EXAM #3   December 17, 2007

1. Pressures are sometimes determined by measuring the height of a column of liquid in a vertical tube (See Fig. 1). What diameter of clean glass tubing is required so that the rise of water at 20°C in a tube due to capillary action (as opposed to pressure in the tube) is less than h = 1 mm? (For water at 20°C, σ = 0.0728 N/m, γ = 9,789 N/m^3, contact angle θ = 0°)

2. The drag, F, on a sphere located in a pipe through which a fluid is flowing is to be determined experimentally (see Fig. 2). According to a dimensional analysis the drag force can be expressed as following:

$$\frac{F}{\rho V^2 D^2} = \phi\left(\frac{d}{D}\right)$$

Some experiments using water indicate that for d_m = 0.2 in., D_m = 0.5 in., and V_m = 2 ft/s, the drag F_m is 1.5 × 10^{-3} lb. (a) Determine the sphere diameter located in a 2-ft-diameter pipe to maintain geometric similarity. (b) Estimate the drag on the sphere if water is flowing through the pipe with a velocity of 6 ft/s.

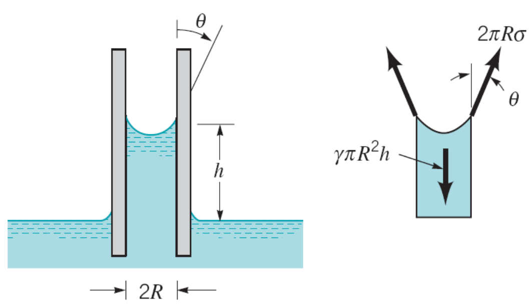

Figure 1

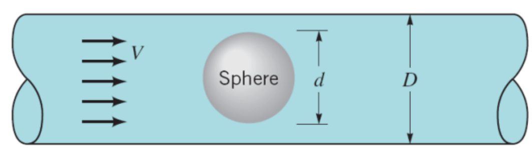

Figure 2

3. Water flows through a horizontal galvanized iron pipe (ϵ = 0.0005 ft) at a rate of 0.12 ft^3/s as shown in Fig. 3. Determine the pressure difference, $\Delta p = p_1 - p_2$, by using the energy equation with head loss, h_L. Use following equation to calculate the friction factor, f, if necessary. (γ = 62.4 lb/ft^3, ν = 1.21 × 10^{-5} ft^2/s)

$$f = \frac{1.325}{\left\{\ln\left[\left(\frac{\epsilon}{3.7D}\right) + \left(\frac{5.74}{Re^{0.9}}\right)\right]\right\}^2} \quad \text{for } 10^{-6} < \frac{\epsilon}{D} < 10^{-2} \text{ and } 5000 < Re < 10^8$$

4. The pump shown in Fig. 4 delivers a head h_p of 250 ft to the water. Determine the power, $\dot{W}_s$, that the pump adds to the water if the friction factor, f, is 0.0121. The difference in elevation of the two ponds is 200 ft. (γ = 62.4 lb/ft^3, Hint: $\dot{W}_s = \gamma Q h_p$, 1 hp = 550 lb·ft/s)

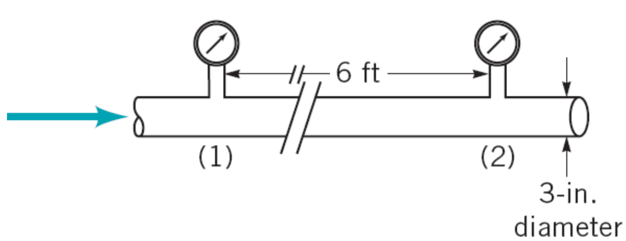

Figure 3

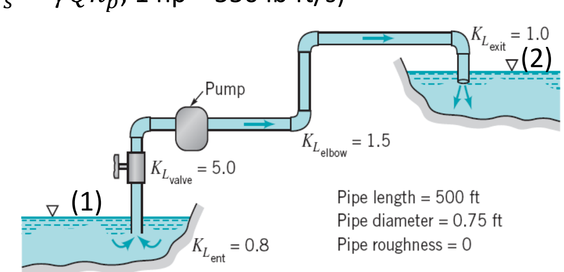

Figure 4

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5. Suppose you buy a 4- by 8-ft sheet of plywood and put it on your roof rack. (See Fig. 5.) You drive home at 35 mi/h. (a) Assuming the board is perfectly aligned with the airflow, how thick is the boundary layer at the end of the board? (b) Estimate the drag on the upper side of the plywood. Assume the boundary layer is turbulent and the wood is smooth. (ν = 1.57 × 10^{-4} ft^2/s, ρ = 2.38 × 10^{-3} slugs/ft^3, 1 mi/h = 1.4667 ft/s, 1 lb = 1 slug·ft/s^2, Drag = $C_f \cdot \frac{1}{2}\rho U^2 A$)

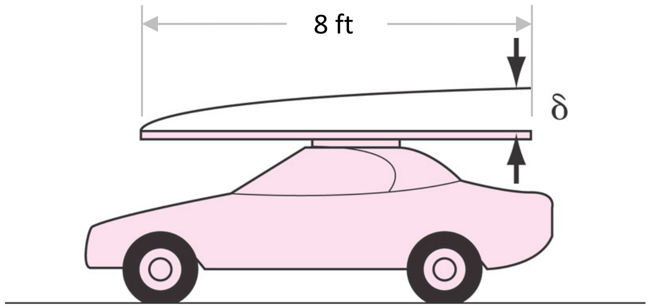
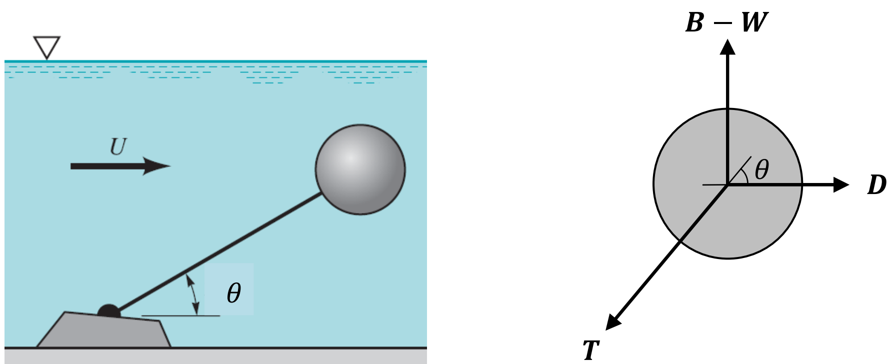


Figure 5

6. A smooth 0.10-m-diameter cork ball (SG = 0.21) is tied to an object on the bottom of a river as is shown in Fig. 6. What is θ if the flow is at U = 1.12 m/s? Neglect the string drag. Drag coefficients of a smooth sphere are given in Fig. 7 as a function of Reynolds number (solid line). (ρ_{water} = 998 kg/m^3, ν_{water} = 1.12 × 10^{-6} m^2/s, $\forall_{sphere} = \frac{4}{3}\pi R^3$)



(**B**uoyancy, **W**eight, **D**rag, and **T**ension forces)

Figure 6

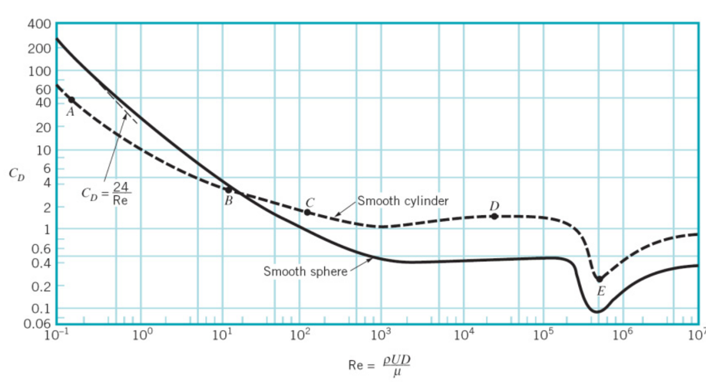


Figure 7