1. (a) Describe the difference between over-expanded, under-expanded and ideally-expanded rocket nozzles.

(b) While on its way into orbit a space shuttle with an initial mass of 100,000 kg burns 1,000 kg of propellant through the engines of its orbital maneuvering system with an exhaust velocity of 2,000 m/s of the burnt out gases. Estimate the change in velocity (\(\Delta V\)) that has taken place.

\[8+8\]

2. (a) Define the following quantities in rocket propulsion:

i. Mass Ratio,
ii. Propellant Mass Fraction,
iii. Velocity Loss due to gravity, and
iv. Altitude loss due to gravity.

(b) A rocket has the following data:

- Propellant flow rate = 5 kg/s
- Nozzle exit diameter = 11 cm
- Nozzle exit pressure = 1.02 bar
- Ambient pressure = 1.013 bar
- Thrust = 7 kN

Determine the effective exhaust jet velocity, actual exhaust jet velocity and specific impulse.

\[8+8\]

3. Consider a spacecraft in an elliptical orbit around the Earth with a perigee altitude of 300 km and an apogee altitude of 1,000 km. Assuming the rocket exhaust velocity as 3,000 ms\(^{-1}\), estimate the magnitude of the change in velocity (\(\Delta V\)) required for orbit circularization. How much fuel, expressed as a fraction of the spacecraft mass, is required to achieve this?

\[16\]

4. (a) Describe the re-entry co-ordinate system.

(b) What are the forces that act on a re-entry vehicle? Among these which is the dominant force during re-entry. Explain clearly.

\[8+8\]

5. (a) How many sets of initial conditions can we use for solving the two body equation of motion? Give an example of one set of these.

(b) Calculate the altitude needed for a circular geosynchronous orbit.

\[8+8\]
6. The space shuttle carried a reconnaissance satellite into a 300 km circular parking orbit. Now the satellite is to be placed into an elliptical orbit with a perigee at 300 km and a period of 24 hours.

(a) Find the velocity of the satellite in the parking orbit.
(b) Find the ∆V required along with the characteristics of the new orbit.
(c) Find the ∆V required for a Hohmann transfer from the surface of a non-rotating Earth to the parking orbit. \[4+6+6\]

7. Write about the spin stabilization of a torque free axisymmetric rigid body. \[16\]

8. Explain the various parts of communication equipment in a satellite and their functions. \[16\]

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1. Write a note on the following:
   (a) Launch vehicles
   (b) Satellites and Interplanetary probes. [8+8]

2. Describe the rocket motion in a homogeneous gravitational field for two cases of pitch angles; (a) 90°, and (b) less than 90°. [16]

3. Consider the motion of a rocket in free space and obtain Tsiolkovsky’s equation to predict the velocity increment in the vehicle. Further, obtain expression for the velocity increment at its burnout condition. Discuss the ideal velocity variation for different mass ratios. [16]

4. Write a short note on the following aspects related to thermal protection systems of a re-entry vehicle:
   (a) Heat sink approach
   (b) Ablation approach
   (c) Radiative cooling approach
   (d) Ballistic coefficient. [4+4+4+4]

5. You are the engineer in charge of launching a satellite of 11,500 kg mass. The satellite will be placed in a circular sun - synchronous orbit, at an altitude of 800 km. What is the kinetic energy of the satellite? Compare this to the kinetic energy of a 400 kg lorry traveling on a straight road at 100 km/hour. Explain clearly whether the comparison is realistic. [16]

6. Write a short note on:
   (a) Hohmann transfer
   (b) Bi - elliptical transfers
   (c) Combined maneuvers. [5+5+6]

7. Explain, using neat sketches, about the mechanism to despin a satellite. [16]

8. Explain briefly about
   (a) Directed antenna
   (b) Omni-directional antenna [8+8]

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1. Explain in detail the potential hazards to a spacecraft due to micro-meteoroids and space junk. [16]

2. Describe the rocket motion in a homogeneous gravitational field for two cases of pitch angles; (a) $90^\circ$, and (b) less than $90^\circ$. [16]

3. Consider the motion of a rocket in free space and obtain Tsiolkovsky’s equation to predict the velocity increment in the vehicle. Further, obtain expression for the velocity increment at its burnout condition. Discuss the ideal velocity variation for different mass ratios. [16]

4. Describe the two requirements (a high value and a low value) for the hypersonic drag coefficient of a re-entry space vehicle. [16]

5. You are the engineer in charge of a satellite of mass 10,000 kg. The satellite will be placed in a circular sun-synchronous orbit, at an altitude of 750 km. One person says that the satellite poses a danger to the public because of its large kinetic energy so close to the Earth. What is the kinetic energy of the satellite? Compare this to the kinetic energy of a 200 kg truck (lorry) traveling on a road at 100 kmph. Is the comparison realistic? Why or why not? [16]

6. Write short notes on
   (a) Orbit Perturbations due to atmospheric Drag
   (b) Orbit perturbations from solar Radiation
   (c) Orbit perturbation due non-spherical Earth.
   (d) Third body perturbation. [4+4+4+4]

7. Write about the spin stabilization of a torque free axisymmetric rigid body. [16]

8. Explain briefly power generation and power storage in a satellite. [16]
1. Write a detailed note on radiation effects to both manned and unmanned spacecrafts.  

2. Explain the necessity of cooling in liquid rocket engines. Describe various active methods available for this purpose.

3. (a) What are the advantages and disadvantages of staging the rockets.
(b) A three stage rocket has been designed with the following characteristics, to deliver small pay loads to low Earth orbit.
   - Specific Impulse of 1st stage, \( I_{sp1} = 300 \) s
   - Specific Impulse of 2nd stage, \( I_{sp2} = 350 \) s
   - Specific Impulse of 3rd stage, \( I_{sp3} = 400 \) s
   - Mass of the pay load = 1,500 kg
   - Structural mass of the 1st stage = 10,000 kg
   - Structural mass of the 2nd and 3rd stages = 7,500 kg each
   - Mass of the propellant for 1st stage = 50,000 kg
   - Mass of the propellant for 2nd stage = 40,000 kg
   - Mass of the propellant for 3rd stage = 35,000 kg

   Estimate:
   i. Initial mass of the entire vehicle
   ii. Final mass of the 1st stage
   iii. Final mass of the 2nd stage
   iv. Final mass of the 3rd stage
   v. Velocity change (\( \Delta V \)) for the 1st stage
   vi. Velocity change (\( \Delta V \)) for the 2nd stage
   vii. Velocity change (\( \Delta V \)) for the 3rd stage
   viii. Initial mass of the 2nd stage
   ix. Initial mass of the 3rd stage
   x. Total velocity change (\( \Delta V \)) of the rocket.

4. Bring out the significance of Re-entry corridor. What do you understand by ‘overshoot’ and ‘undershoot’ boundaries in this context?

5. (a) What are the origin, principal direction and fundamental plane for the geocentric equatorial coordinate system?
(b) A satellite is in the Earth’s orbit with an altitude of perigee of 375 km and an altitude of apogee of 2,000 km
   i. What is the semi-major axis of the orbit?
   ii. What is the eccentricity?
   iii. If the true anomaly is 175°, what is the satellite’s altitude? [8+8]

6. (a) What are the assumptions that allow us to use the Hohmann transfer?
   (b) What makes Hohmann transfer the most energy efficient maneuver between co-planar orbits. [6+10]

7. Write about attitude control of a non-spinning spacecraft using
   i) thrusters and
   ii) using control moment gyros. [8+8]

8. (a) Write the important features of a satellite in geostationary orbit.
   (b) The Virginia Tech earth station is located at 80.438° longitude and 37.229° N latitude. Calculate the look angles (azimuth and elevation angles) to a geosynchronous satellite whose sub-satellite point is located at 121° W longitude.
   (c) Why do signal losses occur in the earth’s atmosphere for satellite communication? Write a note on ionospheric effects. [6+6+4]