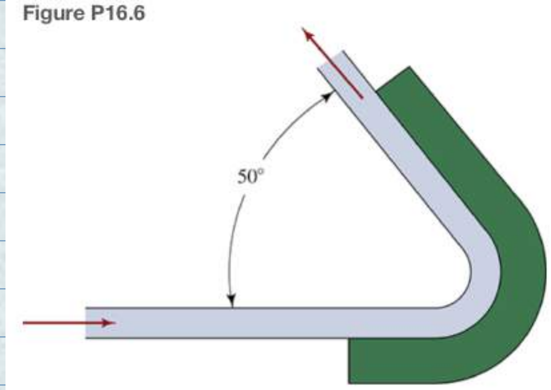
HW 2.2

Group 2: Sanchez, Perkins, Ashley, Wells, Watts

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

Figure P16.6



$F_x = \rho Q(v_{2x} - v_{1x})$

$R_x = \rho Q v_1$

$Q = A_v = (0.246\ ft)(22\ ft/s) = 5.41\ ft^3/s$

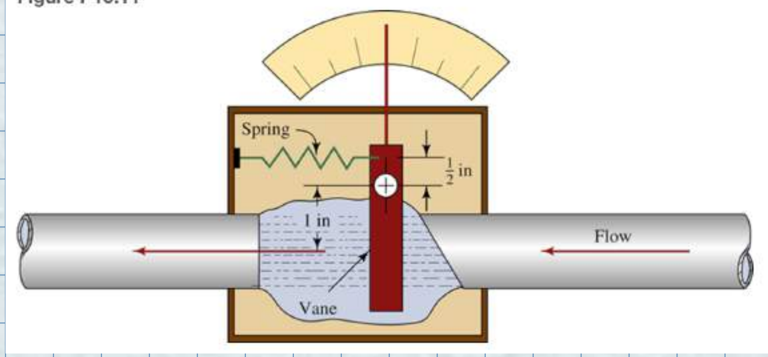
$R_x = \rho Q v_1 = \left(\frac{1.94\ lb s^2}{ft^4}\right)\left(\frac{5.41\ ft^3}{s}\right)\left(\frac{22\ ft}{s}\right) = 230.9\ lb$

$F_y = \rho Q(v_{2y} - v_{1y})$

$R_y = \rho Q v_2 = (1.94)(5.41)(22) = 230.9\ lb$

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.

Figure P16.11



$Q = 100\ gal/min = 0.2228\ ft^3/s$

In Schedule 40 Pipe... $A = 0.006\ ft^2$

$\rightarrow V = \frac{Q}{A} = 37.13\ ft/s$

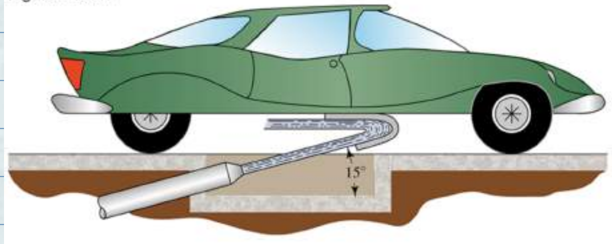
$\rho = 1.94\ slugs/ft^3$

$F_x = \rho Q(v_{2x} - v_{1x}) = 1.94(0.2228)(37.13 - (-37.13))$

$\rightarrow F_x = 32.0\ lb$

16.20 A vehicle is to be propelled by a jet of water impinging on a vane as shown in **Fig. P16.20**. The jet has a velocity of 30 m/s and issues from a nozzle with a diameter of 200 mm. Calculate the force on the vehicle (a) if it is stationary and (b) if it is moving at 12 m/s.

Figure P16.20



$v = 30$ m/s

$d = 200\text{ mm} = 0.2\text{ m}$

$F_x = \rho Q (v_2 - v_1)$

$\rho = 1000$ kg/m³

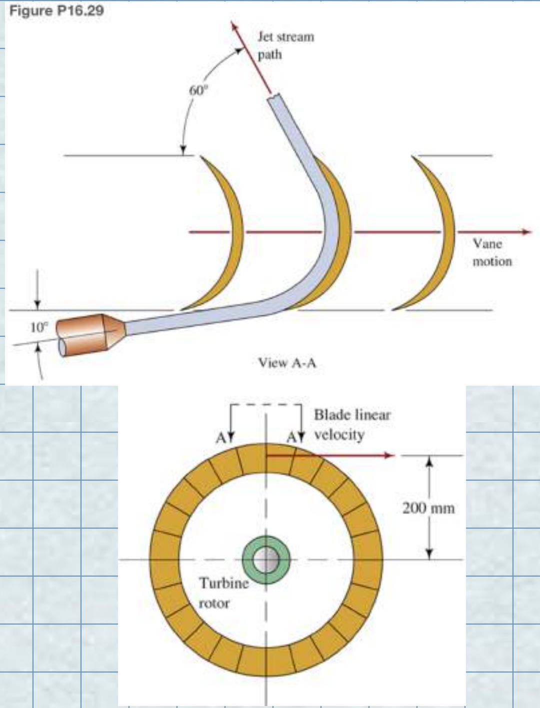
$Q = 30\text{ m/s}\left(\frac{\pi/4\,(0.2)^2}{2}\right) = 0.4712\ \text{m}^3/\text{s}$

$F_x = 1000\ \text{kg/m}^3\,(0.4712)(30-(-30)) + \cos 15^\circ = 21.203\text{ kN}$

$F_y = 1000\ \text{kg/m}^3\,(0.4712)(30-(-30))(\sin 15^\circ) = 13.8\text{ kN}$

16.29 **Figure P16.29** is a sketch of a turbine in which the incoming stream of water at $15\,^\circ\mathrm{C}$ has a diameter of 7.50 mm and is moving with a velocity of 25 m/s. Compute the force on one blade of the turbine if the stream is deflected through the angle shown and the blade is stationary.

Figure P16.29



$v = 25$ m/s

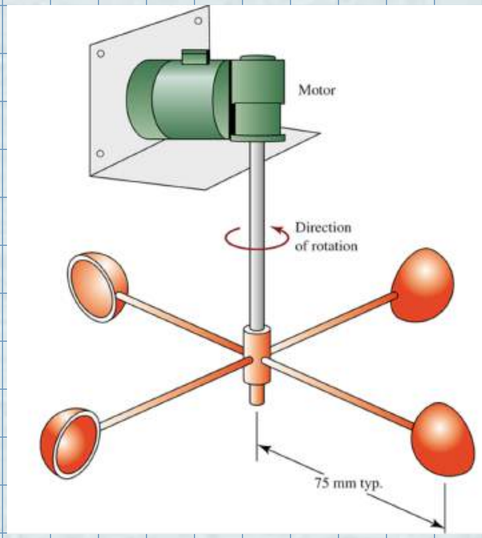
$\rho = 1000$ kg/m³

$D = 7.50$ mm

$F_x = 1000\ \text{kg/m}^3\left(\frac{\pi}{4}(0.0075)^2\right) 25\,(15\cos 10^\circ - 25\cos 60^\circ) = 40.9\text{ N}$

$F_y = 1000\ \text{kg/m}^3\left(\frac{\pi}{4}(0.0075)^2\right) 25\,(25\sin 10^\circ - 25\sin 60^\circ) = 19.1\text{ N}$

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.



a) $\frac{1\,rev}{min} = \frac{2\pi L}{60}\ m/s$, $L = 0.0075$

$v = \frac{20(2\pi L)}{60}\ m/s = 0.157\ m/s$

$A = \frac{\pi(0.025)^2}{4} = 4.908 \times 10^{-4}\ m^2$

Reynolds #:

$R_e = \frac{vD}{\nu}$ where D = Diameter
v = velocity
ν = kinetic energy

$R_e = \frac{(0.157)(0.029)}{1.16 \times 10^{-5}} = 245.31$

$C_D = 1.35$ TABLES

$F_d = C_D\left(\frac{\epsilon v^2}{2}\right)A \longrightarrow \epsilon = 1.164\ kg/m^2$

$F_D = \frac{(1.35)(1.164)(0.152)^2(4.908)(10^{-4})}{2} = 9.5 \times 10^{-6}\ N$

$T = 4F_D r$ where $r = 0.075$

→ $T = 2.85 \times 10^{-6}\ Nm$

b) $R_e = \frac{vD}{\nu}$ where $\nu = 4.72 \times 10^{-7}\ m^2/s$

$R_e = \frac{(6.157)(0.025)}{4.72 \times 10^{7}} = 9300.9$

$C_D = 1.35$

$F_D = C_D\left(\frac{\epsilon v^2}{2}\right)A$ where $\epsilon = 680\ kg/m^3$

→ $F_D = \frac{(1.35)(680)(0.157)^2(4908 \times 10^{-4})}{2} = 0.00555\ N$

$T = 4F_D r = 4(0.00555)\,0.075 = 0.001665\ Nm$

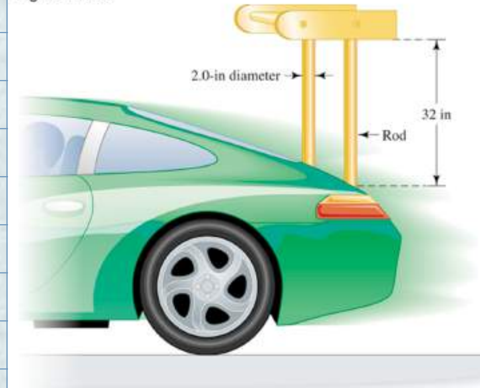
17.14 A wing on a race car is supported by two cylindrical rods, as shown in **Fig. P17.14**. Compute the drag force exerted on the car due to these rods when the car is traveling through still air at $-20^\circ F$ at a speed of 150 mph.

$v = 150$ mph $= 6.7056$ m/sec
$D = 2$ in
$L = 32$ in
$A = 0.04219\ m^2$

$F_D = 2\left(\frac{1}{2}\rho v^2 A\right)$ where $\rho = 1.225\ kg/m^3$

$\rightarrow F_D = 2\left(\frac{1}{2}\right)(1.225)(67.056)^2(0.04219) = 227.43\ N = 51.128\ lbf$

Figure P17.14



17.16 The four designs shown in **Fig. P17.16** for the cross section of an emergency flasher lighting system for police vehicles are being evaluated. Each has a length of 60 in and a width of 9.00 in. Compare the drag force exerted on each proposed design when the vehicle moves at 100 mph through still air at $-20^\circ F$.

$b = 0.75$ ft
$L = 5$ ft
$v = 146.67$ ft/s
$\nu = 1.17 \times 10^{-4}\ ft^2/s$ TABLES
$\rho = 2.80 \times 10^{-3}$ slg/ft^3

for x section a:

$Re = \frac{vL}{\nu} = 9.401 \times 10^5$

$C_D = 2.10$ TABLES

$A = Lb = 3.75\ ft^2$

$F_D = C_D\left(\frac{\rho v^2}{2}\right)A = 237.17\ lb$

for x section b:

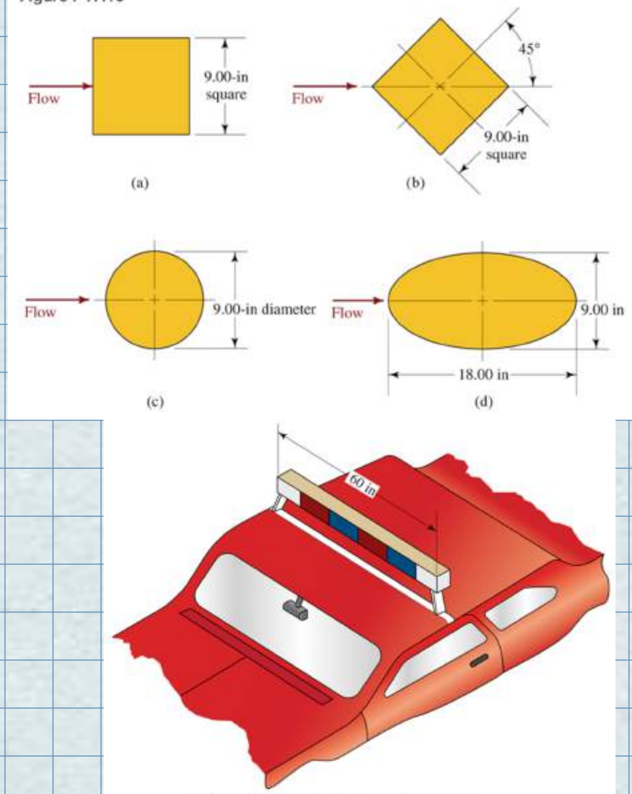
$\sin 45^\circ = \frac{y}{9} \rightarrow y = 0.5302$ ft

$A = L \times 2y = 5.302\ ft^2$

$C_D = 1.6$ TABLES

$F_D = 1.6\left[\frac{(2.8 \times 10^{-3})(146.67)^2}{2}\right](5.302) = 255.48\ lb$

Figure P17.16



(e) Pictorial of light assembly mounted on the car for x section c:

$A = Lb = 3.75\ ft^2$

$Re = \frac{vL}{\nu} = 9.401 \times 10^5$

$c_D = 0.3$ TABLES

$F_D = C_D\left(\frac{\rho v^2}{2}\right)A = 33.88\ lb$

for x section d:

$L/b = 2:1$

$A = Lb = 3.75 ft^2$

$Re = \frac{vL}{\nu} = 1.88 \times 10^6$

$C_D = 0.25$ TABLES

$F_D = c_D\left(\frac{\rho v^2}{2}\right)A = 28.23\ lb$

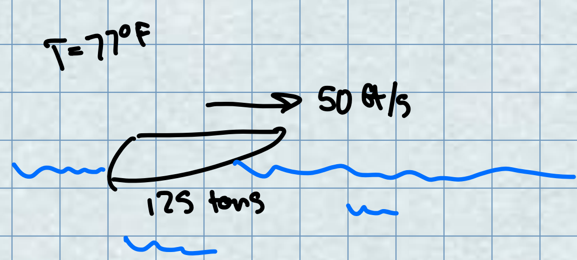
17.26 A small, fast boat has a specific resistance ratio of 0.06 (see Table 17.2) and displaces 125 long tons. Compute the total ship resistance and the power required to overcome drag when it is moving at 50 ft/s in seawater at 77°F.

$\Delta = (125\ tons)(2240\ lb/ton) = 2.8 \times 10^6\ lb$

$R_{ts} = (0.06)(\Delta) = (0.06)(2.8 \times 10^6\ lb) = 168{,}000\ lb$

$P_E = R_{ts}v = (168{,}000\ lb)(50\ ft/s) = 8.4 \times 10^6\ lb\text{-}ft/s$

$P_E = \frac{8.4 \times 10^6\ lb\text{-}ft/s}{550\ lb\text{-}ft/s} = 15{,}273\ hp$



17.30 For the airfoil with the performance characteristics shown in **Fig. 17.11**, determine the lift and drag at an angle of attack of 10°. The airfoil has a chord length of 1.4 m and a span of 6.8 m. Perform the calculation at a speed of 200 km/h in the standard atmosphere at (a) 200 m and (b) 10 000 m.

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

$V = 200\ \text{km/h} = 55.56\ \text{m/s}$

$A = (1.4\,\text{m})(6.8\,\text{m}) = 9.52\ \text{m}^2$

$C_D = 0.25\ ,\ C_L = 0.9$

$200\,\text{m} \longrightarrow \rho = 1.202\ \text{kg/m}^3$

$10{,}000\ \text{m} \longrightarrow \rho = 0.4135\ \text{kg/m}^3$

a) 200m

$$F_D = (0.25)\left(\frac{1.202(55.56)^2}{2}\right)(9.52) = 4415\ \text{N}$$

b) 10,000m

$$F_L = (0.9)\left(\frac{0.4135(55.56)^2}{2}\right)(9.52) = 5468\ \text{N}$$

Weekly Reflection

During this week's lesson we learned about open channel flow and cross sections of open channels, the hydraulic radius, the wetted perimeter and applying hydraulic radius to our Reynolds number equation. In class we can now solve problems on our own that have to do with solving open channel flow problems. Including the open channel flow equation, hydraulic radius using area of the tank and the wetted perimeter which is the perimeter that touches the water. Depending on what problem we solve for we can manipulate the open flow channel equation based on the values given or found for us.