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प्रज्ञानं ब्रह्म

Manipal

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Manipal Institute of Technology, Manipal

(A Constituent Institute of Manipal University)

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MANIPAL INSTITUTE OF TECHNOLOGY

V SEMESTER B.TECH (AERONAUTICAL ENGINEERING)

END SEMESTER EXAMINATIONS, NOV/DEC 2015

SUBJECT: INTRODUCTION TO SPACE TECHNOLOGY [AAE 309]

REVISED CREDIT SYSTEM

Time: 3 Hours MAX. MARKS: 50

Instructions to Candidates:

- Answer **ANY FIVE FULL** the questions.
- Missing data may be suitable assumed.

1A. The orbital period of a planet in a circular orbit of radius R_1 around the Sun is P_1. Find the orbital period of another planet in a circular heliocentric orbit of radius $3R_1$. **(02)**

1B. Consider a lander hovering 10 m above the surface of the Mars, in search for a suitable landing spot. Given $\mu_{Mars} = 42810\times10^9$ m^3/s^2 and $R_{Mars} = 3402\times10^3$ m, Dry mass of vehicle = 500 kg; Specific Impulse (I_{SP}) = 300s. Compute how much propellant would be needed for a maximum hover period of 10 minutes. **(03)**

1C. Consider a spacecraft with a gross weight of 6896 N that is to be the payload of a single stage booster capable of a $\Delta V = 7930$ m/s. The specific impulse is 350s. The structural ratio of the booster is given as 0.095. Estimate the Gross Lift-off weight. If the initial launch thrust to weight ratio (T/W) is 1.5, what would be the approximate burn time? **(05)**

2A. The motion of a planet around a star can be described by its position vector along the orbit referred to the inertial space, $\vec{\mathbf{r}} = R\cos(\Omega t)i + R\sin(\Omega t)j$ with R and Ω are constants, i and j are unit vectors in the x and y coordinates respectively, and t is the time coordinate. Obtain the velocity vector of the planet and show that it is perpendicular to radius vector at all times. **(02)**

2B. State in words the six fundamental orbital parameters and the geometrical meaning for each of them. For a circular orbit, provide a list with the parameters that are undefined and those that best describe the orbit geometry and spacecraft location. **(03)**

2C. We observe an object in the ECI frame at position vector $\vec{\mathbf{r}} = 1.023i + 1.076j + 1.011k$ DU moving with velocity vector $\vec{\mathbf{V}} = 0.62i + 0.7j - 0.25k$ DU/TU. Determine the orbital elements. **(05)**

3A. A satellite is in a circular Earth orbit at an altitude of 400 km. The satellite has a cylindrical shape 2m in diameter by 4m long and has a mass of 1000 kg. The satellite is travelling with its long axis perpendicular to the velocity vector and its drag coefficient is 2.67. Estimate the satellite's time. Radius of Earth = 6378.14 km, Density scale height = 58.2 km and density = 2.62×10^{-12} kg/m^3. **(02)**

3B. Calculate the perturbations in longitude of the ascending node and argument of perigee caused by the Moon and Sun for the International Space Station (ISS) orbiting at an altitude of 400 km, an inclination of 51.6 degrees, and with an orbital period of 92.6 minutes. **(03)**

3C. The gravity potential of the Earth is given by the following equation: **(05)**

$$U = \frac{-\mu}{r}\left[1 - \sum_{n=2}^{\infty} J_n \left(\frac{R_E}{r}\right)^n P_n \sin\delta + \sum_{n=2}^{\infty}\sum_{m=1}^{n} J_{n,m}\left(\frac{R_E}{r}\right)^n P_{n,m}(\sin\delta)\cos\left(m(\lambda - \lambda_{n,m})\right)\right]$$

Here, $P_n(\sin\delta)$ and $P_{n,m}(\sin\delta)$ represent the Legendre Polynomials and functions, respectively:

$$P_n(x) = \frac{1}{(-2)^n n!}\frac{d^n}{dx^n}(1-x^2)^n;\ P_{n,m}(x) = (1-x^2)^{m/2}\frac{d^m P_n(x)}{dx^m}$$

Calculate the radial acceleration due to the term $\mathbf{J_{3,1}}$ for a Geostationary satellite (expressed in numbers, for arbitrary longitude). Use the following data:

μ_{Earth} = 398600.4415 km^3/s^2; R_{Earth} = 6378.14 km; $J_{3,1}$= -1.72×10^{-6}; $\lambda_{3,1}$= -1.0 degree

4A. An Earth satellite is observed to have a perigee height of 100 km and an apogee height of 600 km. Find the period and eccentricity. **(02)**

4B. For a satellite in an Earth orbit with apogee altitude of 3000 km and perigee altitude of 300 km. How long does it take to go from an altitude of 1000 km to 2000 km? **(03)**

4C. A radar site at Cape Canaveral (latitude 28.5° N, longitude 80.5° W) detected a spacecraft passing directly overhead with the following data: **(05)**

ρ = 0.5 DU; A_Z = 45°; E.I = 90° for position relative to the radar site and

$\dot{\rho}$ = 0 DU/TU; $\dot{A}_Z$ = 0; $\dot{E.I}$ = 3 rad/TU for velocity relative to the radar site

Where ρ = Position; A_Z = Azimuth; E.I = Elevation. Assume that the longitude of the radar site with respect to the vernal equinox direction is $\theta = 45$ degree at the time of observation. Transform the spacecraft's position vector **r** from Topocentric horizon coordinate system into geocentric equatorial coordinates and also determine the absolute velocity of the spacecraft in terms of geocentric - equatorial coordinates. Angular speed of Earth is given as $\vec{\omega}_E$ = 0.0 i + 0.0 j + 0.058 k where i, j and k are the unit vectors.

5A. An elliptic orbit of perigee radius, $r_P = 3$ DU and apogee radius, $r_a = 6$ DU is used to transfer a spacecraft between two circular coplanar orbits of initial radius, $r_1 = 3$ DU and final radius, $r_2 = 8$ DU. Is it possible to transfer the spacecraft from initial circular orbit to final circular orbit? Justify your answer. **(02)**

5B. An Earth satellite is to be transferred from a 300 km altitude circular parking orbit to 35,786 km altitude circular orbit. The satellite has a total initial mass of 5700 kg and it is equipped with a small engine that uses hypergolic mixture as propellant for which the specific impulse is 320 s. Both orbits are coplanar. The first tangential burn that converts the initial orbit into a transfer ellipse of eccentricity e = 0.88. Calculate the total time of flight during the one-tangent burn transfer and total mass of propellant spent in the transfer maneuver. **(03)**

5C. Consider a transfer from a circular orbit at 185 km and inclination, i = 5 degree (i.e. launch from kourou) to the Geostationary orbit (eccentricity = 0; inclination = zero degree). The orbital period of the Geostationary orbit is 23 hours 56 minutes and 4 seconds. (a) Compute the radius of the geostationary orbit (b) Compute the circular velocities in the original orbit and in the target orbit (c) Compute the velocities in the perigee and apogee of a Hohmann transfer orbit (assuming that the initial and target orbits are coplanar) (d) Compute the total ΔV that would be required for orbit raising. (e) Compute the ΔV that would be required to only change the inclination of the parking orbit to that of the GEO. $\mu_{Earth} = 398600\ km^3/s^2$ and $R_{Earth} = 6378.14$ km **(05)**

6A. The Ballistic Missile Early Warning System (BMEWS) detects an unidentified object with the following parameters: altitude = 0.5 DU; Speed = 0.8 DU/TU. Is it possible that this object is a space probe intended to escape the Earth? Justify your answer. **(02)**

6B. Consider a round trip mission to Saturn. Determine the Hohmann transfer time for a trip to Saturn. What would be the minimum stay time? $a_{Saturn} = 9.537$AU; Orbital Period of Saturn = 10,759 days, Angular speed of Saturn = 6.7592×10^{-9}; $\mu_{Sun} = 1.3271 \times 10^{11}\ km^3/s^2$; 1AU = 149.6×10^6 km; distance Saturn-Sun = 9.537 AU **(03)**

6C. A Probe is sent in a mission to Jupiter for research of the Jovian soil and atmosphere. The probe is composed of orbiter and lander. The space probe is placed into the payload fairing of Ariane-5 rocket before launch at the launch site with latitude 5^oN and it is to be launched from the place with an azimuth angle of 90 degree into direct orbit. The probe is inserted into LEO of 300 nm altitude. The Earth and Jupiter orbits are assumed to be circular and are both contained in the ecliptic plane, which is inclined 23.4 degree with respect to the Earth's equator. (a) Calculate the ΔV needed to change the plane from the initial circular parking LEO to an identical circular orbit on the ecliptic plane (b) Determine the velocity of the probe at perihelion and apohelion of the transfer ellipse. (c) Obtain the burn-out velocity and ΔV necessary to obtain the injection velocity for the interplanetary trajectory (d) Calculate the Time of Flight during the transfer in days (e) Obtain the needed phase angle departure between the Earth and the Jupiter for the Hohmann transfer to succeed. If this launch opportunity is missed, how long does it take to recover the same relative position between both the planets? **Note 1 nm = 1.852 km and 1 AU/TU = 3.768 DU/TU** **(05)**