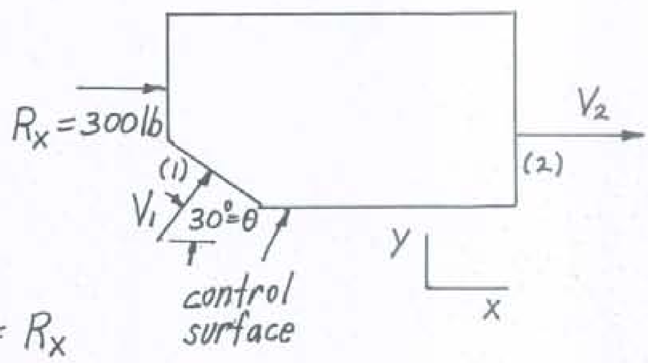
5. 66

5.66 The thrust developed to propel the jet ski shown in **Video V9.11** and Fig. P5.66 is a result of water pumped through the vehicle and exiting as a high-speed water jet. For the conditions shown in the figure, what flowrate is needed to produce a 300-lb thrust? Assume the inlet and outlet jets of water are free jets.

FIGURE P5.66

For the control volume indicated the x-component of the momentum equation

$$\int_{cs} u\,\rho \vec{V}\cdot\hat{n}\,dA = \sum F_x \quad \text{becomes}$$



(1) $(V_1 \cos 30^\circ)\rho(-V_1)A_1 + V_2\,\rho(+V_2)A_2 = R_x$

where we have assumed that $p=0$ on the entire control surface and that the exiting water jet is horizontal.

With $\dot{m} = \rho A_1 V_1 = \rho A_2 V_2$ Eq. (1) becomes

$$R_x = \dot{m}\,(V_2 - V_1 \cos\theta) = \rho V_1 A_1 (V_2 - V_1 \cos 30^\circ) \qquad (1)$$

Also, $A_1 V_1 = A_2 V_2$ so that

$$V_2 = \frac{A_1 V_1}{A_2} = \frac{25\,in.^2}{\frac{\pi}{4}(3.5\,in.)^2}\,V_1 = 2.60\,V_1 \qquad (2)$$

By combining Eqs. (1) and (2):

$$R_x = \rho V_1^2 A_1 (2.60 - \cos 30^\circ)$$

or

$$V_1 = \left[\frac{300\,lb}{\left(1.94\,\frac{slugs}{ft^3}\right)\left(\frac{25}{144}\,ft^2\right)(2.60-\cos 30^\circ)}\right]^{1/2} = 22.7\,\frac{ft}{s}$$

Thus,

$$Q = A_1 V_1 = \left(\frac{25}{144}\,ft^2\right)\left(22.7\,\frac{ft}{s}\right) = \underline{\underline{3.94\,\frac{ft^3}{s}}}$$