8.58

8.58 Air flows through a rectangular galvanized iron duct of size 0.30 m by 0.15 m at a rate of 0.068 m^3/s. Determine the head loss in 12 m of this duct.

$h_L = f\frac{\ell}{D_h}\frac{V^2}{2g}$, where $D_h = \frac{4A}{P} = \frac{4(0.3m)(0.15m)}{2[0.3m+0.15m]} = 0.2\ m$

and

$V = \frac{Q}{A} = \frac{0.068\frac{m^3}{s}}{(0.3m)(0.15m)} = 1.51\frac{m}{s}$ Also, $Re_h = \frac{VD_h}{\nu} = \frac{(1.51\frac{m}{s})(0.2m)}{1.46\times10^{-5}\frac{m^2}{s}} = 20{,}700$

and from Table 8.1,

$\frac{\varepsilon}{D_h} = \frac{0.15\times10^{-3}m}{0.2\,m} = 7.5\times10^{-4}$ Hence, from Fig. 8.20 $f = 0.027$

so that

$h_L = (0.027)\left(\frac{12\,m}{0.2m}\right)\frac{(1.51\frac{m}{s})^2}{2(9.81\frac{m}{s^2})} = \underline{\underline{0.188m}}$

8.59

8.59 Air at standard conditions flows through a horizontal 1 ft by 1.5 ft rectangular wooden duct at a rate of 5000 ft^3/min. Determine the head loss, pressure drop, and power supplied by the fan to overcome the flow resistance in 500 ft of the duct.

$h_L = f\frac{\ell}{D_h}\frac{V^2}{2g}$, where $V = \frac{Q}{A} = \frac{(5000\frac{ft^3}{min})(\frac{1\,min}{60s})}{(1ft)(1.5ft)} = 55.6\frac{ft}{s}$

and $D_h = \frac{4A}{P} = \frac{4(1ft)(1.5ft)}{2[1ft+1.5ft]} = 1.2\ ft$

Also, $Re_h = \frac{VD_h}{\nu} = \frac{(55.6\frac{ft}{s})(1.2ft)}{1.57\times10^{-4}\frac{ft^2}{s}} = 4.25\times10^5$ and from Table 8.1

$\varepsilon \approx 0.0006\ ft$ to $0.003\ ft$. Use an "average" $\varepsilon = 0.0018\ ft$ so that

$\frac{\varepsilon}{D_h} = \frac{0.0018\ ft}{1.2ft} = 0.0015$ Thus, from Fig. 8.20 $f = 0.022$, or

$h_L = (0.022)\left(\frac{500\ ft}{1.2ft}\right)\frac{(55.6\frac{ft}{s})^2}{2(32.2\frac{ft}{s^2})} = \underline{\underline{440\ ft}}$

For this horizontal pipe $\frac{p_1}{\gamma}+\frac{V_1^2}{2g}+z_1 = \frac{p_2}{\gamma}+\frac{V_2^2}{2g}+z_2+h_L$, where $z_1 = z_2$ and $V_1 = V_2$.

Thus, $p_1 - p_2 = \gamma h_L = (7.65\times10^{-2}\frac{lb}{ft^3})(440ft) = 33.7\frac{lb}{ft^2} = 0.234psi$

$\mathcal{P} = \gamma Q h_L = Q(p_1-p_2) = (5000\frac{ft^3}{min})(\frac{1\,min}{60s})(33.7\frac{lb}{ft^2}) = (2810\frac{ft\cdot lb}{s})\left[\frac{1\,hp}{(550\frac{ft\cdot lb}{s})}\right]$

or

$\mathcal{P} = \underline{\underline{5.11\ hp}}$