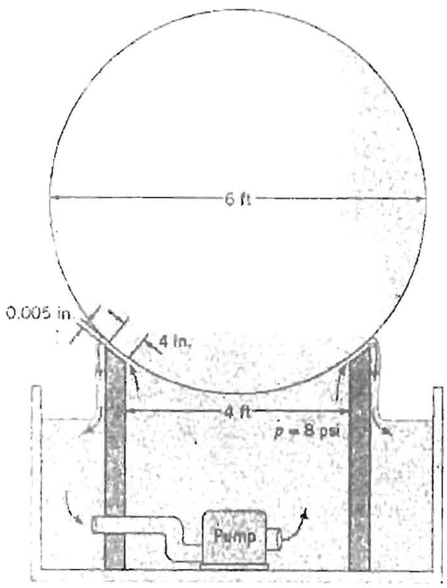

Fig. P3

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4. Water flows through two sections of the vertical pipe shown in Fig. P4. The bellows connection cannot support any force in the vertical direction. The 0.4-ft-diameter pipe weighs 0.2 lb/ft and the friction factor is assumed to be 0.02. At what velocity will the force, F, required to hold the pipe be zero? **Note:** Use the water properties given in Problem 3. **(15 pts)**

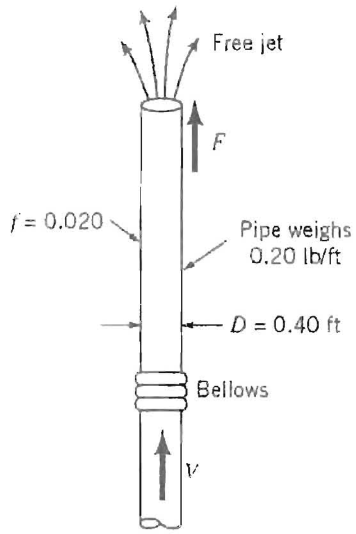

Fig. P4