INDIAN INSTITUTE OF TECHNOLOGY

Date Sept. 24 2002 FN Time : 2 Hrs. Full Marks 20 No. of Students 28

Autumn Mid-Semester, 02-03 Deptt. Aerospace Engineering Sub. No. 114003

IV Yr. B.Tech. (H) / Dual Degree Sub. Name SPACE DYNAMICS

Instruction Answer any FOUR Questions. OPEN BOOK EXAMINATION

1 (a) Consider a rocket vehicle in accelerated flight, in vertical direction through a gravitational field, in the absence of drag. Assuming constant thrust during powered flight obtain an expression for the loss in velocity due to the gravitational field in terms of the effective exhaust velocity, thrust-to-takeoff mass ratio and the mass ratio $\sigma = M_0/m_b$. (4)

(b) If the above vehicle has a thrust-to-takeoff weight ratio of 1.5 and a mass ratio of $\sigma = 8.0$ and develops an effective exhaust velocity of 3600 m/s, determine the loss in velocity due to the gravitational field. What is the percentage loss in over-all velocity increment? (1)

2 (a) Consider the accelerated flight of a flight vehicle at constant pitch angle (thrust altitude, Φ), in a gravitational field in the absence of Drag. If the vehicle axis co-incides with the thrust direction, obtain an expression for the instantaneous velocity of the vehicle. Also obtain an expression for the flight path angle. Under what conditions would the flight path angle β coincide with the pitch angle Φ? (3)

(b) A two-stage rocket launched vertically from earth consists of a first stage with $m_{s_1} = 200$ kg and $m_{p_1} = 1200$ kg, a second stage with $m_{s_2} = 50$ kg and $m_{p_2} = 500$ kg and a final payload, $m_L = 200$ kg. I_{sp} for each stage is 250 s. Calculate maximum altitude reached by the payload: (i) when the two stages ignite in series without any coasting between the stages, (ii) when the second stage is allowed to coast to its maximum altitude after the first stage burn-out and separation and is then ignited in a burn-coast-burn-coast strategy. Ignore the effects of burn time and atmospheric drag in both the cases. Which strategy will lead to higher altitude and why? Will this vehicle insert the payload into a circular orbit of radius 6600 km around earth? (2)

3 (a) $\vec{r}_0$ and $\vec{v}_0$ are the position and velocity vectors at time t_0 when a satellite is at a true anomaly of θ_0. Using two-body equation of motion, show that the eccentricity vector is given by: $\vec{e} = \frac{\mu e}{h^2}(e + \cos\theta_0)\vec{r}_0 - \frac{r_0 e}{h}\sin\theta_0 \vec{v}_0$ where h is the specific angular momentum (2)

(b) A satellite of mass 360 kg is orbiting the earth with an apogee height of 1600 km and a perigee height of 240 km. Determine the eccentricity of the orbit.

PTO

N.B. 1. Questions must not be written beyond the border lines. 2. Please use only BLACK INK

Signature of the Paper - Setter

B.N. SREEDHAR
Name in Capital Letter

An apogee boost motor with a 220N constant thrust, on board the Satellite is fired to place the Satellite on a circular orbit at the apogee. How long should the boost motor should be fired? would you consider this as an impulsive maneuver? (3)

4 Determine, if possible, the six orbital elements for the objects A, B and C, executing the following motion :

(a) Object A crossing the negative $\hat{J}$ axis in a direct, equatorial, circular orbit at an altitude of 6378 Km.

(b) Object B departing from a point $\vec{r} = -6378\,\hat{k}$ km with the local escape speed in the direction of $-\hat{I}$

(c) Object C departing from a point $\vec{r} = 6378\hat{k}$ km with $\vec{V} = 11.18(\hat{I}+\hat{J})$ km/s. (5)

5 (a) A radar station makes the observation of a probe and gives the following range and argument of true anomaly data, reduced to geocentric equatorial Co-ordinates: (12756 Km, 144°), (13531 km, 189°) and (13150 Km, 159°). Determine whether this probe will escape from earth, or is an earth satellite or is actually a missile. (2)

(b) Consider the Hohmann transfer between two circular orbits of radii $r_1 = 1$ unit and $r_2 = 2$ units. Assume that $\mu = 1$ unit for simplicity. For the transfer orbit, determine the eccentricity and the specific angular momentum. Determine the total velocity increment required for successful transfer. What is the difference in angular momentum between the transfer orbit and the final circular orbit? Determine the time of flight on the transfer trajectory. (3)

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