Indian Institute of Space Science and Technology

AE614/AE457 - Flight Dynamics and Control

Mar 11, 2025

Midterm Exam

(Open Notes Exam)

Duration: 120 min **Maximum marks: 60**

- 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. Using the aircraft details provided in Table 2, find out the following characteristics for the reduced order Short Period mode, for the listed scenarios below.

   - Settling Time
   - Time to half of the amplitude
   - Number of cycle to half of the amplitude
   - Maximum Overshoot

   Q9

   $$\frac{\xi \omega_n}{\omega_n\sqrt{1-\xi^2}} = \frac{4.05}{3.98}$$

   $$\frac{\xi}{\sqrt{1-\xi^2}} =$$

   (a) Flight at the sea level, with non-zero $C_{L_{\dot\alpha}}$ and $C_{m_{\dot\alpha}}$ [8]

   (b) Flight at an altitude of 3 km, with non-zero $C_{L_{\dot\alpha}}$ and $C_{m_{\dot\alpha}}$ [8]

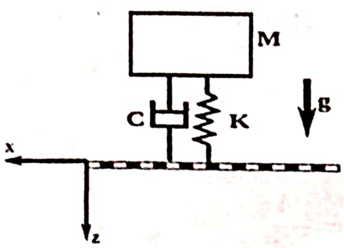
   (c) Flight at the sea level, with zero $C_{L_{\dot\alpha}}$ and $C_{m_{\dot\alpha}}$ [6]

   (d) Which flight is beneficiary from the perspective of a calm passenger? Provide your answer with logical reasoning. [4]

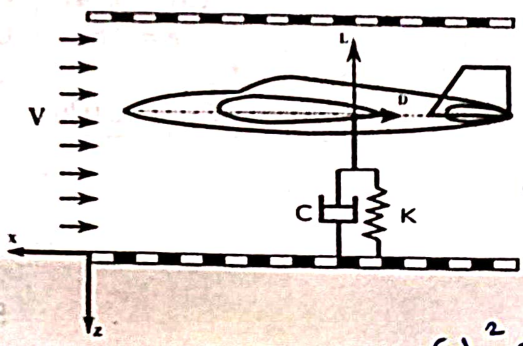
   $$\xi^2 = (1.0355)(1-\xi^2)$$

2. (a) Derive the equation of motion for the system shown in the figure 1a. [3]

   (b) Express the condition for equilibrium. [2]



(a) Fig 1a



(b) Fig 1b

$$\lambda_1^2 C_1 + \lambda_2^2 C_2 = \frac{\partial L}{m}$$

$$(\lambda_1^2 - \lambda_2^2) C_1 = \frac{L}{m}$$

3. The aircraft has been tested inside the wind tunnel, as shown in figure 1b. The aircraft can move only along the Z axis. Assume, L = fn(V, z and $\dot z$).

   (a) Derive the equation of motion for the system. [3]

   (b) Express the condition for equilibrium. [2]

   (c) Find the solution of the homogeneous system using State space Method, with initial conditions as derived from the equilibrium expression. [9]

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 the tail arm of a conventional aircraft reduces, the aircraft becomes dynamically unstable. (True/False) [5]

   (b) A conventional aircraft can be made more dynamically stable by adding a canard surface before the wing. (True/False) [5] Reduce stat, fast pitching C_{m_α}

   (c) Long spanned birds are more stable than shorter span birds during glide flight. (True/False) [5] Phugoid Mode short spanned

Aircraft details

Table 1: *Geometry, Mass and Inertia Characteristics*

$V = \theta - \alpha$

Mean Aerodynamic Chord, $\bar{c}$	$1.211\ m$
Wing Span, b	$10.47\ m$
Aspect Ratio, AR	8.8
Wing Area, S	$12.47\ m^2$
Mass, m	$750\ kg$
Moment of Inertia, I_{xx}	$873\ kg-m^2$
Moment of Inertia, I_{yy}	$907\ kg-m^2$
Moment of Inertia, I_{zz}	$1680\ kg-m^2$
Moment of Inertia, I_{xz}	$1144\ kg-m^2$
Engine Thrust, T	$1136\ N$
Trim speed, V_∞	$60\ m/s$

The aerodynamic derivatives are provided as below.

Table 2: Aerodynamic Derivatives

(a) *Longitudinal*

$C_{D_0} = 0.036$	$C_{L_0} = 0.365$	$C_{m_0} = 0.05$
$C_{D_\alpha} = 0.041$	$C_{L_\alpha} = 4.98$	$C_{m_\alpha} = -0.59$
$e = 0.8$	$C_{L_q} = 27.3$	$C_{m_q} = -9.3$
	$C_{L_{\dot\alpha}} = 8.3$	$C_{m_{\dot\alpha}} = -4.3$
$C_{D_{\delta_e}} = 0.026$	$C_{L_{\delta_e}} = 0.26$	$C_{m_{\delta_e}} = -1.008$

NSM

Formulae Sheet

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

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

$$\text{Number of cycles to '(1/n)}^{th}\text{' the initial amplitude, } N_{\frac{1}{n}} = \frac{\ln n}{2\pi}\frac{\sqrt{1-\zeta^2}}{\zeta}$$

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