Hall Ticket No | | | | | | | | | | | Question Paper Code: AAEC24

INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)

Dundigal-500043, Hyderabad

B.Tech VI SEMESTER END EXAMINATIONS (REGULAR) - JULY 2023

Regulation: UG-20

AIRCRAFT STABILITY AND CONTROL

Time: 3 Hours **(AERONAUTICAL ENGINEERING)** **Max Marks: 70**

Answer ALL questions in Module I and II

Answer ONE out of two questions in Modules III, IV and V

All Questions Carry Equal Marks

All parts of the question must be answered in one place only

MODULE – I

1. (a) Formulate an expression for contribution of the main wing to moment about the center of gravity of an airplane. [BL: Understand| CO: 1|Marks: 7]

   (b) A wing–body model is tested in a subsonic wind tunnel. The lift is found to be zero at a geometric angle of attack $\alpha = -1.5°$. At $\alpha = 5°$ the lift coefficient is measured as 0.52. Also, at $\alpha = 1.0°$ and 7.88°, the moment coefficients about the center of gravity are measured as -0.01 and 0.05, respectively. The center of gravity is located at 0.35 c. The area and chord of the wing are $0.1m^2$ and 0.1 m, respectively. Now assume that a horizontal tail is added to this model. The distance from the airplane's center of gravity to the tail's aerodynamic center is 0.17 m; the tail area is $0.02m^2$; the tail-setting angle is 2.7°; the tail lift slope is 0.1 per degree; and from experimental measurement, $\epsilon_0 = 0$ and $\frac{\partial \epsilon}{\partial \alpha} = 0.35$. Check whether the model has longitudinal static stability and balance. [BL: Apply| CO: 1|Marks: 7]

MODULE – II

2. (a) Summarize about the rudder requirements under any four dominant needs.
   [BL: Understand| CO: 2|Marks: 7]

   (b) Consider an aircraft with the following parameters:
   Vertical stabilizer area (S_v) : $10m^2$
   Vertical stabilizer arm (l_v) : $3m$
   Aerodynamic side force derivative (Y_β) : -0.08
   Aerodynamic yawing moment derivative (Y_β) : -0.15
   Aircraft mass (m): 5000 kg Wing span (b): 15 m
   i) Calculate the static directional stability derivative $(C_{n\beta})$ of the aircraft.
   ii) Determine the static directional stability of the aircraft.
   iii) Find the neutral point (NP) location relative to the wing's mean aerodynamic chord (MAC).
   iv) Calculate the yawing moment (N) generated when a sideslip angle (β) of 2 degrees is experienced.
   [BL: Apply| CO: 2|Marks: 7]

MODULE – III

3. (a) Indicate the process of transforming a vector from the earth axes system to the body axes system of an aircraft using the earth to body axis transformation matrix. Include the role of Euler angles and how the transformation allows us to relate the aircraft's motion and orientation to its own reference frame. [BL: Understand| CO: 3|Marks: 7]

   (b) Consider an aircraft in steady level flight with the following velocity vector in the earth axes system: velocity vector (V) = (100 m/s, -10 m/s, 5 m/s)

   i) Calculate the angles of attack (α) and sideslip angle (β) of the aircraft.

   ii) Determine the Euler angles (roll angle Φ, pitch angle θ) in degrees.

   [BL: Apply| CO: 3|Marks: 7]

4. (a) Outline the process of transforming a vector from the stability axes system to the body axes system of an aircraft using the stability axis to body axis transformation matrix.

   [BL: Understand| CO: 4|Marks: 7]

   (b) Consider an aircraft in flight with the following information:

   Roll angle (Φ): 10 degrees

   Pitch angle (θ): -5 degrees

   Yaw angle (ψ): 20 degrees

   Roll rate (p): 0.1 rad/s

   Pitch rate (q): -0.05 rad/s

   Yaw rate (r): 0.03 rad/s

   Determine the rates of change of Euler angles (Φ', θ', ψ') in degrees per second.

   [BL: Apply| CO: 4|Marks: 7]

MODULE – IV

5. (a) Determine the linearized equations of aerodynamic forces as a function of motion variables using small disturbance theory. [BL: Understand| CO: 5|Marks: 7]

   (b) Consider an aircraft flying in steady, level flight at a reference speed of 200 knots (approximately 102.6 m/s). The aircraft has a mass of 10,000 kg and is subject to perturbations in the form of a gust that creates an additional vertical force of 5000 N acting upward. The aircraft's lift coefficient is 0.6, and the drag coefficient is 0.05.

   i) Determine the equation of motion in perturbation variables for the aircraft in the vertical direction.

   ii) Calculate the resulting vertical acceleration of the aircraft due to the gust.

   [BL: Apply| CO: 5|Marks: 7]

6. (a) Summarize about the derivatives of axial, normal force components and pitching moment with respect to the velocity, angle of attack, angle of attack rate, pitch rate, and elevator angle.

   [BL: Understand| CO: 5|Marks: 7]

   (b) Consider an aircraft with the following data:

   Axial force component (X) derivative with respect to velocity (V): 0.1

   Axial force component (X) derivative with respect to angle of attack (α): 0.2

   Normal force component (Z) derivative with respect to velocity (V): 0.05

   Normal force component (Z) derivative with respect to angle of attack (α): 0.15

   Pitching moment (M) derivative with respect to velocity (V): -0.03

Pitching moment (M) derivative with respect to angle of attack (α): -0.1

i) Calculate the axial force component (X) for the given conditions of velocity (V = 200 knots) and angle of attack ($\alpha = 5$ degrees).

ii) Determine the normal force component (Z) for the same conditions.

iii) Calculate the pitching moment (M) for the given conditions. [BL: Apply| CO: 5|Marks: 7]

MODULE – V

7. (a) Describe the characteristics and significance of the principal modes of motion in the dynamic stability of an aircraft. [BL: Understand| CO: 6|Marks: 7]

   (b) An aircraft in level flight encounters a vertical gust, which excites the phugoid mode. The phugoid motion completes 10 cycles in 50s and its amplitude reduces to half of its maximum value in 25s. Find the eigenvalues of this phugoid mode. [BL: Apply| CO: 6|Marks: 7]

8. (a) Illustrate the two primary forms and one secondary form of longitudinal oscillations with regard to an airplane attempting to return to equilibrium after being disturbed.

   [BL: Understand| CO: 6|Marks: 7]

   (b) Consider an aircraft with the following coefficients of the characteristic equation for the longitudinal motion: A = 1, B = -0.2 and C = 0.05

   Find the values of the roots (eigenvalues) of the characteristic equation and determine the stability characteristics of the aircraft. [BL: Apply| CO: 6|Marks: 7]

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