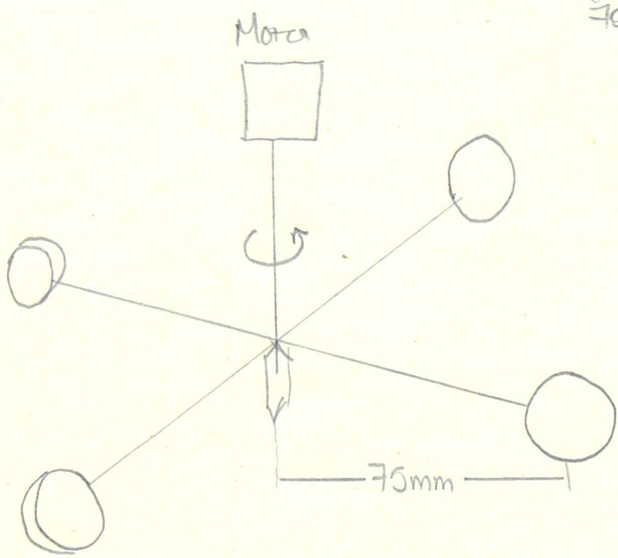
problem 11

A typical level indicator incorporates 4 hemispherical cups with open fronts mounted as shown below. Each cup is 25mm 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 20rpm.



25mm = 0.025m
75mm = 0.075m

$$\frac{20\,rev}{min} \times \frac{1\,min}{60\,s} = 0.33\,\frac{rev}{s}$$

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

$$Re = \frac{\rho \cdot V \cdot D}{\eta}$$

$$F_L = C_L \cdot \left(\frac{\rho \cdot V^2}{2}\right) \cdot A$$

· use A of sphere (projected area)
· ρ of water

η of air in Appendix E
ρ of air in Appendix E
C_D is from ch17 charts once Re known.

20 rpm is not a velocity, though. Not sure how to get velocity.

0.075 m is radius of a horizontal circle, whose circumference is the distance one sphere travels in one rev.

$C_{circle} = 2\pi r = 0.4712\,m$

$$\frac{0.33\,rev}{sec} \times \frac{0.4712\,m}{1\,rev} = 0.1555\,\frac{m}{s} = V_{cup}$$

$$Re = \frac{\rho \cdot V \cdot D}{\eta} = \frac{1.225\,\frac{kg}{m^3} \cdot 0.155\,\frac{m}{s} \cdot 0.025\,m}{1.789 \times 10^{-5}\,Pa \cdot s \times \frac{1\,N/m^2}{1\,Pa} \times \frac{1\,\frac{kg \cdot m}{s^2}}{1\,N}}$$

· assuming 15°C at sea level for air

$Re = 265.3368$

=>

Referencing figure 17.4,

C_D for a sphere at 2.65×10^2 is $\sim 8\times10^{-1}$

Area of a sphere is $A = 4\pi r^2 = 4\times\pi\times\left(\frac{0.025m}{2}\right)^2 = 1.963\times10^{-3}\,m^2$

* Torque is measured in N-m.

$$F_D = C_D \cdot \frac{\rho\cdot V^2}{2} \cdot A = 8\times10^{-1} \cdot \frac{1.225\frac{kg}{m^3}\cdot\left(0.1555\frac{m}{s}\right)^2}{2} \cdot 1.963\times10^{-3}m^2$$

$$F_D = 2.3258\times10^{-5}\ \frac{kg\cdot m}{s^2} \times \frac{1N}{1\frac{kg\cdot m}{s^2}} = 2.3258\times10^{-5}N.$$

as a moment:

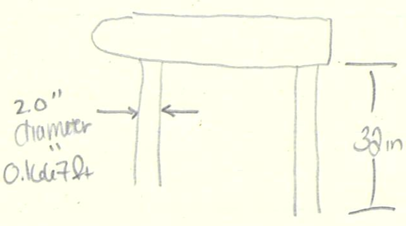
$$0.075m\times F_D = 0.075m\times 2.3258\times10^{-5}N = \boxed{1.744\times10^{-6}\,N\cdot m}$$

so, I think I went wrong somewhere, but not sure where.

problem 14

A wing on a racecar is supported by 2 cylindrical rods, as shown below. Compute the drag force exerted on the car due to these rods when the car is travelling through still air at -20F at a speed of 150mph.

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



$\rho_{air_{-20F}} = 2.80\ \frac{slugs}{ft^3}$

$V = 150\frac{mi}{h}\times\frac{5280ft}{1mi}\times\frac{1hr}{3600s} = 220\frac{ft}{s}$

A cylinder: $\frac{\pi D^2}{4} = 0.02183ft^2$

$$R = \frac{\rho\cdot V\cdot D}{\eta} = \frac{2.80\frac{slugs}{ft^3}\cdot 220\frac{ft}{s}\cdot 0.1667ft}{3.27\times10^{-7}\ \frac{lb-s}{ft^2}}$$

$C_D =$

$$\frac{slugs}{\cancel{ft}\cdot s}\cdot\frac{ft^{\cancel{2}}}{lb-s} = \frac{slug\text{-}ft}{lb\cdot s^2}\times\left[\frac{1\frac{ft}{lb\cdot s^2}}{1slug}\right]$$

$R = 314.028E6$

Reynolds number too big for provided charts.

using eq 17.5

$$R = \frac{\rho \cdot v \cdot L}{\eta} = \frac{2.80\,\frac{slugs}{ft^3} \cdot 220\,\frac{ft}{s} \cdot 2.667\,ft}{3.27\times10^{-7}\,\frac{lb\cdot s}{ft^2}}$$

$$Re = 7.308\times10^{9}$$ even worse.

whatever.

Referencing table 17.1, as $\frac{L}{d} \rightarrow \infty$, $Cd \rightarrow 1$

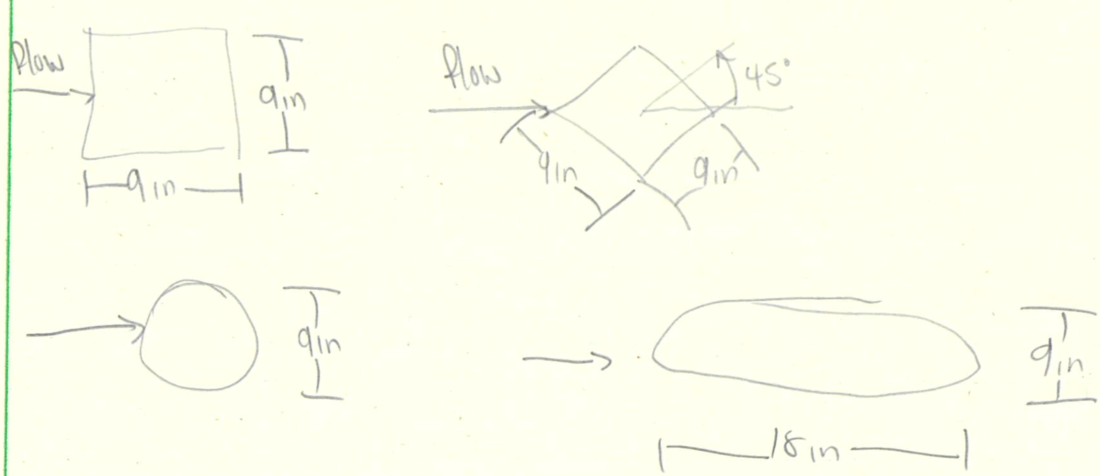
$$F_D = C_D \cdot \frac{\rho \cdot V^2}{2} \cdot A = 1 \cdot \frac{2.80\,\frac{slugs}{ft^3} \cdot \left(220\,\frac{ft}{s}\right)^2}{2} \cdot 0.02183\,ft^2$$

$$\boxed{F_D = 1479.20\,lb}$$

$$\frac{\cancel{slugs}}{\cancel{ft^3}} \cdot \frac{\cancel{ft^2}}{\cancel{s^2}} \cdot \cancel{ft^2} \cdot \frac{\frac{\cancel{ft}}{lb\cdot \cancel{s^2}}}{1\,\cancel{slug}}$$

Problem 16

The four designs shown for the cross section of an emergency flasher lighting system for the police vehicles are being evaluated. Each has a length of 60 in and a width of 9 in. Compare the drag force exerted on each proposed design when the vehicle moves at 100 mph through still air at −20F.



$\rho_{air_{-20F}} = 2.80\times10^{-3}\ \frac{slugs}{ft^3}$ ← cool. wrote the wrong in 14.

$\eta_{air_{-20F}} = 3.27\times10^{-7}\ \frac{lb\text{-}s}{ft^2}$

$\frac{150\,mi}{h} \cdot \frac{5280\,ft}{1\,mi} \cdot \frac{1\,hr}{3600\,s} = 220\ \frac{ft}{s}$

$$Re = \frac{\rho \cdot V D}{\eta} = \frac{2.80\times10^{-3}\ \frac{slugs}{ft^3} \cdot 220\frac{ft}{s} \cdot 9\,in \times \frac{1\,ft}{12\,in}}{3.27\times10^{-7}\ \frac{lb\text{-}s}{ft^2}}$$

$Re = 1.413\times10^{6}$

from table 17.1

$C_{D_{square\,cyl}} = 1.60$ $\qquad C_{D_{triangle}} = 2.15$ (each half)

$C_{D_{sphere}} = 1.22$ $\qquad C_{D_{oval}} = 0.4$

figure 17.6

$F_D = C_D \cdot \frac{\rho \cdot V^2}{2} \cdot A$ rect

① $F_D = 1.60 \times \frac{2.80\times10^{-3}\frac{slugs}{ft^3} \cdot \left(220\frac{ft}{s}\right)^2}{2} \cdot 9\,in \times 60\,in \times \frac{1\,ft^2}{144\,in^2}$

$\frac{1}{2} \cdot b \cdot h \times 2$

$F_D = 406.56\,lb.$

② $F_D = 2.15 \cdot \frac{2.80\times10^{-3}\frac{slugs}{ft^3} \cdot \left(220\frac{ft}{s}\right)^2}{2} \cdot 9\,in \cdot 60\,in \cdot \frac{1\,ft^2}{144\,in^2}$

$F_D = 546.31\,lb.$ tilted rect

③ $F_D = 1.22 \cdot \dfrac{2.80\times10^{-3}\,\frac{slugs}{ft^3}\cdot\left(220\,\frac{ft}{s}\right)^2}{2} \cdot 9in \cdot 60in \cdot \dfrac{1\,ft^2}{144\,in^2}$

$\boxed{F_D = 310.002\text{ lb.}}$ sphere.

projected area behaves like a rectangle

④ $F_D = 0.4 \cdot \dfrac{2.80\times10^{-3}\,\frac{slugs}{ft^3}\cdot\left(220\,\frac{ft}{s}\right)^2}{2} \cdot 9in \cdot 60in \cdot \dfrac{1\,ft^2}{144\,in^2}$

$\boxed{F_D = 101.64\text{ lb}}$ oval

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revisiting problem 14

$Re = \dfrac{\rho \cdot V \cdot D}{\eta} = \dfrac{2.80\times10^{-3}\,\frac{slugs}{ft^3}\cdot 220\,\frac{ft}{s}\cdot 0.1667ft}{3.27\times10^{-7}\,\frac{lb\cdot s}{ft^2}}$

$Re = 3.14\times10^5$

there we go.

$C_D \sim 1.3$

$F_D = C_D \cdot \dfrac{\rho \cdot V^2}{2} \cdot A$

projected area

$= 1.3 \times \dfrac{2.80\times10^{-3}\,\frac{slugs}{ft^3}\left(220\,\frac{ft}{s}\right)^2}{2} \cdot \underbrace{2in \times 32in}_{} \times \dfrac{1\,ft^2}{144\,in^2}$

$\boxed{F_D = 39.150\text{ lb}}$ problem 14 problem 26

A small, fast boat has a specific resistance ratio of 0.06 and displaces 125 long tons (1 long ton = 2240 lb). Compute the total ship resistance & the power required to overcome drag when it is moving 50 ft/s in seawater at 77F.

$$P_E = R_{TS} \cdot V$$

$$R_{TS}/\Delta = 0.06$$

$$\Delta = (125 \text{ long tons}) \cdot \frac{2240 \text{ lb}}{\text{long ton}} = 280k \text{ lb}$$

$$R_{TS} = 0.06 \cdot \Delta = 16,800 \text{ lb}.$$

$$P_E = 16800 \text{ lb} \cdot 50 \frac{ft}{s} = 840,000 \frac{lb\text{-}ft}{s} \times \frac{1 \text{ hp}}{550 \frac{lb\text{-}ft}{s}} = \boxed{1,527 \text{ hp}}$$

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problem 30

For the airfoil w/ the characteristics shown in figure 17.11, determine lift & 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 200 km/h in the standard atmosphere at a) 200m b) 1000m.

pressure

$P_{200m} = 98.91 kPa$
$P_{10km} = 26.5 kPa$

$$200 \frac{km}{h} \cdot \frac{1 hr}{3600 s} \cdot \frac{1000 m}{1 km} = 55.56 \frac{m}{s}$$

$$F_L = C_L \cdot \frac{\rho \cdot V^2}{2} \cdot A$$

$$F_D = C_D \cdot \frac{\rho \cdot V^2}{2} \cdot A$$

A = span · chord length
$$A = 6.8m \cdot 1.4m = 9.52 m^2$$

$$\rho_{air_{200m}} = 1.202 \frac{kg}{m^3}$$

$$\rho_{air_{10km}} = 0.4135 \frac{kg}{m^3}$$

C_L @10° = 0.87
C_D @10° = 0.055

200m

$$F_L = 0.87 \cdot \frac{1.202 \frac{kg}{m^3} \cdot \left(55.56 \frac{m}{s}\right)^2}{2} \cdot 9.52 m^2 = 15.366 kN$$

$$F_D = 0.055 \cdot \frac{1.202 \frac{kg}{m^3} \cdot \left(55.56 \frac{m}{s}\right)^2}{2} \cdot 9.52 m^2 = 971.4 N$$

10km

$$F_L = 0.87 \cdot \frac{0.4135 \frac{kg}{m^3} \cdot \left(55.56 \frac{m}{s}\right)^2}{2} \cdot 9.52 m^2 = 5.309 kN$$

$$F_D = 0.055 \cdot \frac{0.4135 \frac{kg}{m^3} \cdot \left(55.56 \frac{m}{s}\right)^2}{2} \cdot 9.52 m^2 = \underline{335.626 N}$$