Indian Institute of Space Science and Technology

AE614/AE457 - Flight Dynamics and Control

Mar 03, 2025

Midterm Exam

(Open Notes Exam)

Duration: 120 min **Maximum marks: 50**

- Please provide clear steps and expressions for the problems. Steps carry mark.
- State any assumptions you make and justify them.
- **Only hand-written notes are allowed. No photocopies allowed.**

1. An aircraft flying at a constant altitude of 2000 m at a trim speed of 90 m/s has the following parameters. m = 2000 kg, S = 25 m^2, $\bar{c}$ = 2.5 m, Stall ~~speed,~~ $C_{L_{max}} = 1.9$. The drag polar is $C_D = 0.018 + 0.24 * C_L^2$. Find the following characteristics for the long period mode. [25]

    - Settling Time
    - Time to half of the amplitude
    - Time Period
    - Maximum Overshoot

    What is your suggestion to the pilot such that there is a reduce in the settling time by one-eighth of the current value and the time period by half of the current value, both simultaneously? Explain the suggestion with proper justification/calculations.

2. A conventional aircraft model in figure 1 has been tested inside a wind tunnel. The model is fixed with the ground support at the C. G and allowed to have only pitching motion. A torsional spring with damping parameter K_q and spring constant K_θ has been attached to resist the pitching motion. The aircraft has linear aerodynamic model.

    (a) Derive the equation of motion for the system. [5]

    (b) Derive the expressions for the natural frequency and damping ratio of the system. [4]

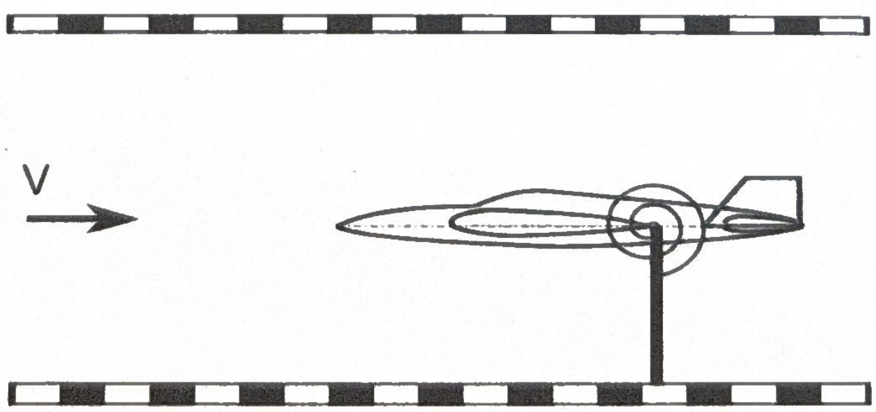

Figure 1

3. An unmanned aerial vehicle has a special design concept. The horizontal tail arm(l_t) can be varied during the flight, between $0.05\bar{c}$ to $2\bar{c}$. Find out the value of l_t such that [10]

the maximum overshoot and settling time are 5% and 0.9s, respectively. Assume that the C.G variations are negligible due to the tail variation. Use the aircraft details are given in the table 1. The aircraft flies at an altitude of 1000 m at a trim speed of 100 m/s. The effect of $\dot{\alpha}$ on the coefficients can be neglected.

$\log z = y$ $z = e^y$

$\log y = 2$ $y = e^2$

Table 1: **Aircraft parameters**

m = 2000 kg	S = 25 m^2
$\bar{c}$ = 2.5 m	I_y = 1500 kg-m^2
C_{L_0} = 0.2	C_{m_0} = 0.05
C_{L_α} = 5.44	$C_{L_{q_1}}$ = 1.2
C_{m_α} = -0.1	$C_{m_{q_1}}$ = -0.55
C_{D_0} = 0.018	K= 0.24

Correspond to first & II

4. Please choose the correct answer and give proper justification, with required maths and derivation if required, for your choice. **No justification, no marks.**
   (a) As span of the wing for a conventional aircraft increases, the aircraft becomes more stable. (True/False) [3]
   (b) The tail-less aircraft makes the aircraft less responsive to disturbance than a canard surface. (True/False) [3]

↳ very slow to respond.

Atmospheric Density Model:

$$\sigma = e^{-h/\beta}$$
$$\beta = 9296 \text{ m}$$

Formulae Sheet

$$\text{Settling Time, } T_s = \frac{4}{\zeta\omega_n}$$

$$\text{Time to '(1/n)}^{th}\text{' the initial amplitude, } t_{\frac{1}{n}} = \frac{\ln n}{\zeta\omega_n}$$

$$\text{Time Period,} T = \frac{2\pi}{\omega_n\sqrt{1-\zeta^2}}$$

$$\text{Maximum Overshoot, \% } M_p = e^{\frac{-\zeta\pi}{\sqrt{1-\zeta^2}}}$$