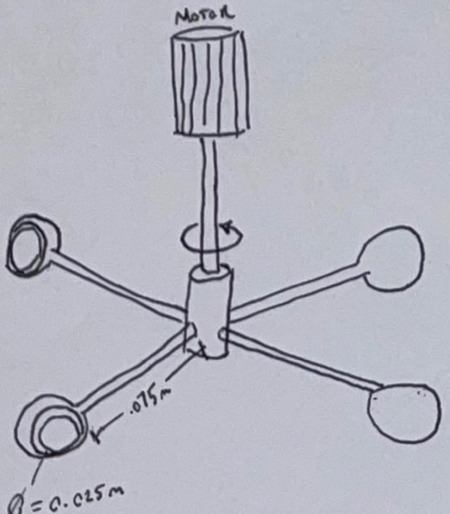
17.11) HEMISPHERICAL CUPS, EACH 25mm Ø. FIND TORQUE THAT THE MOTOR MUST PRODUCE TO MAINTAIN MOTION AT 20 RPM WHEN THE CUPS ARE IN AIR AT 30°C, GASOLINE AT 20°C.



GIVEN: $D_c = 25\,mm = 0.025\,m$

$C_D = 1.35$ (CH.17, pg 478)

$t_{AIR} = 30°C \rightarrow \rho = 1.164\,\frac{kg}{m^3}$

$t_{GAS} = 20°C \rightarrow \rho = 680\,\frac{kg}{m^3}$

$V = 20\,\frac{REV}{MIN} \cdot \frac{\pi(0.075m)}{30} = 0.1571\,\frac{m}{s}$

$d = 75mm = 0.075m$

SOLUTION: PROJECTED AREA $\rightarrow A = \frac{\pi(0.025m)^2}{4} = 0.000491\,m^2$

$F_D = C_D\left(\frac{\rho V^2}{2}\right)A \rightarrow (1.35)\left(\frac{1.164\frac{kg}{m^3} \times 0.1571^2 \frac{m}{s}}{2}\right)(0.000491\,m^2)$

$F_D = 9.521 \times 10^{-6}\,N$

$T = F_D \cdot d \rightarrow (9.521 \times 10^{-6} N)(0.075M)$

$T = 7.141 \times 10^{-7}\,N\text{-}M$

(a) TORQUE REQD., $T_R = 4T \rightarrow 4(7.141 \times 10^{-7}\,N\text{-}M)$

$$\underline{\underline{T_R = 2.856 \times 10^{-6}\,N\text{-}M}}$$

$F_D = C_D\left(\frac{\rho V^2}{2}\right)A \rightarrow (1.35)\left(\frac{680\frac{kg}{m^3} \times 0.1571^2 \frac{m}{s}}{2}\right)(0.000491\,m^2)$

$F_D = 0.005562\,N$

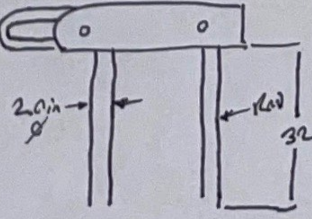
$T = F_D \cdot d \rightarrow (0.005562\,N)(0.075m)$

$T = 0.000417\,N\text{-}M$

(b) TORQUE REQD., $T_R = 4T \rightarrow 4(0.000417\,N\text{-}M)$

$$\underline{\underline{T_R = 1.668 \times 10^{-3}\,N\text{-}M}}$$

17.14) A WING ON A RACECAR IS SUPPORTED BY 2 CYLINDRICAL RODS. COMPUTE THE DRAG FORCE EXERTED ON THE CAR DUE TO THESE RODS WHEN THE CAR IS TRAVELING THROUGH STILL AIR AT -20°F AT 150 mph.



GIVEN: $V = 150\ \cancel{mph} \cdot \frac{1\ \cancel{hr}}{60\ \cancel{min}} \cdot \frac{1\ \cancel{min}}{60\ sec} \cdot \frac{5280\ ft}{1\ \cancel{mile}} = 220\ \frac{ft}{sec}$

$D_R = 2\ in \cdot \frac{1\ ft}{12\ in} = 0.167\ ft$

$L = 32\ in = 2.67\ ft$

$A = \cancel{2}(32\ in) = 64\ in^2 = \overset{0.444}{\cancel{5.33}}\ ft^2$

$(-20)\ \rho_{AIR} = 0.087\ \frac{lb}{ft^3}$ $\quad \nu = 1.249 \times 10^{-4}\ \frac{ft^2}{s}$

$C_D =$ [illegible] 0.275 (CHART)

SOLUTION: $F_D = C_D\left(\frac{\rho V^2}{2}\right)A$ $\quad N_R = \frac{VL}{\nu} = \frac{(\overset{220\ \frac{ft}{sec}}{\cancel{2.249 \times 10^{-4}}})(2.67\ ft)}{1.249 \times 10^{-4}\ \frac{ft^2}{s}}$

$= 4.703 \times 10^{+6}$

$\longrightarrow A = \overset{(0.167\ ft)\times}{\cancel{2}}(5.33\ ft)$

~~$= 40.66\ ft^2$~~

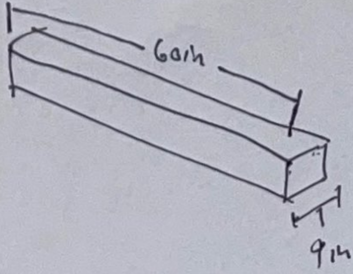
$= 0.89011\ ft^2$

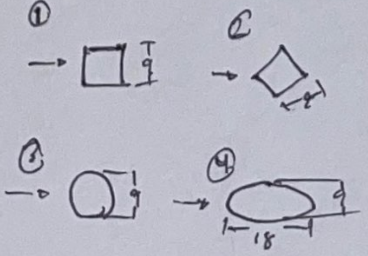
$\longrightarrow = (0.275)\left(\frac{0.087\ \frac{lb}{ft^3} \times 220\ \frac{ft}{sec}^2}{2}\right)\left(\overset{0.444}{\cancel{0.89011}}\ ft^2\right)$

~~$F_D = 515.36\ lb$~~

$F_D = 257.069\ lb$

17.16)





$w = 9\text{in} = 0.75\text{ FT}$

$L = 60\text{in} = 5\text{FT} = 1.524\text{m}$

GIVEN: $V = 100\text{ mph} =$ [redacted]

(-20F) $\rho_{ATM} =$ [redacted] $1.452 \frac{kg}{m^3}$

$\nu = 1.08 \times 10^{-5} \frac{m^2}{s}$

SOLUTION: $V = 100\text{ mph} \cdot \frac{0.44704 \frac{m}{s}}{1\text{mph}} = 44.7 \frac{m}{s}$

①

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

~~$N_R = \frac{VL}{\nu} = \frac{(44.7 \frac{m}{s})(1.524m)}{1.08 \times 10^{-5} \frac{m^2}{s}}$~~ $= 6.308 \times 10^6$

~~$C_D =$~~ [redacted] (CHART)

(JUST USE GIVEN C_D)

$\frac{L}{W} = \frac{60\text{in}}{9\text{in}} = 6.67 = C_D = 1.23$

$A = 0.75 \times 5 = 3.75\text{ FT}^2 \cdot \frac{0.0929\text{ m}^2}{1\text{FT}^2}$

$= 0.348\text{ m}^2$

$$F_D = 1.23\left(\frac{1.452 \frac{kg}{m^3} \times 44.7 \frac{m^2}{s}}{2}\right)(0.348\text{ m}^2)$$

$= 620.921\text{ N} \cdot \frac{0.2248\text{ lb}}{1\text{N}}$

$F_D = 139.583\text{ lb}$ ①

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

$= 1.6\left(\frac{1.452 \frac{kg}{m^3} \times 44.7 \frac{m}{s}}{2}\right)(0.348\text{m}^2)$

$= 807.702\text{ N} \cdot \frac{0.2248}{1\text{N}} = 181.571\text{lb}$

$F_D = 181.571\text{ lb}$

③ $F_D = C_D \left(\frac{\rho V^2}{2}\right) A$

$A =$ ~~1~~ (PROJECTED AREA IS SAME), 0.348m^2)

$C_D = 1.2$, (CHART)

$F_D = 1.2\left(\frac{1.452 \frac{kg}{m^3} \times 44.7 \frac{m}{s}}{2}\right)(0.348\text{m}^2)$

$= 605.776\text{ N} \cdot \frac{0.2248\text{ lb}}{1\text{N}} = 136.178$

$F_D = 136.178\text{ lb}$

④ 2:1 ELLIPTICAL CYLINDER, $C_D = 0.45$?

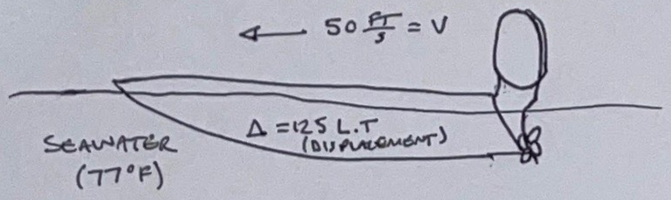
$N_R = \frac{(44.7)(1.524m)}{1.08 \times 10^{-5} \frac{m^2}{s}} = 6.308 \times 10^6$

$F_D = 0.45\left(\frac{1.452 \frac{kg}{m^3} \times 44.7 \frac{m}{s}}{2}\right)(0.348\text{m}^2)$

$= 227.166\text{ N} \cdot \frac{0.2248\text{ lb}}{1\text{N}}$

$F_D = 51\text{ lb}$

17.26) A SMALL FAST BOAT HAS A SPECIFIC RESISTANCE RATIO OF 0.06 (TABLE 17.2) AND DISPLACES 125 LONG TONS. COMPUTE THE TOTAL SHIP RESISTANCE AND THE POWER REQUIRED TO OVERCOME DRAG WHEN ITS MOVING AT 50 FT/S IN SEAWATER AT 77°F.



GIVEN: 1 LONG TON = 2240 lb

$V = 50\ FT/S$

$\rho_{SW} = 2\ \frac{SLUGS}{FT^3}$

$\nu = 1.08 \times 10^{-5}\ \frac{FT^2}{S}$

SOLUTION:

$$\Delta = 125\ \text{LONG TONS} \cdot \frac{2240\ lb}{1\ \text{LONG TONS}} = 280{,}000\ lb$$

$$R_{TS} = (0.06)(280{,}000\ lb) = \underline{\underline{16{,}800\ lb}}$$

$$P_E = R_{TS} \cdot \nu = (16{,}800\ lb)\left(\overset{50\ \frac{FT}{S}}{\cancel{1.08 \times 10^{-5}\ \frac{FT^2}{S}}}\right)$$

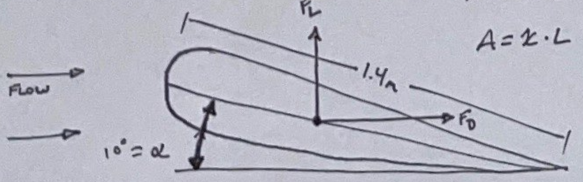
$$= 840{,}000\ \frac{lb\ FT}{S} \cdot \frac{1\ Hp}{550\ \frac{FT\ lb}{S}}$$

$$\underline{\underline{P_E = 1527.27\ Hp}}$$

17.30) FOR THE AIRFOIL WITH THE PERFORMANCE CHARACTERISTICS SHOWN, DETERMINE THE LIFT + DRAG AT AN ANGLE OF ATTACK OF 10°. CORD LENGTH OF 1.4m, SPAN OF 6.8m SPEED OF 200 Km/h (STD. ATM.) AT 200m AND 10,000m.

DIMENSION, χ NOT SHOWN,
$\chi = 6.8m$

$A = \chi \cdot L = 6.8m \cdot 1.4m$
$= 9.52 m^2$



GIVEN: $\alpha = 10°$

$V = 200 \frac{km}{h} \cdot \frac{1000m}{1km} \cdot \frac{1h}{60min} \cdot \frac{1min}{60sec} = 55.56 \frac{m}{s}$

$L_c = 1.4m$

$\chi = 6.8m$

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

$\rho_{10,000} = 0.4135 \frac{kg}{m^3}$

SOLUTION: AREA, $A = L_c \cdot \chi = 1.4m \times 6.8m = 9.52 m^2$

(a) C_D AT 10° = 0.05
C_L AT 10° = 0.~~85~~ 0.85
} FROM CHART PROVIDED.

$\rightarrow F_D = C_D \left(\frac{\rho V^2}{2}\right) A \rightarrow 0.05\left(\frac{1.202\frac{kg}{m^3}\times 55.56^2\frac{m}{s}}{2}\right)(9.52m^2)$

$\underline{\underline{F_D = 883.09 N}}$

$\rightarrow F_L = C_L \left(\frac{\rho V^2}{2}\right) A \rightarrow 0.85\left(\frac{1.202\frac{kg}{m^3}\times 55.56^2\frac{m}{s}}{2}\right)(9.52m^2)$

$\underline{\underline{F_L = 15,012.6 N}}$

(b) C_D + C_L SAME, A is SAME, V is SAME

$\rightarrow F_D = C_D \left(\frac{\rho V^2}{2}\right) A \rightarrow 0.05\left(\frac{0.4135\frac{kg}{m^3}\times 55.56^2\frac{m}{s}}{2}\right)(9.52m^2)$

$\underline{\underline{F_D = 303.79 N}}$

$\rightarrow F_L = C_L \left(\frac{\rho V^2}{2}\right) A \rightarrow 0.85\left(\frac{0.4135\frac{kg}{m^3}\times 55.56^2\frac{m}{s}}{2}\right)(9.52m^2)$

$\underline{\underline{F_L = 5164.47 N}}$

WATCHING THE VIDEOS OF THE LECTURE AND LOOKING AT THE PRACTICE PROBLEMS I LEARNED SEVERAL THINGS ABOUT DRAG AND LIFT. FOR STARTERS, DRAG IS THE FORCE ACTING IN THE HORIZONTAL DIRECTION AGAINST AN OBJECT. LIFT IS THE FORCE THAT ACTS IN THE VERTICAL DIRECTION IN RELATION TO THE OBJECT. THE METHODS FOR SOLVING MOST DRAG/LIFT PROBLEMS RELATE BACK TO THINGS THAT WE LEARNED IN STATICS AND STRENGTHS. WHAT I MEAN BY THIS IS THAT WE CAN SOLVE FOR FORCES IN A SIMILAR MANNER AS WELL AS FOR THE MOMENT ABOUT A GIVEN POINT, IF REQUIRED. WHEN SOLVING FOR DRAG AND LIFT FORCES, THE SHAPE AND PROJECTED AREA OF THE OBJECT ARE IMPORTANT BECAUSE THEY FACTOR IN TO FINDING THE REYNOLD'S NUMBER WHEN MULTIPLIED BY THE VELOCITY. WITH THE REYNOLD'S NUMBER, THE DRAG/LIFT COEFFICIENT CAN BE DETERMINED (THIS CAN ALSO BE FOUND IN A TABLE FOR CERTAIN STANDARD SHAPES.). THE COEFFICIENT WILL BE MULTIPLIED BY THE DENSITY OF THE FLUID THE OBJECT IS SUBJECTED TO AND BY THE VELOCITY SQUARED AND DIVIDED BY TWO. THIS PRODUCT WILL THEN BE MULTIPLIED BY THE PROJECTED AREA TO FIND THE LIFT OR DRAG FORCE. ($F_D = C_D\left(\frac{\rho v^2}{2}\right)A$, $F_L = C_L\left(\frac{\rho v^2}{2}\right)A$)