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प्रज्ञानं ब्रह्म

Manipal

INSPIRED BY LIFE

Manipal Institute of Technology, Manipal

(A Constituent Institute of Manipal University)

V SEMESTER B.TECH (AERONAUTICAL ENGINEERING)

END SEMESTER EXAMINATIONS, DEC 2015/JAN 2016

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 spacecraft has an initial mass of 30,000 kg. Its engine ejects mass at a rate of 30 kg/s with an exhaust velocity of 3,100 m/s. What is the change in velocity if the spacecraft burns its engine for one minute? **(02)**

1B. Explain the causes for the man-made environment and its effects over the performance of the spacecraft. **(03)**

1C. A two-stage rocket has the following masses: 1st-stage propellant mass 120,000 kg, 1st-stage dry mass 9,000 kg, 2nd-stage propellant mass 30,000 kg, 2nd-stage dry mass 3,000 kg, and payload mass 3,000 kg. The specific impulses of the 1st and 2nd stages are 260 s and 320 s respectively. Calculate the rocket's total ΔV. **(05)**

2A. How does the Earth rotation affect the ΔV – budget of a space mission? **(02)**

2B. An artificial Earth satellite is in an elliptical orbit which brings it to an altitude of 250 km at perigee and out to an altitude of 500 km at apogee. Calculate the velocity of the satellite at both perigee and apogee. **(03)**

2C. The position vector and velocity vector of a spacecraft at a given instant are described by: **r** = 0.67 $\bar{\mathbf{i}}$ + 0.67 $\bar{\mathbf{j}}$ + 0.55 $\bar{\mathbf{k}}$ DU and **V** = 0.61 $\bar{\mathbf{i}}$ - 0.01 $\bar{\mathbf{j}}$ - 0.74 $\bar{\mathbf{k}}$ DU/TU. (a) calculate the specific angular momentum of the spacecraft (b) determine the eccentricity vector and characterize the shape of the orbit (c) calculate the perigee and apogee altitudes of the orbit (d) calculate the longitude of ascending node. **(05)**

3A. An Earth satellite is observed to have a height of perigee of 185.2 km and a height of apogee of 12000 km. Find the period of the orbit. **(02)**

3B. A satellite is in an orbit with a semi-major axis of 7,500 km, an inclination of 28.5 degrees, and an eccentricity of 0.1. Calculate the J_2 perturbations in longitude of the ascending node and argument of perigee. **(03)**

3C. A satellite is in an orbit with a semi-major axis of 7,500 km and an eccentricity of 0.1. Calculate the time it takes to move from a position 30 degrees past perigee to 90 degrees past perigee. **(05)**

4A. The molniya 3-3 satellite was launched in 1975 by the Soviet Union for communication, surveillance and military purposes, and it was inserted into a high inclination Earth orbit of perigee altitude 2,646.5 km and apogee altitude 37,715.4 km. Calculate the satellite velocity when its altitude is 10000 km. **(02)**

4B. The gravity potential of the Earth is given by the following equation: **(03)**

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

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 East-West acceleration due to the term $J_{2,2}$ for a Geostationary satellite (expressed in numbers, for arbitrary longitude). Use the following data to calculate the perturbation

μ_{Earth} = 398600.4415 km^3/s^2; R_{Earth} = 6378.14 km; $J_{2,2}$ = 1.816×10^{-6}; $\lambda_{2,2}$ = -14.9 degree

4C. At a given time, the geocentric equatorial position vector of the International Space Station (ISS) is $\bar{r}$ = -2032.4 i + 4591.2 j - 4544.8 k (km). When the position vector of the observer to be $\bar{R}$ = -1673 i + 4598 j - 4078 k (km), determine the azimuth and elevation angle relative to observer whose latitude is $\phi = -40^{\circ}$ and local sidereal time $\theta = 110^{\circ}$ **(05)**

5A. Calculate the escape velocity of a spacecraft launched from an Earth orbit with an altitude of 200 km. **(02)**

5B. How many days each year is the Earth farther from the Sun than 1 AU? (1 AU = 149,597,870 km) **(03)**

5C. A spacecraft is in a circular parking orbit with an altitude of 200 km. Calculate the velocity change required to perform a Hohmann transfer to a circular orbit at geosynchronous altitude (i.e. 35,786 km). **(05)**

6A. A spacecraft launched from Earth has a burnout velocity of 11,500 m/s at an altitude of 200 km. What is the hyperbolic excess velocity? **(02)**

6B. Calculate the radius of Earth's sphere of influence. Distance between Earth and Sun = 149,597,870 km; Mass of the Earth = 5.9737×10^{24} kg; Mass of the Sun = 1.9891×10^{30} kg. Can we change the launch window? If so, how? A qualitative answer is sufficient. **(03)**

6C. 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 semi-major axis from the initial orbit to the first transfer ellipse is 31,981 km. Calculate the total time of flight during the bi-elliptic transfer and total mass of propellant spent in the transfer maneuver. **(05)**