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13.2 A lubricating line has an inside diameter of 0.1 in and is 30 in long. If the pressure drop is 15 psi, determine the flow rate of the oil. Use the properties given in Problem 13.1.

$$\rho V_{avg} A \left[F + \Delta\left(\frac{P}{\rho}\right) + \frac{1}{2}\Delta(\alpha V_{avg}^2) + g\Delta z \right] = 0$$

$$2 f_f \frac{l}{D} V^2 = -\frac{\Delta P}{\rho}$$

$\nu = 0.08 \times 10^{-3} \ \frac{ft^2}{s}$

$\rho = 57 \ lbm/ft^3$

$D = 0.1 in = 0.083 ft$

$L = 30 in = 2.5 ft$

$$\Delta P = \frac{2 f_f l V^2 \rho}{D}$$

laminar

$$f_f = \frac{16}{Re} = \frac{16 \cdot \nu}{V \cdot D}$$

$$Re = \frac{\nu}{V \cdot D}$$

$$\Delta P = 2\left(\frac{16 \cdot \nu}{V \cdot D}\right) l V^2 \rho \frac{1}{D}$$

$$\Delta P = \frac{32 V}{D^2} l \nu \rho$$

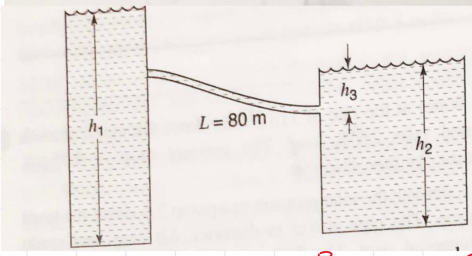
$$V = \frac{\Delta P \cdot D^2}{32 \nu l \nu \rho} = \frac{\Delta P \cdot D^2}{32 \nu l \nu \rho} = \frac{(15 \times 32.2 \times 144) \cdot 0.083^2}{32 \times 57 \times (0.08 \times 10^{-3}) \times 2.5} = 13.13 \ ft/s$$

flow rate $= V \cdot A = 13.13 \times \frac{\pi}{4} D^2 = 13.13 \cdot (0.0000544) = 0.0007 \ \frac{ft^3}{s}$ ※

13.15 Two water reservoirs of height $h_1 = 60$ m and $h_2 = 30$ m are connected by a pipe that is 0.35 m in diameter. The exit of the pipe is submerged at distance $h_3 = 8$ m from the reservoir surface.

a. Determine the flow rate through the pipe if the pipe is 80 m long and the friction factor $f_f = 0.004$. The pipe inlet is set flush with the wall.

b. If the relative roughness $e/D = 0.004$, determine the friction factor and flow rate.



水 at 20°C $\nu = 0.995 \times 10^{-6} \ \frac{m^2}{s}$

(a) $$\rho V_{avg} A \left[F + \Delta\left(\frac{P}{\rho}\right) + \frac{1}{2}\Delta(\alpha V_{avg}^2) + g\Delta z \right] = 0$$

$$F = -g\Delta z$$

$$2 f_f \frac{l}{D} V^2 = g(30 m)$$

$$V = \sqrt{\frac{9.8 \times 30 \times 0.35}{2(0.004)(80)}} = 12.68 \ m/s$$

$$\dot{V} = V \cdot A = 12.68 \times \frac{\pi}{4} D^2 = 1.22 \ m^3/s$$

assume $\nu = \frac{\mu}{\rho} = 0.995 \times 10^{-6} \ \frac{m^2}{s}$

$$Re = \frac{12.68 \times 0.35}{0.995 \times 10^{-6}} = 4460301 > 2300$$ turbulent

(b) $$F = g\Delta z$$

$$2 f_f \frac{l}{D} \frac{V^2}{g} = \Delta z$$

$f_f = 0.007$ (查表) ※

at $\frac{e}{D} = 0.004$

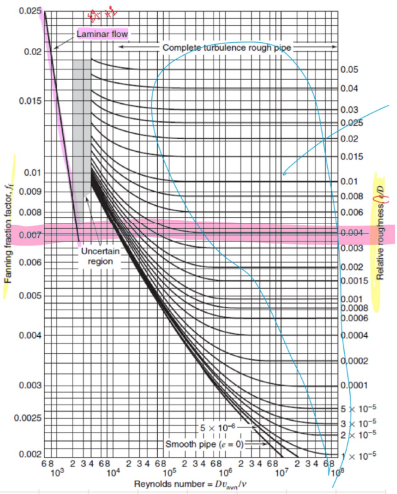
$$V^2 = \frac{g \times 30 \times 0.35}{2 \times (0.007)(80)} = 91.875$$

$V = 9.6 \ m/s$

$$Re = \frac{9.6 \times 0.35}{0.995 \times 10^{-6}} = 3376884 > 2300$$

turbulent

$$\dot{V} = V \cdot A = 9.6 \times \frac{\pi}{4}(0.35)^2 = 0.923 \ m^3/s$$ ※



13.23 Water flows at a volumetric flow rate of 0.25 m^3/s from reservoir 1 to reservoir 2 through three concrete pipes connected in series. Pipe 1 is 900 m long and has a diameter of 0.16 m. Pipe 2 has a length of 1500 m and a diameter of 0.18 m. Pipe 3 is 800 m long and the diameter is 0.20 m. Neglecting minor losses, determine the difference in surface elevations.

...ists of three pipes in series. The total

$\dot{V} = 0.25 \frac{m^3}{s}$ $\quad T = 20°C = 293K$

$\nu = 0.995 \times 10^{-6} \ m^2/s$

pipe 1 : $l = 900 m$, $D = 0.16 m$

pipe 2 : $l = 1500 m$, $D = 0.18 m$

pipe 3 : $l = 800 m$, $D = 0.20 m$

$$\rho V_{avg} A \left[F + \Delta\left(\frac{P}{\rho}\right) + \frac{1}{2}\Delta(\alpha V_{avg}^2) + g\Delta z \right] = 0$$

$$h_L = \frac{\Delta P}{\rho g} = 2 f_f \frac{l}{D}\frac{V^2}{g}$$

$V_1 \cdot \frac{\pi}{4} D_1^2 = 0.25 \frac{m^3}{s}$ $\quad \therefore V_1 = 12.64 \ m/s$

$Re_1 = \frac{D_1 V_1}{\nu} = \frac{0.16 \times 12.64}{0.995 \times 10^{-6}} = 2 \times 10^6$ turbulent

$V_2 \cdot \frac{\pi}{4} D_2^2 = 0.25 \frac{m^3}{s}$ $\quad V_2 = 9.8 \ m/s$

$R_2 = \frac{D_2 V_2}{\nu} = \frac{0.18 \times 9.8}{0.995 \times 10^{-6}} = 1.8 \times 10^6$

$V_3 \cdot \frac{\pi}{4} D_3^2 = 0.25 \frac{m^3}{s}$ $\quad V_3 = 7.9 \ m/s$

$R_3 = \frac{D_3 V_3}{\nu} = \frac{0.20 \times 7.9}{0.995 \times 10^{-6}} = 1.6 \times 10^6$

$$\frac{1}{\sqrt{f_f}} = -3.6 \log_{10}\left[\frac{6.9}{Re} + \left(\frac{e}{3.7D}\right)^{10/9}\right]$$

use trial and error with chart to get f_f

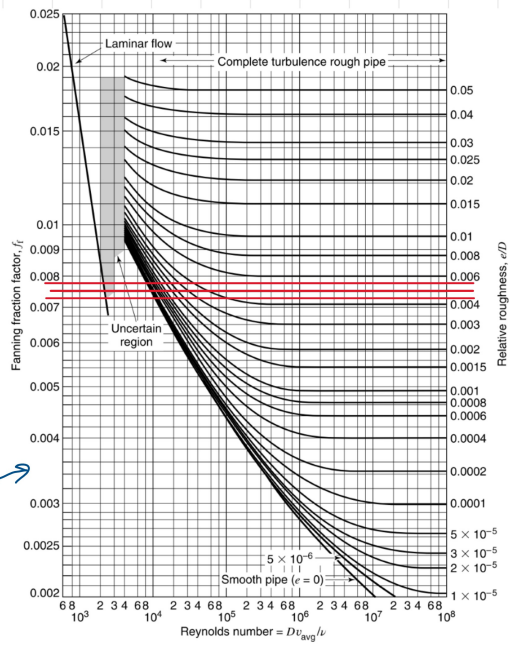


Figure 13.1 The Fanning friction factor as a function of Re and D/e.

$\frac{e}{D_1} = 0.0055$ $\quad f_{f_1} = 0.0078$

$\frac{e}{D_2} = 0.005$ $\quad f_{f_2} = 0.0075$

$\frac{e}{D_3} = 0.0045$ $\quad f_{f_3} = 0.0073$

$$h_L = \frac{\Delta P}{\rho g} = 2 f_f \frac{l}{D}\frac{V^2}{g}$$

$h_1 = 2 \times 0.0078 \frac{900}{0.16} \frac{(12.64)^2}{9.8} = 1385 \ m$ #

$h_2 = 2 \times 0.0075 \frac{1500}{0.18} \frac{(9.8)^2}{9.8} = 1225 \ m$ #

$h_3 = 2 \times 0.0073 \frac{800}{0.20} \frac{(7.9)^2}{9.8} = 372 \ m$ #