6.92 A large room uses a fan to draw in atmospheric air at 20°C through a 30 cm by 30 cm commercial-steel duct 12 m long, as in Fig. P6.92. Estimate (a) the air flow rate in m^3/hr if the room pressure is 10 Pa vacuum; and (b) the room pressure if the flow rate is 1200 m^3/hr. Neglect minor losses.

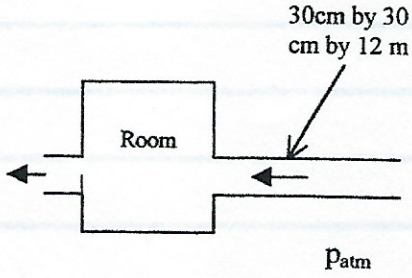

Fig. P6.92

$$\frac{p_1}{\gamma} + \frac{V_1^2}{2g} + z_1 + h_p = \frac{p_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + h_t + h_f$$

$$\frac{p_1 - p_2}{\gamma} = h_f = f\frac{L}{D_h}\frac{V^2}{2g} \qquad f = f\left(Re_{D_h}, \frac{\varepsilon}{D_h}\right)$$

$$D_h = \frac{4A}{P} = \frac{4s^2}{4s} = s = 30\ cm$$

Table 6.4 $b/a = 1$

$f_{RE_{D_h}} = 56.91$

$D_{eff} = \frac{64}{56.91} = 1.125 D_h = 33.74 cm$

$\rho = 1.2\ kg/m^3$ (5) $V = Q/A = \frac{1200/3600}{.3^2} = 3.7\ m/s$

$\mu = 1.8E\text{-}5\ \frac{kg}{m\,s}$

$$Re_{D_h} = \frac{\rho V D_h}{\mu} = \frac{1.2 \times 3.7 \times .3}{1.8E\text{-}5} = 74{,}100$$

$\varepsilon = .046 \qquad \varepsilon/D_h = .000153$

$f = .0198$

$$\Delta p = f\frac{L}{D_h}\frac{\rho V^2}{2} = .0198\,\frac{12}{.3}\,\frac{1.2}{2}\,3.7^2 = 6.53\ Pa$$

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(a) $\Delta p = 10 = f\left(\frac{12}{.3}\right)\left(\frac{1.2}{2}\right)V^2 \qquad V = \frac{Q}{.3^2}$ i.e. below p_{atm}

$$f = f\left(\frac{1.2\,V.3}{1.8E\text{-}5},\ \varepsilon/D_h = .000153\right)$$

guess and iterate

$f_1 = .01 \Rightarrow V_1 = 6.46\ m/s \quad Re_{D_h} = 129151$

$f_2 = .0185 \Rightarrow V_2 = 4.74\ m/s \quad Re_{D_h} = 94953$

$f_3 = .019 \Rightarrow V_3 = 4.69\ m/s \quad Re_{D_h} = 93800$

$Q = .422\ m^3/s = 1520\ m^3/h$

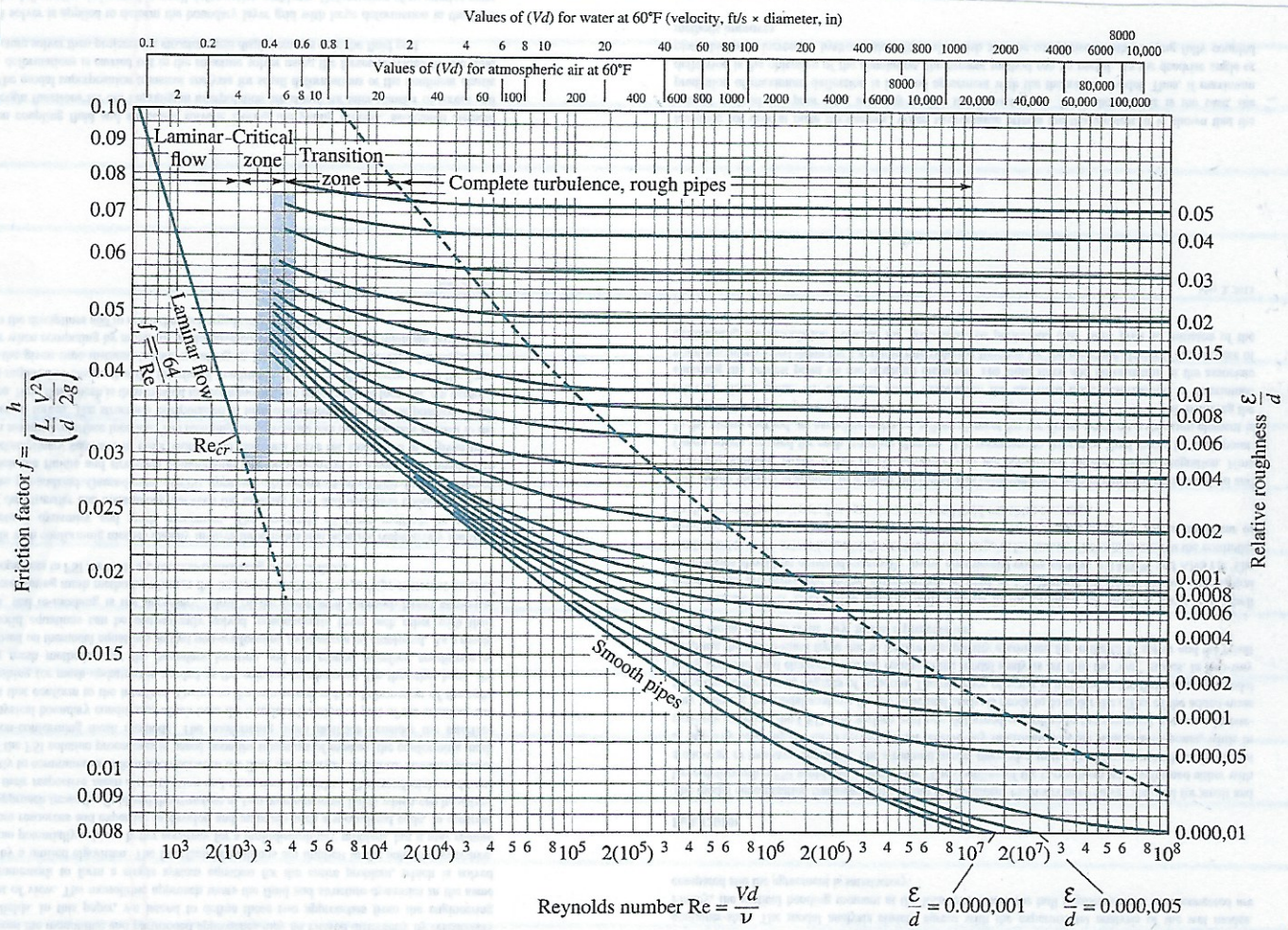


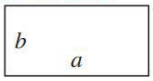
Fig. 6.13 The Moody chart for pipe friction with smooth and rough walls. This chart is identical to Eq. (6.48) for turbulent flow. *(From Ref. 8, Source: ASME.)*

ble 6.1 Recommended ughness Values for Commercial cts

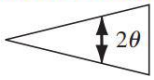
		ε		
Material	Condition	ft	mm	Uncertainty, %
Steel	Sheet metal, new	0.00016	0.05	±60
	Stainless, new	0.000007	0.002	±50
	Commercial, new	0.00015	0.046	±30
	Riveted	0.01	3.0	±70
	Rusted	0.007	2.0	±50
Iron	Cast, new	0.00085	0.26	±50
	Wrought, new	0.00015	0.046	±20
	Galvanized, new	0.0005	0.15	±40
	Asphalted cast	0.0004	0.12	±50
Brass	Drawn, new	0.000007	0.002	±50
Plastic	Drawn tubing	0.000005	0.0015	±60
Glass	—	Smooth	Smooth	
Concrete	Smoothed	0.00013	0.04	±60
	Rough	0.007	2.0	±50
Rubber	Smoothed	0.000033	0.01	±60
Wood	Stave	0.0016	0.5	±40

Table 6.4 Laminar Friction Constants $f\text{Re}$ for Rectangular and Triangular Ducts

Rectangular



Isosceles triangle



b/a	$f\text{Re}_{D_h}$	θ, deg	$f\text{Re}_{D_h}$
0.0	96.00	0	48.0
0.05	89.91	10	51.6
0.1	84.68	20	52.9
0.125	82.34	30	53.3
0.167	78.81	40	52.9
0.25	72.93	50	52.0
0.4	65.47	60	51.1
0.5	62.19	70	49.5
0.75	57.89	80	48.3
1.0	56.91	90	48.0