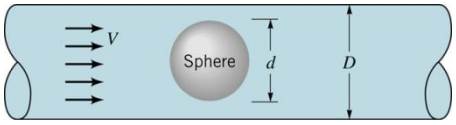
NAME

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, ρ.



(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 × 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 $\rho \doteq FL^{-4}T^2$, 5 – 3 = 2 pi terms required. By inspection

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

and by using the exponent method

$$\Pi_2 = R\rho^a V^b D^c = (F)(FL^{-4}T^2)^a (LT^{-1})^b (L)^c = F^0 L^0 T^0$$

or

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

(b) The similarity requirement is

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

so that

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

And,

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

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

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