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MANIPAL INSTITUTE OF TECHNOLOGY

MANIPAL

(A constituent unit of MAHE, Manipal)

FIRST SEMESTER M.TECH. (AEROSPACE ENGG.)

END SEMESTER DEGREE EXAMINATIONS, NOVEMBER - 2019

SUBJECT: ORBITAL MECHANICS [ICE 5174]

TIME: 3 HOURS MAX. MARKS: 50

Instructions to candidates :*Answer ALL questions and missing data may be suitably assumed.*

1A. Obtain the expression for velocity of a body in an elliptical orbit.

1B. Identify the type of orbits given the following data:

a) $\vec{r} = 6372\hat{I} + 6372\hat{J}, \vec{v} = -4.7028\hat{I} + 4.7028\hat{J}(\frac{km}{s})$

b) $\vec{e} = 0.07\hat{I} + 0.021\hat{J} + 0.021\hat{K}$

c) $\vec{h} = 2.3\hat{J}\ DU^2/TU$

d) $\vec{h} = -3.5\hat{J}\ DU^2/TU$

1C. A meteoroid is first observed approaching the earth when it is 402,000 km from the center of the earth with a true anomaly of 150^0. If the speed of the meteoroid at that time is 2.23 km/s, calculate (a) the eccentricity of the trajectory; (b) the altitude at closest approach; and (c) the speed at the closest approach.

(3+4+3)

2A. Find the classical orbital elements for the following state vector:

$$\vec{r}_{IJK} = 6524.834\hat{I} + 6862.875\hat{J} + 6448.296\hat{K}(km)$$

$$\vec{v}_{IJK} = 4.901327\hat{I} + 5.533756\hat{J} - 1.976341\hat{K}(\frac{km}{s})$$

2B. Illustrate the transformation from the geocentric equatorial coordinate system to the perifocal coordinate system with rotation matrices.

2C. A tracking station at latitude -20^0 and elevation 500 m makes the following observations of a satellite at the given times.

Time (min)	Local Sidereal Time (^{0})	Azimuth (^{0})	Elevation (^{0})	Range (km)
0	60.0	165.931	9.53549	1214.89
2	60.5014	145.967	45.7711	421.441
4	61.0027	2.40962	21.8825	732.079

Use the Gibbs method to calculate the state vector of the satellite at the central observation time.

(4+3+3)

3A. For a Mars transfer orbit, given: $\vec{r}_1 = 0.473265\hat{I} - 0.899215\hat{J}(AU)$, $\vec{r}_2 = 0.066842\hat{I} + 1.561256\hat{J} + 0.030948\hat{K}(AU)$, $p = 1.250633\ AU$, $a = 1.320971\ AU$, $\Delta\theta = 149.770967^0$, $\mu = 3.964016 \times 10^{-14}\ AU^3/s^2$. Calculate the departure and intercept velocity vectors.

3B. Illustrate the sensitivity of Hohmann transfer due to small inaccuracies of the transfer injection impulse with equations.

3C. Determine which of the following orbits could be used to transfer between two circular-coplanar orbits with radii 1 .2 DU and 4 DU respectively.

(a) $\vec{r}_p = 1DU, e = 0.5$ (b) $a = 2.5DU, e = 0.56$ (c) $\xi = -0.1\, DU^2/TU^2, h = 1.34\, DU^2/TU$ (d) $p = 1.95DU, e = 0.5$

(3+3+4)

4A. With a single delta-v maneuver, the earth orbit of a satellite is to be changed from a circle of radius 15,000 km to a collinear ellipse with perigee altitude of 500 km and apogee radius of 22,000 km. Calculate the magnitude of the required delta-v. What is the minimum total delta-v if the orbit change is accomplished instead by a Hohmann transfer?

4B. After a Hohmann transfer from earth to Mars, calculate

(a) the minimum delta-v required to place a spacecraft in orbit with a period of 7 h.

(b) the periapsis radius.

(c) the aiming radius.

(d) the angle between periapsis and Mars' velocity vector.

4C. What are the elements a and e of a lunar arrival orbit if the arrival point (at the sphere of influence) has the following properties: velocity = 1.3133 km/s Flight path angle = -86.1445 deg.

(4+3+3)

5A. Briefly explain the stability and dynamics of a body placed in the Lagrangian points.

5B. Illustrate Encke's method in orbit perturbation with equations.

5C. Determine the semi major axis of an Earth satellite orbit with eccentricity equal to 0.17 and $d\omega/dt = 0$ and the orbit is sun-synchronous.

(3+4+3)

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