Solutions to HW#11 SP07

#1.

Water flows through an inclined 8-cm-diameter pipe. At sections A and B the following data are taken: $p_A = 186$ kPa, $V_A = 3.2$ m/s, $z_A = 24.5$ m, and $p_B = 260$ kPa, $V_B = 3.2$ m/s, $z_B = 9.1$ m. Which way is the flow going? What is the head loss in meters?

Solution: Guess that the flow is from A to B and write the steady flow energy equation:

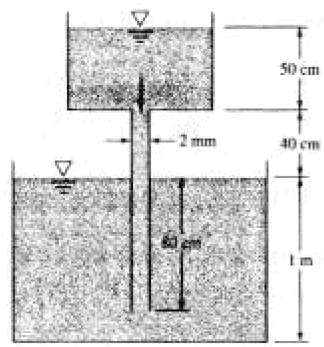
$$\frac{p_A}{\rho g} + \frac{V_A^2}{2g} + z_A = \frac{p_B}{\rho g} + \frac{V_B^2}{2g} + z_B + h_f, \quad \text{or:} \quad \frac{186000}{9790} + 24.5 = \frac{260000}{9790} + 9.1 + h_f,$$

or: $43.50 = 35.66 + h_f$, solve: $\mathbf{h_f = +7.84\ m}$ *Yes, flow is from A to B.* *Ans.* (a, b)

#2.

For the configuration shown below, the fluid is ethyl alcohol and the tanks are very wide. Find the flow rate which occurs in m^3/h. Is the flow laminar?

Solution: For ethanol, take ρ = 789 kg/m^3 and μ = 0.0012 kg/m·s. Write the energy equation from upper free surface (1) to lower free surface (2):



$$\frac{p_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{V_2^2}{2g} + z_2 + h_f,$$

with $p_1 = p_2$ and $V_1 \approx V_2 \approx 0$

Then $h_f = z_1 - z_2 = 0.9\text{ m} = \dfrac{128\mu LQ}{\pi\rho g d^4} = \dfrac{128(0.0012)(1.2\text{ m})Q}{\pi(789)(9.81)(0.002)^4}$

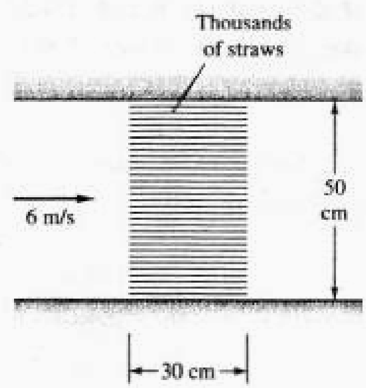
Solve for $Q \approx 1.90\text{E}{-6}\ m^3/s =$ **$0.00684\ m^3/h$.** *Ans.*

Check the Reynolds number $Re = 4\rho Q/(\pi\mu d) \approx 795$ – **OK, laminar flow.**

#3.

For straightening and smoothing an airflow in a 50-cm-diameter duct, the duct is packed with a "honeycomb" of thin straws of length 30 cm and diameter 4 mm, as in Fig. The inlet flow is air at 110 kPa and 20°C, moving at an average velocity of 6 m/s. Estimate the pressure drop across the honeycomb.

Solution: For air at 20°C, take $\mu \approx$ 1.8E−5 kg/m·s and $\rho = 1.31\ \text{kg/m}^3$. There would be approximately 12000 straws, but each one would see the average velocity of 6 m/s. Thus



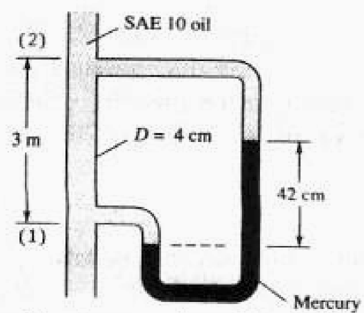
$$\Delta p_{laminar} = \frac{32\mu LV}{d^2} = \frac{32(1.8E{-}5)(0.3)(6.0)}{(0.004)^2} \approx \mathbf{65\ Pa} \quad \textit{Ans.}$$

Check $Re = \rho Vd/\mu = (1.31)(6.0)(0.004)/(1.8E{-}5)$

≈ 1750 OK, laminar flow.

#4.

SAE 10 oil flows through the 4-cm-diameter vertical pipe as shown. For the mercury manometer reading h = 42 cm shown, *(a)* calculate the volume flow rate in m^3/h and *(b)* state the direction of flow.



Solution: For SAE 10 oil, take ρ = 870 kg/m^3 and μ = 0.104 kg/m·s. The pressure at the lower point (1) is considerably higher than p_2 according to the manometer reading:

$$p_1 - p_2 = (\rho_{Hg} - \rho_{oil})g\Delta h = (13550 - 870)(9.81)(0.42) \approx 52200 \text{ Pa}$$

$$\Delta p/(\rho_{oil} g) = 52200/[870(9.81)] \approx 6.12 \text{ m}$$

This is more than 3 m of oil, therefore it must include a friction loss: **flow is *up*.** *Ans.* (b)

The energy equation between (1) and (2), with $V_1 = V_2$, gives

$$\frac{p_1 - p_2}{\rho g} = z_2 - z_1 + h_f, \quad \text{or} \quad 6.12 \text{ m} = 3 \text{ m} + h_f, \quad \text{or:} \quad h_f \approx 3.12 \text{ m} = \frac{128\mu LQ}{\pi \rho g d^4}$$

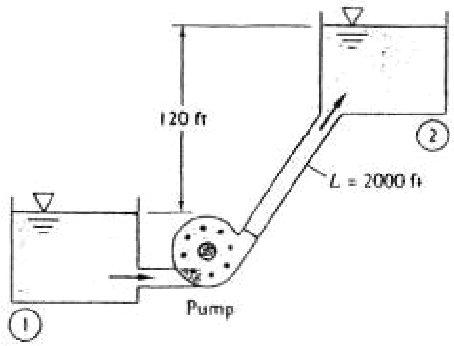
$$\text{Compute} \quad Q = \frac{(6.12 - 3)\pi(870)(9.81)(0.04)^4}{128(0.104)(3.0)} = 0.00536 \frac{m^3}{s} \approx \mathbf{19.3} \frac{\mathbf{m^3}}{\mathbf{h}} \quad \textit{Ans.} \text{ (a)}$$

Check $Re = 4\rho Q/(\pi \mu d) = 4(870)(0.00536)/[\pi(0.104)(0.04)] \approx 1430$ (OK, laminar flow).

#5.

Water is to be pumped through 2000 ft of pipe from reservoir 1 to 2 at a rate of 3 ft^3/s, as shown. If the pipe is cast iron of diameter 6 in and the pump is 75% efficient, what horsepower pump is needed? (roughness value for cast iron , $\varepsilon = 0.00085$ ft)

Solution: For water at 20°C, take $\rho = 1.94\ slug/ft^3$ and $\mu = 2.09E{-5}$ slug/ft·s. For cast iron, take $\varepsilon \approx 0.00085$ ft, or $\varepsilon/d = 0.00085/(6/12) \approx 0.0017$. Compute V, Re, and *f*:



$$V = \frac{Q}{A} = \frac{3}{(\pi/4)(6/12)^2} = 15.3\ \frac{ft}{s};$$

$$Re = \frac{\rho V d}{\mu} = \frac{1.94(15.3)(6/12)}{2.09E{-5}} \approx 709000$$

$$\varepsilon/d = 0.0017, \quad f_{Moody} \approx 0.0227$$

The energy equation, with $p_1 = p_2$ and $V_1 \approx V_2 \approx 0$, yields an expression for pump head:

$$h_{pump} = \Delta z + f\frac{L}{d}\frac{V^2}{2g} = 120\ ft + 0.0227\left(\frac{2000}{6/12}\right)\frac{(15.3)^2}{2(32.2)} = 120 + 330 \approx 450\ ft$$

Power: $$P = \frac{\rho g Q h_p}{\eta} = \frac{1.94(32.2)(3.0)(450)}{0.75} = 112200 \div 550 \approx \mathbf{204\ hp} \quad \textit{Ans.}$$