5.65

5.65 A 3-in.-diameter horizontal jet of water strikes a flat plate as indicated in Fig. P5.65. Determine the jet velocity if a 10-lb horizontal force is required to (**a**) hold the plate stationary, (**b**) allow the plate to move at a constant speed of 10 ft/s to the right.

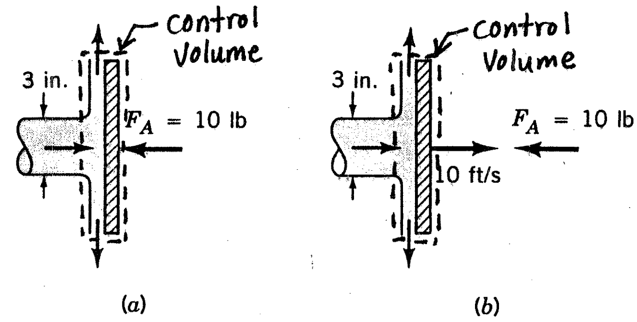

FIGURE P5.65

The control volume shown in the sketch is used. The stationary plate case is considered first. Application of the horizontal or x-direction component of the linear momentum equation yields

$$-u_1 \rho u_1 A_1 = -F_{A,x}$$

or

$$u_1 = \left(\frac{F_{A,x}}{\rho A_1}\right)^{\frac{1}{2}} = \left(\frac{F_{A,x}}{\rho \frac{\pi D_1^2}{4}}\right)^{\frac{1}{2}}$$

Thus

$$u_1 = \left[\frac{(10\ \text{lb})}{\left(1.94\ \frac{\text{slugs}}{\text{ft}^3}\right)\frac{\pi (3\ \text{in.})^2}{4\left(12\ \frac{\text{in.}}{\text{ft}}\right)^2}\left(\frac{1\ \text{lb}}{\text{slug}\ \frac{\text{ft}}{\text{s}^2}}\right)}\right]^{\frac{1}{2}}$$

and $u_1 = \underline{\underline{10.2\ \frac{\text{ft}}{\text{s}}}}$ stationary plate

When the plate moves to the right with a speed, $U = 10\ \frac{\text{ft}}{\text{s}}$, the x-direction component of the linear momentum equation yields

$$-(u_1 - U)\rho(u_1 - U)A_1 = -F_{A,x}$$

or

$$u_1 - U = \left(\frac{F_{A,x}}{\rho A_1}\right)^{\frac{1}{2}} = \left(\frac{F_{A,x}}{\rho \frac{\pi D_1^2}{4}}\right)^{\frac{1}{2}}$$

and

$$u_1 = \left(\frac{F_{A,x}}{\rho \frac{\pi D_1^2}{4}}\right)^{\frac{1}{2}} + U = 10.2\ \frac{\text{ft}}{\text{s}} + 10\ \frac{\text{ft}}{\text{s}} = \underline{\underline{20.2\ \frac{\text{ft}}{\text{s}}}}$$

moving plate