# AOE 3134 Homework #1

Assigned: January 18, 2007
Due: January 30, 2007 (Place your homework in the box outside my office by 5 PM.)

**Problem 1.** Wind tunnel tests yield the following data for lift coefficient and pitch moment coefficient about the half chord line of a given wing:

| $\bar{\alpha}$ (deg) | $C_L$ | $C_{m_{1/2}}$ |
|---|---|---|
| -4.0 | -0.257 | 0.149 |
| -2.0 | 0.030 | 0.084 |
| 0.0 | 0.194 | 0.062 |
| 2.0 | 0.210 | 0.020 |
| 4.0 | 0.540 | -0.033 |
| 6.0 | 0.752 | -0.066 |

Using the software of your choice (e.g., Matlab or Excel), determine $C_L(\bar{\alpha})$ and $C_{m_{1/2}}(\bar{\alpha})$ using a linear least squares fit. Plot the data and the curve fits. Determine $h_{\text{ac}}$ and $C_{m_{\text{ac}}}$.

**Problem 2.** Consider a 30 pound, rectangular flying wing with a span $b = 10$ feet and a chord length $c = 2$ feet. For this aircraft, $C_{m_{0L}} = 0.018$ and $C_{m_\alpha} = -0.003$ per degree, where $C_m$ is computed about the center of gravity. The slope of the lift curve is $C_{L_\alpha} = 0.1$ per degree and $C_{L_0} = 0$. Determine the speed required for equilibrium flight at sea level.

**Problem 3.** Consider a lighter-than-air vehicle modeled as a prolate spheroid with a horizontal stabilizer. (See Figure 1 on the following page.) For longitudinal, equilibrium flight, the pitch moment about the center of buoyancy (CB) is

$$M_{\text{CB}} = (m_w - m_u)\, V^2 \alpha - mg\Delta\theta - \left(\frac{1}{2}\rho V^2\right) \text{Vol}_t C_{L_{\alpha_t}} \alpha.$$

The first term above is the so-called "Munk moment," a potential flow effect which tends to destabilize longitudinal translation. In this expression, $m_w$ is the *added mass* along the $\boldsymbol{z}_\text{B}$ axis and $m_u$ is the added mass along the $\boldsymbol{x}_\text{B}$ axis. The second term is a moment due to the vertical separation between the center of gravity (CG) and the CB – the "bottom-heaviness" parameter $\Delta$ has units of length and is positive when the CG is *below* the CB. The third term accounts for the moment due to the horizontal stabilizer, where the "horizontal tail volume" $\text{Vol}_t$ is the product of the horizontal stabilizer area ($S_t$) and the moment arm ($l_t$) from the CB to the tail.

Consider a 9 meter long airship with a 3 meter diameter that has the following properties:

$$I_y = 350 \text{ kg m}^2, \quad m = 52 \text{ kg}, \quad m_u = 6 \text{ kg}, \quad m_w = 42 \text{ kg}, \quad \text{and} \quad C_{L_{\alpha_t}} = 1 \text{ rad}^{-1}$$

Assume that the vehicle's flight path is somehow constrained to be horizontal so that $\theta = \alpha$ in the pitch moment expression given above. In analogy to aircraft, static pitch stability requires that $\partial M_{\text{CB}}/partial\alpha < 0$. On a plot for which $\Delta$ is the abscissa ($x$-axis) and $\text{Vol}_t$ is the ordinate ($y$-axis), indicate the parameter regions in which flight at $V = 1$ m/s and $V = 5$ m/s are statically stable, respectively. Discuss your results.

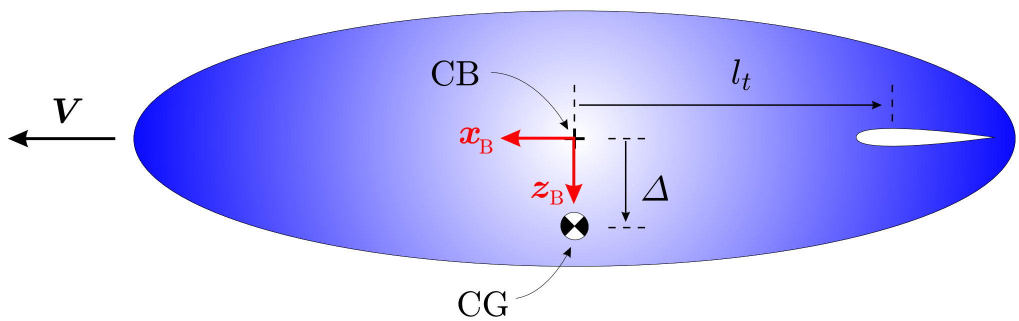


Figure 1: An airship.