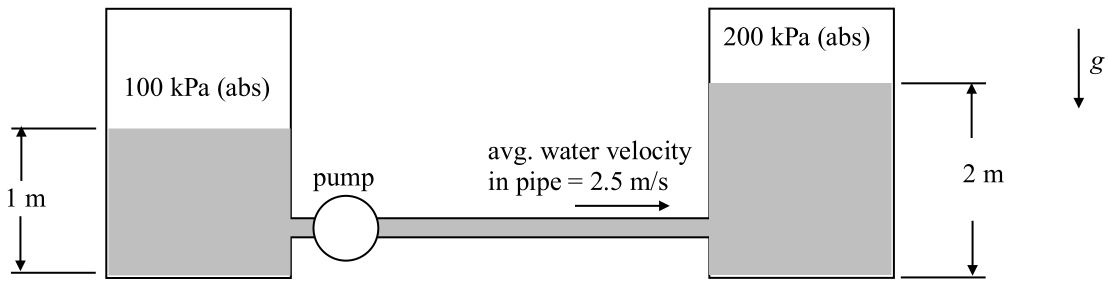
Consider the pipe system shown in the figure below.



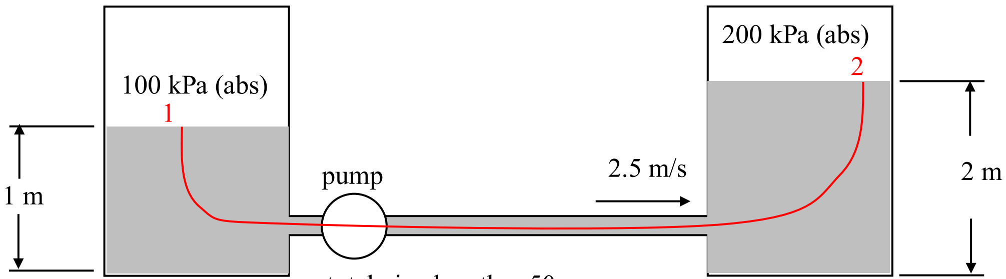
water density = 1000 kg/m^3
water kinematic viscosity = $1.0*10^{-6}$ m^2/s

total pipe length = 50 m
pipe diameter = 0.02 m
pipe roughness = $2.0*10^{-5}$ m
total minor loss coefficient = 5

Determine the power the pump must provide to the water to maintain the given conditions.

SOLUTION:

Apply the Extended Bernoulli Equation from point 1 to point 2.



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$$\left(\frac{p}{\rho g}+\alpha\frac{\bar{V}^2}{2g}+z\right)_2=\left(\frac{p}{\rho g}+\alpha\frac{\bar{V}^2}{2g}+z\right)_1-H_L+H_S \qquad (1)$$

Re-arrange to solve for the shaft head term,

$$H_S=\left(\frac{p_2-p_1}{\rho g}\right)+\left(\alpha_2\frac{\bar{V}_2^2}{2g}-\alpha_1\frac{\bar{V}_1^2}{2g}\right)+(z_2-z_1)+H_L \qquad (2)$$

where

$g = 9.81\ \text{m/s}^2$ and $\rho = 1000\ \text{kg/m}^3$ (3)

$p_1 = 100$ kPa (abs) and $p_2 = 200$ kPa (abs) (4)

$\bar{V}_1 \approx 0$ and $\bar{V}_2 \approx 0$ (5)

$z_1 = 1$ m and $z_2 = 2$ m (6)

$$H_L=\left[f\left(\frac{L}{D}\right)+K_{\text{minor}}\right]\frac{\bar{V}_{\text{pipe}}^2}{2g} \qquad (7)$$

and

$L = 50$ m and $D = 0.02$ m (8)

$K_{\text{minor}} = 5$ (9)

$$e/D=\left(2.0*10^{-5}\ \text{m}\right)/\left(0.02\ \text{m}\right)=0.001 \qquad (10)$$

$$\text{Re}=\frac{\bar{V}_{\text{pipe}}D}{\nu}=\frac{(2.5\ \text{m/s})(0.02\ \text{m})}{\left(1.0*10^{-6}\ \text{m}^2/\text{s}\right)}=50{,}000 \qquad (11)$$

Use the Moody diagram to find the friction factor for this Reynolds number and relative roughness,

$f = 0.024$ (12)

Using the given data,

$H_S = 31.7$ m (13)

The power may be found from the shaft head term using,

$$W_S=\rho Q g H_S=\rho V_{\text{pipe}}\tfrac{\pi}{4}D^2 g H_S \qquad (14)$$

Thus,

$$\boxed{W_S=244\ \text{W}} \qquad (15)$$