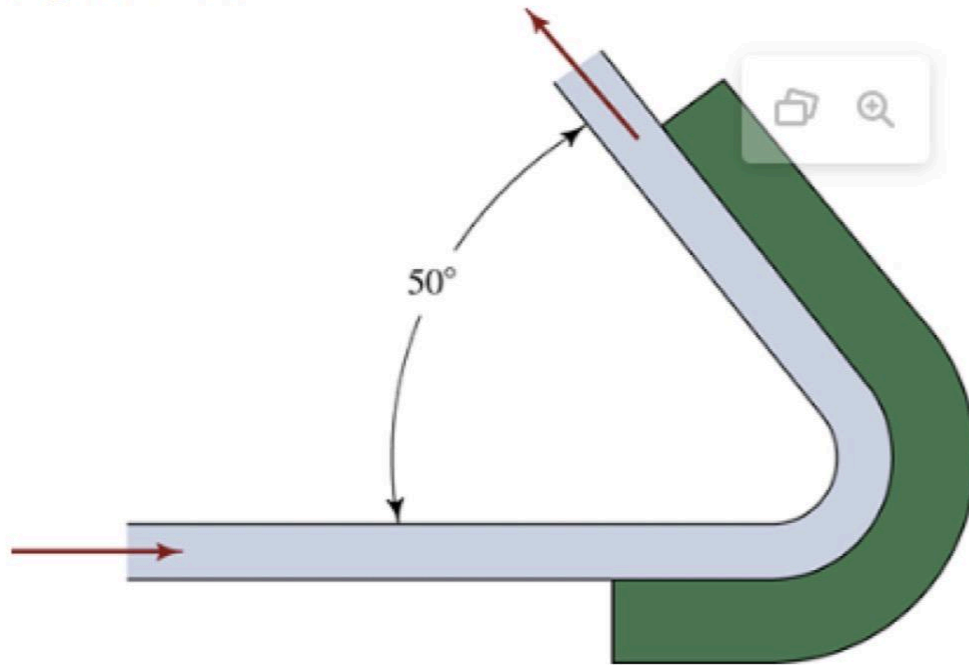


16.6 Figure P16.6 shows a free stream of water at 180F being deflected by a stationary vane through a 130degree angle. The entering stream has a velocity of 22.0 ft/s. The cross-sectional area of the stream is constant at 2.95in^2 throughout the system. Compute the forces in the horizontal and vertical directions exerted on the water by the vane.

Figure P16.6



$$\rho = 1.88 \text{ slug/ft}^3$$

$$V_1 = 22.0 \text{ ft/s}$$

$$V_2 = 22.0 \text{ ft/s}$$

$$A = 2.95 \text{ in}^2$$

$$A = \frac{2.95 \text{ in}^2}{144 \text{ in}^2/\text{ft}^2} \approx 0.02049 \text{ ft}^2$$

$$V_{1x} = 22.0 \text{ ft/s}$$

$$V_{1y} = 0 \text{ ft/s}$$

$$V_{2x} = -22.0 \cdot \cos(50) = -14.14 \text{ ft/s}$$

$$V_{2y} = 22.0 \cdot \sin(50) = 22.0 \cdot 0.7660 = 16.85 \text{ ft/s}$$

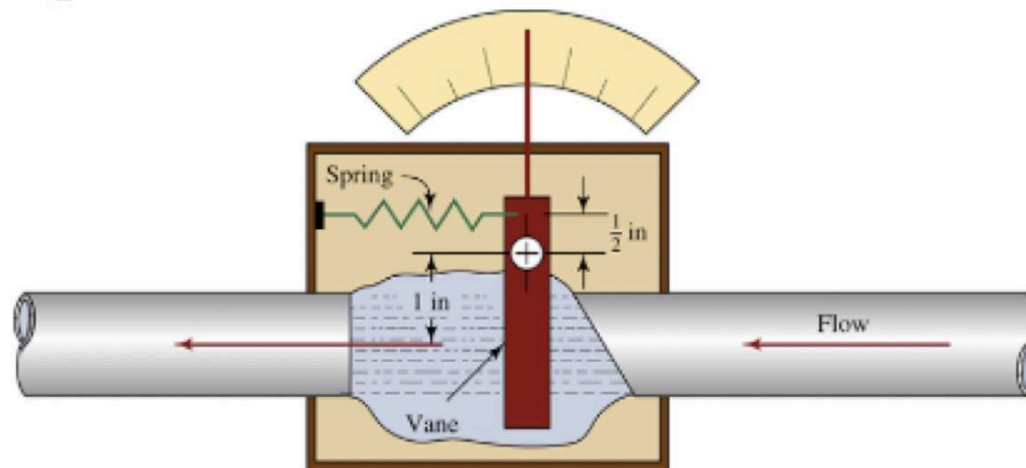
$$\dot{m} = \rho A V_1 = \frac{1.88 \text{ slug}}{\text{ft}^3} \cdot 0.02049 \text{ ft}^2 \cdot \frac{22.0 \text{ ft}}{\text{s}} = 0.8475 \frac{\text{slug}}{\text{s}}$$

$$F_x = \dot{m} (V_{2x} - V_{1x}) = 0.8475 \cdot (-14.14 - 22.0) = -30.63 \text{ lb}$$

$$F_y = \dot{m} (V_{2y} - V_{1y}) = 0.8475 \cdot (16.85 - 0) \approx 14.28 \text{ lb}$$

16.11 Figure P16.11 represents a type of flowmeter in which the flat vane is rotated on a pivot as it deflects the fluid stream. The fluid force is counterbalanced by a spring. Calculate the spring force required to hold the vane in a vertical position when water at 100 gal/min flows from the 1-in Schedule 40 pipe to which the meter is attached. The fluid passes through a vertically erected vane with a hole. The vane connects to a needle that points to a calibrated scale. The flowmeter is a square shaped box with a horizontal spring on the top-left side. The free end of the spring connects to the vane. The fluid flows to the left through the cylindrical pipe. The center of the hole is at a vertical height of half-an-inch below the spring. The vertical distance between the center of the hole in the vane and the center of the stream of fluid is labeled 1-inch.

Figure P16.11



$$A = .00600 \text{ ft}^2$$

$$Q = 100 \text{ gal/min} \cdot \left(\frac{1 \text{ ft}^3/\text{s}}{448.83 \text{ gal/min}} \right) = .2228 \text{ ft}^3/\text{s}$$

$$V_1 = \frac{Q}{A} = \frac{0.2228 \text{ ft}^3/\text{s}}{0.00600 \text{ ft}^2} = 37.13 \text{ ft/s}$$

$$\dot{m} = \rho Q = (1.94 \text{ slugs/ft}^3)(0.2228 \text{ ft}^3/\text{s}) = 0.4322 \text{ slugs/s}$$

$$F_{\text{fluid}} = \dot{m} V_1 = (0.4322 \text{ slugs/s})(37.13 \text{ ft/s}) = 16.0516$$

$$\sum M_{\text{pivot}} = 0$$

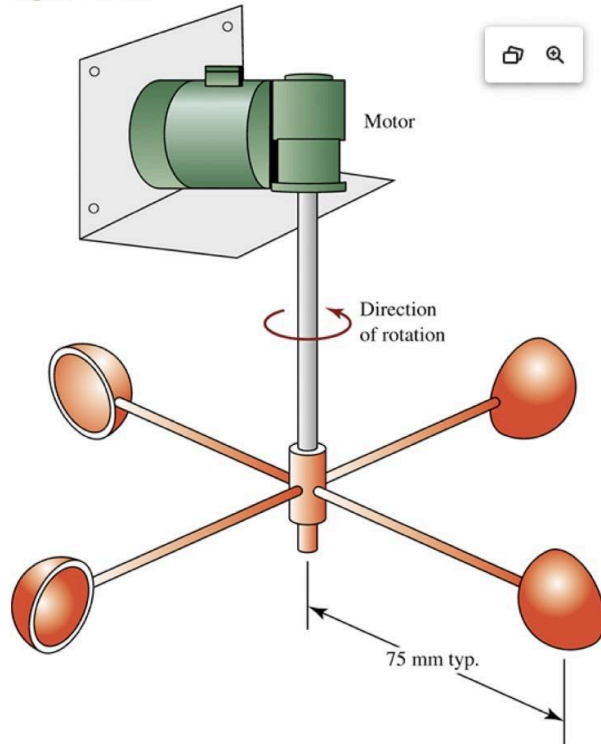
$$F_{\text{fluid}} \cdot 1.0 = F_{\text{spring}} \cdot (0.5 \text{ in})$$

$$16.0516 \cdot 1.0 \text{ in} = F_{\text{spring}} \cdot (0.5 \text{ in})$$

$$F_{\text{spring}} = \frac{16.0516 \cdot 1.0 \text{ in}}{0.5 \text{ in}} = 32.16$$

17.11 A type of level indicator incorporates four hemispherical cups with open fronts mounted as shown in Fig. P17.11. Each cup is 25 mm in diameter. A motor drives the cups at a constant rotational speed. Calculate the torque that the motor must produce to maintain the motion at 20 rpm when the cups are in (a) air at 30°C and (b) gasoline at 20°C

Figure P17.11



$$\rho = 1.165 \text{ kg/m}^3$$

$$v = 0.1571 \text{ m/s}$$

$$A = 4.909 \times 10^{-4} \text{ m}^2$$

$$r = 0.075 \text{ m}$$

$$F_D = C_D \cdot \left(\frac{1}{2} \rho v^2 A \right)$$

$$F_D = 1.35 \cdot \left(\frac{1}{2} \cdot 1.165 \cdot (0.1571)^2 \cdot 4.909 \times 10^{-4} \right) = 9.531 \times 10^{-6} \text{ N}$$

$$T = 4 \cdot (F_D \cdot r)$$

$$= 4 \cdot (9.531 \times 10^{-6} \text{ N} \cdot 0.075 \text{ m}) = 2.85 \times 10^{-6} \text{ N} \cdot \text{m}$$

$$F_D = 1.35 \cdot \left(\frac{1}{2} \cdot 680 \cdot (0.1571)^2 \cdot 4.909 \times 10^{-4} \right) = 5.561 \times 10^{-3} \text{ N}$$

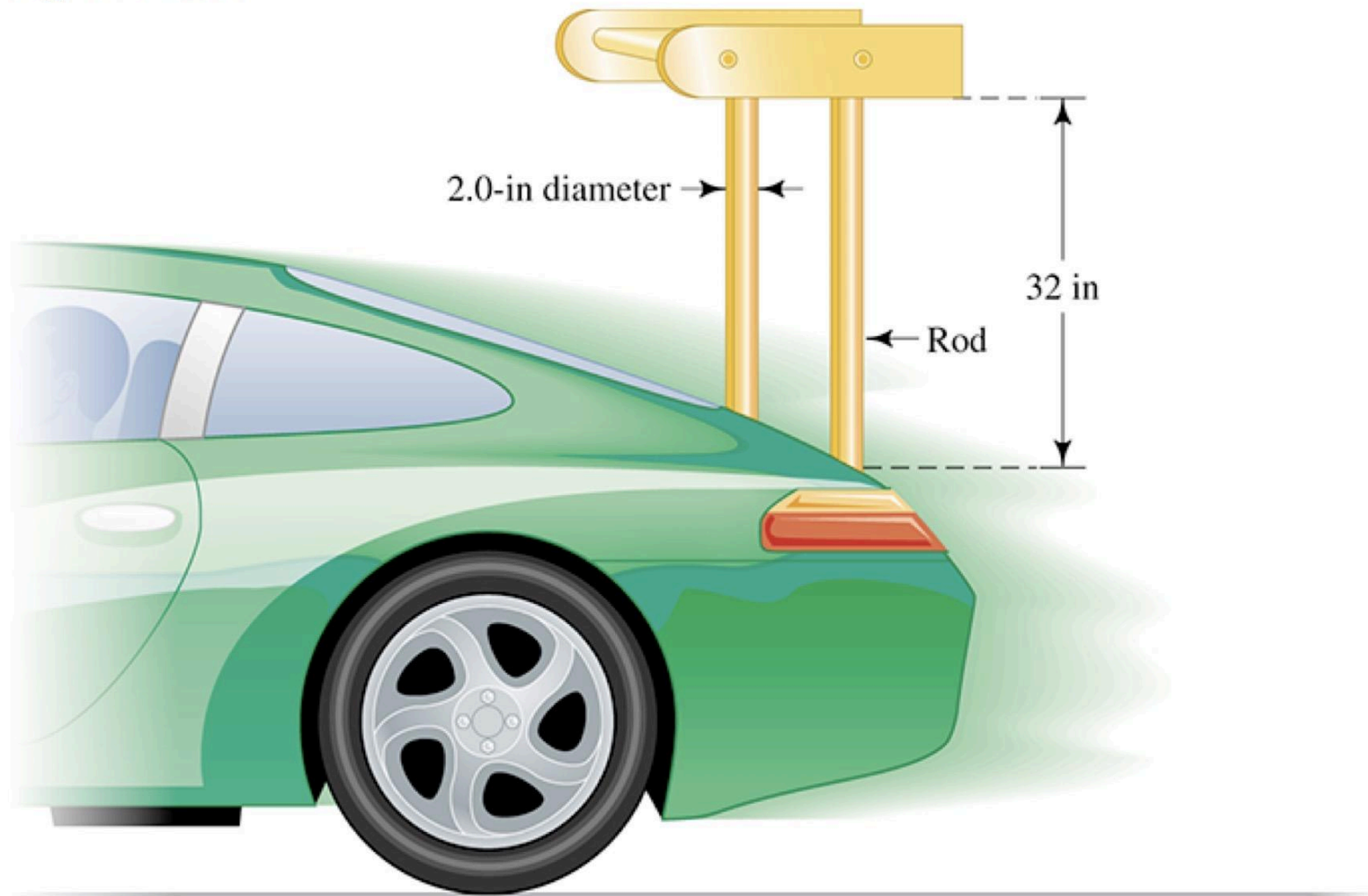
$$T = 4 \cdot (F_D \cdot r)$$

$$T = 4 \cdot (5.561 \times 10^{-3} \text{ N} \cdot 0.075 \text{ m}) = 1.67 \times 10^{-3} \text{ N} \cdot \text{m}$$



17.14 A wing on a race car is supported by two cylindrical rods, as shown in Fig. P17.14. Compute the drag force exerted on the car due to these rods when the car is traveling through still air at -20°F at a speed of 150 mph.

Figure P17.14



of rods: 2

$$D: 20\text{in} = 0.1667\text{ft}$$

$$L: 32\text{in} = 2.667\text{ft}$$

$$A = D \cdot L = 0.1667\text{ft} \cdot 2.667\text{ft} = 0.4445\text{ft}^2$$

$$V = 150\text{mph} \cdot \left(\frac{44\text{ft/s}}{30\text{mph}} \right) = 220\text{ft/s}$$

$$\rho: 2.80 \times 10^{-5} \text{ slugs/ft}^3$$

$$\nu: 1.17 \times 10^{-4} \text{ ft}^2/\text{s}$$

$$Re = \frac{V \cdot D}{\nu} = \frac{220 \cdot 0.1667}{1.17 \times 10^{-4}} \approx 3.13 \times 10^5$$

$$\rho: 2.80 \times 10^{-5} \text{ slugs/ft}^3$$

$$A: 0.4445\text{ft}^2$$

$$F_D = 1.20 \cdot \left(\frac{1}{2} \cdot (2.80 \times 10^{-5}) \cdot (220)^2 \cdot 0.4445 \right) = 43.3716$$

$$F_{\text{total}} = 2 \cdot 43.3716 = 86.7432$$