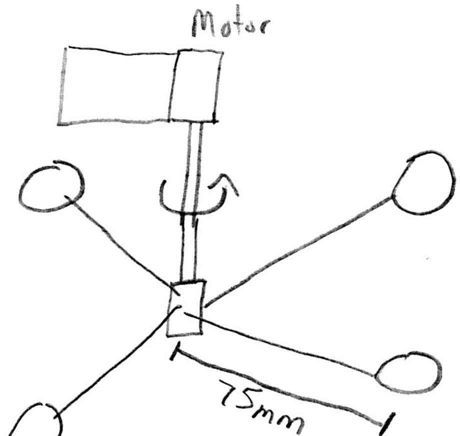
Homework 1.7 Chapter 17 Giant Falcon

17.11 A type of level indicator incorporates four hemispherical cups with open fronts mounted as shown in figure. 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.



We know $20\frac{\cancel{rev}}{\cancel{min}}\left(\frac{2\pi L\,m}{1\,\cancel{rev}}\right)\left(\frac{1\,\cancel{min}}{60\,s}\right)$

$= 20\,(2\pi(0.075m))\left(\frac{1}{60s}\right)$

$= 0.157\,m/s$

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

Area is same for a) + b) $A = \frac{\pi D^2}{4} = \frac{\pi(0.025m)^2}{4} = 4.909\times10^{-4}\,m^2$

a) We know $Re = \frac{\rho v D}{\eta} = \frac{(1.164\,kg/\cancel{m^3})(0.157\,\cancel{m}/\cancel{s})(0.025\,\cancel{m})}{1.86\times10^{-5}\,kg\cdot \cancel{m}/\cancel{s^2}\cdot \cancel{s}/\cancel{m^2}} = 245.63$ (Table E.1)

From Figure 17.4, $C_D = 0.65$, so $F_D = 0.65\left(\frac{(1.164\,kg/m^3)(0.157\,m/s)^2}{2}\right)(4.909\times10^{-4}\,m^2)$

$\rightarrow F_D = 4.578\times10^{-6}\,N$

We know Torque $= F_D\cdot r\cdot \sin(\overset{=90°}{\theta}) = F_D\cdot r = (4.578\times10^{-6}N)(0.075m)$

$= 3.43\times10^{-7}\,N\cdot m$

Since there are four (4) cups, Torque $= 4(3.43\times10^{-7}N\cdot m) = \boxed{1.373\times10^{-6}\,N\cdot m}$

b) We know $Re = \frac{\rho v D}{\eta} = \frac{(680\,kg/m^3)(0.157\,m/s)(0.025m)}{2.87\times10^{-4}\,Pa\cdot s} = 9299.7$

From Figure 17.4, $C_D = 0.40$, so $F_D = (0.40)\left(\frac{(680\,kg/m^3)(0.157\,m/s)^2}{2}\right)(4.909\times10^{-4}\,m^2)$

$\rightarrow F_D = 1.646\times10^{-3}\,N$

Torque $= F_D\cdot r\cdot \sin(\theta) = (1.646\times10^{-3}N)(0.075m) = 1.234\times10^{-4}\,N\cdot m$

So Torque $= 4(1.234\times10^{-4}N\cdot m) = \boxed{4.937\times10^{-4}\,N\cdot m}$

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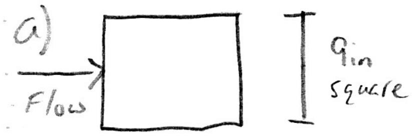
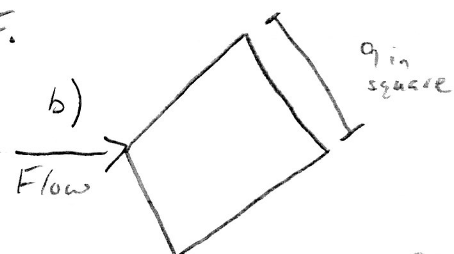
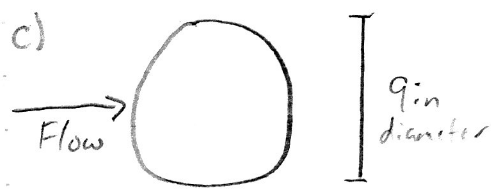
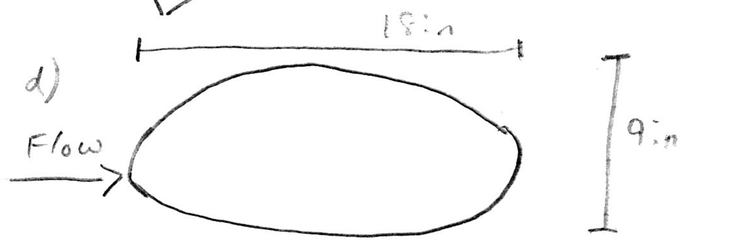
17.16. The four designs shown in the figure for the cross-section of an emergency flasher lighting system for police vehicles are being evaluated. Each has a length of 60in and a width of 9.00in. Compare the drag force exerted on each proposed design when the vehicle moves at 100 mph through still air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

a) 

b) 

c) 

d) 

We know $F_D = C_D\left(\frac{\rho v^2}{2}\right)A$ and $Re = \frac{\rho v D}{\eta}$

So for air at $-20°F$ $\rho = 2.80\times10^{-3}\ \text{slugs/ft}^3$ $\eta = 3.27\times10^{-7}\ \frac{\text{lb}\cdot\text{s}}{\text{ft}^2}$

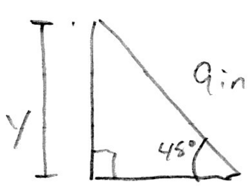
And $100\ \frac{\cancel{\text{miles}}}{\cancel{\text{hour}}}\left(\frac{5280\text{ft}}{1\ \cancel{\text{mile}}}\right)\left(\frac{1\ \cancel{\text{hour}}}{3600\text{s}}\right) = 146.67\ \text{ft/s}$

a) $Re = \frac{(2.80\times10^{-3}\ \text{slugs/ft}^3)(146.67\ \text{ft/s})(\frac{9}{12}\text{ft})}{3.27\times10^{-7}\ \text{lb}\cdot\text{s/ft}^2} = 9.419\times10^5$

So $C_D = 2.10$ and $A = \left(\frac{9}{12}\text{ft}\right)\left(\frac{60}{12}\text{ft}\right) = 3.75\text{ft}^2$

Then $F_D = 2.10\left(\frac{(2.80\times10^{-3}\ \text{slugs/ft}^3)(146.67\ \text{ft/s})^2}{2}\right)(3.75\text{ft}^2)$

$\boxed{F_D = 237.17\text{lb}}$

b) 

We know $\sin(45°) = \frac{Y}{9\text{in}} \rightarrow Y = 9\text{in}\cdot\sin(45°)$

$\rightarrow Y = 6.36\text{in}$ or 0.53ft

$A = (2)(0.53\text{ft})\cdot\left(\frac{60}{12}\text{ft}\right) = 5.3\text{ft}^2$

$C_D = 1.60$ (Table 17.1)

Then $F_D = (1.60)\left(\frac{2.80\times10^{-3}\ \text{slugs/ft}^3)(146.67\ \text{ft/s})^2}{2}\right)(5.3\text{ft}^2)$

$\boxed{F_D = 255.39\text{lb}}$

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17.16 continued

c) $A = (\frac{9}{12} ft)(\frac{60}{12} ft) = 3.75 ft^2$

$Re = \frac{(2.80 \times 10^{-3} slugs/ft^3)(146.67 ft/s)(\frac{9}{12} ft)}{3.27 \times 10^{-7} lb \cdot s/ft^2} = 9.419 \times 10^5$

$C_D = 0.30$ from Figure 17.4

$F_D = 0.30\left(\frac{(2.80 \times 10^{-3} slugs/ft^3)(146.67 ft/s)^2}{2}\right)(3.75 ft^2)$

$\boxed{F_D = 33.88 lb}$

d) $L = 18 in$ $b = 9 in$ $\frac{L}{b} = 2:1$

$A = (\frac{9}{12} ft)(\frac{60}{12} ft) = 3.75 ft^2$

$Re = \frac{(2.80 \times 10^{-3} slugs/ft^3)(146.67 ft/s)(\frac{18}{12} ft)}{3.27 \times 10^{-7} lb \cdot s/ft^2} = 1.884 \times 10^6$

$C_D = 0.25$

$F_D = 0.25\left(\frac{(2.80 \times 10^{-3} slugs/ft^3)(146.67 ft/s)^2}{2}\right)(3.75 ft^2)$

$\boxed{F_D = 28.23 lb}$

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17.30 For the airfoil with the performance characteristics shown in Figure 17.11, determine the lift and drag at an angle of attack of 10°. The airfoil has a chord length of 1.4m and a span of 6.8m. Perform the calculation at a speed of 200 km/h in the standard atmosphere at (a) 200m and (b) 10000m.

We know $200\,\cancel{km}/\cancel{hr}\left(\frac{1000m}{1\,\cancel{km}}\right)\left(\frac{1\,\cancel{hr}}{3600s}\right) = 55.56\,m/s$

We know that
$$F_D = C_D\left(\frac{\rho V^2}{2}\right)A$$
$$F_L = C_L\left(\frac{\rho V^2}{2}\right)A$$
$$A = \text{wing span} \times \text{chord} = (6.8m)(1.4m) = 9.52m^2$$

From the performance curve, $C_D = 0.05$ + $C_L = 0.90$

a) At 200m,
$$F_D = 0.05\left(\frac{(1.202\,kg/m^3)(55.56\,m/s)^2}{2}\right)(9.52m^2)$$
$$F_D = \boxed{883.09\,N}$$

$$F_L = 0.90\left(\frac{(1.202\,kg/m^3)(55.56\,m/s)^2}{2}\right)(9.52m^2)$$
$$F_L = \boxed{15895.7\,N}$$

b) At 10000m,
$$F_D = 0.05\left(\frac{(10.4135\,kg/m^3)(55.56\,m/s)^2}{2}\right)(9.52m^2)$$
$$F_D = \boxed{303.79\,N}$$

$$F_L = 0.90\left(\frac{(10.4135\,kg/m^3)(55.56\,m/s)^2}{2}\right)(9.52m^2)$$
$$F_L = \boxed{5468.3\,N}$$

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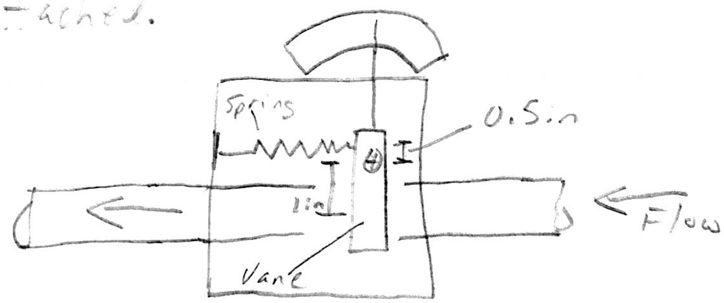
16.11 The figure represents a type of flowmeter in which the flat vane is rotated on a pivot as it deflects the fluid stream. The fluid force is counterbalanced by a spring. Calculate the spring force required to hold the vane in a vertical position when water at 100 gal/min flows from the 1in Schedule 40 pipe to which the meter is attached.



We know $Q = 100 \frac{gal}{min} \left(\frac{35.315\ ft^3/s}{15850\ gal/min} \right) = 0.2228\ ft^3/s$

We know $F = \rho Q (V_{2x} - V_{1x})$

So $V = \frac{Q}{A} = \frac{0.2228\ ft^3/s}{0.00600\ ft^2} = 37.13\ ft/s$ (Table F.1)

Then $F = (1.94\ slugs/ft^3)(0.2228\ ft^3/s)(37.13\ ft/s - (-37.13\ ft/s))$

$\boxed{F = 32.1\ lb}$

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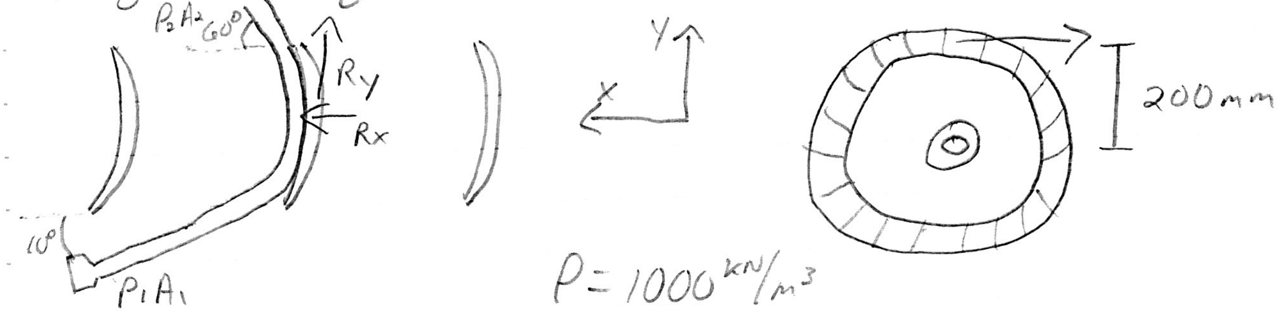
16.29. The figure is a turbine in which the incoming stream of water at 15°C has a diameter of 7.50mm and is moving with a velocity of 25 m/s. Compute the force on one blade of the turbine if the stream is deflected through the angle shown and the blade is stationary.



$\rho = 1000\ kN/m^3$

We know $\Sigma F_x \rightarrow R_x = \rho Q (V_{2x} - V_{1x})$

$\Sigma F_y \rightarrow R_y = \rho Q (V_{2y} - V_{1y})$

$V = \frac{Q}{A} \rightarrow Q = AV$

$A = \frac{\pi D^2}{4} = \frac{\pi (0.0075 m)^2}{4} = 4.418 \times 10^{-5} m^2$

$V = V_1 = V_2 = 25\ m/s$

So $Q = AV = (4.418 \times 10^{-5} m^2)(25 m/s)$

$Q = 1.104 \times 10^{-3}\ m^3/s$

Then $R_x = 1000\ kg/m^3 (1.104 \times 10^{-3}\ m^3/s)(25 m/s \cdot \cos(60°) + 25 m/s \cdot \cos(10°))$

$\boxed{R_x = 40.98\ N}$

Then $R_y = 1000\ kg/m^3 (1.104 \times 10^{-3}\ m^3/s)(25 m/s \cdot \sin(60°) - 25 m/s \cdot \sin(10°))$

$\boxed{R_y = 19.11\ N}$