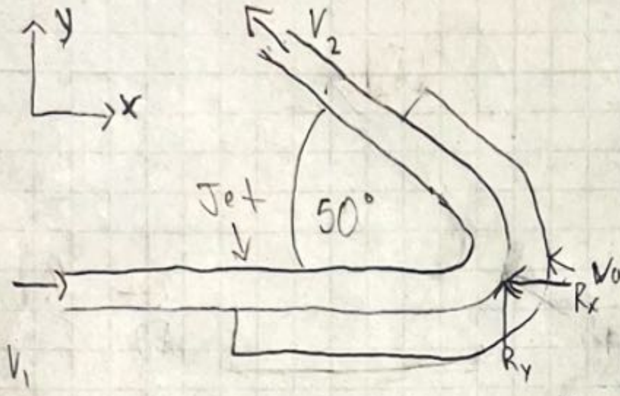
16.6

Problem:

The figure 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 2.95 in² throughout the system. Compute the forces in the horizontal an vertical directions on the water by the vane



$F_x = \rho Q(V_{2_x} - V_{1_x})$

$F_y = \rho Q(V_{2_y} - V_{2_x})$

$\Sigma F_x = R_x \qquad \Sigma F_y = R_y$

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

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

$\rho = 1.88 \ \text{slug}/\text{ft}^3$
$V = 22.0 \ \text{ft/s}$
$A = 0.020 \ \text{ft}^2$
$Q = 0.44 \ \text{ft}^3/\text{s}$

$R_x = 1.88 \frac{\text{lb}\cdot\text{s}^2}{\text{ft}^4} \cdot 0.44 \ \text{ft}^3/\text{s} \, (-22 \ \text{ft/s} \cos(50°) + 22 \ \text{ft/s})$

$\boxed{R_x = 29.9 \ \text{lb}}$

$R_y = 1.88 \frac{\text{lb}\cdot\text{s}^2}{\text{ft}^4} \cdot 0.44 \ \text{ft}^3/\text{s} \, (22 \ \text{ft/s} \sin(50°) - 0)$

$\boxed{R_y = 13.9 \ \text{lb}}$

HW 2.2	P 16.11	MET 330

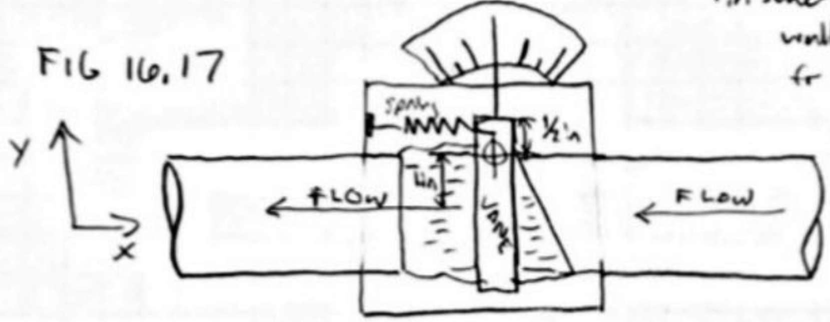
Figure 16.17 represents a type of flowmeter in which the flat vane is rotated on a pivot as it deflects the fluid stream. The fluid force is counterbalanced by a spring. Calculate the spring force req'd to hold the vane in a vertical position when water at 100 gpm flows fr. the 1 in Sched 40 pipe to which the meter is attached.

$Q = 100$ gpm

1 in sched 40 pipe

wall thickness $= 0.133$ in fr table F.1

FIG 16.17



Convert gpm to ft³/s

$1\text{ gpm} = 0.0022\text{ ft}^3/\text{s}$

$$Q = 100\text{gpm}\left(\frac{0.0022\text{ ft}^3/\text{s}}{1\text{ gpm}}\right) = 0.22\text{ ft}^3/\text{s}$$

Spring Force

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

$V = \frac{Q}{A}$; $Q = 0.22\text{ ft}^3/\text{s}$

$A_{1\text{in sched }40} = 0.006\text{ ft}^2$ (from Table F.1) $\Rightarrow V = \frac{0.22\text{ ft}^3/\text{s}}{0.006\text{ ft}^2} = 36.67\text{ ft/s}$

ρ of H_2O @ 80° $= 1.94$ slugs/ft³ fr text book

$$F_x = (1.94\text{ slugs/ft}^3)(0.22\text{ ft}^3/\text{s})\left[36.67\text{ ft/s} - (-36.67\text{ ft/s})\right]$$

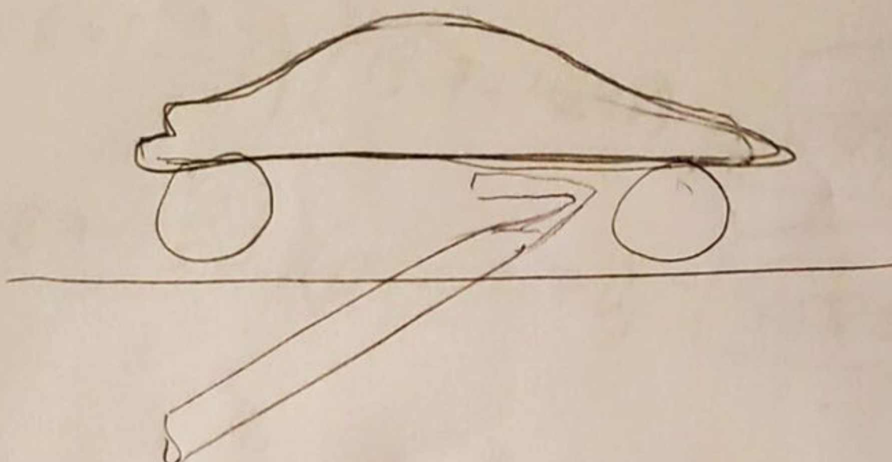
$$F_x = (0.4268\text{ slugs/s})(73.34\text{ ft/s})$$

$$F_x = 31.30\text{ slugs ft/s}^2 = \boxed{31.3\text{ lb}}$$

16.20 17.16

(16.20) GIVEN: A Vehicle is to be propelled by a jet of water impinging on a vane as shown. The jet has a velocity of 30 m/s and issues from a nozzle with a diameter of 200 mm.

Problem: Calculate the force on the vehicle ⓐ if it is stationary ⓑ if it is moving at 12 m/s.



FBD

ⓐ

$\angle 15^\circ$

$V_1 = 30 \frac{m}{s}$

$\varnothing = 200\,mm = .2\,m$

$V_2 = 12 \frac{m}{s}$

$V_e = V_1 - V_0$

$Q_e = A_1 V_e$

$R_x = \rho Q_e v_e \cos\theta - (-\rho Q_e V_e) = \rho Q_e V_e (1 + \cos\theta)$

$R_y = \rho Q_e v_e \sin\theta - 0$

$Q_e = A_1 V_e = \left(\frac{\pi}{4}(.2[m])^2\right)\left(30\left[\frac{m}{s}\right]\right) = .9425 \frac{m^3}{s}$

$R_x = \left(1000\left[\frac{kg}{m^3}\right]\right)\left(.9425\left[\frac{m^3}{s}\right]\right)\left(30\left[\frac{m}{s}\right]\right)(1 + \cos 15^\circ) = \boxed{55586.6\,N}$

$R_y = \left(1000\left[\frac{kg}{m^3}\right]\right)\left(.9425\left[\frac{m^3}{s}\right]\right)\left(30\left[\frac{m}{s}\right]\right)(\sin 15^\circ - 0) = \boxed{7318.1\,N}$

ⓑ

$V_x = V_{2x} - V_{1x} = 30\cos 15 - 12 = 16.98\left[\frac{m}{s}\right]$

$V_y = 30\sin 15 = 7.76\left[\frac{m}{s}\right]$

$V = \sqrt{(16.98)^2 + (7.76^2)} = 18.7 \frac{m}{s}$

$M = \rho A V = \left(1000\left[\frac{kg}{m^3}\right]\right)\left(\frac{\pi}{4}(.2[m])^2\right)\left(18.7\left[\frac{m}{s}\right]\right) = 587 \frac{kg}{s}$

$$\phi_2 = \tan^{-1}\left(\frac{V_y}{V_x}\right) = \tan^{-1}\left(\frac{7.76}{16.98}\right) = 24.56°$$

$$\phi = \phi_2 - \phi_1 = 24.56° - 15° = 9.56°$$

$$R_x = \left(587\left[\frac{kg}{s}\right]\right)(18.7 - 16.98) = \boxed{1009.64\ \frac{kg \cdot m}{s^2}}$$

$$R_y = \left(587\left[\frac{kg}{s}\right]\right)(0 - 7.76) = \boxed{4555.12\ \frac{kg \cdot m}{s^2}}$$

6.29.)

$d = 7.50 = 0.0075\ m$

$Temp = 15°C$

$V = 25\ m/s$

$R_x = \rho Q[(v_2 \cos 60°) + (v_1 \cos 10°)]$

$R_y = \rho Q[(v_2 \sin 60°) + (v_1 \sin 10°)]$

$A = \frac{\pi d^2}{4} = \frac{\pi (0.0075)^2}{4} = 4.418 \times 10^{-5}\ m^2$

$V_1 = V_2 = 25 \quad Q = (4.418 \times 10^{-5}) \times (25)$

$Q = 1.1045 \times 10^{-3}\ m^3/s$

$R_x = 1000 \times 1.1045 \times 10^{-3}[(25 \cos 60°) + (25 \cos 10°)]$

$\boxed{R_x = 40.99\ N}$

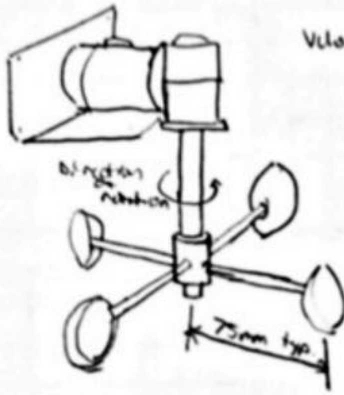
$R_y = 1000 \times 1.1045 \times 10^{-3}[(25 \sin 60°) - (25 \sin 10°)]$

$\boxed{R_y = 19.12\ N}$

HW2.2 | P 17.11

A Type of level indicator incorporates 4 hemispherical cups w/ open fronts mounted as shown in Fig 17.13. Each cup is 25mm in diameter. A motor drives the cups @ constant speed. Calculate the torque that the motor must produce to maintain motion @ 20 rpm

$d_{cup} = 25mm \Rightarrow 0.025\,m$



Velocity fr rpm:

$$1\,rpm = \frac{2\pi\,(L\text{ meters})}{60}\,(v)$$

$$20\,rpm = \frac{2\pi\,(0.075m)}{60}\,(v)$$

$$v = \frac{(20)(2\pi)(0.075m)}{60\,s}$$

$$v = \frac{9.425}{60\,s}$$

$$v = 0.16\,m/s$$

Area of cups:

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

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

$$A = \frac{0.0020\,m^2}{4}$$

$$A = 0.0005\,m^2$$

$$A = 5.0\times10^{-4}\,m^2$$

Reynolds number:

$$N_R = \frac{VD}{\nu} \qquad V = 0.16\,m/s \qquad D_{cup} = 0.025m \qquad \nu_{@\,0°C} = 1.33(10^{-5})\,m^2/s$$

$$N_R = \frac{(0.16m/s)(0.025m)}{1.33(10^{-5})\,m^2/s} = \frac{0.004\,m^2/s}{1.33(10^{-5})\,m^2/s} = 300.75 \qquad \rho_{air\,@\,0°C} = 1.242\,kg/m^3$$

Drag coefficient fr: Fig 17.4 pg 436 : $C_D \approx 0.7$

Force of Drag:

$$F_{drag} = C_D\left(\frac{\rho V}{2}\right)A \Rightarrow \frac{0.7}{1}\left(\frac{1.242\,kg/m^3\,(0.16m/s)}{2}\right)\left(\frac{5.0\,(10^{-4})\,m^2}{1}\right) = 3.62(10^{-5})\,N$$

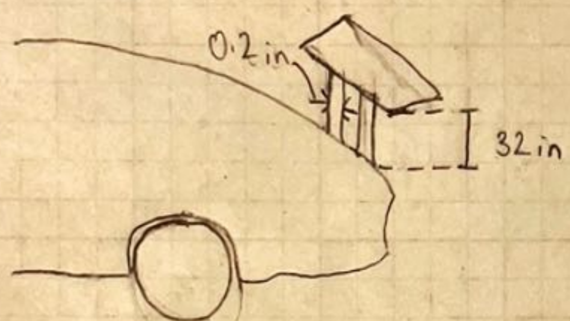
Torque: $T_{@\,0°C} = 4\,F_{drag}\,r \Rightarrow T = 4\,(3.62(10^{-5})N)\,(0.075m)$

$$\boxed{T_{@\,0°C} = 1.086\,N\cdot m}$$

MET330 Homework 2.2 | Micajah Paynter | 3/3/2022 | 1/

17.14 Problem:

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



$$\frac{150\ \cancel{miles}}{1\ hr} \left| \frac{1\ \cancel{hr}}{3600\ s} \right| \frac{5280\ ft}{1\ mile}$$

$V = 220\ ft/s$

$$C_D = \frac{F_D/A}{\frac{1}{2}\rho V^2}$$

$\rho = 2.80 \times 10^{-8}\ slug/ft^3$

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

$F_D = C_D A \frac{1}{2} \rho V^2$

$N_R = \frac{\rho V L}{\nu}$

Projected area: Rectangle

$A = (32\ in \cdot \frac{1\ ft}{12\ in}) \cdot (0.2\ in \cdot \frac{1\ ft}{12\ in})$

$A = 0.04\ ft^2$

$$N_R = \frac{(2.80 \times 10^{-3}\ slug/ft^3)(220\ ft/s)(32(\frac{1}{12})\ ft)}{1.17 \times 10^{-4}\ ft^2/s}$$

$N_R = 14040$

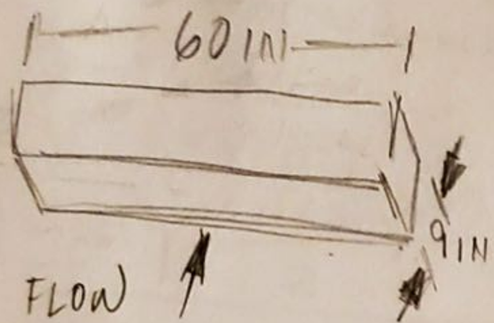
$C_D = 2.0$

$$F_D = \left[\frac{(2.0)(0.04\ \cancel{ft^2})(2.80 \times 10^{-4}\ slug/\cancel{ft^3})(220\ \cancel{ft/s})^2}{2}\right] 2$$

$\boxed{F_D = 1.08\ lb}$

17.16 GIVEN: CROSS SECTION OF AN EMERGENCY FLASHER LIGHTING SYSTEM FOR POLICE VEHICLES ARE BEING EVALUATED. EACH HAS A LENGTH 60 IN AND A WIDTH OF 9.00 IN.

PROBLEM: COMPARE THE DRAG FORCE EXERTED ON EACH PROPOSED DESIGN WHEN THE VEHICLE MOVES AT 100 MPH THROUGH STILL AIR AT -20 °F



DRAG & LIFT

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

$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} = \frac{P_s}{\gamma}$

$P_s = P_1 + \gamma V_1^2/2g = P_1 + \rho V_1^2/2$

LENGTH $= 60\,\cancel{IN}\left(\frac{1\,FT}{12\,\cancel{IN}}\right) = 5\,FT = 1.524\,[m]$

WIDTH $= 9.00\,\cancel{IN}\left(\frac{1\,FT}{12\,\cancel{IN}}\right) = .75\,FT = 0.2286\,[m]$

$V = \left(100\left[\frac{\cancel{MILES}}{\cancel{HOURS}}\right]\right)\left[\frac{1\,\cancel{HOUR}}{3600\,S}\right]\left(\frac{1609.34\,[m]}{1\,\cancel{MILE}}\right) = 44.7\left[\frac{m}{s}\right]$

Temp $= (-20\,°F - 32)\frac{5}{9} = -28.8\,°C \approx -30\,°C$

$\boxed{\text{TABLE E.1}}$

Density $= \rho = 1.452\left[\frac{kg}{m^3}\right]$

$S_W = \gamma = 14.24\left[\frac{N}{m^3}\right]$

Dynamic Viscosity $= \eta = 1.56 \times 10^{-5}\,[Pa \cdot S]$

Kinematic viscosity $= \nu = 1.08 \times 10^{-5}\,[m^2/s]$

$A = wl = 1.524\,[m] \times 0.2286\,[m] = .3483864\,m^2$

Square cylinder $C_D = 1.60$

$F_D = C_D\left(\frac{\rho V^2}{2}\right)A = 1.60\left(\frac{\left(1.452\left[\frac{kg}{m^3}\right]\right)\left(44.7\left[\frac{m}{s}\right]\right)^2}{2}\right)\left(.3483864\,[m^2]\right)$

$F_D = 808.6\left[\frac{kg \cdot m}{s^2}\right]$

(a)

$\frac{kg \cdot m}{s^2} = N$

PAGE 458

$N_R = \frac{VL}{\nu} = \frac{(44.7[\frac{m}{s}])(0.2286[m])}{1.08 \times 10^{-5}[\frac{m^2}{s}]} = 946150$

Triangular cylinder (NO ANGLE)

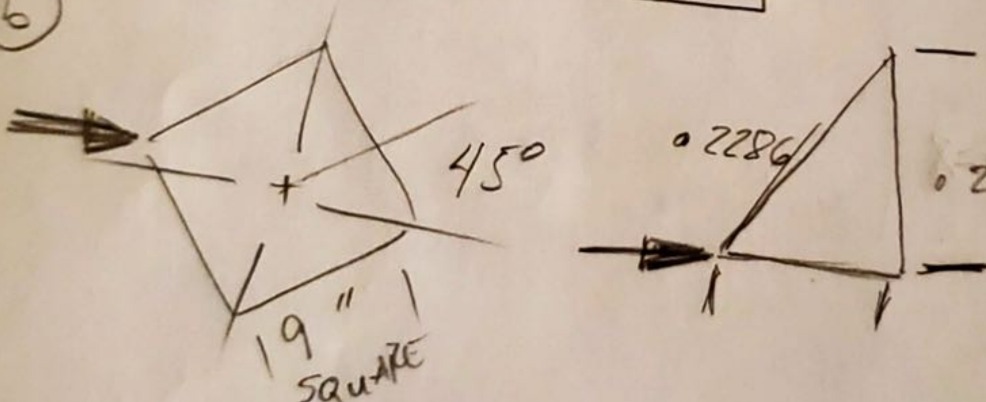
$C_D = 2.05$

$A = .3483864\ m^2$

$F_D = 2.05\left(\frac{(1.452\frac{kg}{m^3}(44.7^2)}{2}\right)(.3483864[m^2]) = 1061.29N$

$\boxed{F_D = 1061.29N}$

(b)



$.2286 \sin 45 = .1616$

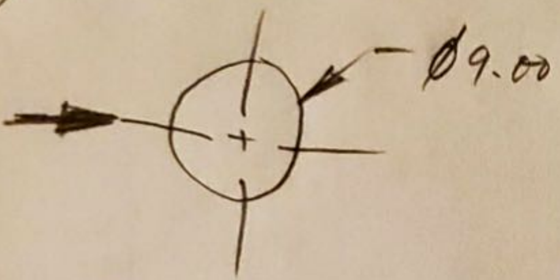
SQUARE CYLINDER $C_D = 1.60$

$A = 1.524[m] \times 2 \times .2286 \sin 45 = .4927\ m^2$

$F_D = 1.60\left(\frac{(1.452\frac{kg}{m^3})(44.7^2)}{2}\right)(.4927[m^2]) = 1143.5[\frac{kg \cdot m}{s}]$

$\boxed{F_D = 1143.5\ \frac{kg\,m}{s}}$

(c)



$N_R = 946150$

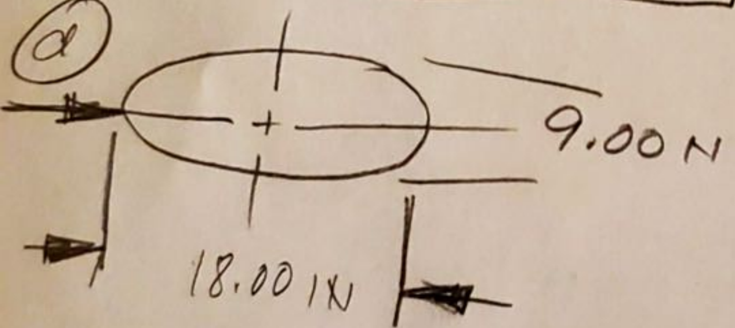
FIGURE 17.4

$C_D = 4 \times 10^{-1} = .4$

$$F_D = .4\left(\frac{(1.452\frac{kg}{m^3})(44.7^2)}{2}\right)(.3483864[m^2]) = 202\,\frac{kg\cdot m}{s}$$

$$\boxed{F_D = 202\,\frac{kg\cdot m}{s}}$$

(d)



$$\frac{L}{D} = \frac{18''}{9''} = \frac{.4572[m]}{0.2286[m]} = 2[m]$$

$$N_R = \frac{VL}{\nu} = \frac{(44.7[\frac{m}{s}]).4572[m]}{1.08\times10^{-5}[\frac{m^2}{s^2}]} = 1892300$$

$C_D = .2$

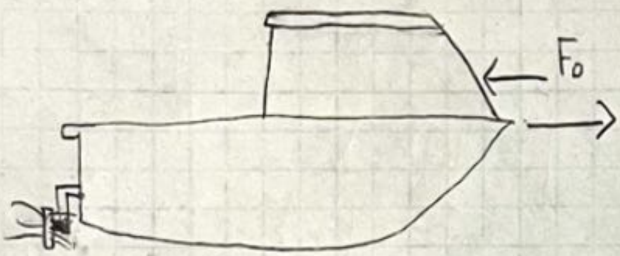
$$F_D = .2\left(\frac{(1.452\frac{kg}{m^3})(44.7^2)}{2}\right)(.3483864[m^2]) = 101\,\frac{kg\cdot m}{s}$$

$$\boxed{F_D = 101\,\frac{kg\cdot m}{s}}$$

17.26

Problem:

A small fast boat has a specific resistance ratio of 0.06 + displaces 125 long tons. Compute the total ship resistence + the power requried to overcome drag when moving at 30 ft/s in sea water at 77°F



$R_{ts}/\Delta = 0.06$

125 long tons

1 long ton = 2240 lb

125 long ton = (125)(2240 lb

$\Delta = 2.8\times10^5$ lb

$R_{ts} = \Delta \cdot \frac{R_{ts}}{\Delta} = 2.8\times10^5 \text{ lb } (0.06)$

$R_{ts} = 1.68\times10^4$ lb

$P_E = R_{ts} \cdot V$

$P_E = (1.68\times10^4 \text{ lb})(30 \text{ ft/s})$

$P_E = 5.04\times10^5 \frac{\text{ft}\cdot\text{lb}}{\text{s}}$

$1 \text{hp} = 550 \frac{\text{ft}\cdot\text{lb}}{\text{s}}$

$\frac{5.04\times10^5 \cancel{\frac{\text{ft}\cdot\text{lb}}{\text{s}}}}{550 \cancel{\frac{\text{ft}\cdot\text{lb}}{\text{s}}}} = \text{hp}$

$\boxed{P_E = 916.4 \text{ hp}}$

17.301

$C = 1.4 m$

$b = 6.8 m$

$V = 200 km/h = 55.55 m/s$

$\alpha = 10°$

$A = 1.4 \times 6.8 = 9.52 m^2$

$C_D = 0.05$

$C_L = 0.9$

$$F_D = C_D \left(\frac{\rho v^2}{2}\right) A = \frac{(0.05) \times (1.202) \times (55.55)^2 \times (9.52)}{2}$$

$$\boxed{F_D = 882.72 \text{ N At } 200 m}$$

$$F_L = C_L \left(\frac{\rho v^2}{2}\right) A = \frac{(0.9) \times (1.202) \times (55.55)^2 \times (9.52)}{2}$$

$$\boxed{F_L = 15889.9 \text{ N At } 200 m}$$

$$F_D = \frac{(0.05) \times (0.4135) \times (55.55)^2 \times 9.52}{2}$$

$$\boxed{F_D = 303.683 \text{ N At } 10{,}000 m}$$

$$F_L = \frac{(0.9) \times (0.4138) \times (55.55)^2 \times (9.52)}{2}$$

$$\boxed{F_L = 5466.29 \text{ N At } 10{,}000 m}$$