December 3, 2014

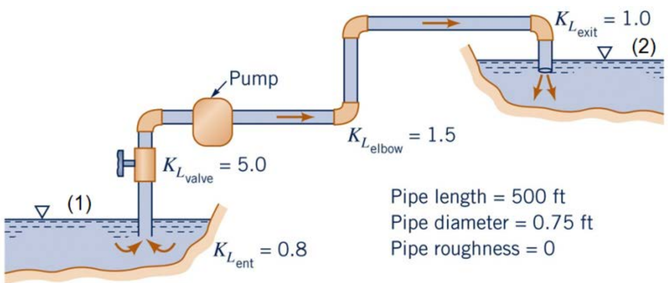
NAME

Fluids-ID

Quiz 12. The pump shown in Figure delivers a head of 250 ft to the water. The differene in elevation of the two ponds is 200 ft. ($P = \rho g Q h_p$; ρ = 1.94 slugs/ft^3; μ= 2.34×10^{-5} lb·s/ft^2; g = 32.2 ft/s^2; 1 hp = 550 ft·lbf/s; Reynolds number, $Re = \rho VD/\mu$)

Energy Equation

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



Friction Factor Equation (The Haaland eq.)

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

Note: Attendance (+2 points), format (+1 point)

a) Simplify energy equation using the given conditions and determine velocity, V, as a function of friction factor, f.

b) Use the given conditions and determine Reynolds number, Re, as a function of velocity, V.

c) Determine velocity V by following the steps listed below

1) Assume f = 0.02 as your first guess and find V using the equation from (a)
2) Find Re using the equation from (b) and the V from the previous step
3) Find a new f using the Haaland equation and Re from step 2)
4) Find a new V using the f from step 3) and the equation from (a)
5) Repeat the steps 2) through 4) until f is converged to the thousandth decimal point

d) Determine the power P that pump adds to the water.

<u>Solution:</u>

Where $p_1 = p_2, V_1 = V_2 \approx 0$, the energy equation becomes

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

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

(+2 point)

$$2\times 32.2(250-200)=V^2\left(f\frac{500}{0.75}+0.8+4\times1.5+5+1\right)$$

$$(667f+12.8)V^2=3220$$

$$V = \sqrt{\frac{3220}{(667f + 12.8)}} \ (1)$$

(+1 point)

Reynolds number

$$Re = \frac{\rho V D}{\mu} = \frac{1.94 \times V \times 0.75}{2.34 \times 10^{-5}}$$

$$Re = 6.22 \times 10^4 V \ (2)$$

(+1 point)

Rearranging friction factor equation

$$f = \left[-1.8 \log\left(\frac{6.9}{Re}\right)\right]^{-2} (3)$$

Solving for velocity iteratively using equations (1), (2) and (3)

Assume $f = 0.02 \rightarrow V = 11.1 \frac{ft}{s} \rightarrow Re = 6.9 \times 10^5 \rightarrow f = 0.012$

Assume $f = 0.012 \rightarrow V = 12.4 \frac{ft}{s} \rightarrow Re = 7.7 \times 10^5 \rightarrow f = 0.0121$

Thus

$$V = 12.4 \frac{ft}{s}$$

(+2 point)

Calculating pump power

$$P = \rho g Q h_p = \rho g V A h_p$$

$$P = 1.94 \times 32.2 \times 12.4 \times \frac{\pi}{4}(0.75)^2 \times 250 = 8.55 \times 10^4 \frac{ft\ lb}{s} = 155\ hp$$

(+1 point)