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.

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

and

$$V = \frac{Q}{A} = \frac{0.068 \frac{m^3}{s}}{(0.3m)(0.15m)} = 1.51 \frac{m}{s}$$

Also, $Re_h = \frac{VD_h}{\nu} = \frac{(1.51 \frac{m}{s})(0.2m)}{1.46 \times 10^{-5} \frac{m^2}{s}} = 20700$

and from Table 8.1,

$$\frac{E}{D_h} = \frac{0.15 \times 10^{-3} \text{m}}{0.2 \text{m}} = 7.5 \times 10^{-4} \text{ Hence, from Fig. 8.20 } f = 0.027$$

so that

$$h_L = \frac{(0.027) (12 \text{ m})}{(0.2 \text{ m})} \frac{(1.51 \frac{m}{s})^2}{2(0.81 \frac{m}{s})} = 0.188 \text{ m}$$

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.

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

and

$$D_h = \frac{4A}{P} = \frac{4(1 \text{ ft})(1.5 \text{ ft})}{2(1 \text{ ft})(1.5 \text{ ft})} = 1.2 \text{ ft}$$

Also,

$$Re_h = \frac{VD_h}{\nu} = \frac{(55.6 \frac{ft}{s})(1.2 \text{ ft})}{1.57 \times 10^{-5} \frac{ft^2}{s}} = 4.25 \times 10^6 \text{ and from Table 8.1,}$$

$$E \approx 0.0006 \text{ ft} \text{ to } 0.003 \text{ ft} \text{. Use an "average" } E = 0.0018 \text{ ft so that }$$

$$\frac{E}{D_h} = \frac{0.0018 \text{ ft}}{1.2 \text{ ft}} = 0.0015$$

Thus, from Fig. 8.20 $f = 0.022$, or

$$h_L = (0.022) (500 \text{ ft}) \frac{(55.6 \frac{ft}{s})^2}{2(32.2 \frac{ft}{s})} = 440 \text{ ft}$$

For this horizontal pipe $h_L = \frac{V^2}{2g} + \frac{V^2}{2g} + Z_1 = \frac{V^2}{2g} + Z_2 + h_L$, where $Z_1 = Z_2$ and $V_1 = V_2$.

Thus,

$$\rho_1 - \rho_2 = \gamma h_L = (7.65 \times 10^{-2} \frac{lb}{ft^3})(440 \text{ ft}) = 33.7 \frac{lb}{ft} = 0.234 \text{ psi}$$

$$P = \gamma Q h_L = (5000 \frac{ft^3}{min})(1 \frac{min}{60s})(33.7 \frac{lb}{ft}) = \frac{2810 \frac{ft \cdot lb}{s}}{\frac{550 \frac{ft \cdot lb}{s}}{\frac{lb}{ft}}}$$

or

$$P = 5.11 \text{ hp}$$