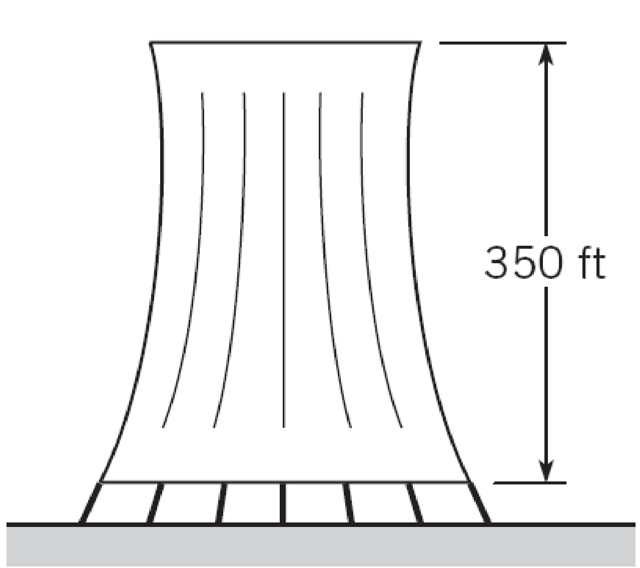
CHAPTER (11)

DRAG & LIFT

HOMEWORK (3)

11.10, 11.21, 11.28, 11.49, 11.68

Problem (11.10)



Situation: Wind acts on a cooling tower. Height is $H = 350\,\text{ft}$.
Average diameter is $D = 250\,\text{ft}$. Wind speed is $V_o = 200$ mph $= 293.3\,\text{ft/s}$.

Find: Drag (F_D) acting on the cooling tower.

Properties: Air at 60 °F (Table A.3) has properties of $\rho = 0.00237$ slugs/ft^3; $\nu = 1.58 \times 10^{-4}$ ft^2/s.

Assumptions: 1.) Assume the coefficient of drag of the tower is similar to the coefficient of drag for a circular cylinder of infinite length (see Fig. 11.5).
2.) Assume the coefficient of drag for a cylinder is constant at high Reynolds numbers.

Problem (11.10)

Reynolds number

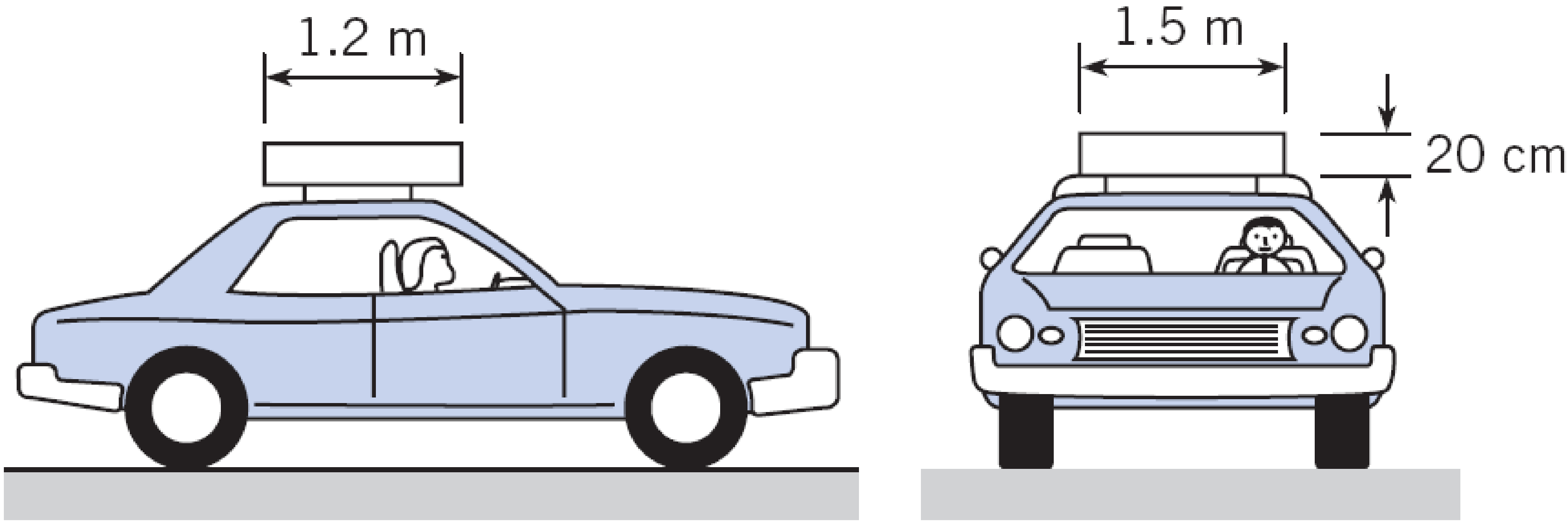
$$\begin{aligned}\mathrm{Re} &= \frac{V_o D}{\nu} \\ &= \frac{293.3 \times 250}{1.58 \times 10^{-4}} \\ &= 4.641 \times 10^{8}\end{aligned}$$

From Fig. 11-5 (extrapolated) $C_D \approx 0.70$. The drag force is given by

$$\begin{aligned}F_D &= C_D A_{\mathrm{Ref}} \frac{\rho V^2}{2} \\ &= 0.70 \times (250\,\mathrm{ft} \times 350\,\mathrm{ft}) \frac{(0.00237\ \mathrm{slugs/ft^3})\,(293.3\,\mathrm{ft/s})^2}{2} \\ &= 6.244 \times 10^{6} \frac{\mathrm{slug} \cdot \mathrm{ft}}{\mathrm{s}^2}\end{aligned}$$

$$\boxed{F_D = 6.24 \times 10^{6}\ \mathrm{lbf}}$$

Problem (11.21)



Find: Additional power required due to the carrier.

Assumptions: Density, $\rho = 1.20\ \mathrm{kg/m^3}$. C_D will be like that for a rectangular plate: $\ell/b = 1.5/0.2 = 7.5$

Problem (11.21)

ANALYSIS

From Table 11-1

$$C_D \approx 1.25$$

The air speed (relative to the car) is

$$\begin{aligned} V &= 100 \text{ km/hr} \\ &= 27.78 \text{ m/s} \end{aligned}$$

The additional power is

$$\Delta P = F_D V$$

$$V_{car} = 80\, km/h$$

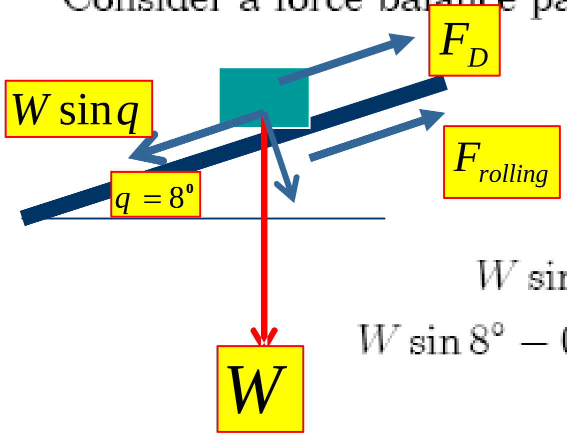
Substituting drag force

$$\begin{aligned} \Delta P &= C_D A_p (\rho V^2/2) V \\ &= 1.25 \times 1.5 \times 0.2 \times 1.20 \times 27.78^2/2 \times 80000/3600 \\ &= \boxed{3.86 \text{ kW}} \end{aligned}$$

Problem (11.28)

ANALYSIS

Consider a force balance parallel to direction of motion of the bicyclist:



$$\begin{aligned}
\sum F &= 0 \\
+F_{\text{wgt. comp.}} - F_D - F_{\text{rolling resist.}} &= 0 \\
W \sin 8^\circ - C_D A_p \rho V_R^2/2 - 0.02\, W \cos 8^\circ &= 0 \\
W \sin 8^\circ - 0.5 \times 0.5 \times 1.2 V_R^2/2 - 0.02 W \cos 8^\circ &= 0
\end{aligned}$$

$$\begin{aligned}
W &= 80g = 784.8 \text{ N} \\
W \sin 8^\circ &= 109.2 \text{ N} \\
W \cos 8^\circ &= 777.2 \text{ N}
\end{aligned}$$

Then

$$109.2 - 0.15 V_R^2 - .02 \times 777.2 = 0$$

$$V_R = 25.0 \text{ m/s} = V_{\text{bicycle}} + 5 \text{ m/s}$$

Note that 5 m/s is the head wind so the relative speed is $V_{\text{bicycle}} + 5$.

$$\boxed{V_{\text{bicycle}} = 20.0 \text{ m/s}}$$

Problem (11.49)

PROBLEM 11.49

Situation: A weighted wood cylinder falls through a lake (see the problem statement for all the details).

Find: Terminal velocity of the cylinder.

Assumptions: For the water density, $\rho = 1000 \text{ kg/m}^3$.

APPROACH

Apply equilibrium with the drag force and buoyancy force.

ANALYSIS

Buoyancy force

$$\begin{aligned} F_{\text{buoy}} &= V\gamma_{\text{water}} \\ &= 0.80 \times (\pi/4) \times 0.20^2 \times 9810 \\ &= 246.5 \text{ N} \end{aligned}$$

Problem (11.49)

Then the drag force is

$$\begin{aligned} F_D &= F_{\text{buoy}} - W \\ &= 246.5 - 200 \\ &= 46.5 \text{ N} \end{aligned}$$

$$\frac{L}{d} = \frac{80}{20} = 4$$

From Table 11-1 $C_D = 0.87$. Then

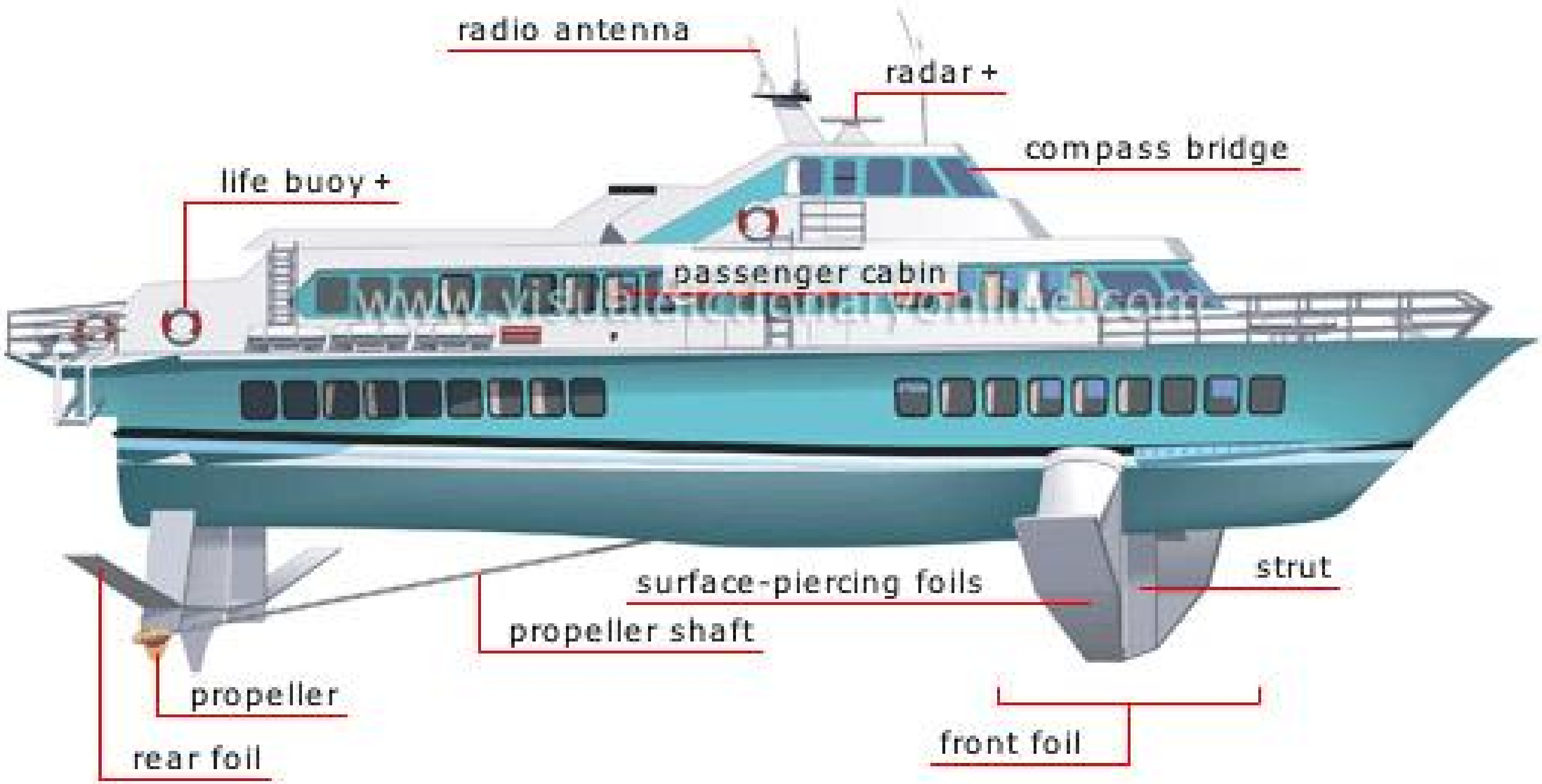
$$46.5 = \frac{C_D A_p \rho V_0^2}{2}$$

or

$$V_0 = \sqrt{\frac{2 \times 46.5}{C_D A_p \rho}}$$

$$\begin{aligned} V_0 &= \sqrt{\frac{2 \times 46.5}{0.87 \times (\pi/4) \times 0.2^2 \times 1000}} \\ &= \boxed{1.84 \text{ m/s}} \end{aligned}$$

Problem (11.68)



Problem (11.68)

PROBLEM 11.68

Situation: A lifting vane for a boat of the hydrofoil type is described in the problem statement.

Find: Dimensions of the foil needed to support the boat.

ANALYSIS

Use Fig. 11-23 for characteristics; $b/c = 4$ so $C_L = 0.55$

$$\boxed{\frac{b}{c} = 4}$$

$$\boxed{A_p = bc = 4c^2}$$

$$\begin{aligned} F_L &= C_L A \rho V_0^2/2 \\ 10,000 &= 0.55 \times 4c^2 \times (1.94/2) \times 3,600 \\ c^2 &= 1.30 \text{ ft} \\ c &= 1.14 \text{ ft} \\ b &= 4c = 4.56 \text{ ft} \end{aligned}$$

Use a foil $\boxed{1.14 \text{ ft wide} \times 4.56 \text{ ft long}}$

END OF HOMEWORK