Flight Mechanics/Dynamics

(Course Code: AE 305/305M/717)

Department of Aerospace Engineering
Indian Institute of Technology Bombay

Instructor: Shashi Ranjan Kumar

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Time: **120 Minutes**

Mid-Semester Examination

Total Points: 100

Instructions

- All questions are mandatory.
- In case a question is missing some data/information, assume the same suitably and clearly mention it in your answer sheet.
- You are only allowed to open lecture slides of the course, any other form of help/reference is not permitted.
- In cases where the answers of two students are found to be copied, both of them will be awarded zero marks for that particular question.
- Answer sheets need to be submitted in a single "Roll_Number.pdf" format on Moodle.
- You will get 15 minutes duration for submission of your answer sheet on Moodle after the exam time.

1. Table 1 shows the variation of the pitching moment coefficient, C_m, about 0.67 chord ahead the trailing edge, with the lift coefficient C_l for a certain airfoil section. Obtain the location of aerodynamic center and the centre of pressure for $C_l = 0.5$, with respect to the leading edge of airfoil. [5+5]

C_l	0.20	0.40	0.60	0.80
C_m	-0.02	0	0.02	0.04

Table 1: C_m variation for different C_l values

2. Consider a wing-body configuration with lift coefficient, drag coefficient, zero-lift drag coefficient, Oswald's efficiency factor and the aspect ratio denoted by C_L, C_D, C_{D_0}, e and AR, respectively.

   (a) Show that the ratio $C_L^{3/2}/C_D$ is maximum when $C_{D_0} = (1/3)C_{D_i}$, where C_{D_i} is the induced drag coefficient.

(b) Derive an expression for $\left[\dfrac{C_L^{3/2}}{C_D}\right]_{\max}$ in terms C_{D_0}, e and AR.

[10+5]

3. Consider an aircraft with canard-wing-tail configuration, with the setting angle for tail and canard surfaces are i_t and i_c, respectively. The aerodynamic center of the canard and tail are located at a distance of l_c and l_t from the CG of the aircraft. The canard and tail have a surface area of S_c and S_t, respectively. Assume the other necessary variables and mention the same. Derive expression for the location of the neutral point, by assuming the small angle of attack and neglecting the effects of downwash and upwash. [20]

4. For the data shown in Fig. 1, find the stick fixed neutral point location. Also, if we wish to fly at a speed of 125 ft/s at sea-level then what would be the trim-lift coefficient and elevator angle to trim? Assume air density at sea-level to be 0.002377 slug/ft^3.

[5+10 Points]

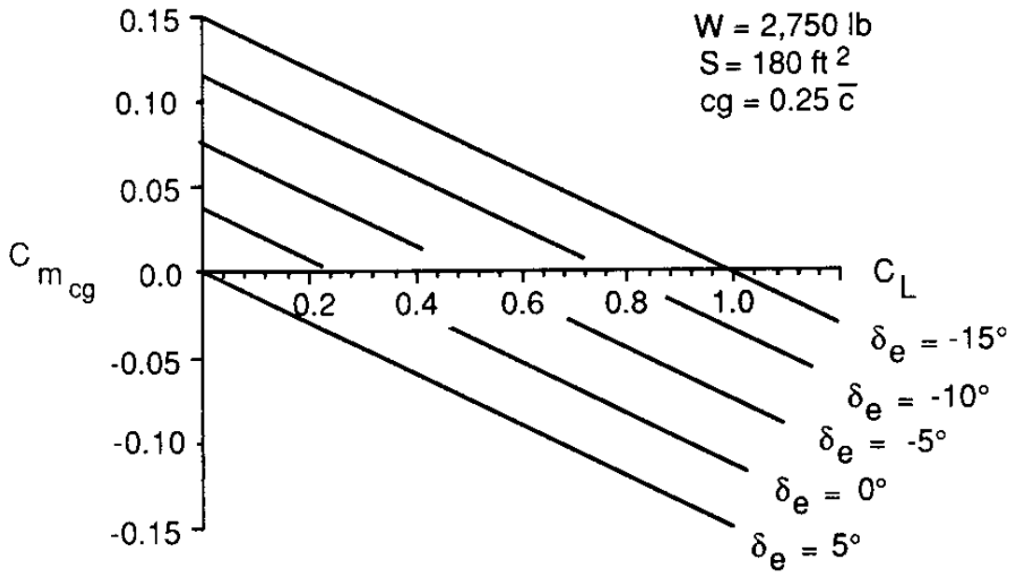

Figure 1: $C_{m_{cg}}$ vs C_L curve.

5. For a tailed aircraft with weight of 22700 N and wing area of 19 m^2 which is flying at a trim speed of 61 m/s at sea-level. The value of zero-lift moment coefficient is 0.06, while the values of other parameters are as given below.

$$C_{L_\alpha} = 0.08/\text{deg},\ C_{L_{\delta_e}} = 0.016/\text{deg},\ C_{m_\alpha} = -0.0133/\text{deg},\ C_{m_{\delta_e}} = -0.0176/\text{deg}.$$

The coefficients related to the elevator hinge moment are given by

$$C_{he_0} = 0,\ C_{he_\alpha} = -0.003/\text{deg},\ C_{he_{\delta_e}} = -0.006/\text{deg}, C_{he_{\delta_t}} = -0.003/\text{deg}$$

(a) Calculate the trim tab deflection necessary to trim the aircraft such that the pilot does not need to apply any control force.

(b) If the trim tab deflection is $-5°$, compute the control force required by the pilot to maintain a trimmed flight? Assume that the value of $G = G_1 - G_2 = 5$ rad/m, where G_1 and G_2 denote elevator and boost gearings, respectively. The elevator chord length and surface area are $\bar{c}_e = 0.61$ m and $S_e = 3.72$ m^2, respectively.

[10+5 Points]

6. For a large jet transport airplane (wing body plus tail configuration), C_m vs α curve is given in Fig. 2. The lift coefficient for the airplane is given as $C_L = 0.03 + 0.08\alpha$, where α is in degrees. Consider the limits of elevator deflection as: $-25° \leq \delta_e \leq 20°$ and $\alpha_{\text{stall}} = 20°$, the CG is located at 0.29 chord (that is $h = 0.29$). Determine the location of neutral point, $C_{m_{\delta_e}}$, $C_{L_{\delta_e}}$, $\dfrac{d\delta_{e_{\text{trim}}}}{dC_{L_{\text{trim}}}}$, and most forward CG location.

   Hint: The forward most CG location corresponds to the trim at stall angle of attack and maximum up elevator deflection. [4+5+5+4+7 Points]

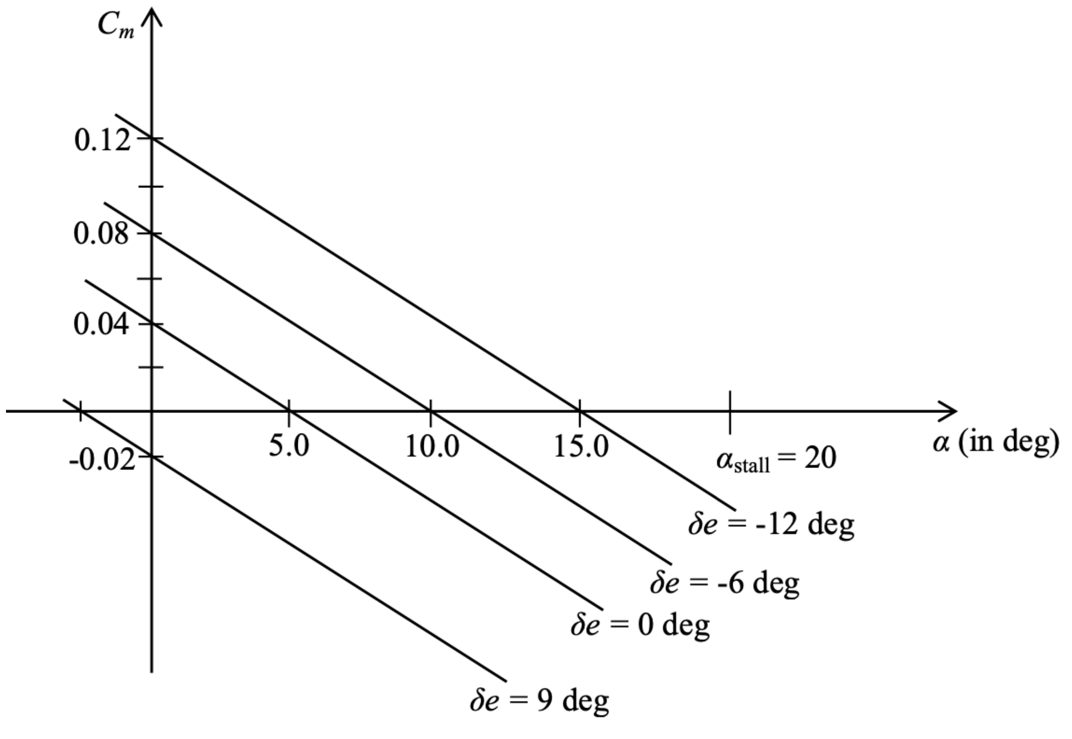

Figure 2: C_m vs α curve.