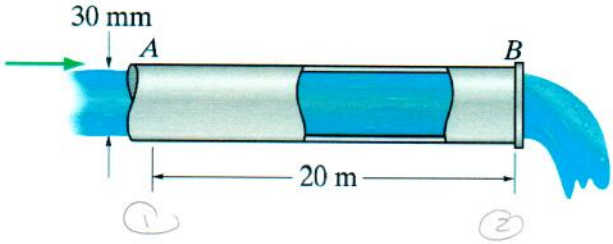
CHEN.3030 Fluid Mechanics
Short Quiz: Pipe Flow Applications

The 30 mm diameter 20 m long commercial steel pipe ($\varepsilon = 0.000045$ m) transports water at room temperature. If the pressure at Point A is 200 kPa, determine the volumetric flow rate through the pipe.



Note:

Water properties: $\rho = 1000$ kg/m^3 $\mu = 0.001$ N-s/m^2

Friction Factor: $f_{lam} = 64/Re$ and $\frac{1}{\sqrt{f}} = -1.8\log_{10}\left(\left(\frac{\varepsilon/D}{3.7}\right)^{1.11} + \frac{6.9}{Re}\right)$ where $Re = \frac{\rho v D}{\mu}$

Energy Eqn (1) ⇒ (2) no much devices

$\frac{P_1}{\gamma} + \frac{\alpha V_1^2}{2g} + z_1 + h_A - h_R - h_L = \frac{P_2}{\gamma} + \frac{\alpha V_2^2}{2g} + z_2$

$V_1 = V_2$ same area

$z_1 = z_2$ horizontal

$\rightarrow 0$ free jet

$\therefore \frac{P_1}{\gamma} = h_L = f\frac{L}{D}\frac{V^2}{2g}$ $\rightarrow V^2 = \frac{2P_1}{\rho}\frac{D}{L}\frac{1}{f}$

or $V = \sqrt{\frac{2P_1}{\rho}\frac{D}{L}\frac{1}{f}}$

$\frac{P_1}{\rho} = \frac{200\times10^3 \text{ kg-m/s}^2}{\text{m}^2} \cdot \frac{1}{1000 \text{ kg/m}^3} = 200 \frac{\text{m}^2}{\text{s}^2}$

$\frac{L}{D} = \frac{20}{0.03} = 666.7$

$\frac{\varepsilon}{D} = \frac{0.000045}{0.03} = 0.0015$

or $V = \left(\frac{2(200)}{666.7}\right)^{1/2}\frac{1}{\sqrt{f}}$

$V = 0.7746\frac{1}{\sqrt{f}}\frac{m}{s}$

assume turbulent flow

$Re = \frac{\rho v D}{\mu} = \frac{(1000)(0.03)}{0.001}V$

$Re = 30000\,V$

$\frac{1}{\sqrt{f}} = -1.8\log_{10}\left[\left(\frac{\varepsilon/D}{3.7}\right)^{1.11} + \frac{6.9}{Re}\right]$

$= -1.8\log_{10}\left[1.717\times10^{-4} + \frac{6.9}{Re}\right]$

guess $\frac{1}{\sqrt{f}_1} = -1.8\log(1.717\times10^{-4}) = 6.777$

Iteration	$1/\sqrt{f}$	V (m/s)	Re	$1/\sqrt{f}$
1	6.777	5.249	1.57×10^5	6.600
2	6.600	5.112	1.54×10^5	6.596
3	6.596			

close enough

$\therefore Q = VA = (5.112)\left(\frac{\pi}{4}\right)(0.03)^2$

$Q = 3.61\times10^{-3}\frac{m^3}{s}$

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fixed typo 0.000045 m

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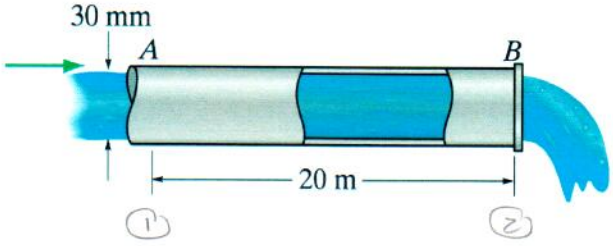

Note:

Water properties: $\rho = 1000$ kg/m^3 $\mu = 0.001$ N-s/m^2

Friction Factor: $f_{lam} = 64/Re$ and $f_{turb} = \dfrac{0.25}{\left[\log_{10}\left(\dfrac{\varepsilon/D}{3.7} + \dfrac{5.74}{Re^{0.9}}\right)\right]^2}$ where $Re = \dfrac{\rho v D}{\mu}$

Energy Eqn ① → ② no mechanical devices

$$\frac{P_1}{\gamma} + \alpha\frac{v_1^2}{2g} + z_1 + h_A - h_R - h_L = \frac{P_2}{\gamma} + \alpha\frac{v_2^2}{2g} + z_2$$

$v_1 = v_2$ same area $z_1 = z_2$ horizontal $P_2 = 0$ free jet

$$\therefore \frac{P_1}{\gamma} = h_L = f\frac{L}{D}\frac{v^2}{2g} \rightarrow v^2 = \frac{2P_1}{\rho}\frac{D}{fL}$$

or $$V = \sqrt{\frac{2P_1}{\rho}\frac{D}{fL}}$$

$$= \left(\frac{2(200)}{666.7}\right)^{\frac{1}{2}}\frac{1}{\sqrt{f}}$$

$$V = 0.7746\,\frac{1}{\sqrt{f}}\ \frac{m}{s}$$

$$\frac{P_1}{\rho} = \frac{200\times10^3\ \frac{kg\cdot m/s^2}{m^2}}{1000\ kg/m^3} = 200\ \frac{m^2}{s^2}$$

$$\frac{L}{D} = \frac{20}{0.03} = 666.7$$

$$\frac{\varepsilon}{D} = \frac{0.000045}{0.03} = 0.0015$$

assume turbulent flow

$$Re = \frac{\rho V D}{\mu} = \frac{(1000)(0.03)}{0.001}V$$

$$Re = 30000\,V$$

$$f = \frac{0.25}{\left[\log_{10}\left(\frac{0.0015}{3.7} + \frac{5.74}{Re^{0.9}}\right)\right]^2}$$

0.0004054

guess $f_1 = \dfrac{0.25}{[\log(0.0004054)]^2} = 0.0217$

turbulent ok

Iteration	f	V m/s	Re	f
1	0.0217	5.255	1.577×10^5	0.02325
2	0.02325	5.080	1.524×10^5	0.02329

close enough ans

$$\therefore Q = VA = (5.080\ m/s)\left(\frac{\pi}{4}\right)(0.03\ m)^2 = 3.59\times10^{-3}\ m^3/s$$