Exam 3, December 14, 2009

1. Water flows through a circular nozzle, exits into the air as a jet, and strikes a plate as shown in Fig. 1. The force required to hold the plate steady is 70 N. Assuming steady, frictionless, one-dimensional flow, estimate (a) the velocity at sections (1) and (2) and (b) the mercury manometer reading *h*. (Water, ρ = 998 kg/m^3; Mercury, ρ = 13,600 kg/m^3)

2. Consider the inviscid, incompressible, steady flow along the horizontal streamline *A* – *B* in front of the sphere of radius *a* = 10 cm, as shown in Fig. 2. From a more advanced theory of flow past a sphere, the fluid velocity along this streamline is $V = V_0(1+a^3/x^3)$ where V_0 = 10 m/s. At *x* = -2*a*, determine (a) the acceleration a_x and (b) the pressure gradient *dp*/*dx* of the fluid. (ρ = 1.23 kg/m^3; Euler equation $\rho a_x = -\frac{dp}{dx}$)

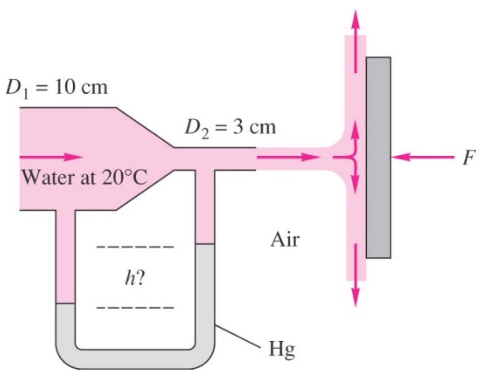

Fig. 1

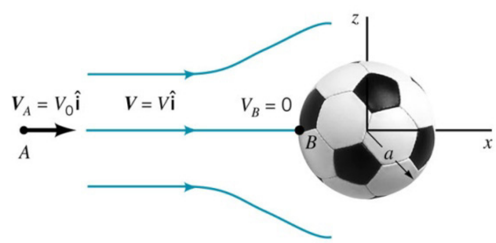

Fig. 2

3. In some locations with very "hard" water, a scale can build up on the walls of pipes to such an extent that not only does the roughness increases with time, but the diameter significantly decreases with time. Consider a case for which the roughness and diameter vary as ε = 0.02 + 0.01*t* mm, *D* = 50(1 – 0.02*t*) mm, where *t* is in years. Calculate the flow rate *Q* for *t* = 10 years (ε = 0.12 mm and *D* = 40 mm) if the pressure drop per ℓ = 12 m of horizontal pipe remains constant at Δp = 1.3 kPa. First assume a friction factor *f* = 0.0315 and start the iteration process. You may use the following formula. (ρ = 999 kg/m^3, ν = 1.12 × 10^{-6} m^2/s)

$$\frac{1}{\sqrt{f}} = -1.8\log\left[\left(\frac{\varepsilon/D}{3.7}\right)^{1.11} + \frac{6.9}{Re}\right]$$

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4. The system in Fig. 3 consists of 1200 m of 5 cm cast iron pipe, two 45° and four 90° flanged long-radius elbows, a fully open flanged globe valve, and a sharp exit into a reservoir. If the elevation at point 1 is 400 m, what gage pressure is required at point 1 to deliver 0.005 m^3/s of water at 20°C into the reservoir? Assume friction factor $f = 0.0315$.
   (45° long-radius elbow, K_L= 0.2; 90° long-radius elbow, K_L = 0.3; Open flanged glove valve, K_L = 8.5; sharp exit, K_L = 1.0; ρ = 998 kg/m^3; μ = 0.001 kg/m·s)

5. A delivery vehicle carries a long sign on top, as in Fig. 4. If the sign is very thin and the vehicle moves at 65 mi/h (29.06 m/s), estimate the force on the sign with no cross wind. Assume a turbulent smooth-wall flow from the leading edge of the sign. (ρ = 1.2 kg/m^3; $\mu = 1.8 \times 10^{-5}$ kg/m·s)

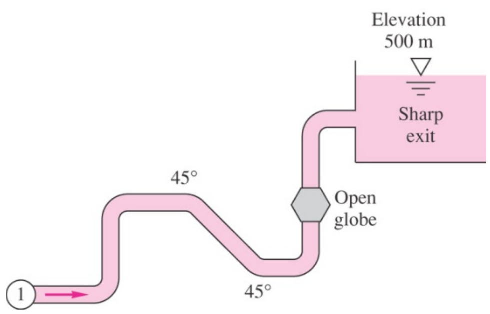

Fig. 3

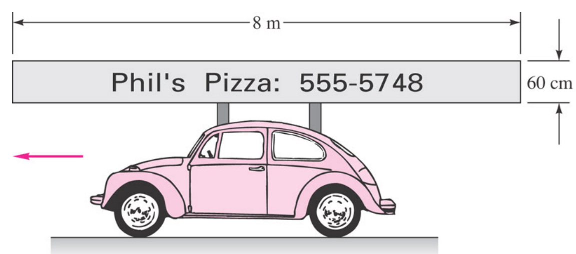

Fig. 4

6. A well-hit golf ball (diameter D = 1.69 in.) can travel at U = 200 ft/s as it leaves the tee. Determine the drag on (a) a golf ball and (b) a smooth golf ball without dimples on its surface ($\varepsilon/D = 0$). Use the chart in Fig. 5 to find appropriate drag coefficients. ($\nu = 1.57 \times 10^{-4}$ ft^2/s, ρ = 0.00238 slugs/ft^3)

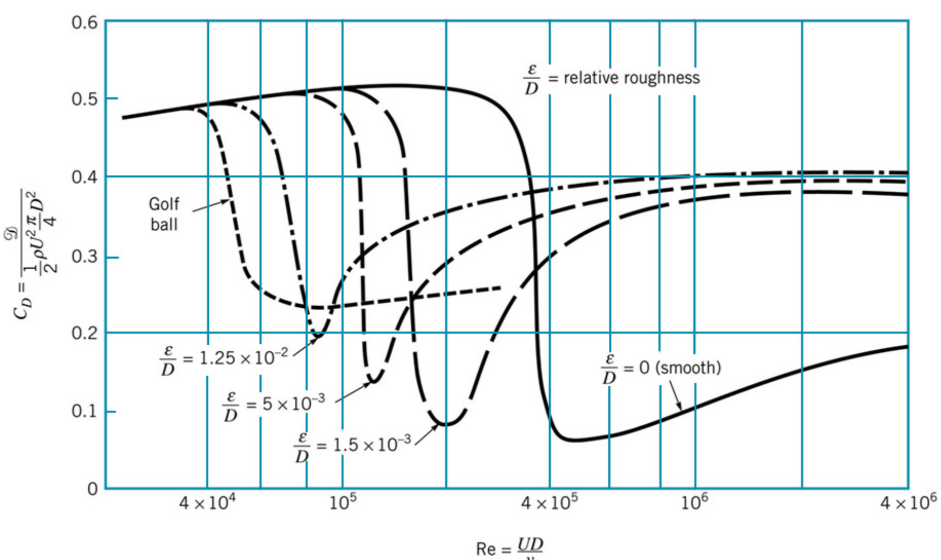

Fig. 5 The drag coefficient C_D of a sphere.