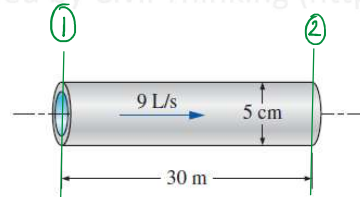
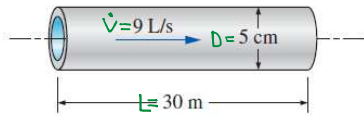


Water at 15°C ($\rho = 999.1 \text{ kg/m}^3$ and $\mu = 1.138 \times 10^{-3} \text{ kg/m}\cdot\text{s}$) is flowing steadily in a 30-m-long and 5-cm-diameter horizontal pipe made of stainless steel at a rate of 9 L/s. Determine (a) the pressure drop, (b) the head loss, and (c) the pumping power requirement to overcome this pressure drop

8-39 Water at 15°C ($\rho = 999.1 \text{ kg/m}^3$ and $\mu = 1.138 \times 10^{-3} \text{ kg/m}\cdot\text{s}$) is flowing steadily in a 30-m-long and 5-cm-diameter horizontal pipe made of stainless steel at a rate of 9 L/s. Determine (a) the pressure drop, (b) the head loss, and (c) the pumping power requirement to overcome this pressure drop.



Applying Bernoulli's Equation between 1 and 2:

$$\frac{P_1}{\rho g} + \frac{v_1^2}{2g} + z_1 + h_L = \frac{P_2}{\rho g} + \frac{v_2^2}{2g} + z_2 \quad \text{--- ①}$$

$$z_1 = z_2 = 0 \quad [\text{same height}]$$

$$v_1 = v_2 = \frac{\dot{V}}{A} = \frac{9 \text{ L/s} \times 10^{-3}}{\frac{\pi}{4} \cdot (5 \times 10^{-2})^2} = 4.584 \text{ m/s} = v$$

Eq. ① becomes :

$$\frac{P_1}{\rho g} + h_L = \frac{P_2}{\rho g} \Rightarrow \frac{P_2}{\rho g} - \frac{P_1}{\rho g} = h_L$$

$$\Rightarrow P_2 - P_1 = \rho g h_L = \Delta P$$

$$h_L = h_f = \frac{f L v^2}{2g d}$$

$f \Rightarrow$ Depends on type of flow.

$$Re = \frac{\rho v D}{\mu} = \frac{999.1 \text{ kg/m}^3 \times 4.584 \text{ m/s} \times 5 \times 10^{-2} \text{ m}}{1.138 \times 10^{-3} \text{ kg/m}\cdot\text{s}} \approx 201224.7$$

$\Rightarrow Re > 4000 \Rightarrow$ Turbulent flow

$$\text{Relative Roughness} = \frac{\epsilon}{D} = \frac{0.002 \times 10^{-3} \text{ m}}{5 \times 10^{-2} \text{ m}} = 0.00004$$

from moody chart

Equivalent roughness values for new commercial pipes*

Material	Roughness, ϵ	
	ft	mm
Glass, plastic	0 (smooth)	

from moody chart

Solved by Civil Thinking (<https://civilthinking.com>)

$$f = 0.01594$$

Solved by Civil Thinking (<https://civilthinking.com>)

$$\Rightarrow h_L = \frac{0.01594 \times 30 \text{ m} \times 4.584 \text{ m/s}^2}{2 \times 9.81 \times 5 \times 10^{-2} \text{ m}} = 10.2 \text{ m}$$

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we found:

$$\Delta P = \rho g h_L = 999.1 \text{ kg/m}^3 \times 9.81 \text{ m/s}^2 \times 10.2 \text{ m}$$

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$$= 99971.9 \text{ kgm/s}^2 = 99.9 \text{ kPa}$$

$$\approx 100 \text{ kPa}$$

$$\Rightarrow \Delta P \approx 100 \text{ kPa}$$

$$\text{Pumping Power} = \dot{W}_{\text{pump}} = \dot{V} \times \Delta P$$

$$= 9 \times 10^{-3} \text{ m}^3/\text{s} \times 100 \text{ kPa}$$

$$\Rightarrow \dot{W}_{\text{pump}} = 0.9 \text{ kW}$$

Material	Roughness, ϵ	
	ft	mm
Glass, plastic	0 (smooth)	
Concrete	0.003–0.03	0.9–9
Wood stave	0.0016	0.5
Rubber, smoothed	0.000033	0.01
Copper or brass tubing	0.000005	0.0015
Cast iron	0.00085	0.26
Galvanized iron	0.0005	0.15
Wrought iron	0.00015	0.046
Stainless steel Commercial	0.000007	0.002
steel	0.00015	0.045

*The uncertainty in these values can be as much as ± 60 percent.

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