NAME

Fluids-ID

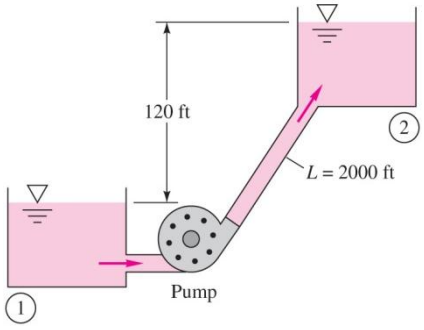
Quiz 13. Water at 20°C (ρ = 1.94 slug/ft^3 and μ = 2.09 × 10^{-5} slug/ft·s) is to be pumped through 2000 ft of pipe from reservoir 1 to 2 at a rate of 3 ft^3/s. If the pipe is cast iron (ε = 0.00085 ft) of diameter 6 in, what horsepower (1hp = 550 ft·lbf/s) pump is needed? (Note: g = 32.2 ft/s^2)

- Energy equation:

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

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

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



Solution:

Compute V and Re:

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

$$Re=\frac{\rho VD}{\mu}=\frac{\left(1.94\ \frac{\text{slug}}{\text{ft}^3}\right)\left(15.3\ \frac{\text{ft}}{\text{s}}\right)\left(\frac{6}{12}\ \text{ft}\right)}{2.09\times10^{-5}\ \frac{\text{slug}}{\text{ft}\cdot\text{s}}}=709000 \qquad \text{(+2 points)}$$

With *V*and *Re* and ε/D = (0.00085 ft)/(6/12 ft) = 0.0017, by using the equation (3),

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

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:

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

Thus, the pump power is

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