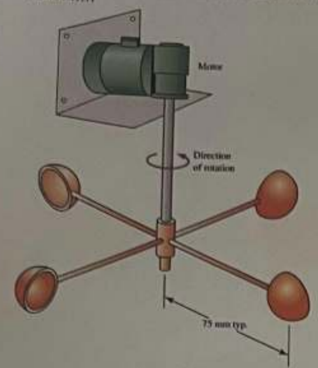
17.11 A type of level indicator incorporates four hemispherical cups with open fronts mounted as shown in Fig. P17.11. Each cup is 25 mm in diameter. A motor drives the cups at a constant rotational speed. Calculate the torque that the motor must produce to maintain the motion at 20 rpm when the cups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

Figure P17.11



$A = (.025m)^2 \cdot \pi = (.001963 m^2)(4\ cups) = .007853$

$R = 75mm = .075m$

$circumference = 2\pi r = 2\pi(.075) = .471m$

$\frac{20\ rotations}{minute} \cdot \frac{.471m}{1\ rota} \cdot \frac{1\ min}{60s} = .157\ m/s$

Air

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

$= 1.35\left(\frac{1.164\ (.157)}{2}\right)(.00753\ m^2)$

$= .000146\ \frac{kg}{m^3} \cdot \frac{m^2}{s} \cdot m^2$

$= .000146\ N$

gas

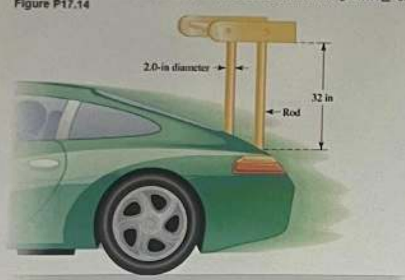
$F_D = C_D\left(\frac{\rho v^2}{2}\right)A$

$= 1.35\left(\frac{680\ kg/m^3\ (.157\ m/s)^2}{2}\right) \times (.00753 m^2)$

$= .0852\ N$

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



$T = -20F \quad V = 150\ mph$

$d = 2\ in \quad l = 32\ in \quad \rho = 2.80 \times 10^{-3}$

$A = 2(32) = 64\ in^2 \left(\frac{1}{144}\right)\frac{in^2}{ft^2}$

$A = .444\ ft^2 \quad Re = V\frac{D}{\nu} =$

$150(1.467)\left(\frac{2/12}{1.17 \times 10^{-4}}\right) =$

3.13×10^5

$C_D = \frac{1.333}{\sqrt{3.13 \times 10^5}} = .00238$

$F_D = 2(.00238)(.5(2.8 \times 10^{-3})(.444)(150(1.467))^2$

$F_D = 0.287\ lbF$

Chapter 17 Problem 16

$l = 60"$

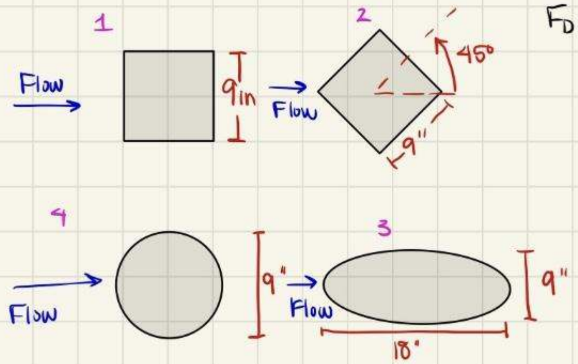
$F_D = C_D \left(\frac{\rho v^2}{2}\right) A$ (const. ρ; changes v, A; changes C_D)

Velocity $= 100 \frac{\text{miles}}{\text{hour}} \cdot \frac{5280 \text{ ft}}{1 \text{ mile}} \cdot \frac{1 \text{ hr}}{3600 \text{ s}}$

$= 146.67 \text{ ft/s}$

$\rho_{Air @ -20°F} = 2.8 \times 10^{-3} \frac{\text{Slugs}}{\text{ft}^3}$

$\nu_{Air @ -20°F} = 1.17 \times 10^{-4} \frac{\text{ft}^2}{\text{s}}$



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1)

$A = 60 \text{ in} \cdot 9 \text{ in} = 540 \text{ in}^2 \left(\frac{1 \text{ ft}}{12 \text{ in}}\right)^2 =$

$\frac{60}{9} = 6.66$

$C_D = 1.6$

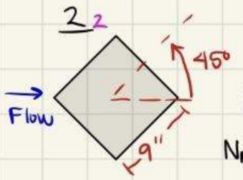
$F_D = C_D \left(\frac{\rho v^2}{2}\right) A$

$= 1.6 \left(\frac{(2.80 \times 10^{-3} \frac{\text{slug}}{\text{ft}^3})(146.67 \frac{\text{ft}}{\text{s}})^2}{2}\right)(3.75 \text{ ft}^2)$

$= 180.701 \ \frac{\text{slug}}{\text{ft}^3} \cdot \frac{\text{ft}^2}{\text{s}^2} \cdot \text{ft}^2$

$= 180.701 \ \frac{\text{slug} \cdot \text{ft}}{\text{s}^2} \cdot \frac{32.174 \text{ lbm}}{1 \text{ slug}} \cdot \frac{1 \text{ lb}_f}{32.174 \frac{\text{lbm} \cdot \text{ft}}{\text{s}^2}}$ $= 180.701 \text{ lb}_f$

2



Area $= (9 \text{in} + 9 \text{in})(60 \text{in}) = 1080 \text{ in}^2 = 7.5 \text{ ft}^2$

$C_d = 1.22$

$N_R = \frac{vL}{\nu} \left(\frac{(5 \text{ ft})(146.67 \frac{\text{ft}}{\text{s}})}{1.17 \times 10^{-4} \frac{\text{ft}^2}{\text{s}}}\right) = 6.3 \times 10^6$

cd 30°	1.05
cd 45°	x
cd 60°	1.39

$\frac{x - 1.05}{1.39 - 1.05} = \frac{45 - 30}{60 - 30}$

$5.1 = 30(x - 1.05)$

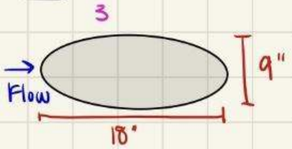
1.22

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

$= 1.22 \left(\frac{(2.80 \times 10^{-3} \frac{\text{slug}}{\text{ft}^3})(146.67 \frac{\text{ft}}{\text{s}})^2}{2}\right)(7.5 \text{ ft}^2)$

$= 275.57 \text{ lb}_f$

3



2:1 Eclipse

$N_R = \frac{vD}{\nu} = \frac{(0.75 \text{ft})(146.67 \frac{\text{ft}}{\text{s}})}{1.17 \times 10^{-4} \frac{\text{ft}^2}{\text{s}}} = 940{,}192.31$

9.4×10^5

$P = \pi \sqrt{2 \cdot (a^2 + b^2)}$

$C_D = 0.5$ circumference of ellipse $= \frac{\quad}{2}$

$\frac{\quad}{2}$

$= 3.725 \text{ ft} \cdot 5 \text{ ft}$

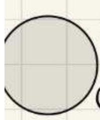
$= 18.625 \text{ ft}^2$

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

$= 0.5 \left(\frac{(2.80 \times 10^{-3} \frac{\text{slug}}{\text{ft}^3})(146.67 \frac{\text{ft}}{\text{s}})^2}{2}\right)(18.625)$

$= 280.463 \text{ lb}_f$

4



$\frac{60}{9} = 6.66$

$C_D \approx 1.12$

$N_R = \frac{vD}{\nu} = \frac{(0.75 \text{ft})(146.67 \frac{\text{ft}}{\text{s}})}{1.17 \times 10^{-4} \frac{\text{ft}^2}{\text{s}}} = 940{,}192.31$

9.4×10^5

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

$= 1.12 \left(\frac{(2.80 \times 10^{-3} \frac{\text{slug}}{\text{ft}^3})(146.67 \frac{\text{ft}}{\text{s}})^2}{2}\right)(5.89 \text{ ft}^2)$

$= 97.482 \text{ lb}_f$

Circumfere $= 2\pi r = 2\pi(4.5 \text{in})$

$= 28.274 / 2 =$ Half Circle $= 14.137 \text{ in} \cdot 60 \text{ in} = 848.22 \text{ in}^2 = 5.89 \text{ ft}^2$ (Area)

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 $77^{\circ}\mathrm{F}$.

$R_{ts}/\Delta = .06$

$\Delta = 125$ long tons $V = 50$ ft/s

$R_{ts} = (0.06)(125(2240)) = \boxed{16800 \text{ lb}}$

$P_E = R_{ts}V = (16800)(50) = .84 \times 10^6 \frac{\text{lb-ft}}{s}$

$P_E = .84 \times 10^6 \left(\frac{1}{550}\right) = \boxed{1527.3 \text{ hp}}$

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.

Given: $\alpha = 10^{\circ}$
$c = 1.4$ m
$b = 6.8$ m
$V = 200$ km/h $= 55.55$ m/s
$h_a = 200$ m
$h_b = 10000$ m

$C_D @ 10^{\circ} = .06$
$C_L @ 10^{\circ} = .09$

Area of air foil
$A = cb$
$1.4 \cdot 6.8$
$A = 9.52 \text{ m}^2$

Density of air @ 200
$\rho = 1.202$ kg/m³
Density of air @ 10000
$\rho = .4135$ kg/m³

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

$= .06\left(\frac{1.202 \cdot 55.55^2}{2}\right)(9.52)$

$\boxed{F_D = 1060 \text{ N} \approx 1.06 \text{ kN}}$

$F_L = C_L \frac{\rho v^2}{2}(A)$

$F_L = .9\left(\frac{1.202 \cdot 55.55}{2}\right)(9.52)$

$\boxed{F_L = 15893.37 \text{ N}}$

B) $F_D = .06\left(\frac{.4135 \cdot 55.55}{2}\right) \times 9.52$

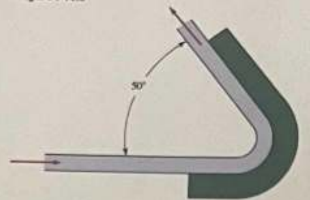
$\boxed{F_D = 364.5 \text{ N}}$

$F_L = .9\left(\frac{.4135 \cdot 55.55}{2}\right) \times 9.52$

$\boxed{F_L = 5467.5 \text{ N}}$

16.6 Figure P16.6 shows a free stream of water at 180°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 in² throughout the system. Compute the forces in the horizontal and vertical directions exerted on the water by the vane.

Figure P16.6



$T = 180\,°F$ $\quad \theta = 30°$

$V_1 = 22.0$ ft/s $\quad A = 2.95\,m^2 = .0205$ ft²

$V_1 = V_2 \quad \rho = 1.88$ slug/ft³

$Q = VA = 22(.0205) = .451$ ft³/s

$F_x = \rho Q(V_{2x} - V_{1x}) = 1.88(.451)(22\cos(50) - (22))$

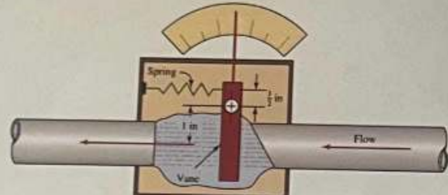
$\boxed{F_x = 30.64 \text{ ft}}$

$F_y = \rho Q(V_{2y} - V_{1y}) = 1.88(.451)(22\sin(50) - 0)$

$\boxed{F_y = 14.29 \text{ ft}}$

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



Given: $Q = 100 \frac{gal}{min}$

$d_1 = 1\text{ in} = 1/12$ ft

$Q = 100\text{ gal/min} \cdot \frac{1\text{ ft}^3/s}{449}$

$Q = 0.223$ ft³/s

$\rho = 1.94\text{ slug/ft}^3 \cdot \frac{lbf\,\frac{s^2}{ft}}{slug}$

$\rho = 1.94 \frac{lbf \cdot s^2}{ft^4}$

$Q = VA$

$.223 = .006V$

$V = 37.167$ ft/s

$F = \rho Q \Delta V$

$R_x = \rho Q(V_{2x} - V_{1x})$

$R_x = (1.94)(.223)(0 - (-37.167))$

$R_x = 16.08$ lbf

$\Sigma M_a = 0$

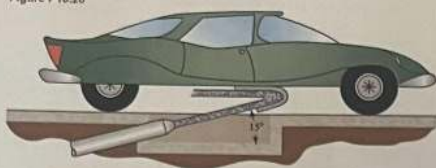
$F_s(.5) = R_x(1)$

$F_s(.5) = 16.08(1)$

$\boxed{F_s = 32.16 \text{ lbf}}$

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



$Q = VA$

$V_{Jet} = 30\ m/s$

$d = 200mm = (.2)^2 \pi = 12.5 m^2$

$Q = (30\ m/s)(.125\ m^2)$

$Q = 3.7699\ m^3/s$

Stationary

$F = \rho Q \Delta V$

$= (1000\ kg/m^3)(3.7699\ m^3/s)(30\ m/s)$

$= 113,097 N$

$= 113.1\ kN$

$113.1 kN (\cos 15) = F_x$

$F_x = 109.25 kN$

Moving

$F = \rho Q \Delta V$

$= (1000\ kg/m^3)(3.7699\ m^3/s)(18\ m/s)$

$= 67858.2 N$

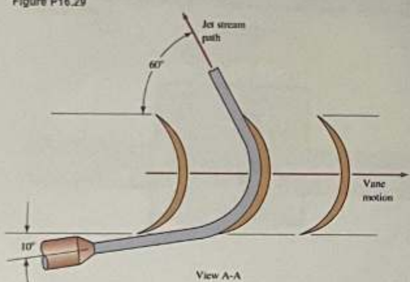
$= 67.9\ kN$

$67.9(\cos 15) = F_x$

$F_x = 65.586\ kN$

16.29 **Figure P16.29** is a sketch of a turbine in which the incoming stream of water at 15 °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



Given: $V_1 = 25\ m/s$

$d_1 = .0075 m$

$T = 15°C$

$Q = VA$

$= \frac{\pi}{4} d_1^2 \cdot V_1$

$= \frac{\pi}{4} (.0075)^2 (25)$

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

$V_{1x} = -V_1 \cos 60° = -24.62\ m/s$

$V_{2x} = V_2 \cos 60° = 12.5\ m/s$

$V_{1y} = V_1 \sin 10° = 4.34\ m/s$

$V_{2y} = V_2 \sin 60° = 21.65\ m/s$

$F = \rho Q \Delta V$

$R_x = \rho Q (V_{2x} - V_{1x})$

$= 1000(1.104 \times 10^{-3})(12.5 - (-24.62$

$R_x = 40.98 N$

$F = \rho Q \Delta V$

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

$R_y = (1000)(1.104 \times 10^{-3})(21.65 - 4.$

$R_y = 19.11 N$