

3.16 Water in a container and air in a tornado flow in horizontal circular streamlines of radius r and speed V as shown in Video V3.6 and Fig. P3.16 Determine the radial pressure gradient, $\partial p / \partial r$, needed for the following situations: (a) The fluid is water with $r = 3$ in. and $V = 0.8$ ft/s. (b) The fluid is air with $r = 300$ ft and $V = 200$ mph.

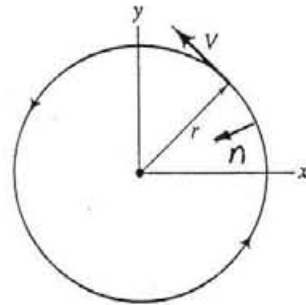


FIGURE P3.16

For curved streamlines,

$$-\frac{dp}{dn} = \frac{\rho V^2}{R} + \gamma \frac{dz}{dn}, \text{ or with } \frac{dz}{dn} = 0 \text{ (horizontal streamlines), } R = r, \\ \text{and } \frac{d}{dn} = -\frac{d}{dr} \text{ this becomes}$$

$$\frac{dp}{dr} = \frac{\rho V^2}{r}$$

a) With $r = \frac{3}{12}$ ft and $V = 0.8 \frac{\text{ft}}{\text{s}}$ and water ($\rho = 1.94 \frac{\text{slugs}}{\text{ft}^3}$),

$$\frac{dp}{dr} = \frac{1.94 \frac{\text{slugs}}{\text{ft}^3} (0.8 \frac{\text{ft}}{\text{s}})^2}{(\frac{3}{12} \text{ ft})} = 4.97 \frac{\text{slug s}}{\text{ft}^2 \cdot \text{s}^2} = \underline{\underline{4.97 \frac{\text{lb}}{\text{ft}^3}}}$$

(b) With $r = 300$ ft and $V = 200 \text{ mph} \left(\frac{88 \frac{\text{ft}}{\text{s}}}{60 \text{ mph}} \right) = 293 \frac{\text{ft}}{\text{s}}$

and air ($\rho = 0.00238 \frac{\text{slugs}}{\text{ft}^3}$),

$$\frac{dp}{dr} = \frac{0.00238 \frac{\text{slugs}}{\text{ft}^3} (293 \frac{\text{ft}}{\text{s}})^2}{300 \text{ ft}} = 0.681 \frac{\text{slug s}}{\text{ft}^2 \cdot \text{s}^2} = \underline{\underline{0.681 \frac{\text{lb}}{\text{ft}^3}}}$$