

**MAE 5510 : Exercise Set 1**

Group					
Date					
Leader					
Member					
Member					
Member					

**1.1** Draw a 3-view of an aircraft and label the control surfaces, translational axes, and moment about each axis. Next to each of the axes, include the letter symbol used to denote the force along that axis, the moment about that axis, and the rotation rate about the axis. Label each component as longitudinal (O) or lateral (A).

**1.2** Write the equation that expresses the requirement for an aircraft to be stable in pitch.

**1.3** Consider a conventional aircraft with a main wing and horizontal tail. Assume the main wing, horizontal stabilizer, and center of gravity all lie along the fuselage reference line, and that the thrust and fuselage reference line are aligned with the direction of flight. Draw a side view of the aircraft with the longitudinal forces and moments labeled including the forces and moments on each lifting surface.

**1.4** Using the aircraft given in problem 1.3 write an equation for the force balance in the direction of lift if the aircraft is trimmed with a climb angle of  $\gamma$ . Apply the small-angle approximation for the downwash angle and drop very small terms.

**1.5** Using the aircraft given in problem 1.3, write an equation for the pitching-moment if the aircraft is trimmed with a climb angle of  $\gamma$ . Apply the small-angle approximation for the downwash angle and drop very small terms.

**1.6** Write the solutions to problems 1.4 and 1.5 in nondimensional form.

**1.7** Applying the small-angle approximation, write the expression for the lift coefficient of a main wing as a function of lift slope, mounting angle, and zero-lift angle of attack.

**1.8** Applying the small-angle approximation, write the expression for the lift coefficient of a horizontal stabilizer as a function of lift slope, mounting angle, zero-lift angle of attack, downwash, elevator effectiveness, and elevator deflection.

**1.9** Assuming a linear relationship between control-surface deflection and pitching moment, write the expression for the pitching-moment coefficient on the horizontal stabilizer as a function of elevator deflection.

**1.10** Combine the solutions from problems 1.6, 1.7, 1.8, and 1.9 to develop equations for the lift coefficient and pitching-moment of the aircraft as a function of wing and horizontal stabilizer geometric and aerodynamic properties, as well as the elevator deflection.

**1.11** Starting from the pitching-moment equation developed in problem 1.10, develop an expression for the pitch stability criteria as a function of the wing and horizontal stabilizer geometric and aerodynamic properties.

**1.12** For an aircraft to be trim, both equations in problem 1.10 must be satisfied. This provides a system of two equations that can be expressed in terms of two unknown operating parameters,  $\alpha$  and  $\delta_e$  as

$$\begin{bmatrix} C_{L,\alpha} & C_{L,\delta_e} \\ C_{m,\alpha} & C_{m,\delta_e} \end{bmatrix} \begin{Bmatrix} \alpha \\ \delta_e \end{Bmatrix} = \begin{bmatrix} C_L - C_{L0} \\ -C_{m0} \end{bmatrix}$$

where the known geometric and aerodynamic information of the aircraft is contained in the variables

$$C_{L,\alpha} =$$

$$C_{L,\delta_e} =$$

$$C_L =$$

$$C_{L0} =$$

$$C_{m,\alpha} =$$

$$C_{m,\delta_e} =$$

$$C_{m0} =$$

Consider a version of the British Spitfire with the following geometric and aerodynamic characteristics:

$$\begin{aligned} S_w &= 244 \text{ ft}^2, & b_w &= 36.83 \text{ ft}, & C_{L_w, \alpha} &= 4.62, & \alpha_{L0_w} &= -2.2^\circ, & C_{m_w} &= -0.053, \\ S_h &= 31 \text{ ft}^2, & b_h &= 10.64 \text{ ft}, & C_{L_h, \alpha} &= 4.06, & \varepsilon_e &= 0.60, & C_{m_h, \delta_e} &= -0.55, \\ & & W &= 8,375 \text{ lbf}, & l_h - l_w &= 18.16 \text{ ft} \end{aligned}$$

For the following problems, assume that the center of gravity lies at the quarter-chord of the main wing, the horizontal stabilizer has a symmetric airfoil, and neglect any effects from downwash.

**1.13** Find the mounting angle of the main wing and horizontal stabilizer required for the aircraft to be trim in steady-level flight at sea level at a velocity of 200 mph with zero elevator deflection and zero angle of attack.

**1.14** Compute the aircraft static margin.

**1.15** If the main wing and horizontal stabilizer both have zero mounting angles, compute the angle of attack and elevator deflection required to trim the aircraft in a steady climb at an altitude of 5,000 ft and a climb angle of 20 deg at a speed of 200 mph.