Question 1

A small aircraft has a wing area of 35 m^2, a lift coefficient of 0.45 at takeoff settings, and a total mass of 4000 kg. Determine (a) the takeoff speed of this aircraft at sea level at standard atmospheric conditions and (b) the required power to maintain a constant cruising speed of 300 km/h for a cruising drag coefficient 0.035. ($\rho = 1.225$ kg/m^3)

(a)

There are two forces acting on the aircraft during takeoff: lift and weight. Then

$$\begin{aligned} F_L &= F_W \\ \frac{1}{2}\rho V^2 S C_L &= mg \end{aligned}$$

Solving for V,

$$\begin{aligned} V &= \sqrt{\frac{2mg}{\rho S C_L}} \\ &= \sqrt{\frac{2(4000)(9.81)}{(1.225)(35)(0.45)}} \\ &= 63.778 \text{ m/s} \end{aligned}$$

(b)

During cruising, in the tangent direction, the force is drag. Thus,

$$\begin{aligned} \dot{W} &= F_D V \\ &= \frac{1}{2}\rho V^3 A C_D \\ &= \frac{1}{2}(1.225)(300 \times 1000/3600)(35)(0.035) \\ &= 434.2 \text{ kW} \end{aligned}$$

Question 2

A 2.4-in-diameter smooth ball rotating (anticlockwise) at 500 rpm is dropped in a water stream at 60°F flowing at 4 ft/s. Determine the lift and the drag force acting on the ball when it is first dropped in the water. ($\rho = 62.36$ lbm/ft^3, $\mu = 7.536 \times 10^{-4}$ lb/(ft·s)) Note: for smooth rotating ball $C_D = \frac{F_D}{\frac{\pi}{8}\rho V^2 D^2}$, $C_L = \frac{F_L}{\frac{\pi}{8}\rho V^2 D^2}$.

Find the Reynolds number:

$$\begin{aligned} Re &= \frac{\rho V D}{\mu} \\ &= \frac{(62.36)(4)(2.4/12)}{7.536 \times 10^{-4}} \\ &= 6.62 \times 10^4 \end{aligned}$$

Nondimensional rate of rotation is

$$\begin{aligned} \frac{1}{2}\omega D/V &= \frac{1}{2} 500 \times 2\pi/60 \frac{2.4}{12 \times 4} \\ &= 1.309 \end{aligned}$$

From Figure 1, $C_D = 0.55$ and $C_L = 0.35$. Then

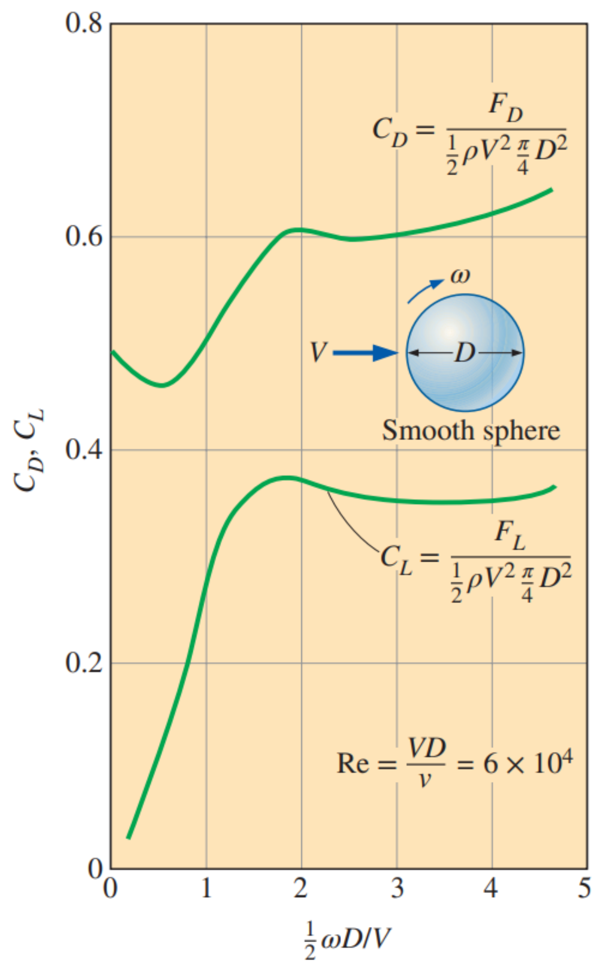

Figure 1: Drag and lift coefficients for a smooth rotating sphere with nondimensional rate of rotation $\mathrm{Re} = 6 \times 10^4$

$$
\begin{aligned}
F_L &= \frac{\pi}{8}\rho V^2 D^2 C_L \\
&= \frac{\pi}{8}(62.36)(4)^2(2.4/12)^2(0.35) \times \frac{1}{32.174}\boxed{0.1705 \text{ lbf}} \\
F_D &= \frac{\pi}{8}\rho V^2 D^2 C_D \\
&= \frac{\pi}{8}(62.36)(4)^2(2.4/12)^2(0.55) \times \frac{1}{32.174}\boxed{0.268 \text{ lbf}}
\end{aligned}
$$

Question 3

A 2-m-high, 4-m-wide rectangular advertisement panel is attached to a 4-m-wide, 0.15-m-high rectangular concrete blocks (density = 2300 kg/m^3) by two 5-cm-diameter, 4-m-high (exposed part) poles. If the sigh is to withstand 150 km/h winds from any direction, determine (a) the maximum drag force on the panel, (b) the drag force acting on the poles, and (c) the minimum length L of the concrete block for the panel to resist the winds. Take the density of air to be 1.30 kg/m^3. Assume turbulent flow, and check the drag coefficient from Table (Lecture Note 18)

(a)

First, for a rectangular plate, from the table,

$$
\begin{aligned}
C_D &= 1.10 + 0.02(L/D + D/L) \\
&= 1.10 + 0.02(4/2 + 2/4) \\
&= 1.15
\end{aligned}
$$

Then,

$$
\begin{aligned}
F_D &= \frac{1}{2}C_D \rho V^2 A \\
&= \frac{1}{2}(1.15)(1.30)(150 \times 1000/3600)^2(4)(2) \\
&= \boxed{10.382 \text{ kN}}
\end{aligned}
$$

(b)

For a rod under turbulent flow, from the table, $C_D = 0.3$. Then,

$$
\begin{aligned}
F_D &= \frac{1}{2}C_D \rho V^2 A_c \\
&= \frac{1}{2}(0.3)(1.30)(150 \times 1000/3600)^2(0.05)(4) \\
&= \boxed{67.71 \text{ N}}
\end{aligned}
$$

For two rods, the total drag force is $\boxed{2F_D = 135.42 \text{ N}}$.

(c)

Drawing a FBD,

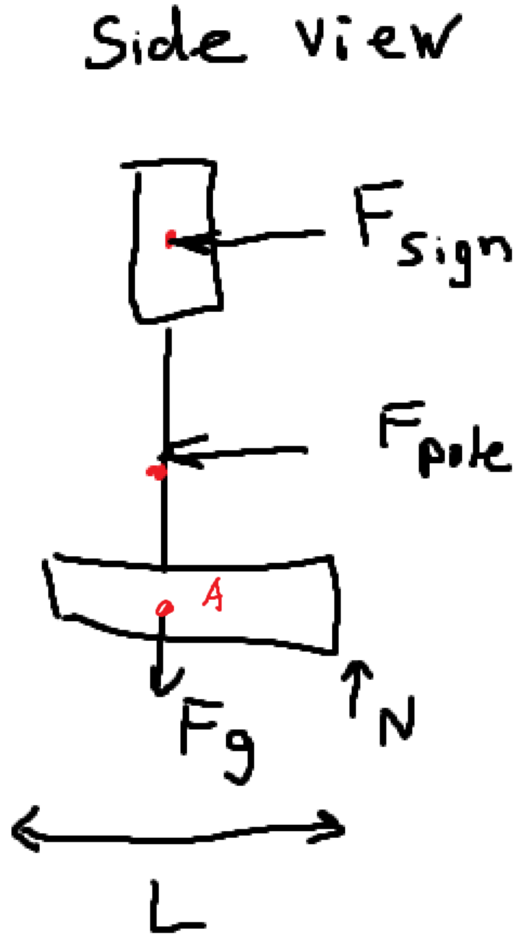

Figure 2: FBD of the concrete block

Finding the moment about point A,

$$\begin{aligned}\sum M_A &= 0 \\ N(L/2) - 2F_{D,\text{pole}}(2) - F_{D,\text{panel}}(5) &= 0 \\ g(LWH)\rho(L/2) - 4F_{D,\text{pole}} - 5F_{D,\text{panel}} &= 0\end{aligned}$$

Solving for L,

$$\begin{aligned} L &= \sqrt{\frac{10F_{D,\text{panel}} + 8F_{D,\text{pole}}}{gWH\rho}} \\ &= \sqrt{\frac{10(10.382 \times 10^3) + 8(67.71)}{(9.81)(4)(0.15)(2300)}} \\ &= \boxed{2.78 \text{ m}} \end{aligned}$$