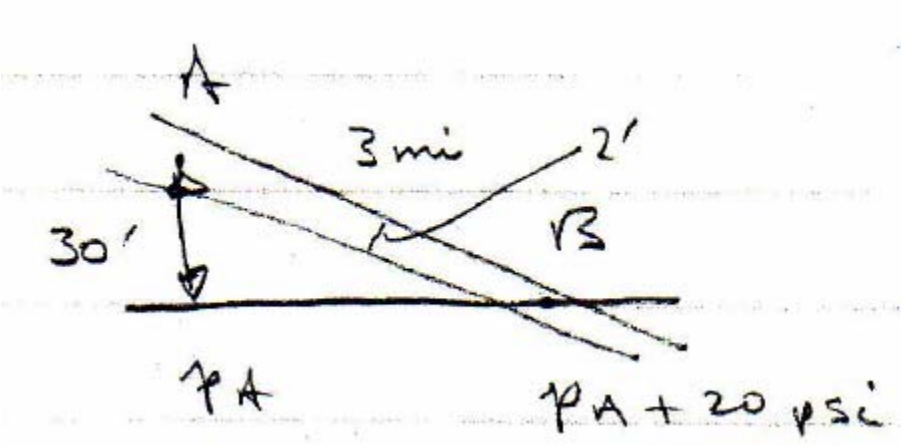
10.60 Points A and B are 3 mi apart along a 24-in. new cast-iron pipe carrying water ($T = 50°F$). Point A is 30 ft higher than B. The pressure at B is 20 psi greater than that at A. Determine the direction and rate of flow.



Solution:

$$h_f = -\Delta h = -\left[\frac{(p_A + 20\,psi)}{\gamma} - \frac{(p_A)}{\gamma} + (0 - 30)\right]$$

$$= -\frac{20 \times 144}{62.4} + 30 = -16.2\,ft$$

$\Delta h > 0$, adverse pressure gradient and flow right to left

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

$$V = \left[\frac{2gh_f}{L/D}\right]^{1/2} \quad f^{-1/2} = \left[\frac{2 \times 32.2 \times 16.2}{(3 \times 5280)/2}\right]^{1/2} \quad f^{-1/2} = 0.3629\, f^{-1/2}$$

$$k_s/D = 0.0004$$

Given $f = 0.017$: $V = 2.78$, $\text{Re} = \dfrac{VD}{\nu} = 3.94 \times 10^5$

$f = 0.0175$: $V = 2.74$

$$Q = VA = 2.74 \times \frac{\pi}{4} \times 2^2 = 8.6 cfs$$