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1. The tank in Fig. 1(a) has a 4-cm-diameter plug at the bottom on the right. The manometer reading h on the left is 14.85 cm. (a) Estimate the water depth H in the tank by using the manometer reading. (b) Determine the hydrostatic force F_R and pressure center y_R on the plug.

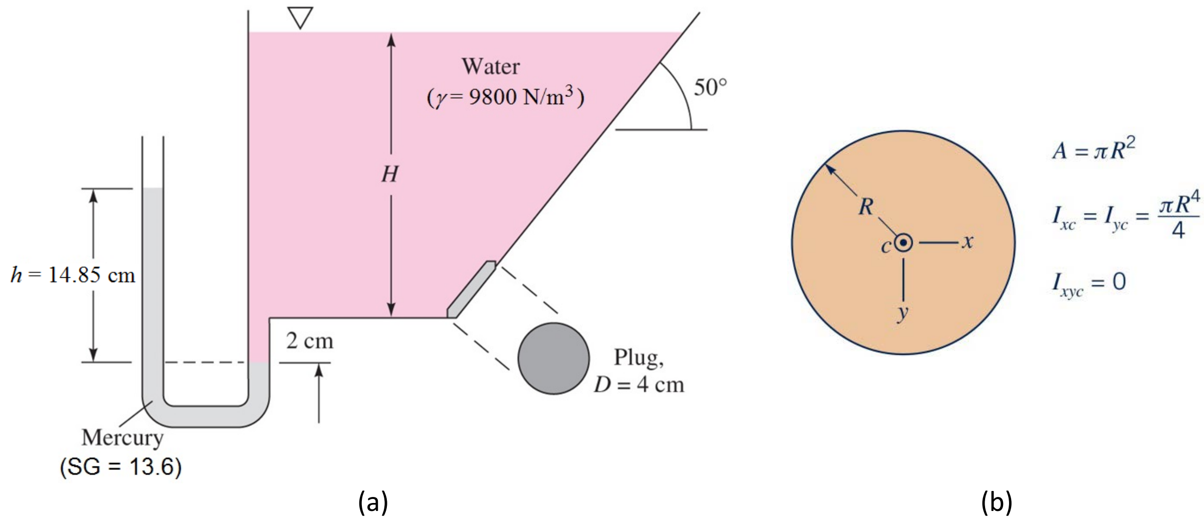

Figure 1

2. A 30° reducing elbow is shown in Fig. 2. The fluid is water (ρ = 999 kg/m³ and γ = 9,800 N/m³). (a) Find the velocities V_1 and V_2. (b) Estimate the pressure p_2 at section 2. (c) Evaluate the components of force, F_x and F_z, to keep the elbow from moving. Assume there are no losses in the elbow.

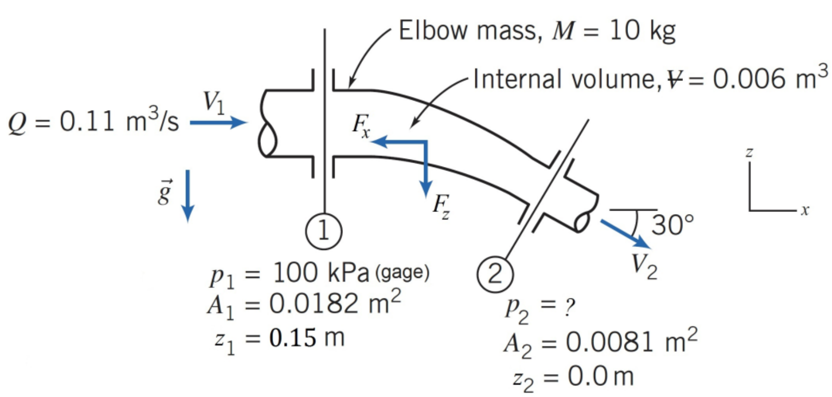

Figure 2

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3. A steady, fully-developed and lamina liquid film of thickness *h* flows down an inclined plane surface as shown in Fig. 3. An exact solution by solving Navier-Stokes equations for this flow is $\underline{V} = (u, v, w)$, where

$$u(y) = \frac{\rho g \sin\theta}{\mu}\left(C \cdot y - \frac{y^2}{2}\right)$$

and $v = w = 0$ and C is a constant. (a) Find an expression for C to complete the solution $u(y)$ by using the boundary condition at the free surface where the shear stress τ is zero. (b) Show that the flow acceleration $\underline{a} = D\underline{V}/Dt$ is zero everywhere. (c) Find the flow rate *Q* = $\int_0^h u(y) b dy$, if the liquid is SAE 30 oil at 15.6°C (ρ = 912 kg/m^3 and μ = 0.38 N·s/m^2), *h* = 1 mm, plane width *b* = 1 m, and θ = 15°.

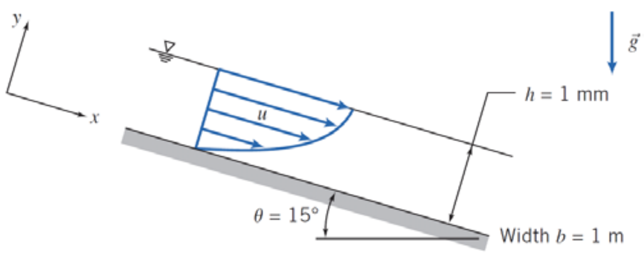

Figure 3

4. The pump shown in Fig. 4 adds a 15-ft head to the water (ρ = 1.94 slugs/ft^3, μ = 2.34 × 10^{-5} lbf·s/ft^2 and γ = 62.4 lbf/ft^3) being pumped from the upper tank to the lower tank. If the pipe has a roughness ε = 0.003 ft, determine the flow rate *Q*. Use *f* = 0.03 as the initial guess then the following equation for the remaining iterations until *f* converges to the thousandth decimal place. (Note: 1 psi = 144 lbf/ft^2 and g = 32.2 ft/s^2)

$$\frac{1}{\sqrt{f}} = -1.8\log\left[\left(\frac{\varepsilon/D}{3.7}\right)^{1.1} + \frac{6.9}{Re}\right]$$

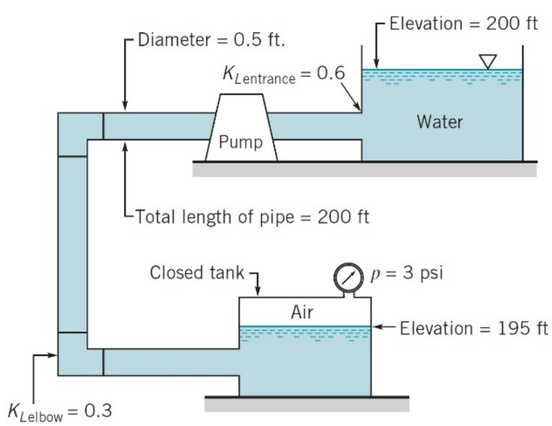

Figure 4

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5. A super tanker is 360 m long and has a beam width of 70 m and a draft of 25 m, cruising at a slow speed of U = 5 knots in seawater at 15.6°C (ρ = 1,030 kg/m^3 and $\mu = 1.20 \times 10^{-3}$ N·s/m^2). The tanker is modeled as a flat plate, of length L and width $b = B + 2D$, in contact with water. (a) Find the flow Reynolds number, $Re_L = \rho UL/\mu$, and the friction drag coefficient C_f. (b) Estimate the friction drag $F_D = ½\rho U^2 A C_f$, where A is the area of the flat plate, and power $P = F_D U$ required to overcome F_D. You may use Figure A1 and A2 in appendix to find formulas for local friction coefficient and friction drag coefficient, respectively. (Note: 1 knot =0.5144 m/s)

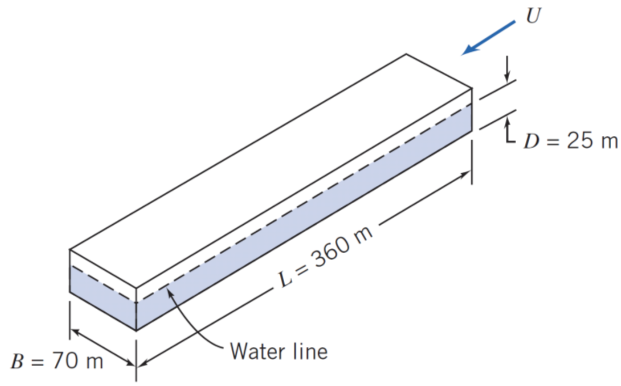

Figure 5

6. Wave-making drag D_w of a ship hull can be expressed as $D_w = f(\ell, U, \rho, g)$, where ℓ is the ship length, U the ship speed, ρ the fluid density and g the gravity. (a) Use dimensional analysis and find a suitable set of dimensionless pi parameters for this problem. Use ℓ, U, ρ as repeating variables. (b) A towing tank experiment is planned for a 1/25-scale model in fresh water (ρ = 999 kg/m^3) for a 100-m long prototype ship cruising at a design speed of 16.3 knots in sea water (ρ = 1,030 kg/m^3). Determine the model towing speed to achieve Froude scaling (or the Fr similarity). (c) Fig. 6 shows the relationship between wave-drag coefficient C_W and Froude number Fr. Estimate the wave-making drag for each of the model and prototype ship. (Note: 1 knot = 0.5144 m/s)

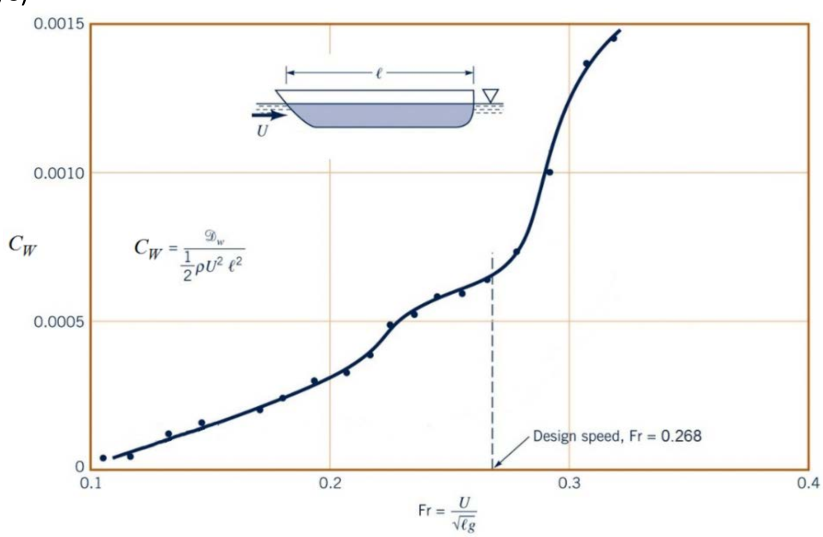

Figure 6

Appendix for Problem 5:

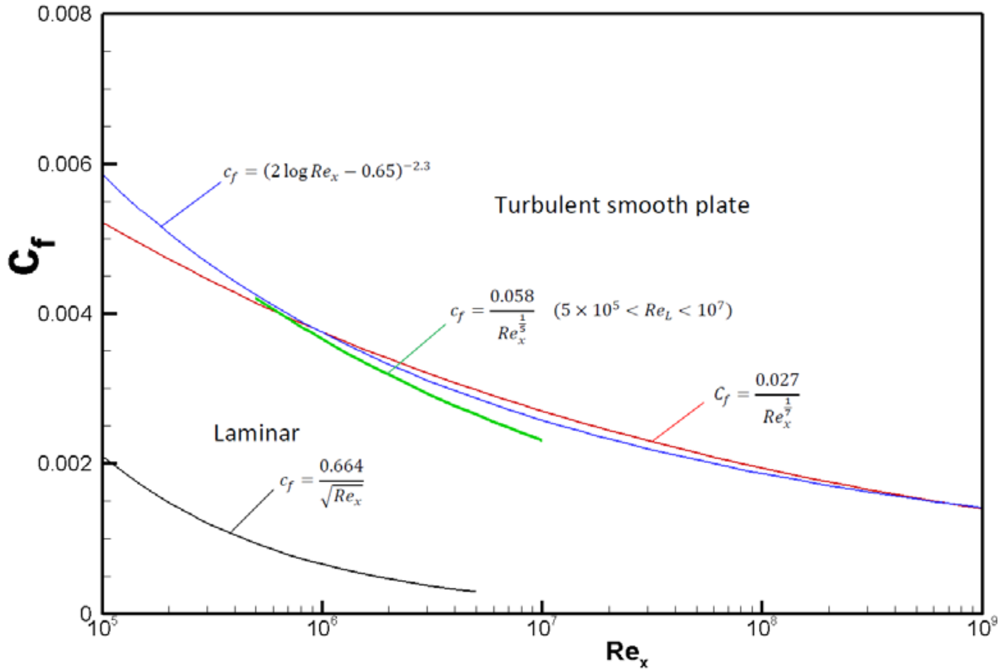

Figure A1: Local friction coefficient

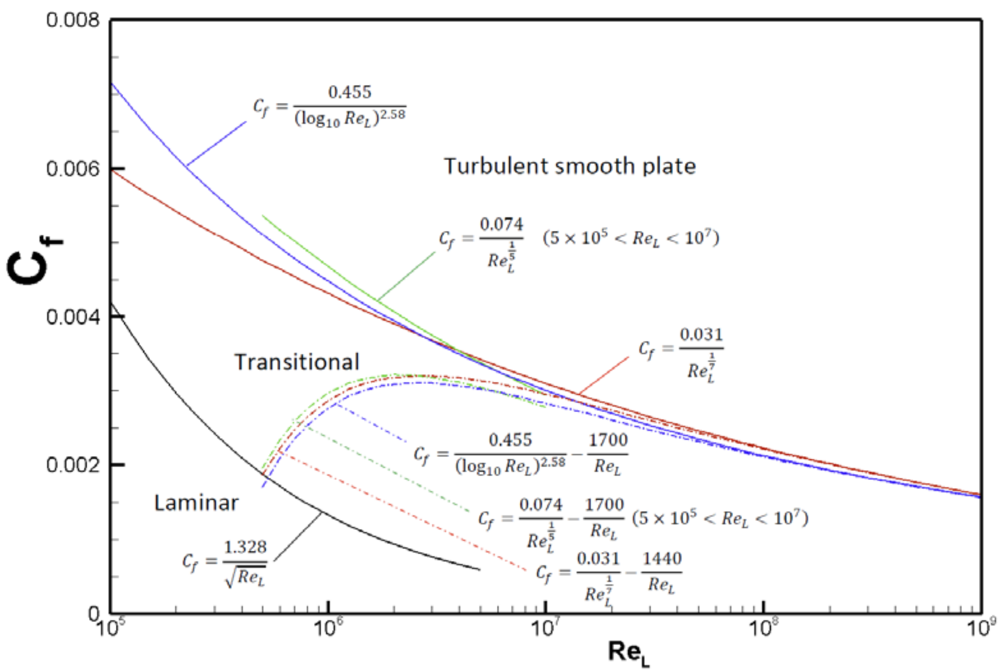

Figure A2: Friction drag coefficient