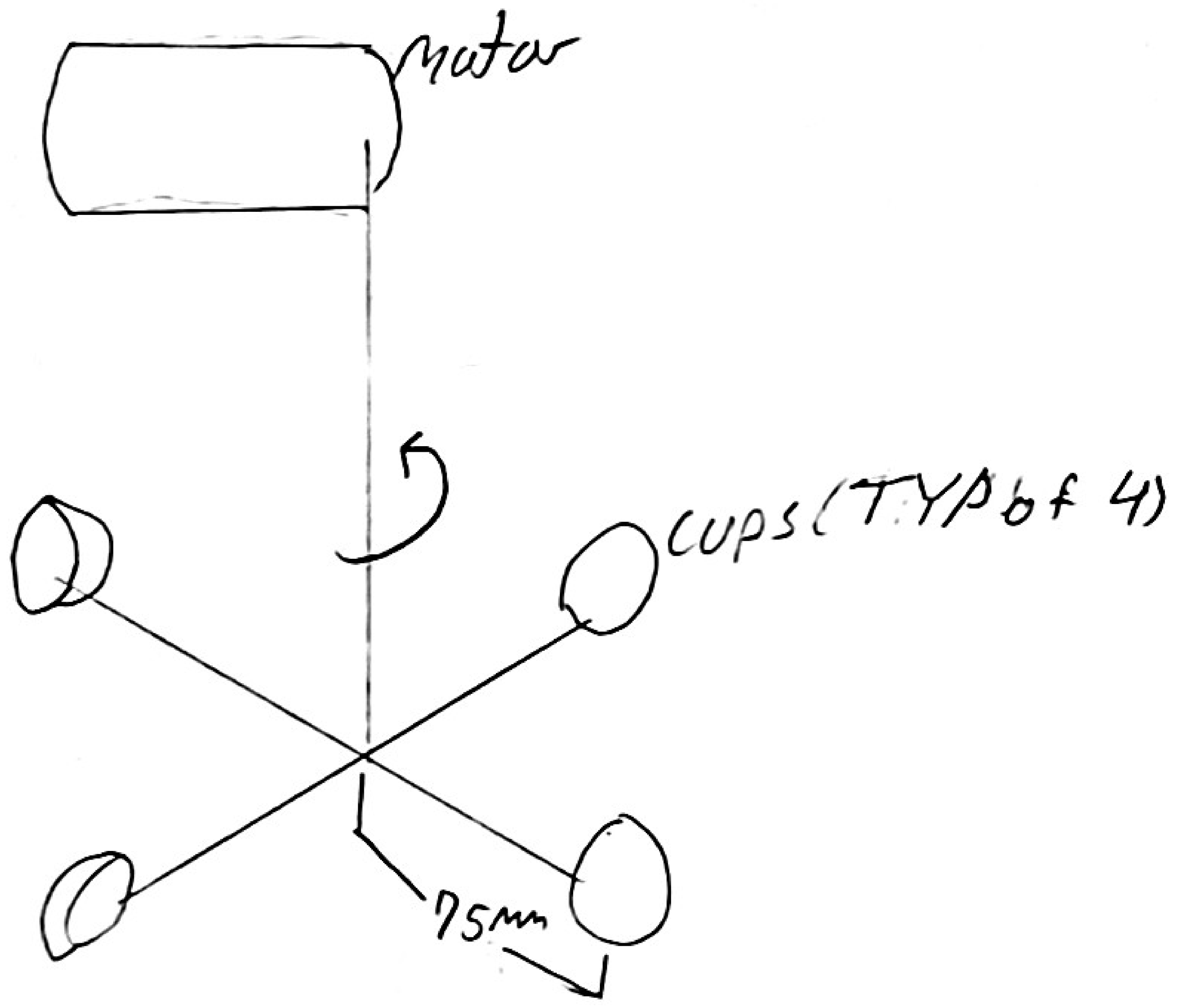
Problem 17.11

Given: Motor drives cups at constant rotational speed. each cup is 25mm in diameter

Find: torque in motor to maintain 20 rpm when
A) Cups are in air at 30°C
B) cups are in gasoline at 20°C

Solution:



A)

$$\tau = 4 F_D \cdot r$$

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

$$\rho = 1.164 \frac{kg}{m^3}$$

$$V = 20 rpm = \frac{2\pi \cdot r}{60} \Rightarrow V = 0.157 \frac{m}{s}$$

$$A = \pi \left(\frac{D}{2}\right)^2 = \pi \left(\frac{0.025}{2}\right)^2 = 0.00049 \, m^2$$

based on table, 17.1 $C_D = 1.35$

$$F_D = 1.35 \left(\frac{1.164 \frac{kg}{m^3} \cdot (0.157 \frac{m}{s})^2}{2}\right) \cdot 0.0049 \, m^2$$

$$F_D = 0.0000948 \, N$$

$$\tau = 4 (0.0000948^N)(0.075^m)$$

$$\underline{\tau = 0.0000284 \, N \cdot m}$$

B

$\tau = 4 \cdot F_D \cdot r$

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

$\rho = 680 \frac{kg}{m^3}$

$v = 0.157 \frac{m}{s}$

$A = 0.00049 m^2$

$C_D = 0.7$

$F_D = 1.35\left(\frac{680 \frac{kg}{m^3} \cdot (0.157 \frac{m}{s})^2}{2}\right) \cdot 0.00049 m^2$

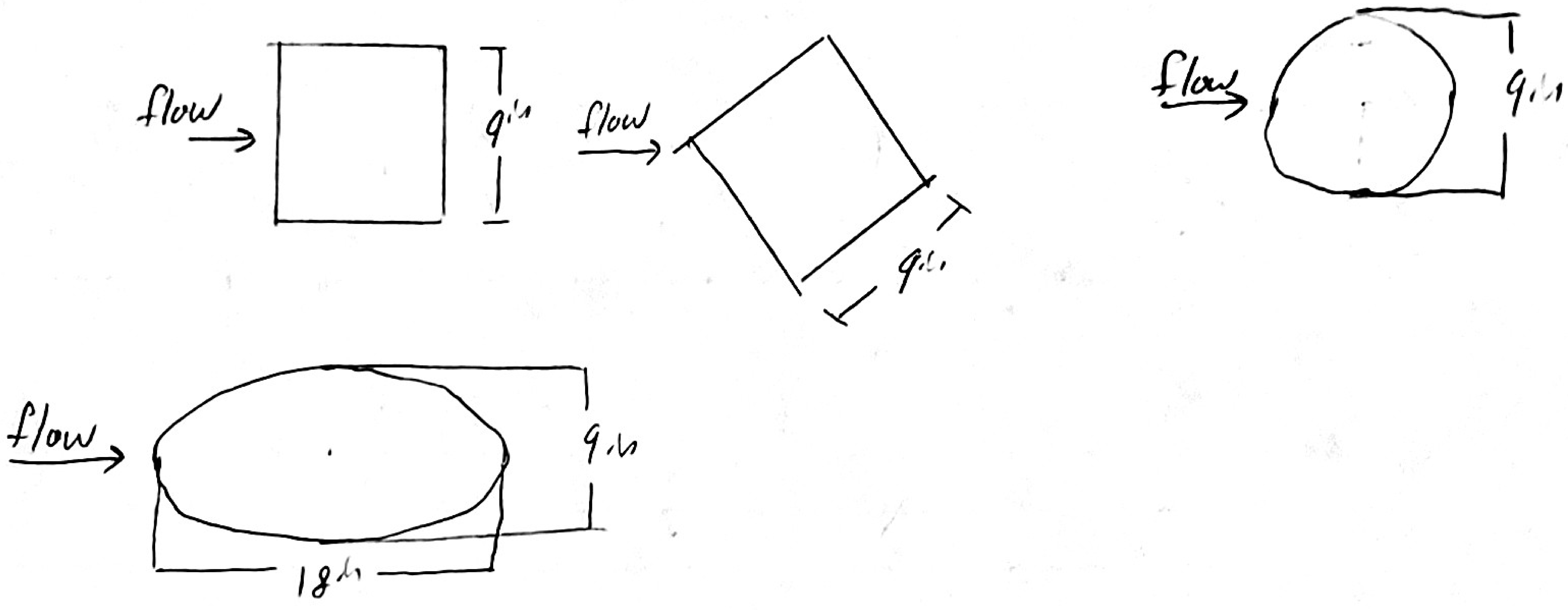
$F_D = 0.00554 N$

$\tau = 4 \cdot (0.00554 N)(0.075 m)$

$\tau = 0.001663 N \cdot m$

Problem 17.16

given: The four designs are given, each has a length of 60 in and a width of 9 in. Vehicle moving at 100mph in -20°F



Find: drag force exerted on each shape.

Solution:

Square

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

Based on table 17.1, $C_D = 1.16$

$F_D = 1.16\left(\frac{0.0028 \frac{slug}{ft^3} \cdot (146.66 \frac{ft}{s})^2}{2}\right) \cdot (5^{ft} \cdot 0.75^{ft})$

$F_D = 130.99 \frac{slug \cdot ft}{s^2} = 4213.97 \frac{lb \cdot ft}{s^2} = \underline{582.6^N}$

diamond

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

based on table 17.1 $C_D = 1.6$

$F_D = 1.6\left(\frac{0.0028 \frac{slug}{ft^3} \cdot (146.66 \frac{ft}{s})^2}{2}\right) \cdot \left(5^{ft} \cdot \frac{\sqrt{9^2+9^2}}{12}\right)$

$F_D = 1.6\left(30.112 \frac{slug}{ft \cdot s^2}\right) \cdot 6.06^{ft^2}$

$F_D = 291.973 \frac{slug \cdot ft}{s^2} = 9392.799 \frac{ft \cdot lb}{s^2} = \underline{1298.6^N}$

Circle

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

$$R_n = \frac{V \cdot D}{\nu} = \frac{146.66\,\frac{ft}{s} \cdot 0.75\,ft}{1.17\times10^{-4}\,\frac{ft^2}{s}} = 940128.2$$

$$\therefore\ C_D = 0.3$$

$$F_D = 0.3\left(\frac{0.0028\,\frac{slug}{ft^3}\cdot(146.66\,\frac{ft}{s})^2}{2}\right)\cdot(5^{ft}\cdot 0.75)$$

$$F_D = 33.876\,\frac{slug\cdot ft}{s^2} = 1084.819\,\frac{lb\cdot ft}{s^2} = \underline{\underline{150.6^N}}$$

Ellipse

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

$$R_n = \frac{V\cdot D}{\nu} = \frac{146.66\cdot 0.75}{1.17\times10^{-4}} = 940128.2$$

$$\therefore\ C_D = 0.2$$

$$F_D = 0.2\left(\frac{0.0028\,\frac{slug}{ft^3}\cdot(146.66\,\frac{ft}{s})^2}{2}\right)\cdot(5^{ft}\cdot 0.75^{ft})$$

$$F_D = 22.58\,\frac{slug\cdot ft}{s^2} = 726.547\,\frac{lb\cdot ft}{s^2} = \underline{\underline{100.4^N}}$$

Problem 17.30

given: Airfoil characteristics shown in fig 17.11
Angle of attack is $10°$. Chord length of 1.4^m
and span of $6.8m$. Speed of $200\frac{km}{h}$ at
height of 200^m and $10\,000m$

Find: lift and drag at 200^m and 10000^m

Solution:

$\underline{\underline{200^m}}$

$$F_{L200} = C_L\left(\frac{\rho \cdot v^2}{2}\right)\cdot A$$

$$C_{L(10°)} = 0.8$$

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

$$V = 200\frac{km}{h} = 55.55\frac{m}{s}$$

$$A = 1.4^m \cdot 6.8^m = 9.52^{m^2}$$

$$F_{L200} = 0.8\left(\frac{1.202\frac{kg}{m^3}(55.55\frac{m}{s})^2}{2}\right)\cdot 9.52^{m^2}$$

$$\underline{\underline{F_{L200} = 14124.38^N}}$$

$$F_{D200} = C_D\left(\frac{\rho \cdot v^2}{2}\right)\cdot A$$

$$C_{D(10°)} = 0.05$$

$$F_{D200} = 0.05\left(\frac{1.202\frac{kg}{m^3}\cdot(55.55\frac{m}{s})^2}{2}\right)\cdot 9.52^{m^2}$$

$$\underline{\underline{F_{D200} = 882.77^N}}$$

$\underline{\underline{10000^m}}$

$$F_{L10000} = C_L\left(\frac{\rho \cdot v^2}{2}\right)\cdot A$$

$$\rho_{10000} = 0.4135\frac{kg}{m^3}$$

$$F_{L10000} = 0.8\left(\frac{0.4135\cdot(55.55^2)}{2}\right)\cdot 9.52$$

$$\underline{\underline{F_{L10000} = 4858.92^N}}$$

$$F_{D10000} = 0.05\left(\frac{0.4135\cdot(55.55)^2}{2}\right)\cdot 9.52$$

$$\underline{\underline{F_{D10000} = 303.68^N}}$$

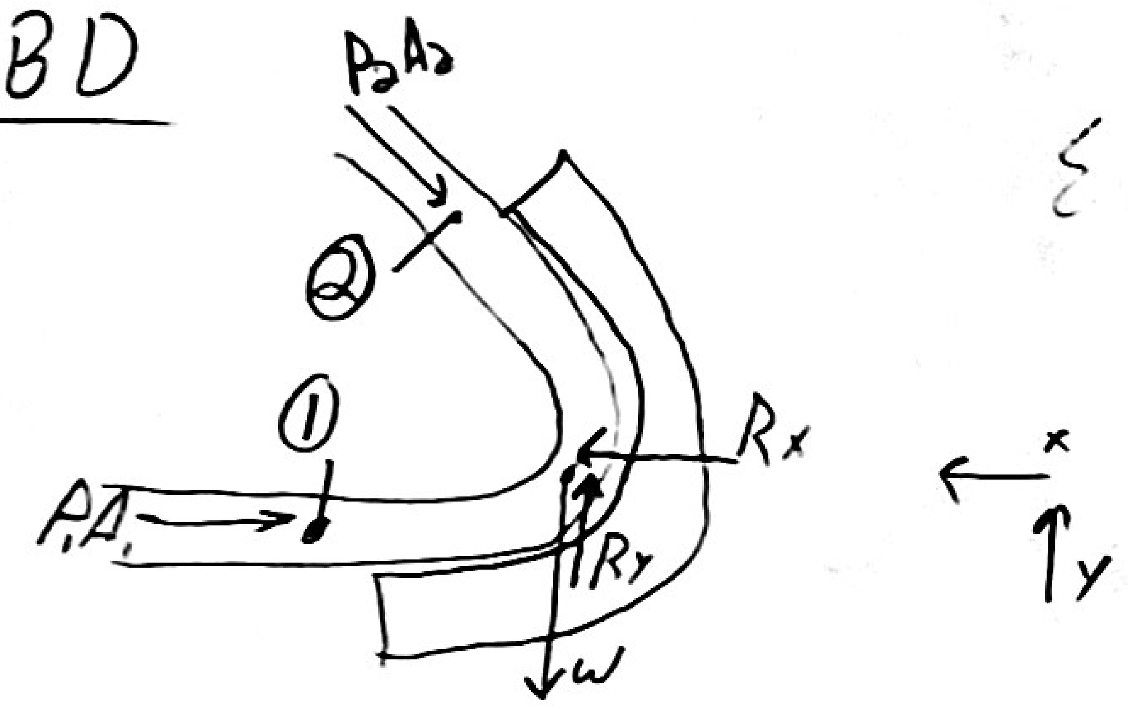
Problem 16.6

Given: Free stream of water at 180° is deflected through a 130° vane. Stream is flowing at $22\frac{ft}{s}$ and has cross-sectional area of $2.95\,in^2$

Find: Forces in horizontal and vertical directions

Solution:

FBD



EQ 16.5 $\quad F_x = \rho Q(V_{2x} - V_{1x}) = R_x$

$$R_x = \left(1.88\frac{slug}{ft^3}\right)\left(22\frac{ft}{s}\cdot\frac{2.95\,in^2}{144\,ft^2}\right)\left(22\frac{ft}{s}\cos 50 + 22\frac{ft}{s}\right)$$

$$R_x = 30.62\ \frac{slug\text{-}ft}{s} =$$

EQ 16.6 $\quad F_y = \rho Q(V_{2y} - V_{1y}) = R_y$

$$R_y = \left(1.88\frac{slug}{ft^3}\right)\left(22\frac{ft}{s}\cdot\frac{2.95\,in^2}{144}\right)\left(22\frac{ft}{s}\sin 50 + 0\right)$$

$$R_y = 14.27\ \frac{slug\text{-}ft}{s}$$

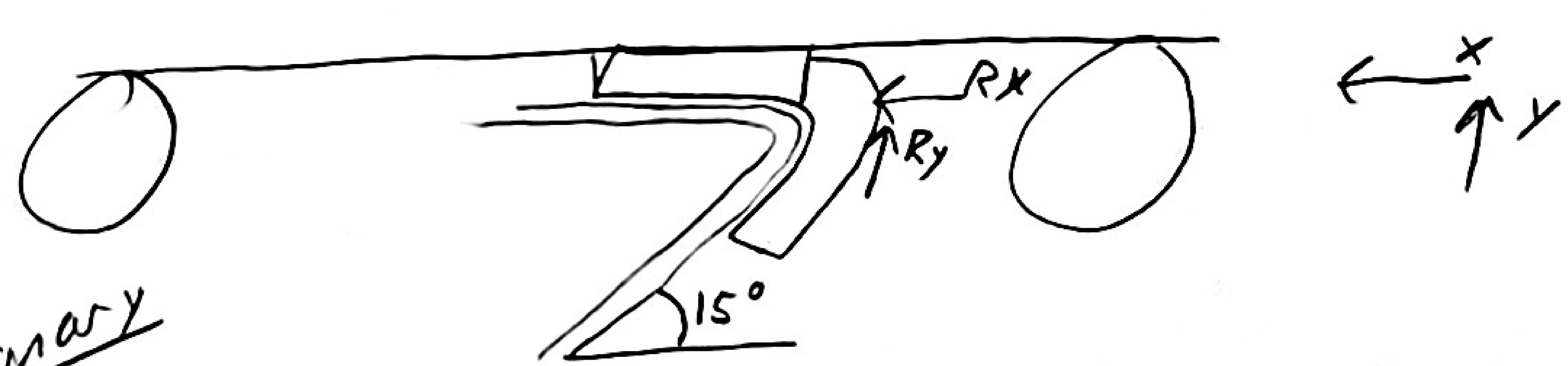
Problem 16.20

Given: Vehicle is to be propelled by a jet of water pushing on a vane. Velocity of jet is $30\frac{m}{s}$ and diameter is 200^{mm}

Find: a) force if vehicle is stationary
B) force if vehicle is moving at $12\frac{m}{s}$

Solution:

FBD



stationary

$\Sigma F_x = \rho \cdot Q\,(V_{2x} - V_{1x}) = R_x$

$R_x = (1000\frac{kg}{m^3})(30\frac{m}{s} \cdot \pi(\frac{0.2}{2})^2)(30\frac{m}{s} + 30 \cdot \cos 15)$

$\underline{R_x = 55577.91^N}$

$\Sigma F_y = \rho \cdot Q\,(V_{2y} - V_{1y}) = R_y$

$R_y = (1000\frac{kg}{m^3})(30\frac{m}{s} \cdot \pi(\frac{0.2^m}{2})^2)(0 + 30\sin 15)$

$\underline{R_y = 7317.93^N}$

moving

$V = V_{fluid} - V_{car} \Rightarrow V = 30\frac{m}{s} - 12\frac{m}{s} = 18\frac{m}{s}$

$\Sigma F_x = \rho \cdot Q\,(V_{2x} - V_{1x}) = R_x$

$R_x = (1000)(18 \cdot \pi(\frac{0.2}{2})^2)(18 + 18\cos 15)$

$\underline{R_x = 20006.41^N}$

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

$R_y = (1000)(18 \cdot \pi(\frac{0.2}{2})^2)(0 + 18\sin 15)$

$\underline{R_y = 2634.03^N}$