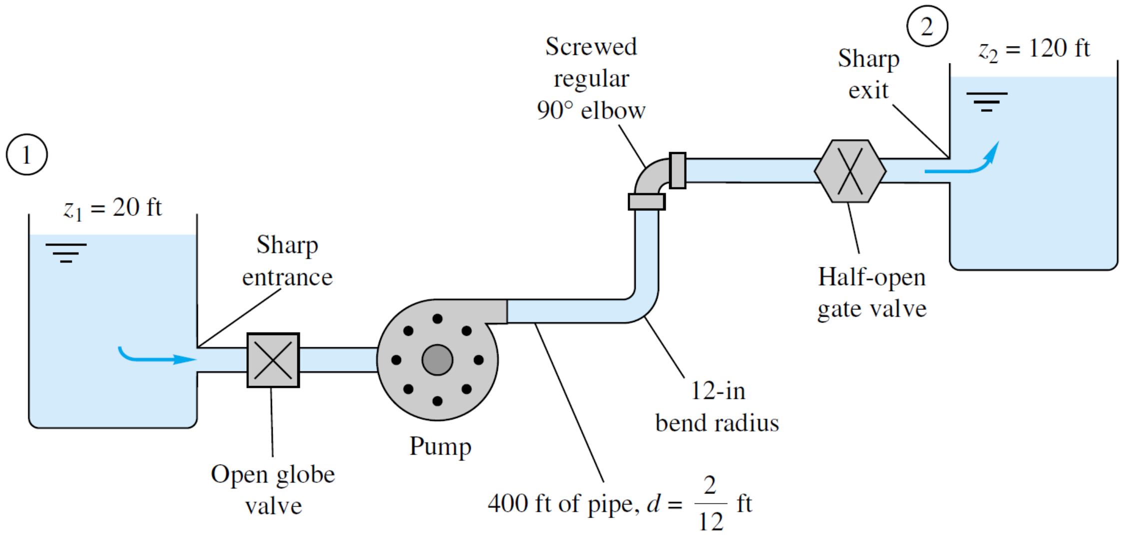
Example 1

Water, $\rho = 1.94$ slugs/ft^3 and $\nu = 0.000011$ ft^2/s, is pumped between two reservoirs at 0.2 ft^3/s through 400 ft of 2-in-diameter pipe and several minor losses, as shown in Fig. . The roughness ratio is $\epsilon/d = 0.001$. Compute the pump horsepower required.



Datum, Z=0

Loss	K
Sharp entrance (Fig. 6.21)	0.5
Open globe valve (2 in, Table 6.5)	6.9
12-in bend (Fig. 6.20)	0.15
Regular 90° elbow (Table 6.5)	0.95
Half-closed gate valve (from Fig. 6.18b)	2.7
Sharp exit (Fig. 6.21)	1.0

Solution

Apply Energy Equation between (1) and (2)

$$\frac{P_1}{\gamma} + Z_1 + \frac{v_1^{\,2}}{2g} + EP = \frac{P_2}{\gamma} + Z_2 + \frac{v_2^{\,2}}{2g} + (h_f + h_m)$$

$$Q = V.A,\ V = Q/A$$

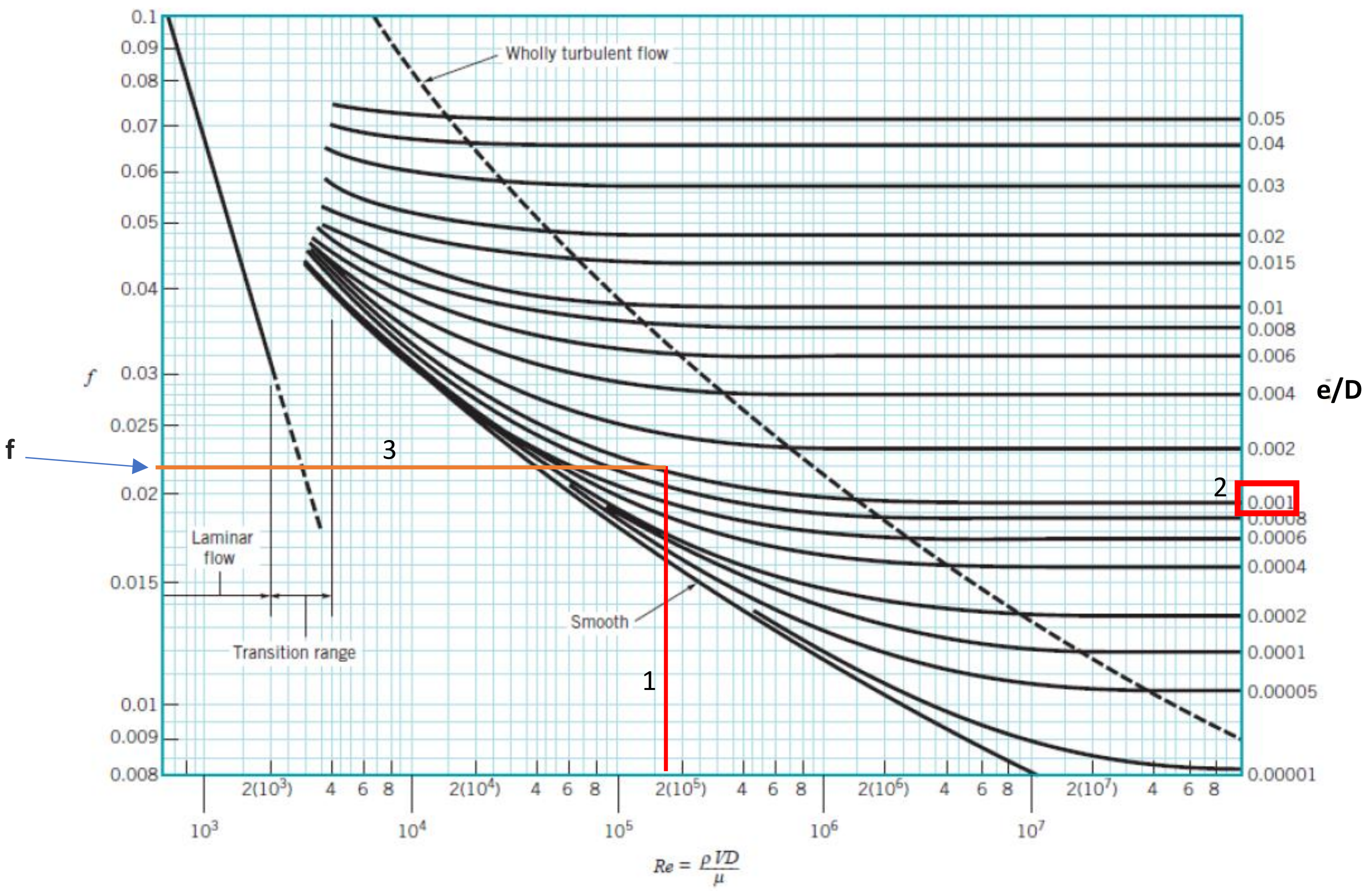
$$V = \frac{0.2}{\frac{(2/12)^2\pi}{4}} = 9.17\,\frac{ft}{sec}$$

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

$$R_e = \frac{VD}{\nu} = \frac{9.17 * (\frac{2}{12})}{0.000011} = 139{,}000$$

$$f = \frac{1.325}{[\ln(\frac{e}{3.7D} + \frac{5.74}{Re^{0.9}})]^2} = \frac{1.325}{[\ln(\frac{0.001}{3.7} + \frac{5.74}{(139{,}000)^{0.9}})]^2} = 0.0217$$

Or from Moody diagram



$$h_f = 0.0217 * \frac{400}{\left(\frac{2}{12}\right)} * \frac{(9.17)^2}{2(32.2)} = 66.4\ ft$$

$$h_m = \sum k \frac{V^2}{2g} = (0.5 + 6.9 + 0.15 + 0.95 + 2.7 + 1.0) \frac{(9.17)^2}{2(32.2)} = 15.9\, ft$$

$$\cancelto{0}{\frac{P_1}{\gamma}} + Z_1 + \cancelto{0}{\frac{v_1^2}{2g}} + E_P = \cancelto{0}{\frac{P_2}{\gamma}} + Z_2 + \cancelto{0}{\frac{v_2^2}{2g}} + +(h_f + h_m)$$

$$E_P + 20 = 120 + 66.4 + 15.9$$

$$E_P = 182.3\ ft$$

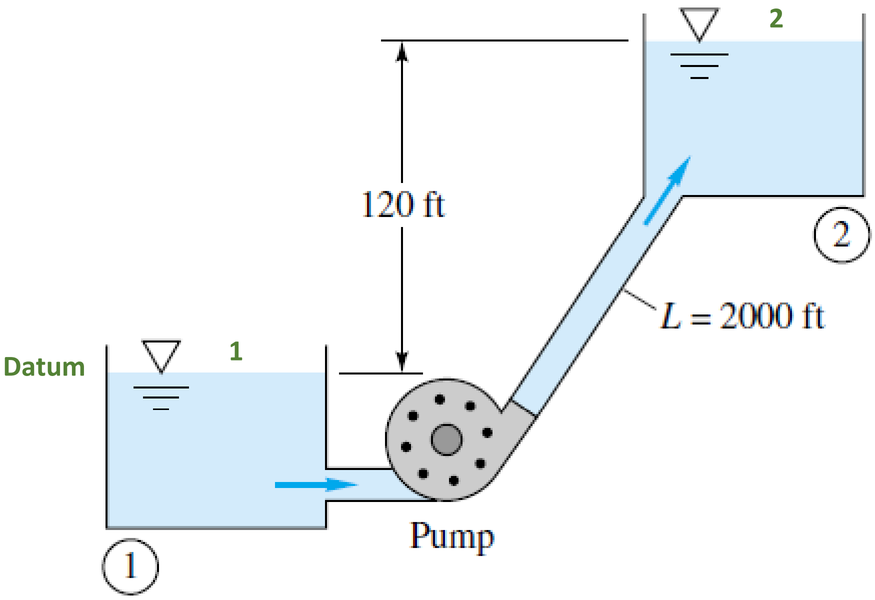
Output power of pump= $E_P * \gamma * Q$= 182.3* 62.4 * 0.2 = 2275.1 ft.Ib/s.

The pump must provide a power to the water of

$$power = \frac{2275.1}{550} = \boxed{4.14\text{ hp}}$$

Example 2

Water at 20°C is to be pumped through 2000 ft of pipe from reservoir 1 to 2 at a rate of 3 ft^3/s, as shown in Fig. P6.68. If the pipe is cast iron of diameter 6 in and the pump is 75 percent efficient, what horsepower pump is needed? Use (e/D) = 0.0017. Ignore minor losses. μ =$2.09*10^{-5}$ slug ft/sec.



Apply Energy Equation between (1) and (2), assume datum at 1

$$\frac{P_1}{\gamma} + Z_1 + \frac{{v_1}^2}{2g} + EP = \frac{P_2}{\gamma} + Z_2 + \frac{{v_2}^2}{2g} + (h_f)$$

Q=V.A, V=Q/A

$$V = \frac{3}{\frac{(6/12)^2\pi}{4}} = 15.3\,\frac{ft}{sec}$$

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

$$R_e = \frac{\rho V D}{\mu} = \frac{1.94 * 15.3 * (\frac{6}{12})}{2.09 * 10^{-5}} = 710{,}096$$

$$f = \frac{1.325}{[\ln(\frac{e}{3.7D} + \frac{5.74}{Re^{0.9}})]^2} = \frac{1.325}{[\ln(\frac{0.0017}{3.7} + \frac{5.74}{(710{,}096)^{0.9}})]^2} = 0.0228$$

$$h_f = 0.0228 * \frac{2000}{\left(\frac{6}{12}\right)} * \frac{(15.3)^2}{2(32.2)} = 331.5\,ft$$

$$\cancelto{0}{\frac{P_1}{\gamma}} + \cancelto{0}{Z_1} + \cancelto{0}{\frac{{v_1}^2}{2g}} + E_P = \cancelto{0}{\frac{P_2}{\gamma}} + Z_2 + \cancelto{0}{\frac{{v_2}^2}{2g}} + + h_f$$

$$E_P = 120 + 331.5 = 451.5\,ft$$

Output power of pump= E_P* ρ*g * Q= 451.5* 1.94 * 32.2 *3 = 84613 ft.Ib/s.

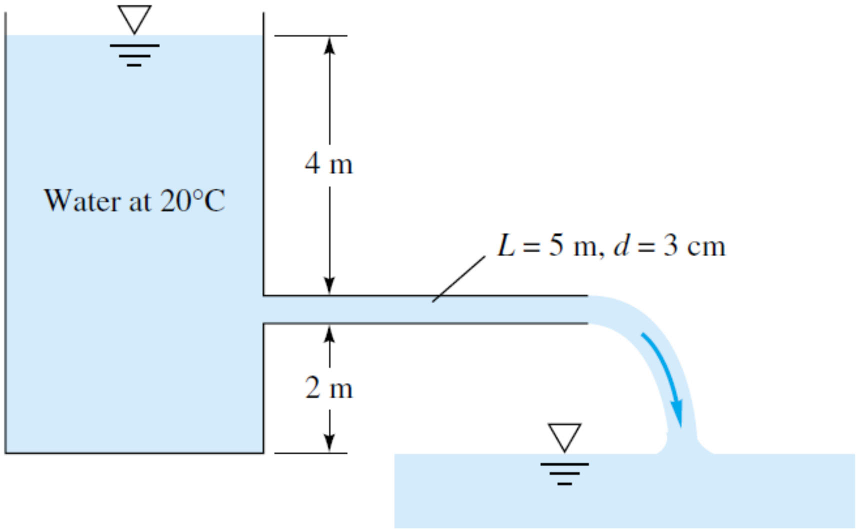
$$Efficiency = \frac{Output\ power}{Input\ power}$$

$$0.75 = \frac{84613}{Input\ power}$$

Input power= 112817.3 ft.Ib/s.=====➔ $Input\ power = \frac{112817.3}{550}$ = 205 hp

Homework

The tank-pipe system of Fig. is to deliver at least 11 m^3/h of water at 20°C to the reservoir. What is the maximum roughness height (e) allowable for the pipe? μ =0.001 kg.m/sec.



Answer: e=0.012 mm