
MANIPAL INSTITUTE OF TECHNOLOGY

MANIPAL

A Constituent Institution of Manipal University

VI SEMESTER B.TECH. (AERONAUTICAL ENGINEERING)

END SEMESTER EXAMINATIONS, APRIL/MAY 2017

SUBJECT: SPACEFLIGHT DYNAMICS [AAE 4015]

REVISED CREDIT SYSTEM
(29/04/2017)

Time: 3 Hours MAX. MARKS: 50

Instructions to Candidates:

- Answer **ALL** the questions.
- Missing data may be suitable assumed.

1A. State the definitions of an inertial reference system and a non-inertial reference system. Newton formulated his laws with respect to a reference system fixed relative to the stars; is the system used by Newton a truly inertial reference system? Is the Earth an inertial or non-inertial reference system? **(02)**

1B. Find the components of the velocity vector at t = 1 second. If the position vector is given by $\bar{r} = (4 + 6t)\hat{e}_1 + t\hat{e}_2 + 3t\hat{e}_3$ **(03)**

1C. The motion of a planet around a star can be described by its position vector along the orbit referred to the inertial space, $\bar{r} = R\cos(\Omega t)i + R\sin(\Omega t)j$, with R and Ω constants, i and j are unit vectors in the x and y coordinates respectively, and t is the time coordinate. **(05)**

a. Show that the motion of the planet follows a direct circular orbit of radius R around the star at an angular velocity Ω.
b. Obtain the velocity vector of the planet, and show that it is perpendicular to $\bar{r}$ at all times.
c. Obtain the acceleration vector of the planet, and show that its direction is towards the origin at all times, and that the modulus of the acceleration is always proportional to the distance from the origin.
d. Calculate the specific angular momentum vector of the planet, and show that it is constant and perpendicular to the orbital plane at all times.

2A. State whether the following statements are true or false: **(02)**

a. The angular momentum in a central motion is constant and normal to the orbit plane.

b. The specific mechanical energy of a satellite orbiting around the Earth is constant if the satellite is subjected to any dissipative forces or external forces other than gravitational interactions.

2B. State 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. Suppose we observe an object in the ECI frame at position **(05)**

$$\bar{r} = 6524.8\hat{i} + 6862.8\hat{j} + 6448.3\hat{k}\ (\mathrm{km})$$

Moving with velocity

$$\bar{v} = 4.901\hat{i} + 5.534\hat{j} - 1.976\hat{k}\ (\mathrm{km/s})$$

Determine the orbital elements.

3A. At which condition, the Hohmann transfer of the Earth satellite operation becomes inefficient compare to Bi-elliptic transfer? **(02)**

3B. The satellite has a true anomaly of 90 degree. What will be the satellite's position, (i.e. true anomaly) 20 minutes later? **(03)**

3C. Write down the steps that are involved in the iteration to find orbital periods of rendezvous problem for two vehicles in same circular orbit. **(05)**

4A. If XY plane is a plane of symmetry of the body, which are the two products of inertia becomes zero? **(02)**

4B. Derive the transformation matrix to obtain the components of angular velocity ω_1, ω_2 and ω_3 in terms of Euler rates $\dot{\psi}$, $\dot{\theta}$ and $\dot{\phi}$. **(03)**

4C. Find the principal axes of inertia of the inertia tensor for the given principal moments of inertia **(05)**

$$[\bar{\bar{I}}] = \begin{bmatrix} 100 & -20 & -100 \\ -20 & 300 & -50 \\ -100 & -50 & 500 \end{bmatrix} \mathrm{kg.m^2}$$

$$\lambda_1 = 532.052\ \mathrm{kg.m^2};\ \lambda_2 = 295.840\ \mathrm{kg.m^2};\ \lambda_3 = 72.1083\ \mathrm{kg.m^2}$$

5A. Why the shallow angle re-entry is not preferable for ballistic missiles? **(02)**

5B. The cylindrical shell is rotating in torque-free motion about its longitudinal axis. If the axis is wobbling slightly, determine the ratio of l/r for which the precession will be prograde or retrograde. **(03)**

5C. Describe the following briefly: **(05)**

a. Sphere of activity
b. Launch Window
c. Planetary flyby
d. Aerobraking
e. Gravity Gradient Stabilization