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Fluids-ID _____

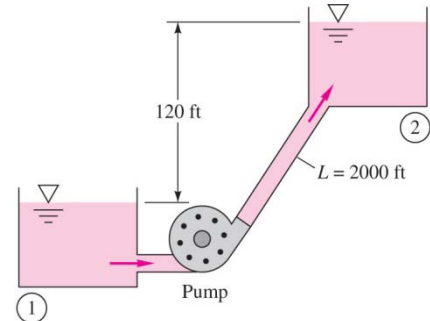
Quiz 10. Water at 20°C ($\rho = 1.94 \text{ slug/ft}^3$ and $\mu = 2.09 \times 10^{-5} \text{ slug/ft}\cdot\text{s}$) is to be pumped through 2000 ft of pipe from reservoir 1 to 2 at a rate of 3 ft³/s. If the pipe is cast iron ($\varepsilon = 0.00085 \text{ ft}$) of diameter 6 in, what horsepower (1hp = 550 ft·lbf/s) pump is needed? (Note: $g = 32.2 \text{ ft/s}^2$)

- Energy equation:

$$\frac{p_1}{\gamma} + \frac{V_1^2}{2g} + z_1 + h_p = \frac{p_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + h_t + h_L \quad (1)$$

$$h_L = h_f = f \frac{L V^2}{d 2g} \quad (2)$$

$$\frac{1}{\sqrt{f}} = -1.8 \log \left[\left(\frac{\varepsilon/D}{3.7} \right)^{1.11} + \frac{6.9}{Re} \right] \quad (3)$$

Solution:

Compute V and Re:

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

$$Re = \frac{\rho V D}{\mu} = \frac{\left(1.94 \frac{\text{slug}}{\text{ft}^3}\right) \left(15.3 \frac{\text{ft}}{\text{s}}\right) \left(\frac{6}{12} \text{ ft}\right)}{2.09 \times 10^{-5} \frac{\text{slug}}{\text{ft}\cdot\text{s}}} = 709000 \quad (+2 \text{ points})$$

With Vand Re and $\varepsilon/D = (0.00085 \text{ ft})/(6/12 \text{ ft}) = 0.0017$, by using the equation (3),

$$f = 0.0227 \quad (+2 \text{ points})$$

The energy equation (1) and the head loss equation (2), along with $p_1 = p_2 = p_a$, $V_1 \approx V_2 \approx 0$, and $h_t = 0$ (no turbine), yield an expression for pump head:

$$h_p = (z_2 - z_1) + f \frac{L V^2}{D 2g} = (120 \text{ ft}) + 0.0227 \left(\frac{2000 \text{ ft}}{6/12 \text{ ft}} \right) \frac{\left(15.3 \frac{\text{ft}}{\text{s}}\right)^2}{2 \left(32.2 \frac{\text{ft}}{\text{s}^2}\right)} = 450 \text{ ft} \quad (+5 \text{ points})$$

Thus, the pump power is

$$P = \rho g Q h_p = \left(1.94 \frac{\text{slug}}{\text{ft}^3}\right) \left(32.2 \frac{\text{ft}}{\text{s}^2}\right) \left(3 \frac{\text{ft}^3}{\text{s}}\right) (450 \text{ ft}) = 84332 \frac{\text{ft}\cdot\text{lbf}}{\text{s}} = 153 \text{ hp} \quad (+1 \text{ point})$$