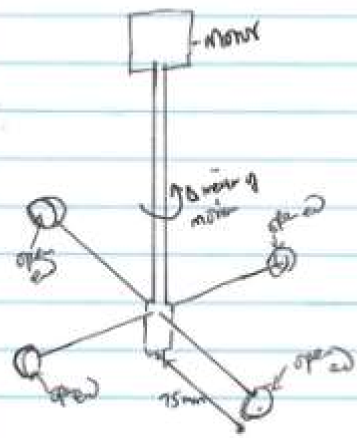
# Homework 2.2

This week we learned about friction, air density, lift, and drag. There are two forces we learned about and used in the homework, lift force and drag force. In order to find the drag force, we must first use the Reynolds number to determine the drag coefficient of our object. After finding the Reynolds number, we simply look at a chart that is for the type of object we are measuring. In some cases, the temperature or the altitude will need to be taken into account, in which case we look up the various properties in the glossary at the back of the book. At the end of the week we touched on flow measurements with variable head types. We also went over a new equation to find the flow rate inside a pipe $v_1 = C\sqrt{\frac{2g\left(\frac{P_1}{P_2}\right)/\gamma}{\left(\frac{A_1}{A_2}\right)^2 - 1}}$ where "C" is the discharge coefficient that we can find by using the Reynolds number and coming it to another graph.

Homework Problems

17.11

Problem 17.11




Four hemispherical cups of 25mm diameter

Calculate the torque that the motor must produce to maintain the motion at 20 rpm. a) in air at 30°C

b) in gasoline at 20°C

$C_D = 1.35$

$A = \frac{\pi}{4}(0.025m)^2$

$= 4.909 \times 10^{-4} m^2$

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

$v = 20 \times \frac{2\pi \times 0.075 m}{60 s}$

$\tau = F_D \cdot r$

$= 0.1571 m/s$

a) at 30°C $\rho_{air} = 1.164 kg/m^3$

$F_D = 1.35 \left(\frac{1.164 kg/m^3 \times (0.1571 m/s)^2}{2}\right) 4.909 \times 10^{-4} m^2$

$= 9.52 \times 10^{-6} kg \cdot m/s^2 = 9.52 \times 10^{-6} N$

$\tau = 9.52 \times 10^{-6} N \times 0.075 m \times 4$

$\boxed{\text{Torque} = 2.856 \times 10^{-6} N \cdot M}$

b) at 20°C $\rho_{gasoline} = 680 kg/m^3$

$F_D = 1.35 \left(\frac{680 kg/m^3)(0.1571 m/s)^2}{2}\right) \times 4.909 \times 10^{-4} m^2$

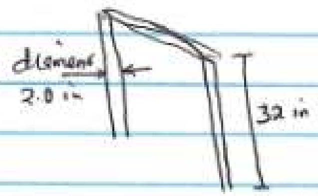
$= 5.56 \times 10^{-3} kg \cdot m/s^2 = 5.56 \times 10^{-3} N.$

$\text{Torque} = 5.56 \times 10^{-3} N \times 0.075 m \times 4$

$\boxed{\text{Torque} = 1.668 \times 10^{-3} N.m}$

17.14

## Problem 17.14




Compute the drag force exerted on the car due to these two rods when the car is travelling through still air at $-20°F$ at a speed of 150 mph.

$\rho_{air} = 2.80\times10^{-3}$ slugs/ft$^3$ $= 0.0902$ lb/ft$^3$

$V = 150$ mph $= 220$ ft/s

$A =$ projected area $= \left(\frac{2.0\times32}{12\times12}\right)\times2$ ft$^2$ $= 0.88$ ft$^2$

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

($v$ = velocity, $\nu$ = kinematic viscosity)

$D = \left(\frac{2}{12}\right)$ ft   Velocity $= 220$ ft/s   Kinematic viscosity $= 1.17\times10^{-4}$ ft$^2$/s

$$= \frac{220\,\text{ft/s}\times(2/12)\,\text{ft}}{1.17\times10^{-4}\,\text{ft}^2/\text{s}} = \underline{3.13\times10^5}$$

Drag coefficient from Fig. 17.4, $C_D \cong 0.8$

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

$$= 0.8\times\frac{0.0902\,\text{lb/ft}^3\times(220\,\text{ft/s})^2}{2}\times0.88\,\text{ft}^2$$

$$\underline{F_D = 1536.72\ \text{lb ft/s}^2}$$

17.16

7-16) $V = 100$ mph $\quad T_{Air} = -20°F \Rightarrow \rho_{Air} = 2.8 \cdot 10^{-3}$ Slugs/ft$^3$

100 mph $= 528000 \frac{ft}{h}$ $\Rightarrow \left(\frac{\rho \cdot V^2}{2}\right) = \frac{((2.8 \cdot 10^{-3}) \frac{slug}{ft^3} \cdot 528000 \, ft/h)^2}{2}$

$\Rightarrow \frac{\rho \cdot v^2}{2} = 3.9 \cdot 10^8 \frac{Slug}{ft^2 \cdot h} \quad \eta = 3.27 \cdot 10^{-7} \frac{lb-s}{ft^2}$

Areas & drag Coefficient

Area

a) $9'' \cdot 9'' = 81''^2 = 0.5625 \, ft^2 = A_a$

b) $9'' \cdot 9\sin(45)'' = 57.2 \, in^2 = 0.3972 \, ft^2 = A_b$

c) $= \pi \cdot \left(\frac{9}{2}\right)^2 = 63.62 \, in^2 = 0.4418 \, ft^2 = A_c$

d) $\pi \cdot \left(\frac{9}{2}\right) \cdot \left(\frac{18}{2}\right) = 127.23 \, in^2 = 0.8835 \, ft^2 = A_d$

Coefficient of drag

a) $a = 60''$ $b = 9''$ $\Rightarrow \frac{a}{b} = 6.67$

$\Rightarrow C_{D_a} = 1.2$

b) $a = 60''$ $b = 6.36'' = (9\sin(45))$

$\Rightarrow \frac{a}{b} = 9.42 \Rightarrow C_{D_b} = 1.26$

C) $N_R = \frac{V \cdot L}{\eta} \Rightarrow \frac{146.66 \frac{ft}{s} \cdot 0.75 ft}{3.27 \cdot 10^{-7} \frac{lb-s}{ft^2}} = 3.36 \cdot 10^8$

$528{,}000 \frac{ft}{h} = 146.66 \frac{ft}{s}$ $\Rightarrow C_D = 1.24$

D) $N_R = \frac{146.66 \frac{ft}{s} \cdot 1.5 ft}{3.27 \cdot 10^{-7}} = 6.72 \cdot 10^8$

$\Rightarrow C_D = 0.35$

drag of each design $\left\{ F_D = C_D \cdot \left(\frac{\rho \cdot v^2}{2}\right) \cdot A \right\}$

a) $F_{D_a} = 1.2 \cdot (3.9 \cdot 10^8) \frac{Slug}{ft^2 \cdot h} \cdot 0.5625 \, ft^2$

$\Rightarrow F_{D_a} = 263250000 \frac{Slugs}{h} = \boxed{73125 \frac{Slugs}{s}}$

b) $F_{D_b} = 1.26 \cdot (3.9 \cdot 10^8) \frac{Slug}{ft^2 \cdot h} \cdot 0.3972$

$F_{D_b} = 195184080 \frac{Slugs}{h} = \boxed{54217.8 \frac{Slugs}{s}}$

C) $F_{D_c} = 1.24 \cdot (3.9 \cdot 10^8) \frac{Slug}{ft^2 \cdot h} \cdot 0.4418 \, ft^2$

$\Rightarrow F_{D_c} = 213654480 \frac{Slugs}{h} = \boxed{59348.47 \frac{Slugs}{s}}$

d) $F_{D_d} = 0.35 \cdot (3.9 \cdot 10^8) \frac{Slug}{ft^2 \cdot h} \cdot 0.8835 \, ft^2$

$F_{D_d} = 120597750 \frac{Slugs}{h} = \boxed{33499.375 \frac{Slugs}{s}}$

* The ellipse experiences the least drag, likely because of it's longer cross-section & rounded shape

17.26

17.26 $R_{a/s} = 0.006$ Displacement = 125 Long Tons = 280000 lbs
$V = 50$ ft/s seawater at 77 °F

Find total Resistance and power required

$R_{TS} = (0.006)(280000) = \boxed{1680}$ $P_E = 1680 \cdot 50 = \boxed{84000 \text{ lb-ft/s}}$

$84000/550 = \boxed{152.727 \text{ hp}}$

17.30

17.30 Determine Lift and Drag at angle of attack of 10°
air foil cord length 1.4 m and span of 6.8 m
speed = 200 km/h in standard atmosphere at:
A. 200 m B. 17000 m $A = 1.4 \cdot 6.8 = 9.52 \text{ m}^2$
$C_D = 0.051$ $C_L = 0.9$
$V = 200$ km/h = 55.56 m/s

A: 200 m $\rho = 1.202$ kg/m³

$F_D = (0.051) \cdot ((1.202)(55.56)^2/2)(9.52) = \boxed{900.754 \text{ N}}$

$F_L = (0.9) \cdot ((1.202)(55.56)^2/2)(9.52) = \boxed{15895.654 \text{ kN}}$

B 10000 m $\rho = 0.4135$

$F_D = (0.051) \cdot ((0.4135)(55.56)^2/2)(9.52) = 309.868$ N

$F_L = (0.9) \cdot ((0.4135)(55.56)^2/2)(9.52) = 5468.264$ kN