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B.M.S. College of Engineering, Bengaluru-560019

Autonomous Institute Affiliated to VTU

September / October 2023 Supplementary Examinations

Programme: B.E. | **Semester: VI**
Branch: Aerospace Engineering | **Duration: 3 hrs.**
Course Code: 20AE6DCDSM | **Max Marks: 100**
Course: Flight Dynamics and Space Mechanics | **Date: 27.09.2023**

Instructions: 1. Answer any FIVE full questions, choosing one full question from each unit.
2. Missing data, if any, may be suitably assumed.

Important Note: Completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages. Revealing of identification, appeal to evaluator will be treated as malpractice.

UNIT - I

1 a) Write down the accepted limits on Euler angles. Convert the co-ordinate of the position vector in the earth axis system defined by **10**

$$\overrightarrow{F_E} = x_E\hat{\imath}_E + y_E\hat{\jmath}_E + z_E\hat{k}_E$$

to body axis system ($\overrightarrow{F_B}$) based on the accepted sequence of Euler angles with possible vector diagrams.

b) Derive the three moment equations of motion (with necessary assumptions) in body axis system of an aircraft starting from the angular momentum equation $\vec{H} = I\,\vec{\omega}$, where I is the Inertia tensor and ω is the angular velocity. **10**

UNIT - II

2 a) Show that the derivative due to the changes in the forward speed (in x-direction with respect to u/U_1) is dependent on the speed damping derivative and the co-efficient of aerodynamic drag under steady state condition. **10**

b) Find the u/U_1 derivative for the F-4C aircraft at 10,500 m and Mach 0.9 (U_1 = 267 m/s, q = 13, 560 N/m^2, S = 50 m^2) if C_{D_1} = 0.03 and C_{D_u} = 0.027. If U is perturbed to 268 m/s, find the perturbed applied aero force along the x stability axis (f_{A_x}). **4**

c) Show that the derivative due to the changes in the forward speed (in x-direction with respect to u/U_1) is dependent on the Mach-Tuck derivative and the co-efficient of moment under steady state condition. **6**

OR

3 a) Show that the derivative due to the change of angle of attack (in z-direction with respect to $\hat{\alpha}$) is dependent on the lift-curve slope and the co-efficient of aerodynamic drag under steady state condition. **10**

b) Find the $\hat{\alpha}$ derivative $\frac{\partial F_{A_z}}{\partial \hat{\alpha}}$ for the F-4C aircraft at the flight conditions at 10,500 m and Mach 0.9 (U_1 = 267 m/s, q = 13, 560 N/m^2, S = 50 m^2) if C_{D_1} = 0.03 and C_{D_u} = 0.027 in which C_{L_α} = 3.75 /rad. If the F-4C is trimmed at an angle of attack of 2.6^0 and then is perturbed to 3.1^0, find the perturbed aero force along the z-stability axis (F_{A_z}). **10**

UNIT - III

4 a) Find the natural frequency and the damping ratio based on two degree of freedom Phugoid approximation is given by the standard equation given below. **12**

$$\begin{bmatrix} s - X_u - X_{T_u} & -X_\alpha & g\cos\Theta_1 \\ -Z_u & [s(U_1 - Z_{\dot{\alpha}}) - Z_\alpha] & [-(Z_q + U_1)s + g\sin\Theta_1] \\ -(M_u - M_{T_u}) & -(M_{\dot{\alpha}}s + M_\alpha + M_{T_\alpha}) & (s^2 - M_q s) \end{bmatrix} \begin{bmatrix} U(s) \\ \alpha(s) \\ \theta(s) \end{bmatrix} = \begin{bmatrix} X_{\delta_e} \\ Z_{\delta_e} \\ M_{\delta_e} \end{bmatrix} \delta_e s$$

b) The following is the longitudinal characteristic equation for an F-89 Scorpion flying at 6,096 m at Mach 0.638. Determine the short period and phugoid natural frequencies and also the damping ratios and damped frequencies for both modes: **8**

$$(s^2 + 4.2102s + 18.2329)\,(s^2 + 0.00899s + 0.003969) = 0$$

UNIT - IV

5 a) Describe the peculiarities of space environment. **10**

b) Describe the effect of space environment on materials of spacecraft structure and astronauts. **10**

UNIT - V

6 a) Prove that $r_o = \frac{L^2}{GMm^2}$ and $e^2 = 1 + \frac{2Er_o}{GMm}$ in an ellipse. Where r_o is the semi-latus rectum. **10**

b) An earth satellite is in an orbit with perigee altitude z_p = 400 km and an eccentricity e = 0.6. Find (i) the perigee velocity (ii) the apogee radius (iii) the semimajor axis (iv) the apogee velocity (v) the period of the orbit. (μ = 3,98,600 km^3/s^2 and the radius of the earth R = 6378 km) **10**

OR

7 a) Calculate the velocity and the orbiting time period of an artificial satellite having a circular orbit around the Earth at an altitude of 200 km above the Earth's surface. (Radius of the earth R = 6,378.14 km and μ = 398600.5 km^3/s^2). **5**

b) In an inertial coordinate system, the position and velocity vectors of a satellite are, respectively, $(1.2756\,\vec{i} + 1.9135\,\vec{j} + 3.1891\vec{k})\,10^7$ m and $(0.7905\,\vec{i} + 1.5811\,\vec{j})\,10^4$ m/s where $\vec{i}$, $\vec{j}$ and $\vec{k}$ are unit vectors. Determine the specific mechanical energy (ξ) and the specific angular momentum (h) Also find the flight path angle, φ. (Take G = 6.67×10^{-11} $m^3\,kg^{-1}s^{-2}$ and $\boldsymbol{\mu}$ = 398600.5 km^3/s^2). **10**

c) State and derive Kepler's third law of planetary motion. **5**

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