8.56

8.56 A fluid flows through a smooth horizontal 2-m-long tube of diameter 2 mm with an average velocity of 2.1 m/s. Determine the head loss and the pressure drop if the fluid is **(a)** air, **(b)** water, or **(c)** mercury.

$$\frac{p_1}{\gamma}+\frac{V_1^2}{2g}+z_1=\frac{p_2}{\gamma}+\frac{V_2^2}{2g}+z_2+h_L\text{, where } h_L=f\frac{\ell}{D}\frac{V^2}{2g},\ z_1=z_2\text{, and } V_1=V_2$$

Thus, $h_L=f\left(\frac{2\,m}{0.002\,m}\right)\frac{(2.1\frac{m}{s})^2}{2(9.81\frac{m}{s^2})}$ or $h_L=225f\ m$ (1)

and

$$\Delta p=p_1-p_2=\gamma h_L$$

Also, $Re=\frac{VD}{\nu}=\frac{(2.1\frac{m}{s})(0.002\,m)}{\nu}=\frac{4.2\times10^{-3}}{\nu}$, where $\nu\sim\frac{m^2}{s}$

Thus:

	fluid	$\nu, \frac{m^2}{s}$	Re	flow	f	h_L, m	$\gamma, \frac{N}{m^3}$	$\Delta p, \frac{N}{m^2}$
a)	air	1.46×10^{-5}	287	laminar	$\frac{64}{Re}=0.223$	50.2	12.0	602
b)	water	1.12×10^{-6}	3750	~turbulent	0.0404	9.09	9800	8.91×10^4
c)	mercury	1.15×10^{-7}	36,500	turbulent	0.0220	4.95	133,000	6.58×10^5

8.57

8.57 Air at standard temperature and pressure flows through a horizontal 2 ft by 1.3 ft rectangular galvanized iron duct with a flowrate of 8.2 cfs. Determine the pressure drop in inches of water per 200-ft length of duct.

$$\frac{p_1}{\gamma}+\frac{V_1^2}{2g}+z_1=\frac{p_2}{\gamma}+\frac{V_2^2}{2g}+z_2+f\frac{\ell}{D_h}\frac{V^2}{2g}\text{, where } z_1=z_2 \text{ and } V_1=V_2$$

Also, $D_h=\frac{4A}{P}=\frac{4(2ft)(1.3ft)}{2[2ft+1.3ft]}=1.576\ ft$

and

$$V=\frac{Q}{A}=\frac{8.2\frac{ft^3}{s}}{(2ft)(1.3ft)}=3.15\frac{ft}{s}$$

Thus, $p_1-p_2=f\frac{\ell}{D_h}\frac{1}{2}\rho V^2$, where for galvanized iron $\varepsilon=0.0005\ ft$ (Table 8.1)

Hence, $\frac{\varepsilon}{D_h}=\frac{0.0005\,ft}{1.576\,ft}=0.000317$ and $Re_h=\frac{VD_h}{\nu}=\frac{(1.576\,ft)(3.15\frac{ft}{s})}{1.57\times10^{-4}\frac{ft^2}{s}}=31{,}600$

so from Fig. 8.20, $f=0.025$

Thus, $p_1-p_2=(0.025)\left(\frac{200\,ft}{1.576\,ft}\right)\frac{1}{2}(2.38\times10^{-3}\frac{slug}{ft^3})(3.15\frac{ft}{s})^2=0.0374\frac{lb}{ft^2}$

or with $p_1-p_2=\gamma_{H_2O}h$,

$$h=\frac{p_1-p_2}{\gamma_{H_2O}}=\frac{0.0374\frac{lb}{ft^2}}{62.4\frac{lb}{ft^3}}=6.00\times10^{-4}ft=\underline{\underline{0.00720\ in.\ of\ water}}$$