INSTITUTEOFAERONAUTICALENGINEERING

(Autonomous)

Dundigal,Hyderabad-500043

AERONAUTICAL ENGINEERING

TUTORIAL QUESTION BANK

Course Name	:	**SPACE MECHANICS**
Course Code	:	**A72124**
Class	:	VI B. Tech I Semester
Branch	:	Aeronautical Engineering
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Course Coordinator	:	Dr P K Mohanta, Associate Professor, Department of AE
Course Faculty	:	Dr P K Mohanta, Associate Professor,Department of AE

OBJECTIVES

To meet the challenge of ensuring excellence in engineering education, the issue of quality needs to be addressed, debated and taken forward in a systematic manner. Accreditation is the principal means of quality assurance in higher education. The major emphasis of accreditation process is to measure the outcomes of the program that is being accredited.

In line with this, Faculty of Institute of Aeronautical Engineering, Hyderabad has taken a lead in incorporating philosophy of outcome based education in the process of problem solving and career development. So, all students of the institute should understand the depth and approach of course to be taught through this question bank, which will enhance learner’s learning process.

SNo.	QUESTION	Blooms taxonomy level	Course Outcomes
	UNIT - I **BASIC CONCEPTS**		
	Part - A (Short Answer Questions)		
1	What are the constituents of solar system?	Remember	1
2	Classify the meteors in its size. Explain each one.	Understand	1
3	Define the first law of Kepler with suitable illustration.	Understand	1
4	What is celestial sphere?	Understand	3
5	What is hoar circle? Explain.	Understand	2
6	Define Equinox.	Remember	1
7	Define duranat motion.	Understand	1
8	What is an elliptic in space science?	Understand	2
9	How many types of reference frame are there? Write briefly about each.	Remember	1
10	What is geocentric reference frame? Explain.	Remember	1

11	What is difference between geocentric non-rotating and rotating reference frame? What is their significance?	Remember	2
12	Explain about the motion of vernal equinox.	Remember	1
13	What do you mean by ECI? Explain.	Understand	1
14	Classify various coordinate systems and explain any one.	Understand	1
15	Compare ECT with GCS.	Understand	1
16	What are the time systems used in space mechanics?	Understand	1
17	What do you mean by Julian date? Explain.	Understand	1
Part - B (Long Answer Questions)			
1	Briefly explain about Solar system.	Remember	1
2	For a circle the distance 'a' and 'b' are equal. Find the eccentricity of a circular orbit and give relationship between the periapsis, apoapsis and semi-major axis distance.	Remember	1
3	Using eccentricity define various types of orbit possible with their eccentric values.	Understand	2
4	On a NASA mission the space shuttle Atlantis orbiter was reported to weigh 239,255 lb just prior to lift-off. On orbit 18 at an altitude of about 350 km, the orbiter's weight was reported to be 236,900 lb. What was the mass, in kilograms, of Atlantis on the launch pad and in orbit?	Remember	2
5	Show that in the absence of an atmosphere, the shape of a low altitude ballistic trajectory is a parabola. Assume the acceleration of gravity g is constant and neglect the earth's curvature.	Understand	2
6	What is a reference frame? Explain various types of reference frame used in space mechanics.	Remember	2
7	Classify different time systems used in space mechanics. What do you mean by universal time and ephemeris time?	Understand	2
8	Describe the different coordinate system used in space manoeuvre. What are the significance of geographic coordinate system?	Understand	1
9	Write a short note on ecliptic system and azimuth coordinate system.	Remember	2
10	Compare the significance of each coordinate system.	Remember	2
Part - C (Problem Solving and Critical Thinking Questions)			
1	If (λ1, β1), (λ2, β2) and (λ3, β3) are the heliocentric ecliptic longitudes and latitudes of a planet at three points in its orbit, prove that $\tan\beta_1 \sin(\gamma_2-\gamma_3)+\tan\beta_2 \sin(\gamma_3-\gamma_1)+\tan\beta_3 \sin(\gamma_1-\gamma_2)=0$	Remember	2
2	With the knowledge that it takes the moon 27.32(sidereal) days to complete one orbit around the earth, determine the semi-major axis of the moon's orbit.	Understand	2
3	The moon is in a slightly elliptical orbit around the earth (e=0.055). Determine the moon's apogee and perigee distance in both miles and kilometers.	Understand	2
4	Due to thrust limitations and the reaches of the atmosphere, the space shuttle is limited to operations between about 200km to 800km altitudes. From this information, determine the orbital parameters associated with an elliptical orbit between these two altitudes.	Remember	2

5	Due to drag considerations, the lowest altitude at which the space shuttle can operate isaround 200km. for a shuttle in a circular orbit at this altitude, determine the following orbital parameters: a) Semi-major axis b) Orbitalperiod c) Totalenergy d) Eccentricity e) Orbital velocity	Understand	2
6	On February 20, 196, John Glenn became the first American to orbit the earth. At apogee. His altitude reached 260.9km and his perigee altitude was 160.9km. Determine the following parameters for his orbit: a) Semi-major axis b) Orbitalperiod c) Totalenergy d) Eccentricity e) Perigeevelocity f) Apogee velocity	Understand	2
7	At some specified time the position of a spacecraft is at a right ascension of 30° and a declination of 60°. The obliquity (inclination) of the ecliptic is 2.5°. a) Find the ecliptic longitude and latitude of the position by using spherical trigonometry. b) Obtain the same result by using the transformation of coordinate systems based on Eulerangles.	Remember	2
8	Let ω (t) be the angular velocity of the orthonormal coordinate frame (x_1, x_2, x_3) relative to the orthonormal coordinate frame (X_1, X_2, X_3). Let ω_1, ω_2, $\omega_3$be the x_1, x_2, $x_3$components of ω. (In many applications to the control of the attitude of space vehicles, the first coordinate frame would be fixed to the vehicle, the second coordinate frame would be an inertial frame. However, the formulation of this problem is purely kinematic, hence independent of the assumption of an inertial frame.) a) Defining the Euler angles for coordinate frame and explain.	Remember	2
UNIT - II TWO-BODY AND RESTRICTED THREE BODY PROBLEMS			
Part – A (Short Answer Questions)			
1	What is a n-body problem?	Remember	4
2	What is three body problem? What are the methods of solutions?	Remember	3
3	Write the Jacobi's integral mathematically and explain each term.	Understand	3
4	Write the Roche equipotential theory.	Remember	3
5	Draw the different points of liberation.	Remember	3
6	What is a two body problem? Explain with examples.	Remember	3
7	Show the velocity hodograph for ellipse, parabolic and hyperbolic motion.	Understand	3
8	Draw a trajectory in conic section showing semi-latus rectum and dietrix.	Remember	3
9	What is period of an elliptical orbit?	Remember	3
10	What are the orbital elements?	Remember	3
Part - B (Long Answer Questions)			
1	What is an n-body problem? What are the limitations in n-body problem?	Understand	3

2	Provethat $Fg = -Gm_i \sum_{j=1}^{n} \frac{m_j}{r_{ji}^{3}} (r_{ji})$ when j≠1	Remember	4
3	Assuming suitably prove that $\ddot{r} + \frac{\mu}{r^3} r = 0$	Remember	4
4	Using conservation of mechanical energy show that $\xi = \frac{\vartheta^2}{2} - \frac{\mu}{r} + c$	Understand	4
5	Explain the conservation of angular momentum and show that h = r× v	Understand	3
6	Prove that $r = \frac{\frac{h^2}{\mu}}{1+\frac{B}{\mu}\cos\gamma}$	Understand	3
7	Write the general equation of conic section and justify $$r = \frac{p}{1 + e\cos\gamma}$$	Understand	1
8	Show that a) $r = \frac{p}{1+e} = a(1-e)$ b) $r = \frac{p}{1-e} = a(1+e)$	Understand	2
9	Using geometry of an orbit prove that $\xi = -\frac{\mu}{2a}$	Remember	4
10	Show that TP $= \frac{2\pi}{\sqrt{\mu}} a^{\frac{3}{2}}$	Remember	4
Part – C (Problem Solving and Critical Thinking)			
1	In an inertial coordinate system, the position and velocity vectors of a satellite are, respectively, (4.185I + 6.2778J + 10.463K) 10^7 ft and (2.5936 I + 5. 1872 J) 10^4 ft/sec where I, J, and K are unit vectors. Determine the specific mechanical energy, ξ, and specific angular momentum, h. Also, find the flight path angle, ϕ.	Understand	2
2	The position and velocity of the satellite at a given instant are described by i. r = 2I + 2J + 2K ii. v = -0.4I + 0.2J + 0.4K where I J K is a non-rotating geocentric coordinate system . Find the specific angular momentum and total specific mechanical energy of the satellite.	Understand	4
3	For a certain satellite the observed velocity and radius at v = $90^0$is observed to be 45000ft/sec and 4000 n mi, respectively. Find the eccentricity of the orbit.	Understand	4
4	Six constants of integration (or effectively, 6 orbital elements) are required for a complete solution to the two-body problem. Why in general, is a completely determined closed solution of the n-body problem an impossibility if $N \geq 3$?	Understand	4
5	A sounding rocket is fired vertically. It achieves a burnout speed of 1000ft/sec at an altitude of 1,00,000ft. Determine the maximum altitude.(Neglect atmospheric drag)	Understand	4
6	Calculate the altitude $z_{GEO}$and speed $v_{GEO}$of a geostationary earth satellite. The speed of the satellite in its circular GEO ofradiusr_{GEO} is $v_{GEO} = \sqrt{\frac{\mu}{r_{GEO}}}$	Remember	4

7	An earth satellite is in an orbit with perigee altitude z_p= 400$km$and an eccentricity e=0.6.find a) Theperigeevelocity,v_p b) Theapogeeradius,r_a c) The Semi-major axis,a d) Thetrueanomaly-averageradius$r\overline{\theta}$ e) The apogee velocity f) The period of the orbit g) Thetrueanomalywhenr=$r\overline{\theta}$ h) Thesatellitespeedwhenr=$r\overline{\theta}$ i) Theflightpathangleγwhenr=$r\overline{\theta}$ j) Themaximumflightpathangleγ_{max}andthetrueanomalyat which itoccurs. The strategy is always to go after the primary orbital parameters, eccentricity and angular momentum, first. In this problem we are given eccentricity, so we will first seek hμ = 398600$\frac{km^3}{s^2}$and also thatR_E = 6378km.	Remember	4
8	The perigee of a satellite in a parabolic geocentric trajectory is 7000km. Find the distance d between point'sP_1 and P_2 on the orbit which are 8000km and 16000km, respectively, from the center of the earth.	Understand	4
9	At a given point of a spacecraft's geocentric trajectory, the radius is 14600km, the speed is 8.6km/sec and the flight path angle is 50^0. Show that the path is in hyperbola and calculate the following a) C_3 b) Angularmomentum c) Trueanomaly d) Eccentricity e) Radius ofperigee f) Turnangle g) Semi major axisand h) Aimingradius	Understand	4
10	Given two spherically symmetric bodies of considerable mass, assume that the only force that acts is a repulsive force, proportional to the product of the masses and inversely proportional to the cube of the distance between the masses that acts along the line connecting the centres of the bodies. Assume that Newton second law holds and derive a differential equation of motion for these bodies.	Understand	4
UNIT-III BASIC ORBITAL MANEUVRES AND ORBIT PERTURBATIONS			
Part - A (Short Answer Questions)			
1	Why it is difficult to keep the satellite at low earth orbit?	Remember	5
2	What are the causes of perturbation of low earth orbit?	Understand	5
3	Why it's better to design a circular orbit at low earth altitudes than an Ellipse?	Understand	5
4	Explain the advantages of design in high altitude earth orbits.	Understand	5
5	Define the synchronous orbit.	Understand	5
6	Draw and explain a trajectory for sending a satellite to high altitude earth orbit.	Remember	5

7	Define Hohmann transfer method with suitable illustration.	Remember	5
8	What do mean by coplanar transfer?	Understand	5
9	Explain the technique of out of plane transfer.	Remember	5
10	Give the mathematical relation of perigee and apogee height corrections.	Understand	5
11	What do you mean by orbit perturbation?	Understand	5
12	What are the causes of perturbation of satellite orbit?	Remember	6
13	Write the earth gravitational effect on perturbation of satellite.	Understand	6
14	Explain about celestial influence like lunisolar effect on orbit perturbation	Remember	6
15	How the solar radiation pressure effect on perturbation of satellite orbit?	Understand	5
16	Discuss the effect of atmospheric drag on satellite path displacement.	Understand	5
17	Write the tidal friction effects on satellite path perturbation.	Remember	5
18	Explain the mutual gravitation disturb the path and cause change of the orbit.	Remember	5
19	What is J_2 and how it effects to satellite motion?	Understand	5
20	What do you mean by critical inclination? Explain its impact on satellite motion.	Remember	5
21	What is a sun-synchronous orbit? Explain with diagram.	Understand	5
22	What is a frozen orbit? Explain about J_3 effect.	Remember	5
23	Write about the effect of the Earth triaxiality.	Remember	5
24	Discuss about east-west station keeping.	Understand	5
Part – B (Long Answer Questions)			
1	What is a low altitude Earth orbit? What are the significances of designing Lowaltitude Earth Orbit?	Understand	5
2	Explain about direct ascent and method of putting satellite at low earth orbit with suitable diagram.	Remember	5
3	Describe the problem associated with low earth orbit design and cause of perturbation.	Remember	6
4	Calculate the design methodology fixation of perigee and apogee distance in low earth orbit and explain.	Understand	6
5	What is high altitude Earth orbit? Describe the uses of high altitude earth orbit. Explain the types of orbit possible at high altitude.	Understand	6
6	What is a synchronous orbit? Write the characteristics of geostationary orbit. What are the methods of sending satellite to synchronous orbit?	Understand	6
7	What are the cause of in plane disturbances and method of correction of the trajectory?	Understand	6
8	Explain about the Hohmann transfer method and explain it with suitable diagram.	Understand	6
9	Explain the methodology used on satellite transfer. Discuss the difference between in plane and out of plane transfer.	Understand	6
10	What are the orbital parameters required to design an orbit? What are the limitations on design?	Understand	6
11	Discuss briefly the various cause of satellite perturbation.	Understand	6
12	Signify the cause of perturbation by the earth oblateness.	Understand	6
13	Justify the effect of J_2 on stability of satellite orbit.	Understand	6

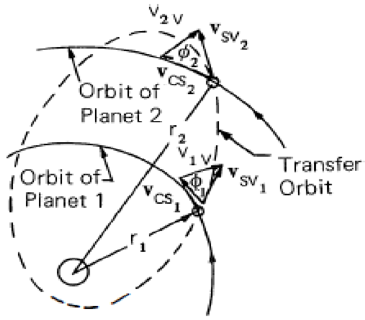
14	Explain the effect of critical inclination and the earth triaxiality on satellite motion.	Understand	6
15	What do you mean by J3? Explain about the frozen orbit.	Understand	6
16	What is east-west station keeping and why it is essential?	Understand	6
Part – C (Problem Solving and Critical Thinking)			
1	A satellite is orbiting the earth in a 500nm circular orbit. The ascending node moves to the west, completing one revolution every 90 days. a) What is the inclination of theorbit? b) It is desired that the ascending node make only one revolution every 135 days. Calculate the new orbital inclination required if the satellite remains at the samealtitude.	Understand	6
2	A communications satellite is in a circular orbit of radius 2DU, find the minimum Δvrequired to double the altitude of the satellite.	Understand	6
3	It is desired to transfer supplies from a 0.1DU circular parking orbit around the earth to a space station in a 4DU coplanar circular orbit. The transfer will be accomplished via an elliptical orbit tangent to the lowest orbit and crossing the high orbit at the end of the minor axis of the transfer orbit. a) Determine the total Δvrequired to accomplish themission. b) If the space station orbit is inclined at an angle of 10^0 to the low parking orbit, calcite the additional Δvrequired for the simple plane change necessary to accomplish the transfer. Assume the plane change is performed after you have established the shuttle vehicle in a 4DU circularorbit.	Understand	6
4	What is the inclination of a circular orbit of period 100 minutes designed such that the trace of the orbit moves eastward at the rate of 3^0per day?	Understand	6
5	Two satellites are orbiting the earth in circular orbits-not at the same altitude or inclination. What sequence of orbit changes and plane changes would most efficiently place the lower satellite in the same orbit as that of the higher one? Assume only one maneuver can be performed at a time, i.e., a plane change or an orbit transfer.	Understand	6
6	Calculate the total Δvrequired to transfer from a circular orbit of radius 1DU to a circular orbit of infinite radius and the back to a circular orbit of 15DU, using Hohmanntransfers. Compare this with the Δvrequired to make a Hohmann transfer from the 1DU circular orbit directly to the 15DU circular orbit. At least 5 digits of accuracy are needed for this calculation.	Understand	6
7	A spacecraft returning from a lunar mission approaches earth on a hyperbolic trajectory. At its closest approach A it is at an altitude of 500km, travelling at 10km/sec. at A retrorockets are fired to lower the spacecraft into a 500km altitude circular orbit, where it is to rendezvous with a space station. Find the location of the space station at retrofire so that rendezvous will occur atB.	Understand	6
8	Find the total –v requirement for a bi-elliptical Hohmann transfer from a geocentric circular orbit of 7000km radius to one of 105000 km radius. Let the apogee of the first ellipse be 210000km. Compare the Δv schedule and total flight time with that for an ordinary single Hohmann transfer ellipse.	Understand	6
9	Spacecraft at A and B are in the same orbit. The chaser vehicle at A executes a phasingmanoeuvre so as to catch the target spacecraft back at A after just one revolution of the chaser's phasing orbit. What is the required total Δv	Understand	6

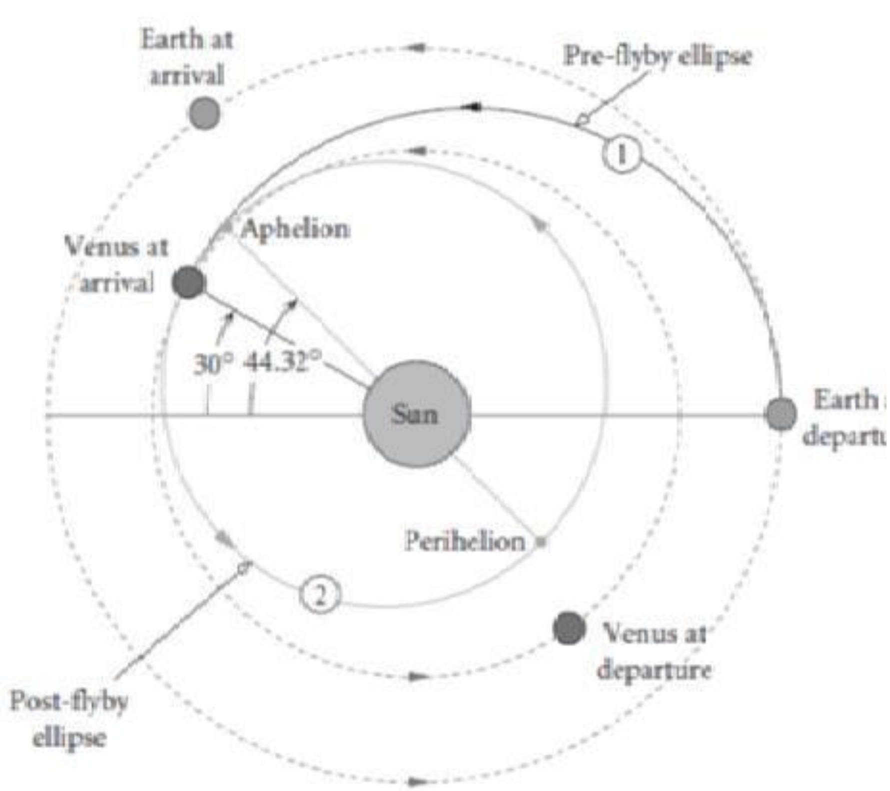
10	It is desired to shift the longitude of GEO satellite 12^0 westward in three revolution of its phasing orbit. Calculate the Δv requirement.	Understand	6
11	Calculate the radius of the earth's sphere of influence on perturbation if the following parameters are taken $m_{earth}=5.974\times10^{24}$kg $m_{sun} = 1.989 \times10^{30}$kg $R_{earth} = 149.6 \times10^6$km	Understand	4
12	Consider a Hohmann transfer from a circular orbit of radius r1 to a second, coplanar circular orbit of radius r_2. Let Δv the sum of the two velocity increments needed for the maneuver.Show that for a fixed gravitational parameter and radius $r_1$the maximum required Δv occurs for r_2= 15.58rl.	Understand	2
13	Consider a spacecraft that costs on a minimum energy elliptic path in thegravitational field of the sun. The path starts at a point P1 in the vicinityof Jupiter. P1 is at 75.00^0ecliptic longitude, 1.00^0ecliptic latitude, and at aradius from the sun's center of 5.150 AU. It ends at point P2 in the vicinity ofPluto. P2 is at 335.00^0ecliptic longitude, - 12.00^0ecliptic latitude and at a radius of 38.00 AU. (1 AU = 1.495979 10^8 km; gravitational parameterf the sun = 1.32712 10^{11}km^3/s^2.) (a) Compute the semi major axis and eccentricity of thepath. (b) Compute the time required to travel from P1 toP2.	Understand	6
	UNIT-IV **BALLISTIC MISSILE TRAJECTORIES**		
	Part – A (Short Answer Questions)		
1	Write about ballistic missile problems.	Remember	7
2	Write down the geometry of the trajectory of a ballistic missile.	Remember	7
3	Write the flight path angle equation.	Remember	7
4	Define maximum range trajectory.	Remember	7
5	Define time of free flight.	Understand	7
6	Write about the errors occurring on range.	Remember	7
7	Define burnout point.	Understand	7
8	Write short notes about zenith.	Remember	7
9	Define burn out flight path angle	Understand	7
10	Explain down range errors.	Understand	7
11	Describe the general ballistic problem.	Remember	4
12	Explain geometry of the trajectory of a ballistic missile.	Understand	4
13	Describe the maximum range trajectory.	Remember	5
14	Explain in detail about the launching errors.	Understand	4
15	Describe about the cross range error	Remember	5
16	Explain the various down range errors.	Understand	4
17	Explain errors in burn out in flight path angle.	Understand	4
18	Describe the movement of the target due to the earth rotation.	Remember	5
19	Describe in detail about the time of free flight.	Remember	5
20	Explain the effect of lateral displacement.	Understand	4

Part – B (Long Answer Questions)			
1	Define the general problems of ballistic missile. Illustrating trajectory of a ballistic missile, mark the flight path and explain.	Remember	7
2	Derive the free flight range equation.	Understand	5
3	Determine the flight path angle equation.	Remember	7
4	Find out the maximum and minimum range of trajectory for ballistic missile.	Understand	4
5	Define the term "time of free flight", what are the parameters to be considered and during free flight conditions?	Remember	5
6	"A ballistic missile was observed to have a burnout speed and altitude" for free flight range. Justify it.	Understand	5
7	Determine the time duration of free flight for a ballistic missile.	Understand	6
8	What do you mean by launching error? Determine the lateral displacement effect on burnout point.	Remember	6
9	What is a cross range error? Explain about it.	Remember	7
10	With suitable diagram explain about the effect of down-range displacement of the burnout point.	Understand	7
11	Calculate the errors in burnout flight path angle $\emptyset_{bo}$	Understand	5
12	Determine the down range errors caused by incorrect burnout height.	Understand	7
13	What are the effects on ballistic trajectory due to the earth rotation?	Understand	7
14	How it can be compensated for initial velocity of the missile due to the earth rotation?	Understand	7
15	Determine the compensation through movement of the target due to the earth rotation.	Understand	7
16	What values of $\emptyset$may be used in $\sin\frac{\psi}{2} = \frac{Q_{bo}}{2-Q_{bo}}$? Why?	Understand	7
Part – C (Problem Solving and Critical Thinking)			
1	The following measurements were obtained during the testing of an ICBM: v_{bo}= .926DU/TU, r_{bo}= 1.05DU $\emptyset_{bo}$= 10°, R_p= 60$n.mi$ R_{re}=300n.mi What is R_t=?	Understand	5
2	A ballistic missile is launched from a submarine in the Atlantic (30°N, 75°W) on an azimuth of 135°. Burnout speed relative to the submarine is 16000ft/sec and at an angle of 30° to the local horizontal. Assume the submarine lies motionless in the water during the firing. What is the true speed of the missile relative to the centre of the rotating earth?	Remember	6
3	A ballistic missiles burnout point is at the end of the semi-minor axis of an ellipse. Assuming burnout altitude equals re-entry altitude, and a spherical earth, what will the value of Q be at re-entry?	Remember	4
4	What is the minimum velocity required for a ballistic missile to travel a distance measured on the surface of the earth of 5040n.mi? Neglect atmosphere and assume r_{bo}=1DU.	Remember	3

5	A ballistic missile is capable of achieving a burnout velocity of 0.83 DU/TU at an altitude of 1.06DU. What is the maximum free-flight range of this missile in nautical miles? Assume a symmetrical trajectory.	Understand	2
6	A rocket testing facility located at 30°N, 100°Wlaunches a missile to impact at latitude of 70°S. a lateral displacement, ΔX; in the launch causes the rocket to burnout east of the intended burnout point. In what direction will the error at impact be?	Remember	6
7	Assuming that the maximum allowable cross-range error at the impact point of a Ballistic missile is 1.0n.mi where the free flight range of the ballistic missile is 5400n.mi, how large can Δx and $\Delta\beta$be?	Understand	9
8	In general will a given $\Delta\emptyset_{bo}$cause a large error in a high or low trajectory? Why?	Understand	7
9	AssumingΔr_{bo}=1.0DUforaballisticmissile,whatistheminimum burnout velocity required achieving a free-flight range of 1800n.mi?	Understand	6
10	Show that for maximum range: Q_{bo}= $1 - e^2$where e is the eccentricity.	Understand	7
UNIT-V INTERPLANETARY TRAJECTORIES			
Part - A (Short Answer Questions)			
1	Write about patched conic approximation	Understand	7
2	Define Bodes law	Remember	4
3	Define heliocentric orbit.	Remember	5
4	Define phase angle of departure.	Remember	5
5	Define synodic period	Remember	6
6	Write about fast interplanetary trajectories	Understand	7
7	Write about trajectory types	Remember	4
8	Define selenocentric orbit.	Remember	3
9	What are planet locations?	Understand	2
10	Define effective collision	Remember	2
11	Explain about the heliocentric orbit.	Remember	1
12	Describe about the phase angle at departure	Remember	2
13	Explain about the escape from the earth's sphere of influence.	Understand	2
14	Explain about the arrival of target planet.	Understand	2
15	Explain effective collision cross section.	Understand	2
16	Explain in detail about the process in locating planets.	Understand	2
17	Describe synodic period with respect to interplanetary trajectories.	Remember	1
18	Describe the process of gravity assist maneuver.	Remember	1
19	Explain fast inter planetary trajectories.	Understand	1
20	Describe about the patched conic approximation.	Remember	1
Part - B (Long Answer Questions)			
1	Explain about Bode's law.	Understand	1
2	What are the orbital elements and physical constants of planetary distribution?	Understand	2
3	What do you mean by Patch conic? Explain briefly. Why it is required on interplanetary trajectory?	Understand	2

4	Describe briefly about the Helio centric transfer orbit with suitable diagram.	Remember	1
5	Calculate velocity and time required on Helio centric transfer.	Remember	3
6	What is a phase angle at departure? Explain through suitable figure.	Understand	1
7	What is a synodic period and how will you determine it?	Remember	1
8	With suitable drawing explain the method of escaping from the earth's sphere of influence.	Understand	2
9	Determine the energy and velocity desired for escaping from the earth's sphere of influence.	Understand	2
10	Explain through suitable drawing, method of space vehicle at another approaching planet.	Understand	2
11	Determine ξ_t, h_t, v_2 and ϕ_2 for approaching space vehicle at some other planet in interplanetary mission.	Understand	2
12	Give a brief account on effect of collision cross section and Understand it through suitable sketches.	Understand	4
13	What is a non-polar interplanetary trajectory? Write the relationship for Δv.	Understand	4
14	Determine the synodic period of Mars.	Understand	2
	Part – C (Problem Solving and Critical Thinking)		
1	Calculate the velocity requirement to fly a solar probe into the surface of the Sun. used a trajectory which causes the probe to fall directly into the Sun (a degenerate ellipse).	Understand	3
2	Calculate the radius of the earth's sphere of influence with respect to the Sun.	Understand	3
3	Find the distance from the Sun at which a space station must be placed in order that a particular phase angle between the station and earth will repeat itself every 4 years.	Understand	4
4	In preliminary planning for any space mission, it is necessary to see if we have the capability of actually producing the velocity required to accomplish this mission. a) The space vehicle is in a circular orbit about the earth of 1.1DU radius. What is the speed necessary to place the vehicle on a parabolic escape path? What is the Δv required? b) Actually we want a hyperbolic excess speed of 5000ft/sec. what must our speed be as we leave the circular orbit? c) It can be shown that $\Delta v = c \ln M$ where c is the effective exhaust velocity of the engine and $M = \frac{m_o}{m_{bo}}$. If c=9000ft/sec what is the ratio of the initial mass to burnout mass?	Understand	2
5	With the use of Hohman transfer analysis calculate an estimate of the total Δv required to depart from Earth and soft land a craft on Mars. What would be an estimate of the return Δv? Give the answer inkm/sec.	Understand	3
6	To accomplish certain measurements of phenomena associated with sunspot activity, it is necessary to establish a heliocentric orbit with a perihelion of 0.5AU. The departure from the Earth's orbit will be at apohelion. What must the burnout velocity be at latitude of 0.2 DU⊙ to accomplish the mission?	Understand	4

7	The figure shown below illustrates the general coplanar interplanetary transfer.  Show that $$V_{iV} = \frac{\left\{\mu_\Theta\left[\frac{3}{r_i} - \frac{(1-e_\Theta^2)}{p_\Theta} - 2\sqrt{\frac{p_\Theta}{r_i^3}}\right]\right\}^{\frac{1}{2}} AU}{TU}$$ $$V_{iV} = \left\{\mu_\Theta\left[\frac{3}{r_i} - \frac{2\varepsilon_\Theta}{\mu_\Theta} - \frac{2h_\Theta}{TP_i\mu_\Theta}\right]\right\}^{\frac{1}{2}} AU/TU$$ where $V_{iV}$is the speed of the space vehicle relative to planet i. $r_i$is the heliocentric orbit radius of planet i. e_Θ is the eccentricity of the heliocentric transfer orbit. p_Θ is the parameter of the heliocentric transfer orbit. ε_Θ is the specific mechanical energy of the heliocentric transfer orbit. h_Θ is the specific angular energy of the heliocentric transfer orbit. TP_i is the period of planet I in sidereal years. Note that $V_{iV}=V_\infty$ at planet i.	Understand	2
8	A spacecraft is launched on a mission to Mars starting from a 300 km circular parking orbit. Calculate (a) the delta-v required; (b) the location of perigee of the departure hyperbola; (c) the amount of propellant required as a percentage of the spacecraft mass before the delta-v burn, assuming a specific impulse of 300 seconds. μ_{sun} =1.327x10^{11} km^3/s^2, μ_{earth} =398600km^3/s^2 and orbital radii of the earth and Mars, R_{earth} = 149.6x10^6 km and R_{Mars} = 227.9x10^6 km.	Understand	6
9	After a Hohmann transfer from earth, calculate the minimum Δv required to place a spacecraft in Mars orbit with a period of seven hours. Also calculate the periapse radius, the aimimg radius and the angle between periapse and Mars' velocity vector. μ_{sun} =1.327x10^{11} km^3/s^2, μ_{Mars} =42830 km^3/s^2 and orbital radii of the earth and Mars, R_{earth} = 149.6x10^6 km and R_{Mars} = 227.9x10^6 km, r_{Mars}= 3396 km.	Understand	3

<table>
<tr><td>10</td><td>A spacecraft departs earth with a velocity perpendicular to the sun line on a flyby mission to Venus. Encounter occurs at a true anomaly in the approach trajectory of - 30^0. Periapse altitude is to be 300km.
(a) For an approach from the dark side of theplanet,
(b) For an approach from the sunlit side of theplanet.

</td><td>Understand</td><td>6</td></tr>
<tr><td>11</td><td>On 1 Dec., 2005 a spacecraft leaves a 180km altitude circular orbit around the earth on a mission to Venus. It arrives at Venus 121 days later on 1 April 2006, entering a 300km by 9000km capture ellipse around the planet. Calculate the total Δv requirement for thismission.</td><td>Understand</td><td>2</td></tr>
<tr><td>12</td><td>Calculate the propellant mass required to launch a 2000kg spacecraft from a 180km circular orbit on a Hohmann transfer trajectory to Saturn. Calculate the time required for the mission and compare it to that of Cassini. Assume the propulsion system has a specific impulse of 300s.</td><td>Understand</td><td>2</td></tr>
<tr><td>13</td><td>Suppose a spacecraft approaches Jupiter on a Hohmann transfer ellipse from the earth. If the spacecraft flies by Jupiter at an altitude of 200000km on the sunlit side of the planet, determine the orbital elements of the post flyby trajectory and Δv imparted to the spacecraft by Jupiter's gravity. Assume that all of the orbits lie in the same (ecliptic) plane.</td><td>Understand</td><td>3</td></tr>
<tr><td>14</td><td>A spacecraft is on a 8000 km radius, circular orbit about Mars. A short duration, impulsive thrust in the direction of motion is applied to increase the spacecraft's velocity further. Find numerically the minimum velocity increment that is needed to cause the spacecraft to escape from the Mars gravitational field. (The gravitational parameter of Mars is $42.81\text{x}10^3\ km^3/s^2$.)</td><td>Understand</td><td>4</td></tr>
</table>

15	An astronaut on the surface of the Moon observes an artificial lunar satellite pass through his zenith with a certain angular velocity. Assuming the satellite to be in a circular orbit at a height of 400 km above the Moon's surface, calculate the observed angular velocity in degrees per second. Calculate the selenocentric radius vector of an artificial lunar satellite moving in a circular orbit in the plane of the lunar equator that would always have the same selenographic longitude. Why is it not possible to have a satellite in such an orbit?	Understand	5
16	Find to four significant figures the distance of the so-called neutral point on the Earth-Moon line of centres from the Earth's centre as a fraction of the Earth-Moon distance (take the Moon's mass to be 1/81.25 that of the Earth). Find the distance from the Earth of the other point on this line at which the magnitudes of the forces of Earth and Moon on a probe are equal.	Understand	5

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