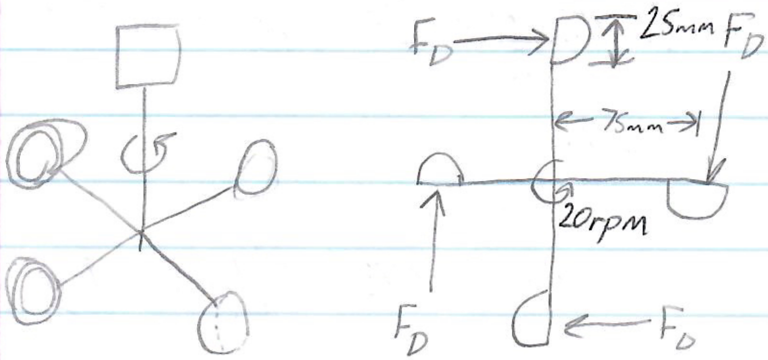
Team 5 HW 2.2

17.11)



a) Air 30°C
b) Gasoline 20°C

Procedure: Solve for linear velocity at the cup. Find drag coefficient from table then use drag force equation. Use force in moment calculation for torque.

$v = \omega r \qquad r = 0.075m$

$\omega = \frac{20 RPM}{60 s/m} \times 2\pi \frac{rad}{rev} = 2.09 \, rad/s$

$v = 2.09 \, rad/s \cdot 0.075m = 0.157 \, m/s$

From table 17.1; use C_D of 1.35

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

$\rho_{air\,30°C} = 1.164 \frac{kg}{m^3}$

$\rho_{gas\,20°C} = 680 \frac{kg}{m^3}$

$A = \frac{\pi}{4}(0.025m)^2 = 0.491 \times 10^{-3} m^2$

$F_{D_{air}} = 1.35 \left(\frac{1.164 \frac{kg}{m^3} \cdot (0.157 \frac{m}{s})^2}{2} \right) \cdot 0.491 \times 10^{-3} m^2$

$F_{D_{air}} = 9.51 \mu N$

$Torque_{air} = 9.51 \mu N \cdot 4 \cdot 0.075m = \boxed{2.85 \mu Nm}$

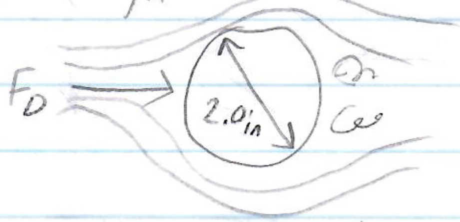
$$F_{D_{gas}} = 1.35\left(\frac{680\frac{kg}{m^3} \cdot (0.157\frac{m}{s})^2}{2}\right) \cdot 0.491 \times 10^{-3} m^2$$

$$F_{D_{gas}} = 5.55\ mN$$

$$Torque_{gas} = 5.55\ mN \cdot 4 \cdot 0.075m = \boxed{1.67\ mNm}$$

17.14)

$V = 150\,mph$



Air @ $-20°F$

$L = 32\,in \times 2$

Find F_D

Procedure: Find Reynold's number. Use N_R to find C_D then solve with drag formula.

$$N_R = \frac{vD}{\nu}$$

$\nu = 1.17 \times 10^{-4}\ \frac{ft^2}{s}$

$v = 150\,mph = 220\,ft/s$

$$N_R = \frac{220\ \frac{ft}{s} \cdot \frac{2}{12}\,ft}{1.17 \times 10^{-4}\ \frac{ft^2}{s}} = 3.1 \times 10^5$$

From figure 17.4 → $C_D = \sim 0.80$. Boundary layer approaching turbulent.

$\rho = 2.80 \times 10^{-3}\ slugs/ft^3$

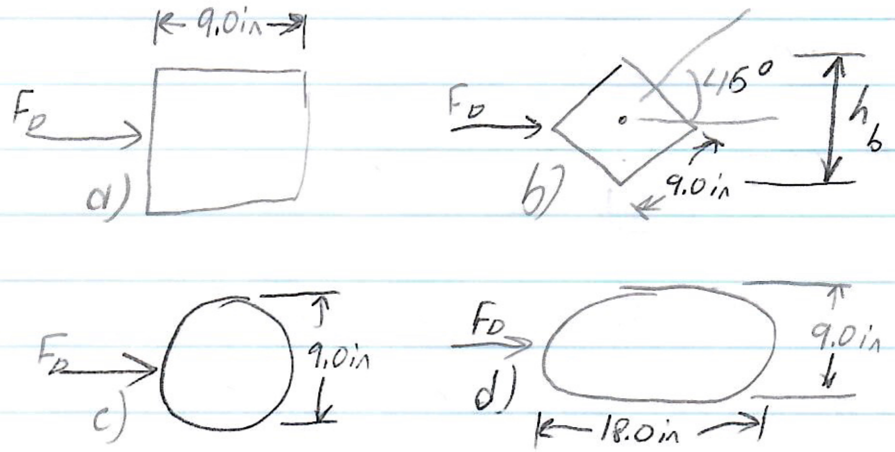
$$F_D = C_D\left(\frac{\rho v^2}{2}\right)A$$

$$A = DL = \frac{2\,in}{12} \cdot \frac{32\,in}{12} \cdot 2 = 0.889\,ft^2$$

$$F_D = 0.80\left(\frac{2.80 \times 10^{-3}\ \frac{slugs}{ft^3} \cdot \left(220\ \frac{ft}{s}\right)^2}{2}\right) \cdot 0.889\,ft^2$$

$$\boxed{F_D = 48.19\ lb_f}$$

17.16



$L = 60.0\,in \quad v = 100\,mph = 146.7\,ft/s$

$\rho = 2.80\times10^{-3}\,slugs/ft^3 \quad \nu = 1.17\times10^{-4}\,\frac{ft^2}{s}$

Procedure: Find C_D for each shape. Use drag formula.

a) $N_R = \frac{vL}{\nu} = \frac{146.7\frac{ft}{s}\cdot\frac{9.0}{12}ft}{1.17\times10^{-4}\frac{ft^2}{s}} = 9.4\times10^5$

From figure 17.4: $C_D = \sim 2.0$

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

$F_D = \frac{2.0}{2}\left(2.80\times10^{-3}\frac{slugs}{ft^3}\cdot\left(146.7\frac{ft}{s}\right)^2\right)\cdot\left(\frac{9}{12}ft\cdot\frac{60}{12}ft\right)$

$\boxed{F_D = 226.0\,lb}$

b) $A = h_b L \quad h_b = 9\sin45°\cdot2 = 12.73\,in$

$A = \frac{12.73}{12}\cdot\frac{60}{12} = 5.30\,ft^2$

C_D from Table 17.1:

$F_D = \frac{1.60}{2}\left(2.80\times10^{-3}\frac{slugs}{ft^3}\cdot(146.7)^2\right)\cdot(5.30\,ft^2)$

$\boxed{F_D = 255.5\,lb}$

c) $N_R = \frac{vD}{\nu} = \frac{(146.7\,\frac{ft}{s})(\frac{9}{12}\,ft)}{1.17\times10^{-4}\,\frac{ft^2}{s}} = 9.4\times10^5$

From Figure 17.4: $C_D \cong 0.30$

$F_D = \frac{0.30}{2}\left(2.80\times10^{-3}\,\frac{slugs}{ft^3}\left(146.7\,\frac{ft}{s}\right)^2\right)\cdot\left(\frac{9}{12}\cdot\frac{60}{12}\right)ft^2$

$\boxed{F_D = 33.9\ lb}$

d) $N_R = \frac{vL}{\nu} = \frac{(146.7\,\frac{ft}{s})(\frac{18}{12}\,ft)}{1.17\times10^{-4}\,\frac{ft^2}{s}} = 1.88\times10^6$

From figure 17.6: $C_D \cong 0.3$ for 2:1 ellipse

$F_D = \frac{0.30}{2}\left(2.80\times10^{-3}\,\frac{slugs}{ft^3}\left(146.7\,\frac{ft}{s}\right)^2\right)\cdot\left(\frac{9}{12}\cdot\frac{60}{12}\right)ft^2$

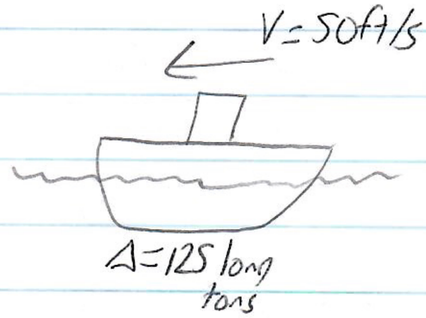
$\boxed{F_D = 33.9\ lb}$

17.26) Small fast boat

$\Delta = 125$ long tons

$V = 50\ ft/s$

seawater @ 77°F



Procedure: Find total ship resistance, R_{TS}
Use to solve for power required.

$$\Delta = (125\ tons)(2240\ lb/ton) = 2.8 \times 10^5\ lb$$

Small fast boat has $R_{TS}/\Delta \simeq 0.01$ to 0.12

Assume 0.06

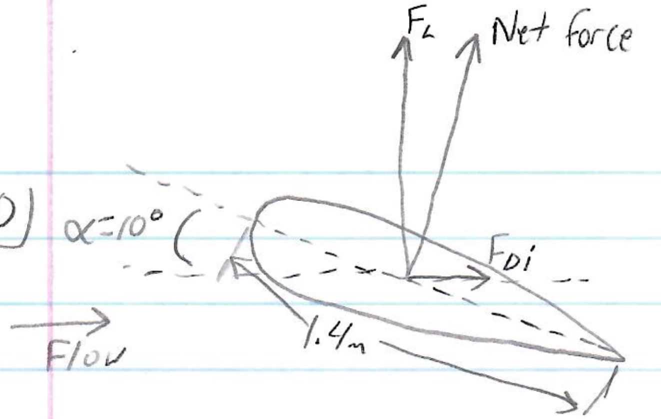
$$R_{TS} = (0.06)(2.8 \times 10^5\ lb) = \boxed{16800\ lb}$$

$$P_E = R_{TS} \cdot V = 16800\ lb \cdot 50\frac{ft}{s} = 8.4 \times 10^5\ \frac{lb\,ft}{s}$$

$$P_E = 8.4 \times 10^5\ \frac{ft\,lb}{s} \cdot \frac{1\ \frac{ft\,lb}{s}}{550\ hp} = 1527\ hp$$

$$\boxed{P_E = 1527\ hp}$$

17.30) $\alpha = 10°$



Span = 6.8m
$v = 200$ km/h
$h_1 = 200m$
$h_2 = 10000m$

Solve lift and drag at each height.
Procedure: Find C_L and C_D at 10° angle.
Use lift and drag equations at each height.

From Figure 17.11: $C_L \cong 0.90$ $\quad C_D \cong 0.06$

ρ_{air} @ 200m = 1.202 kg/m³

$v = 200 kmh = 55.6$ m/s

ρ_{air} @ 10000 m = 0.4135 kg/m³ $\quad A = 6.8 \cdot 1.4 = 9.52$m

At 200m

$$F_L = \frac{C_L}{2}(\rho v^2)A = \frac{0.90}{2}(1.202\,kg/m^3)(55.6\tfrac{m}{s})^2(9.52m)$$

$$\boxed{F_L = 15.92\,kN}$$

$$F_D = \frac{C_D}{2}(\rho v^2)A = \frac{0.06}{2}(1.202\,kg/m^3)(55.6\tfrac{m}{s})^2(9.52m)$$

$$\boxed{F_D = 1.06\,kN}$$

At 10000 m

$$F_L = \frac{0.90}{2}(0.4135\tfrac{kg}{m^3})(55.6\tfrac{m}{s})^2(9.52m)$$

$$\boxed{F_L = 5.48\,kN}$$

$$F_D = \frac{0.06}{2}(0.4135\tfrac{kg}{m^3})(55.6\tfrac{m}{s})^2(9.52m)$$

$$\boxed{F_D = 164\,N}$$

I learned from the lecture problems that solving any problem relating to lift or drag forces needs to start with a free body diagram to identify all the forces. Basic geometry, trigonometry, and statics will likely be necessary in each problem to solve for the equilibrium states. In the case of selecting a drag coefficient, the drag coefficient for abnormal shapes is educated guesswork at best if not supported by experimental data.

The solved homework problems taught me that interpreting the shape and selecting the correct drag coefficient and area for the object is critical to getting accurate answers. In any case where the drag coefficient significantly varies with Reynolds number the Reynolds number must be solved first. The simplest problems to solve are ship resistance problems as they contain very few variables, although what is taught in this class is likely an extremely simplified version of it.

Agreste

Team Five