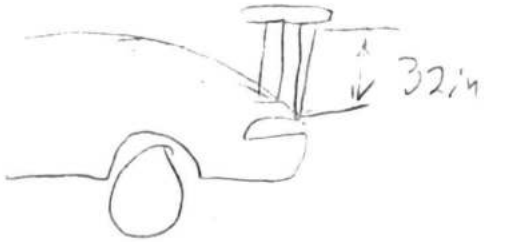
HW 9.2

Ch 17



14. Wing on race car supported by 2 cylindrical rods
$F_D = ?$ Air temp $= -20°F$ $V = 150$ miles per hour

$H = 32 in \cdot \frac{1 ft}{12 in} = 2.667 ft$ $V = \frac{150 miles}{hour} \cdot \frac{5280 feet}{1 mile} \cdot \frac{1 hour}{3600 s} = 220 ft/s$

$D = 2.0 in \cdot \frac{1 ft}{12 in} = 0.1667 ft$

At air temp $= -20°F$, $\rho = 2.80 \times 10^{-3} \frac{slugs}{ft^3} = \frac{lb \cdot s^2}{ft^4}$ $\nu = 1.17 \times 10^{-4}\ ft^2/s$

Force on car $= 2 \times F_D$, due to rods

$F_{car} = 2 \cdot F_D$

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

- To find drag coefficient, I need to calculate Reynolds number.

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

$Re = \frac{VD}{\nu} = \frac{220 \frac{ft}{s} \cdot 0.1667 ft}{1.17 \times 10^{-4} \frac{ft^2}{s}}$ $\frac{\frac{ft^2}{s}}{\frac{ft^2}{s}}$

$F_{car} = 2 \cdot 0.78 \left(\frac{2.8 \times 10^{-3} \frac{lb \cdot s^2}{ft^4} (220 ft/s)^2}{2}\right)(0.167 ft \cdot 2.67 ft)$

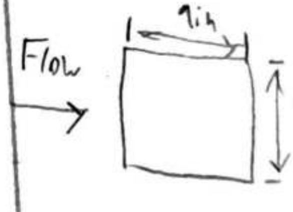
$Re = 313390.31 = 3.13 \times 10^5$

$F_{car} = 47.13 \frac{lb \cdot s^2}{\cancel{ft^4}} \cdot \frac{\cancel{ft^2}}{s^2 \cdot \cancel{ft^2}}$

- From the table for C_D of a cylinder, I read $C_D \cong 0.78$

$F_{car} = 47.13\ lb$

16. Compare drag forces on each of ... designs
$V = 65\,mph \quad T = -20°F \quad W = 60\,in$



$$V = 100\,\frac{mile}{hour} \cdot \frac{5280\,ft}{1\,mile} \cdot \frac{1\,hour}{3600\,sec} = 146.67\,ft/s$$

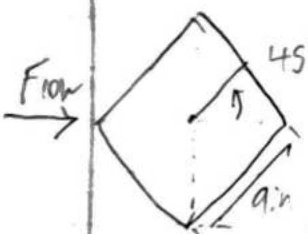
$$\rho = 2.8 \times 10^{-3}\,\frac{slugs}{ft^3} = \frac{lb \cdot s^2}{ft^4} \qquad \nu = 1.17 \times 10^{-4}\,ft^2/s$$

$$Re = \frac{VL}{\nu} = \frac{146.67\,\frac{ft}{s} \cdot 0.75\,ft}{1.17 \times 10^{-4}\,ft^2/s} = 940{,}170.94 \quad 9.4 \times 10^5$$

From table, C_D for a square cylinder is 1.6, but 9.4×10^5 is much larger than the corresponding Reynolds number for 1.6, so I will use 2.0 since that is the largest C_D value given for a square cylinder in the graph

$$F_D = 2.0\left(\frac{2.80 \times 10^{-3}\,\frac{lb \cdot s^2}{ft^4} \cdot \left(146.67\,\frac{ft}{s}\right)^2}{2}\right)(0.75\,ft \cdot 5\,ft)$$

$$F_D = 225.87\,lb$$



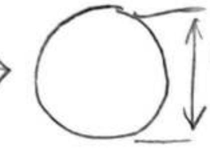
$$45° \quad H = L = 2(0.75\,ft \cdot \cos 45°) = 1.06\,ft$$

$$Re = \frac{VL}{\nu} = \frac{146.67\,\frac{ft}{s} \cdot 1.06\,ft}{1.17 \times 10^{-4}\,ft^2/s} = 1329632.7 \quad 1.33 \times 10^6$$

Again, this value is much larger than the values of Re corresponding to the values of C_D for a square cylinder, so I will choose 2.0

$$F_D = 2.0\left(\frac{2.80 \times 10^{-3}\,\frac{lb \cdot s^2}{ft^4} \cdot \left(146.67\,\frac{ft}{s}\right)^2}{2}\right)(1.06\,ft \cdot 5\,ft)$$

$$F_D = 319.24\,lb$$



9in

$$Re = \frac{VD}{\nu} = \frac{146.67\,\frac{ft}{s} \cdot 0.75ft}{1.17\times10^{-4}\,ft^2/s} = 940193.3$$

9.4×10^5

From the graph, I read $C_D \cong 0.3$

$$C_D = 0.3\left(\frac{2.80\times10^{-3}\,\frac{lb\cdot s^2}{ft^4}\cdot(146.67ft/s)^2}{2}\right)(0.75ft\cdot5ft)$$

$$C_D = 33.882\,lb$$

9in

18in
1.5ft

$$Re = \frac{VL}{\nu} = \frac{146.67\,\frac{ft}{s}\cdot1.5ft}{1.17\times10^{-4}\,ft^2/s} = 1880384.6$$

1.8×10^6

Ellipse ration $= \frac{18in}{2in} = 2:1$

Going to the Chart, I see that the Reynold's numbers corresponding to a ellipse with a 2:1 ratio is 2×10^5. The Reynold's number I have calculated is larger than this, so I will use the largest C_D value I have which correspons to 2×10^5. I read $C_D \cong 0.355$

$$F_D = 0.355\left(\frac{2.80\times10^{-3}\,\frac{lb\cdot s^2}{ft^2}\cdot(146.67ft)^2}{2}\right)(0.75\cdot5ft)$$

$$F_D = 40.093\,lb$$

2 Square $F_D = 225.87$ lb
1 45° square $F_D = 319.74$ lb
3 Circle $F_D = 33.882$ lb
4 Ellipse $F_D = 39.53$ lb

The 45° square has the largest drag force while the circle has the smallest.

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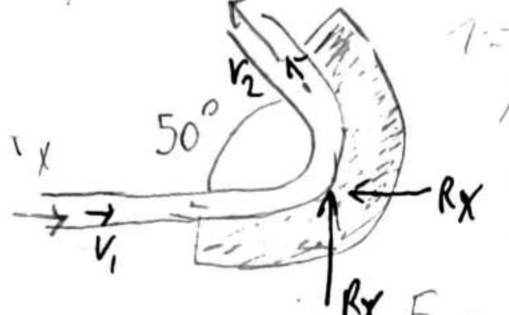
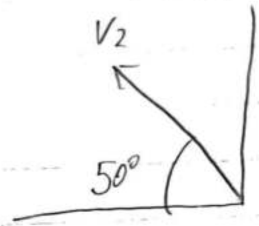


T = 180°F $V = 22.0$ ft/s.
A = 2.95 in² Forces in horizontal and vertical directions exerted on water by vane

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

$V_1 = V_2$

- V_1 is going right so is positive
- V_2 is going left so is negative



$F_x = \rho Q(-V_2 \cdot \cos 50 - (V_{1x})$

$\rho = 1.88 \frac{\text{slugs}}{ft^3}$ $Q = VA = 22\frac{ft}{s} \cdot 2.95 in^2 \cdot \frac{1 ft^2}{144 in^2} = 0.45\ ft^3/s$

$-R_x = \rho Q(-V_2 \cdot \cos 50 - V_1)$

$R_x = \rho Q(V_2 \cdot \cos\theta + V_1)$

$R_x = 1.88 \frac{\text{slugs}}{ft^3} \cdot 0.45 \frac{ft^3}{s} \cdot \left(22 \frac{ft}{s} \cdot \cos 50 + 22 \frac{ft}{s}\right)$

$R_x = 30.576 \text{ slugs} \cdot \frac{ft}{s^2}$

$R_x = 30.576\ lb$

$F_Y = \rho Q (V_{2y} - V_{1y})$

- V_1 has no vertical component so it is zero
- V_2 is going up so it is positive

$R_y = \rho Q(V_2 \cdot \sin\theta - V_1)$

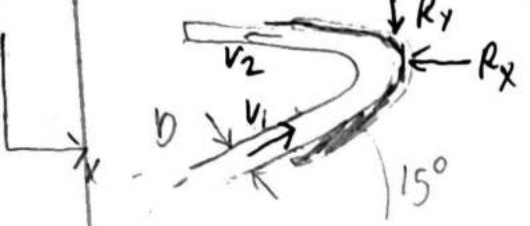
$R_y = 1.88 \frac{\text{slugs}}{ft^3} \cdot \frac{0.45 ft^3}{s} \cdot \left(22 \frac{ft}{s} \cdot \sin 50\right)$

$R_y = 14.26\ lb$

20. Vehicle is propelled by an jet impinging on a water vane

$V = 30\,m/s \quad D = 0.2\,m$

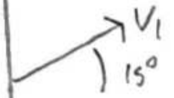
Calc. Force on vehicle if it is stationary and moving at 12 m/s



$\rho = 998\,Kg/m^3$ @ 20°

$Q = VA = 30\frac{m}{s} \cdot \frac{\pi}{4} \cdot (0.2m)^2$

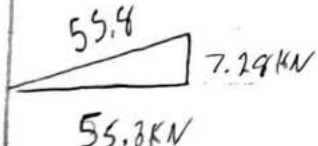
$Q = 0.94\,m^3/s$



$$F_x = \rho Q (V_{2x} - V_{1x})$$
$$-R_x = \rho Q (-V_{2i} - (+V_{1i} \cdot \cos 15)$$
$$-R_x = \rho Q (-V_2 - V_1 \cdot \cos 15)$$

$$R_x = \rho Q (V_2 + V_1 \cdot \cos 15)$$
$$R_x = 998 \frac{Kg}{m^3} \cdot 0.94 \frac{m^3}{s} (30 m/s + 30 m/s \cdot \cos 15)$$
$$R_x = 55328\ Kg \cdot \frac{m}{s^2} \qquad Kg \cdot \frac{m}{s^2} = N$$
$$R_x = 55328\ N = 55.33\ KN$$

$$F_y = \rho Q (V_{2y} - V_{1y})$$
$$-R_y = \rho Q (0 - (+V_1 \cdot \sin 15)$$
$$-R_y = \rho Q (-V_1 \cdot \sin 15)$$
$$R_y = \rho Q (V_1 \cdot \sin 15)$$
$$R_y = 998 \frac{Kg}{m^3} \cdot 0.94 \frac{m^3}{s} (30 m/s \cdot \sin 15)$$



$$R_y = 7284.01\ Kg \cdot m/s^2$$

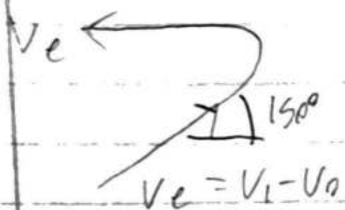
$$R_y = 7.28\ KN$$

$$R = \sqrt{R_x^2 + R_y^2} = 55.8\ KN$$

$$\tan \alpha = \frac{R_x}{R_y} \qquad \alpha = \tan^{-1}\left(\frac{R_y}{R_x}\right) = \tan^{-1} \frac{7.28KN}{55.33}$$

$$\alpha = 7.5^{\circ}$$

$$V_e = V_1 - V_0 \qquad Q_e = A_1 V_e$$



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

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

$$-R_x = \rho Q_e(-V_e - V_e \cdot \cos\theta)$$

$$R_x = \rho Q_e(V_e + V_e \cdot \cos\theta)$$

$$V_e = 30\,m/s - 12\,m/s$$

$$V_e = 18\ m/s$$

$$R_x = 998\,\frac{kg}{m^3} \cdot 0.565\,\frac{m^3}{s}\,(18\,m/s + 18\,m/s \cdot \cos 15)$$

$$Q_e = A \cdot V_e$$

$$= \frac{\pi}{4}(0.2m)^2 \cdot 18\,\frac{m}{s}$$

$$R_x = 19970\,N = 19.97\,KN$$

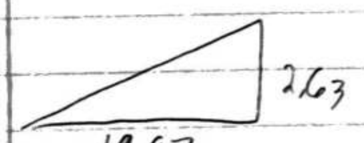
$$Q_e = 0.565\ m^3/s$$

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

$$-R_y = \rho Q_e (0 - (+V_e \cdot \sin\theta))$$

$$R_y = \rho Q_e (V_e \cdot \sin\theta)$$

$$R_y = 998\,\frac{kg}{m^3} \cdot 0.565\,\frac{m^3}{s} \cdot 18\,m/s \cdot \sin 15$$



$$R_y = 2624.93\,N = 2.63\ KN$$

$$R = \sqrt{R_x^2 + R_y^2} = \sqrt{(19.97KN)^2 + (2.63KN)^2}$$

$$R = 20.14\ KN$$

$$\alpha = \tan^{-1}\left(\frac{R_y}{R_x}\right) = \tan^{-1}\left(\frac{2.63}{19.97}\right)$$

$$\alpha = 7.49°$$