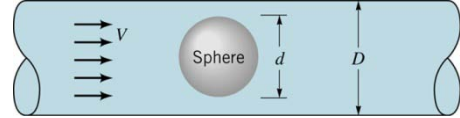


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NAME

Fluids-ID

Quiz 9. The drag force,  $R$ , on a sphere located in a pipe through which a fluid is flowing is to be determined experimentally. Assume that the drag is a function of the sphere diameter,  $d$ , the pipe diameter,  $D$ , the fluid velocity,  $V$ , and the fluid density,  $\rho$ .



(a) What dimensionless parameters would you use for this problem? (b) Some experiments using water indicate that for  $d = 0.2$  in.,  $D = 0.5$  in., and  $V = 2$  ft/s, the drag is  $1.5 \times 10^{-3}$  lb. Estimate the drag on a sphere located in a 2-ft-diameter pipe through which water is flowing with a velocity of 6 ft/s. The sphere diameter is such that geometric similarity is maintained.

Solution:

(a) Given  $R = f(d, D, V, \rho)$ , where  $R \doteq F$ ,  $d \doteq L$ ,  $D \doteq L$ ,  $V \doteq LT^{-1}$ , and  $\rho \doteq FL^{-3}$ , 5 – 3 = 2 pi terms required. By inspection

$$\Pi_1 = \frac{d}{D}$$

and by using the exponent method

$$\Pi_2 = R\rho^a V^b D^c = (F)(FL^{-3})^a (LT^{-1})^b (L)^c = F^0 L^0 T^0$$

or

$$\Pi_2 = \frac{R}{\rho V^2 D^2} \quad (+5 \text{ points})$$

(b) The similarity requirement is

$$\frac{d_m}{D_m} = \frac{d}{D}$$

so that

$$d = \frac{d_m}{D_m} \cdot D = \frac{0.2 \text{ in}}{0.5 \text{ in}} \cdot (2 \text{ ft}) = 0.8 \text{ ft} \quad (+2 \text{ points})$$

And,

$$\frac{R}{\rho V^2 D^2} = \frac{R_m}{\rho_m V_m^2 D_m^2}$$

so that (with  $\rho = \rho_m$ )

$$R = \frac{\rho}{\rho_m} \left(\frac{V}{V_m}\right)^2 \left(\frac{D}{D_m}\right)^2 R_m = \left(\frac{6 \text{ ft/s}}{2 \text{ ft/s}}\right)^2 \left(\frac{2 \text{ ft}}{0.5/12 \text{ ft}}\right)^2 (1.5 \times 10^{-3} \text{ lb}) = 31.1 \text{ lb} \quad (+3 \text{ points})$$