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Due: Dec 5th, 2016

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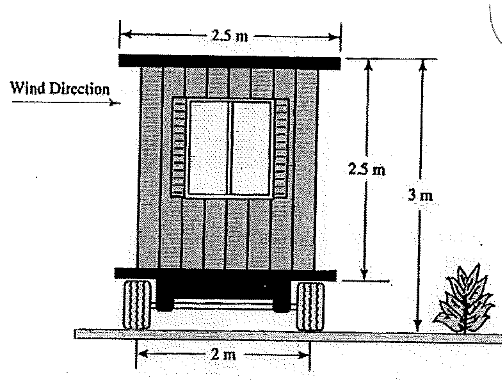
52 – Fluids and Heat Transfer

Assignment 9

Question 1 (Mott, Chapter 17)

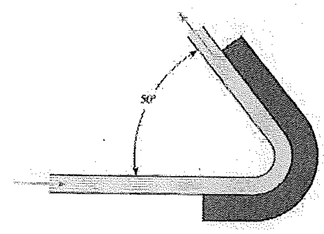
A 10 m long mobile office with a weight of 50 kN, is shown in the figure. Each of its tires has a width of 300 mm. If you consider the mobile office to be a square cylinder (Mott & Online Notes, Figure 17.1), determine the minimum wind velocity required to 'overturn' the mobile office. The air is at 0°C.



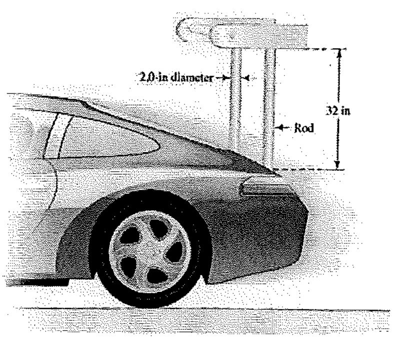
(Note: Regard 'overturn' to mean that the windward wheels just lift off the ground, leaving the leeward wheels to act as hinges, pivoting the mobile office, up and over. In real life, the wheels would not have to lift very far above the ground before the whole mobile office would turn completely over. As the leading edge of the trailer lifts its C_D could go down a little but the area presented to the wind would increase dramatically. The overall effect of a little tipping would mean a rapid rise in the overturning force and the trailer would quickly flip.)

Question 2 (Mott, Chapter 16)

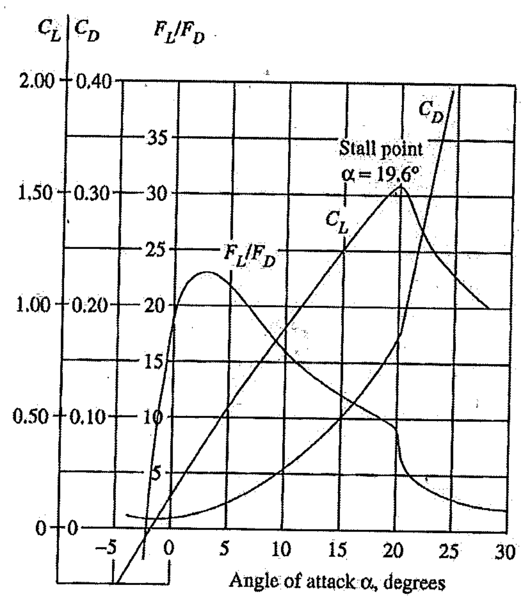
The figure shows a free stream of water, at 90°C, being deflected by a stationary vane through a 130° angle. The entering stream has a velocity of 6.7 m/s. The cross-sectional area of the stream is constant at 1900 mm² throughout the system. Determine the **reaction forces, provided by the vane's supports,** that prevent it from moving against the influence of the water stream.



Question 3 (Mott, Chapter 17)



The figure shows a racing car with an inverted (lift force is down) mounted on its back end that works to increase the downward forces on the back wheels (thus increasing the friction between the back wheels and the road and thereby generating greater friction forces, useful in cornering, etc.). The wing has a chord of 780 mm and a span of 1460 mm. The design vehicle speed for this airfoil arrangement is 150 km/hr and its angle of attack is set at 15°. Also, the design air temperature is 20°C.



a. What is the downward force (kN) generated by the inverted wing?
b. What is the drag force (kN) generated by the wing?
c. What is the drag force (kN) generated by the vertical cylindrical support struts?
d. What is the overall drag force (kN) generated by the wing and the struts?
e. What is the extra horsepower (HP and Watts) needed to drive the car forward if the airfoil/strut arrangement is added to the vehicle?
Do you think it is worth the trouble and horsepower?

Meng 263 Assignment #9

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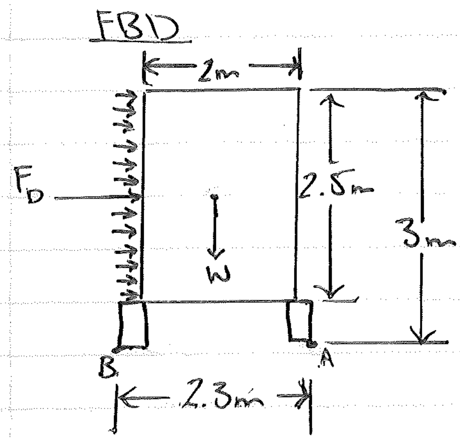
1) $W = 50\,kN$ $\quad L = 10\,m$ $\quad T_A = 0°C$

$C_D = 1.60$ $\quad W_t = 0.3\,m$ $\quad \rho = 1.293\,\frac{kg}{m^3}$ ← Engineering toolbox

FBD



$\circlearrowleft^{+} \Sigma M_A = 0;$

$W(1.15\,m) - F_D(1.75\,m) = 0$

$F_D = \frac{W(1.15\,m)}{(1.75\,m)} = \frac{(50\,kN)(1.15\,m)}{(1.75\,m)}$

$\therefore F_D = 32.86\,kN$ ✓

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

$\Rightarrow V^2 = \frac{2F_D}{C_D \rho A} = \frac{2(32.86\,kN)}{(1.60)(1.293\,\frac{kg}{m^3})(2.5\,m \times 10\,m)}$

$V^2 = 1270\,\frac{m}{s}$

⟶ $\therefore V = 35.65\,\frac{m}{s} \approx 128.3\,\frac{km}{hr}$

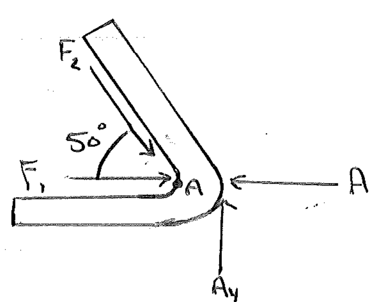
2) $T_w = 90°C$

$\rho = 965.3\,\frac{kg}{m^3}$

$V = 6.7\,\frac{m}{s}$

$A = 1900\,mm^2$

FBD



$\overset{+}{\rightarrow} \Sigma F_x = 0;$

$F_1 + F_2\cos 50 = A_x$

$135.25\,N + 63.1\cos 50 = A_x$

$\therefore A_x = 175.8\,N$ ←

$\uparrow \Sigma F_y = 0;$

$A_y = F_2 \sin 50 = 63.1 \sin 50$

$\therefore A_y = 48.3\,N$ ←

$Q = AV = (1900\,mm^2)(6.7\,\frac{m}{s})$

$\therefore Q = 0.01273\,\frac{m^3}{s}$

$F_1 = \rho Q \Delta V$

$= (965.3\,\frac{kg}{m^3})(0.01273\,\frac{m^3}{s})(6.7\,\frac{m}{s} + 6.7\cos 50)$

$\therefore F_1 = 135.25\,N$ ✓

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$F_2 = \rho Q \Delta V = (965.3\,\frac{kg}{m^3})(0.01273\,\frac{m^3}{s})(0 + 6.7\sin 50)$

$\therefore F_2 = 63.1\,N$ ✓

3) Chord = 780 mm $V = 150 \frac{km}{hr}$ $T = 20°C$

Span = 1460 mm $\rho = 1.204 \frac{kg}{m^3}$ ← Engineering toolbox

$\alpha = 15°$

$C_L = 1.25 \quad C_D = 0.10 \Rightarrow \frac{C_L}{C_D} = 12.5$

(a) A_L = Chord × span = 780 mm × 1460 mm

∴ $A = 1.1388 m^2$

$$F_L = \frac{1}{2} C_L \rho V^2 A_L = \frac{1}{2}(1.25)(1.204 \tfrac{kg}{m^3})(150 \tfrac{km}{hr})^2(1.1388 m^2)$$

→ ∴ $F_L = 1487.8 N$ ✓

(b) $AR = \frac{Span}{Chord} = \frac{1.460 m}{0.780 m}$ $C_D = C_D + \frac{C_L^2}{\pi AR} = (0.10) + \frac{(1.25)^2}{1.8718\pi}$

∴ $AR = 1.8718$ ∴ $C_D = 0.366$

$$F_D = \frac{1}{2} C_D \rho V^2 A = \frac{1}{2}(0.366)(1.204 \tfrac{kg}{m^3})(150 \tfrac{km}{hr})^2(1.1388 m^2)$$

→ ∴ $F_D = 435.6 N$ ✓

(c) Length = L = 32" = 0.8128 m $A_{BLUFF} = L \times D = 0.8128 m \times 0.0508 m$

Diameter = D = 2" = 0.0508 m   ∴ $A_{BLUFF} = 0.0413 m^2$

$C_D = 1.2$ ✓

$$F_D = \frac{1}{2} C_D \rho V^2 A_{BLUFF}\, n = \frac{1}{2}(1.2)(1.204 \tfrac{kg}{m^3})(150 \tfrac{km}{hr})^2(0.0413 m^2)(2)$$

→ ∴ $F_D = 103.60 N$ ✓

(d) $F_{D TOTAL} = F_D$ Wing + F_D Struts = 435.6 N + 103.60 N

→ ∴ $F_{D TOTAL} = 539.19 N$ ✓

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(e) Power = $F_{D TOTAL} \times V$ = 539.19 N × 150 $\frac{km}{hr}$

Power = 22.47 kW

→ ∴ ≈ 30 HP ✓

↳ for the average teenager with his/her pimped out 180Hp honda this certainly is not worth the power reduction.