Solution: For gasoline at 20°C, take $\rho \approx 680\ \text{kg/m}^3 \approx 1.32\ \text{slug/ft}^3$. Compute the power

$$P = 20\times 550 = 11000\ \frac{\text{ft}\cdot\text{lbf}}{\text{s}} = \frac{\rho g Q H}{\eta} = \frac{1.32(32.2)\left(\frac{400}{449}\right)H}{0.80},\quad \text{solve } H \approx \mathbf{232\ ft} \quad \textit{Ans. (a)}$$

$$\text{Then}\quad \Delta p = \rho g H = 1.32(32.2)(232) = 9870\ \text{psf} \div 144 \approx \mathbf{69\ psi} \quad \textit{Ans. (b)}$$

11.14 A pump delivers gasoline at 20°C and 12 m^3/h. At the inlet, p_1 = 100 kPa, z_1 = 1 m, and V_1 = 2 m/s. At the exit p_2 = 500 kPa, z_2 = 4 m, and V_2 = 3 m/s. How much power is required if the motor efficiency is 75%?

Solution: For gasoline, take $\rho g \approx 680(9.81) = 6671\ \text{N/m}^3$. Compute head and power:

$$H = \frac{p_2}{\rho g} + \frac{V_2^2}{2g} + z_2 - \frac{p_1}{\rho g} - \frac{V_1^2}{2g} - z_1 = \frac{500000}{6671} + \frac{(3)^2}{2(9.81)} + 4 - \frac{100000}{6671} - \frac{(2)^2}{2(9.81)} - 1,$$

$$\text{or:}\quad H \approx 63.2\ \text{m},\quad \text{Power} = \frac{\rho g Q H}{\eta} = \frac{6671\left(\frac{12}{3600}\right)(63.2)}{0.75} \approx \mathbf{1870\ W} \quad \textit{Ans.}$$

11.15 A lawn sprinkler can be used as a simple turbine. As shown in Fig. P11.15, flow enters normal to the paper in the center and splits evenly into $Q/2$ and V_{rel} leaving each nozzle. The arms rotate at angular velocity ω and do work on a shaft. Draw the velocity diagram for this turbine. Neglecting friction, find an expression for the power delivered to the shaft. Find the rotation rate for which the power is a maximum.

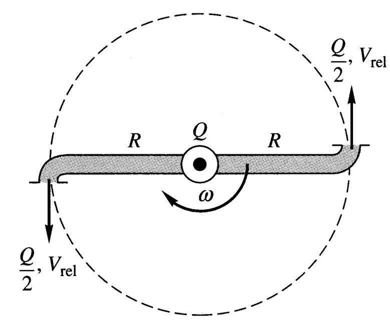
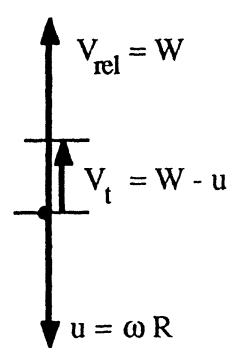


Fig. P11.15

Solution: Utilizing the velocity diagram at right, we apply the Euler turbine formula:



$$P = \rho Q(u_2 V_{t2} - u_1 V_{t1}) = \rho Q[u(W-u) - 0]$$

$$\text{or:}\quad \mathbf{P = \rho Q \omega R(V_{rel} - \omega R)} \quad \textit{Ans.}$$

$$\frac{dP}{du} = \rho Q(V_{rel} - 2u) = 0 \quad \text{if} \quad \omega = \frac{\mathbf{V_{rel}}}{\mathbf{2R}} \quad \textit{Ans.}$$

$$\text{where}\quad P_{max} = \rho Q u(2u - u) = \rho Q(\omega R)^2$$
