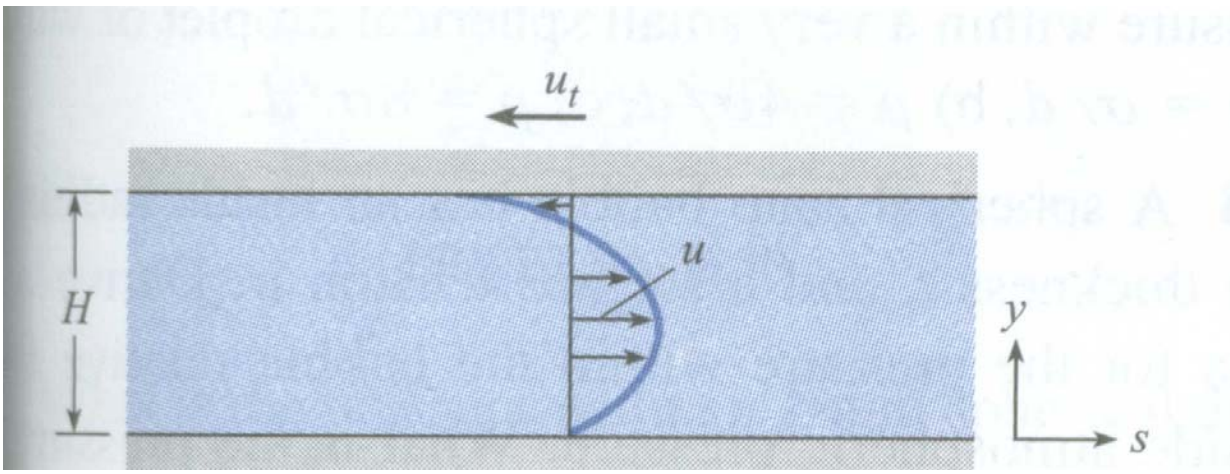
057:20 TEST # 3 Fall 2004

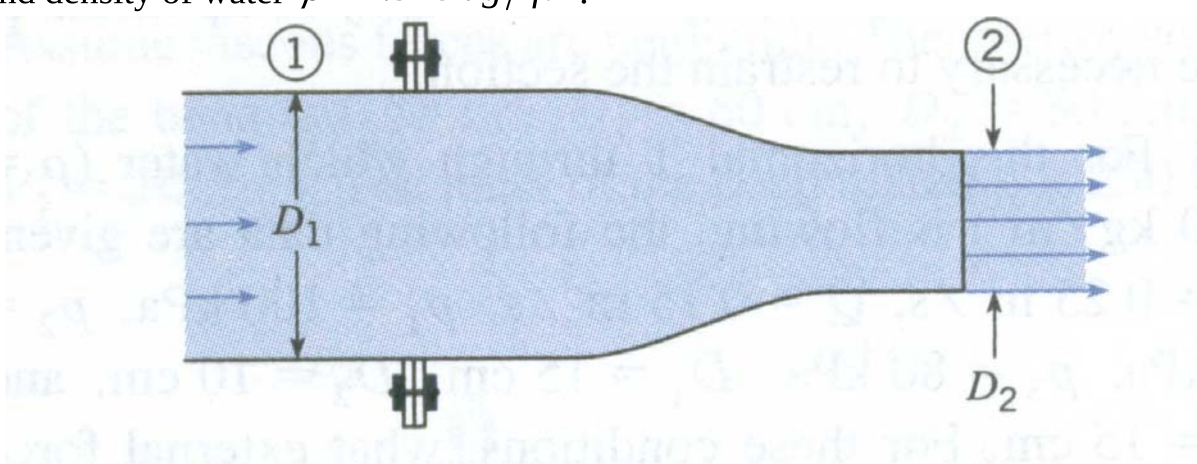
1. A laminar flow occurs between two horizontal parallel plates under a pressure gradient dp/ds (p decreases in the positive s direction). The upper plate moves left (negative) at velocity u_t . The expression for local velocity u is given as

$$u = -\frac{1}{2\mu}\frac{dp}{ds}\left(Hy - y^2\right) + u_t\frac{y}{H}$$

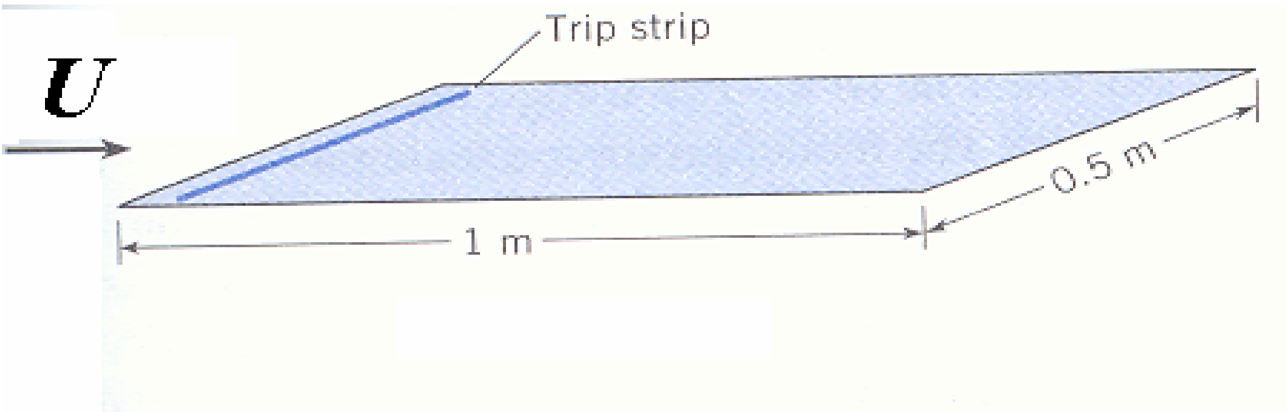
Is the magnitude of the shear stress greater at the moving plate $(y = H)$ or at the stationary plate $(y = 0)$?



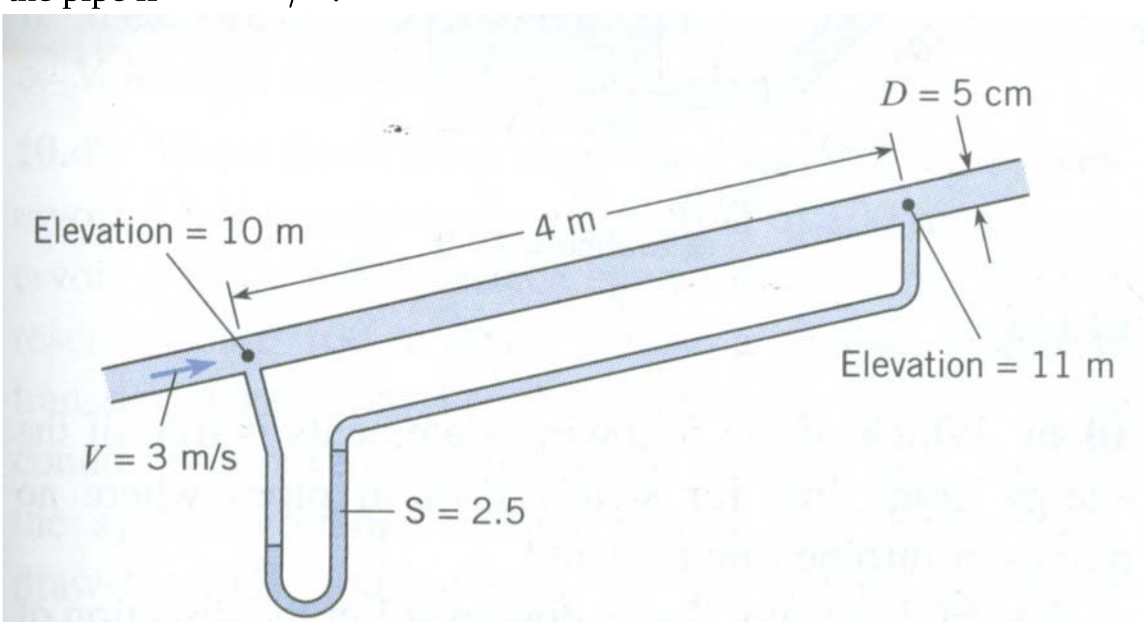
2. Water flows through this nozzle at a rate of $15 cfs$ and discharges into the atmosphere. $D_1 = 12 in.$ and $D_2 = 8 in.$ Determine the force required at the flange to hold the nozzle in place. Negelect gravitaional forces. Assume irrotational flow and density of water $\rho = 1.94\, slug/ft^3$.



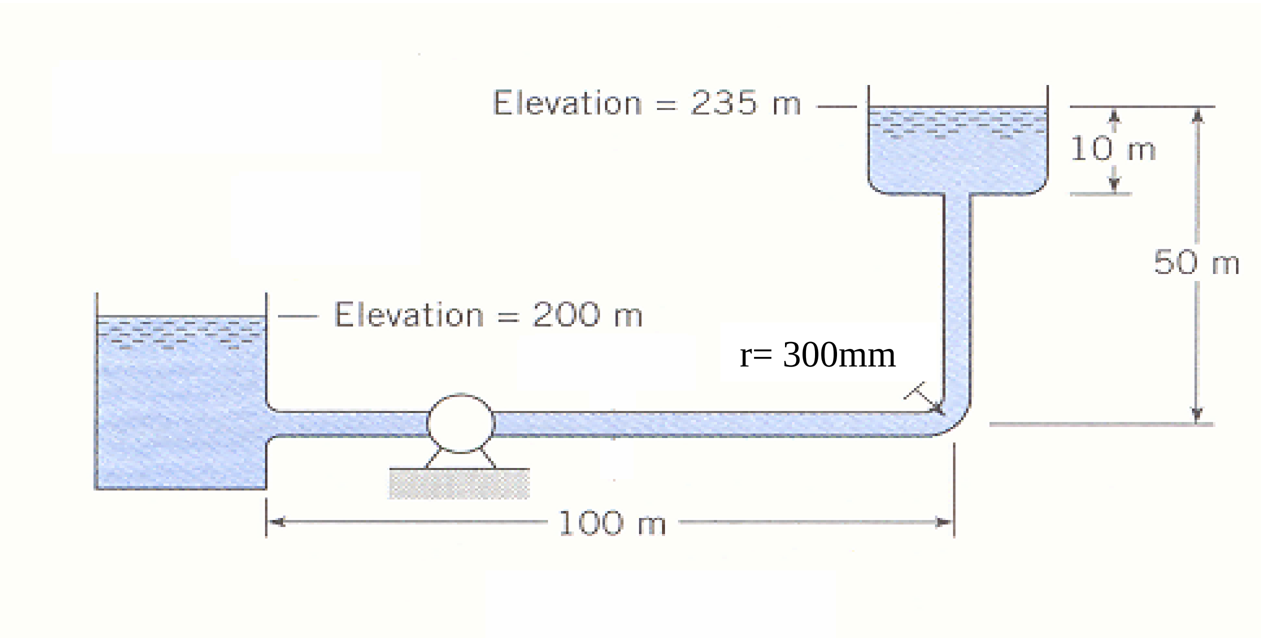
3. A flat plate is oriented parallel to a $15 m/s$ air flow at $20^o C$ and atmospheric pressure. The plate is $1.0 m$ long in the flow direction and $0.5 m$ wide. On one side of the plate, the boundary layer is tripped at leading edge (turbulent flow on that side). Find the total drag force on the tripped side of the plate.



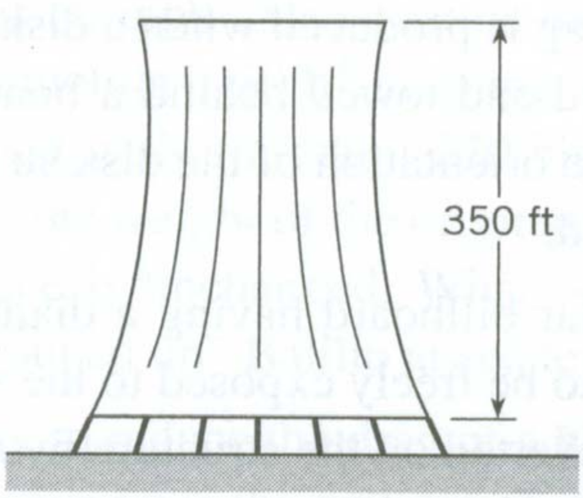
4. Water flows in the pipe shown, and the manometer deflects $80 cm$. What is f for the pipe if $V = 3 m/s$?



5. What power must be supplied by the pump to the flow if water ($T = 20^o C$) is pumped through the 300-*mm* steel pipe from the lower tank to the upper one at a rate of $0.314 m^3/s$?



6. A cooling tower, used for cooling recirculating water in a moder steam power plant, is $350\,ft$ high and $250\,ft$ average diameter. Estimate the drag on the cooling tower in a $4.31 mph$ wind ($T = 60^o F$). $(1 mile = 5,280\,ft)$



057:20 TEST # 3 Fall 2004

Prob. 1

Information and assumptions

Find

Is the magnitude of the shear stress greater at the moving plate or at the stationary plate?

Solution

Develop an equation for the shear stress

$$\tau = \mu \frac{du}{dy}$$ (Eqn. = 7)

$$= -\mu \left(\frac{1}{2\mu} \right) \left(\frac{dp}{ds} \right) (H - 2y) + \mu \frac{u_t}{H}$$

Evaluate τ at $y = H$:

$$\tau_H = \frac{1}{2} \left(\frac{dp}{ds} \right) H + \mu \frac{u_t}{H}$$

Evaluate τ at $y = 0$:

$$\tau_0 = -\frac{1}{2} \left(\frac{dp}{ds} \right) H + \mu \frac{u_t}{H}$$ (Inter. = 2)

Observation of the velocity gradient lets one conclude that the pressure gradient dp/ds is negative. Also u_t is negative. Therefore:

$$|\tau_H| > |\tau_0|$$ (Ans. = 1)

057:20 TEST # 3 Fall 2004

Prob. 2

Information and assumptions

Provided in problem statement

Find

Force at flange to hold nozzle in place

Solution

Velocity calculation

$$v_1 = \frac{Q}{A_1} = \frac{15}{(\pi/4)\times 1^2} = 19.10\ ft/s$$

$$v_2 = \frac{Q}{A_2} = \frac{15}{(\pi/4)\times (8/12)^2} = 42.97\ ft/s$$

(Eqn. + Ans. = 2)

Bernoulli eqaution

$$p_1 + \frac{1}{2}\rho v_1^2 = p_2 + \frac{1}{2}\rho v_2^2$$

(Eqn.= 2)

$$p_1 = 0 + \frac{1}{2}\rho\left(v_2^2 - v_1^2\right)$$

$$= 1,437\, lbf / ft^2$$

(Inter.+ Ans.= 1)

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x-momentum equation

$$\sum F_x = \dot{m}_2 v_2 - \dot{m}_1 v_1$$

(Eqn.= 4)

$$p_1 A_1 + F = (1.94\times 15)\times 42.97 - (1.94\times 15)\times 19.10$$

$$1,437\times\left(\frac{\pi}{4}\right)\times 1^2 + F = (1.94\times 15)\times(42.97 - 19.10)$$

$$F = -434 lbf\ (act\quad to\quad left)$$

(Inter. + Ans. = 1)

057:20 **TEST # 3** **Fall 2004**

Prob. 3

Information and assumptions

Provided in problem statement

From Table A.3 $\nu = 1.5\times10^{-5}\, m^2/s$ and $\rho = 1.2\, kg/m^3$

Find

Total drag force on plate

Solution

The force due to shear stress is

$$F_s = C_f \frac{1}{2}\rho U_0^2 BL$$

(Eqn. = 6)

The Reynolds number based on the plate length is

$$\mathrm{Re}_L = \frac{U_0 L}{\nu} = \frac{15\times1}{1.5\times10^{-5}} = 10^6$$

(Inter. + Ans. = 1)

The average shear stress coefficient on the tripped side of the plate is

$$C_f = \frac{0.074}{\left(10^6\right)^{1/5}} = 0.0047$$

(Inter. + Ans. = 2)

The totaol force is

$$F_x = 0.0047\times\left(\frac{1}{2}\times1.2\times15^2\right)\times\left(1.0\times0.5\right) = 0.317\, N$$

(Inter. + Ans. = 1)

057:20 **TEST # 3** **Fall 2004**

Prob. 4

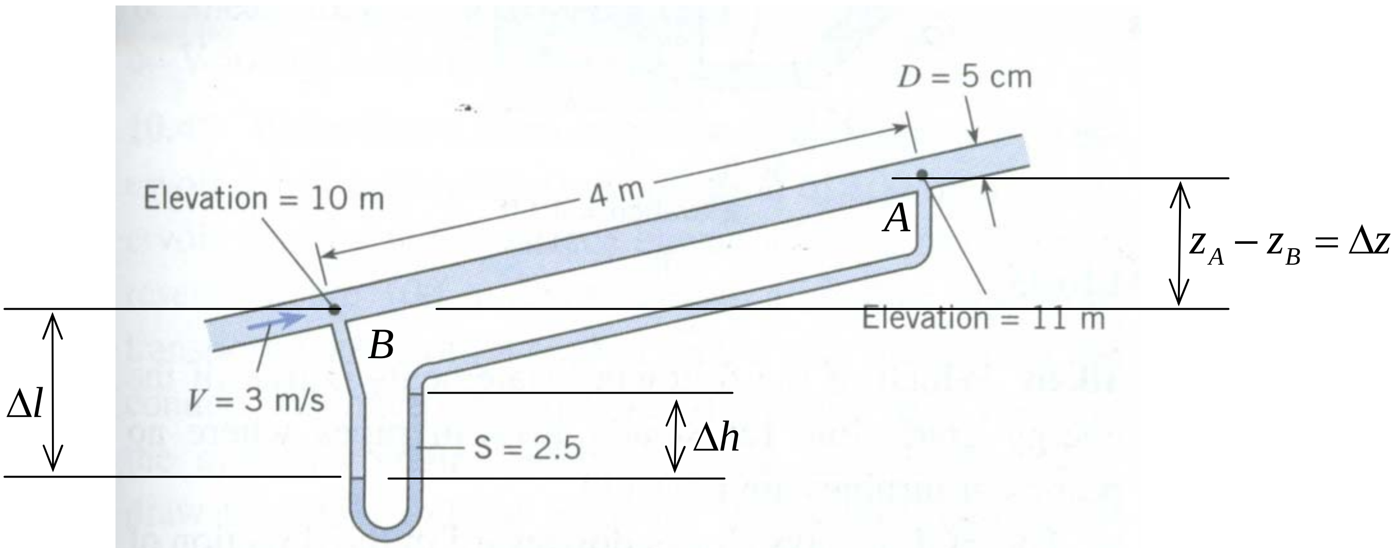
Information and assumptions

Provided in problem statement

Find

Resistance coefficient

Solution



Manometer equation

$$p_B + \gamma_f \Delta l - \gamma_m \Delta h - \gamma_f \left[(\Delta l - \Delta h) + \Delta z \right] = p_A$$

$$p_B - \gamma_m \Delta h - \gamma_f \left[-\Delta h + (z_A - z_B) \right] = p_A$$

$$p_B - (\gamma_m - \gamma_f) \Delta h - \gamma_f z_A + \gamma_f z_B = p_A$$

$$(p_B + \gamma_f z_B) - (p_A + \gamma_f z_A) = (\gamma_m - \gamma_f) \Delta h$$

$$p_{zB} - p_{zA} = (\gamma_m - \gamma_f) \Delta h$$

$$\Delta h = \frac{p_{zB} - p_{zA}}{\gamma_f} = \frac{(\gamma_m - \gamma_f) \Delta h}{\gamma_f} = \left(\frac{\gamma_m}{\gamma_f} - 1 \right) \Delta h = (2.5 - 1) \Delta h$$

$$\Delta h = h_f = 0.80 \times (2.5 - 1) = 1.2 m$$

(Eqn + Inter.+ Ans. = 3)

$$h_f = f \frac{L}{D} \frac{V^2}{2g}$$

(Eqn = 6)

$$f = 1.2 \times \left(\frac{0.05}{4} \right) \times \frac{2 \times 9.81}{3^3} = 0.033$$

(Inter.+ Ans. = 1)

057:20 TEST # 3 Fall 2004

Prob. 5

Information and assumptions

Provided in problem statement

From Table 10.3: $K_e = 0.03$; $K_b = 0.35$; $K_E = 1.0$

From Table A.5, $\nu = 10^{-6}\, m^2/s$

From Table 10.2, $k_s = 0.046mm$

Find

The pump power

Solution

Energy equation from the water surface in the lower reservior to the water surface in the upper reservior

$$p_1/\gamma + V_1^2/2g + z_1 + h_p = p_2/\gamma + V_2^2/2g + z_2 + \sum h_L$$

$$0 + 0 + 200m + h_p = 0 + 0 + 235m + \frac{V_2^2}{2g}\left(K_e + K_b + K_E + f\frac{L}{D}\right)$$

(Eqn = 7)

$$V = \frac{Q}{A} = \frac{0.314}{\left(\frac{\pi}{4}\right)\times 0.3^2} = 4.442\, m/s, \qquad \frac{V^2}{2g} = 1.01m$$

$$\mathrm{Re} = \frac{VD}{\nu} = \frac{4.44\times 0.3}{10^{-6}} = 1.33\times 10^6, \qquad \frac{k_s}{\nu} \approx 0.00015$$

So from Figure 10.8 $f = 0.014$

$$f\frac{L}{D} = 0.014\times\frac{140}{0.3} = 6.53$$

(Inter.+ Ans. = 2)

$$h_p = 235 - 200 + 1.01\times(0.03 + 0.35 + 1 + 6.53) = 43.0m$$

$$p = Q\gamma h_p = 0.314\times 9,790\times 43.0 = 132kW$$

(Inter.+ Ans. = 1)

Prob. 6

Information and assumptions

Provided in problem statement

From Table A.3, $\rho = 0.00237\, slugs/ft^3$; $\nu = 1.58 \times 10^{-4}\ ft^2/s$

Find

Drag on cooling tower

Solution

$$V = 4.31 mph = 6.32\ ft/s$$

$$\mathrm{Re} = \frac{V_0 d}{\nu} = \frac{6.32 \times 250}{1.58 \times 10^{-4}} = 1.0 \times 10^7$$

From Figure 11.5: $C_D = 0.70$ (Eqn. = 2)

Then

$$F_D = C_D A_p \frac{1}{2} \rho V^2$$ (Eqn. = 7)

$$= 0.70 \times 250 \times 350 \times \frac{1}{2} \times 0.00237 \times 6.32^2$$

$$= 2{,}899 lbf$$ (Inter.+ Ans. = 1)
