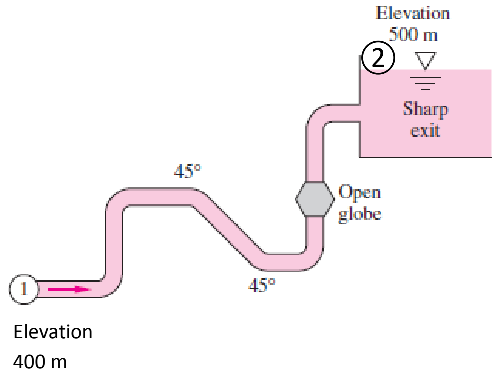
NAME

Fluids-ID

Quiz 14. The system consists of 1200 m of 5 cm diameter cast iron pipe, two 45 ° and four 90° flanged long-radius elbows, a fully open flanged globe valve, and a sharp exit into a reservoir. If the elevation at point 1 is 400 m, what gage pressure is required at point 1 to deliver 0.005 m^3/s of water at 20 ℃ into the reservoir?

($\rho = 998\ kg/m^3; g = 9.81 m/s^2; \mu = 0.001\ kg/m.s; \varepsilon = 0.26\ mm$)



- ***Energy Eq.:***

$$\frac{p_1}{\rho g} + \frac{V_1^2}{2g} + z_1 + h_p = \frac{p_2}{\rho g} + \frac{V_2^2}{2g} + z_2 + \frac{V^2}{2g}\left(\frac{f\ell}{d} + \sum K_L\right)$$

- ***Friction factor, f:***

$$\frac{1}{\sqrt{f}} = -1.8 \log\left[\left(\frac{\varepsilon/d}{3.7}\right)^{1.11} + \frac{6.9}{Re}\right]$$

Loss	K_L
Open flanged globe valve	8.5
90° long-radius elbow	0.3
45° long-radius elbow	0.2
Sharp exit	1.0

Solution:

Since $p_2 = 0$ (gauge pressure) and $V_1 = V$, $V_2 \approx 0$, the energy equation becomes

$$\frac{p_1}{\rho g} + \frac{V^2}{2g} + z_1 = 0 + 0 + z_2 + \frac{V^2}{2g}\left(\frac{f\ell}{d} + \sum K_L\right)$$ (+3 points)

With the flow rate known

$$V = \frac{Q}{A} = \frac{0.005}{\left(\frac{\pi}{4}\right)(0.05)^2} = 2.55\ m/s$$

(+1 point)

Calculate the Reynolds number,

$$Re = \frac{\rho V d}{\mu} = \frac{998(2.55)(0.05)}{0.001} = 127{,}000$$ (+1 point)

For $\varepsilon/d = \frac{0.26mm}{50mm} = 0.0052$, the pipe friction factor,

$$f = \left\{-1.8\log\left[\left(\frac{\varepsilon/d}{3.7}\right)^{1.11} + \frac{6.9}{Re}\right]\right\}^{-2} = 0.0315$$ (+1 points)

Minor losses are

$$\sum K_L = 2(0.2) + 4(0.3) + 8.5 + 1 = 11.1$$ (+1 points)

Thus, the pressure head becomes,

$$\frac{p_1}{\rho g} = z_2 - z_1 + \frac{V^2}{2g}\left(\frac{f\ell}{d} + \sum K_L\right)$$

$$\frac{p_1}{\rho g} = 500 - 400 + \frac{(2.55)^2}{2(9.81)}\left[0.0315\left(\frac{1200}{0.05}\right) + \sum K_L - 1\right] = 354\ m$$

(+2 points)

The pressure at 1 is

$$p_1 = 998 \times 9.81 \times 353 = 3.46\ MPa$$ (+1 point)