INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)

Dundigal, Hyderabad - 500 043

AERONAUTICAL ENGINEERING

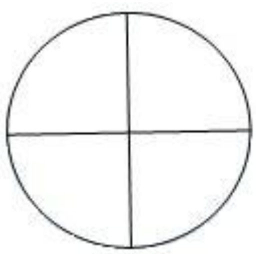
ASSIGNMENT

Course Name	:	**SPACE MECHANICS**
Course Code	:	**A72124**
Class	:	IV B. Tech I Semester
Branch	:	AERO
Year	:	2018 – 2019
Course Coordinator	:	Dr. P K Mohanta, Associate Professor
Course Faculty	:	Dr. P K Mohanta, Associate Professor

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.

S. No	Question	Blooms Taxonomy Level	Course Outcome
	ASSIGNMENT-I **UNIT-I**		
1	Explain about solar system and its various constituents. Discuss the History of Space science and future mission for space.	Understand	1
2	Write the laws of Kepler's. With the Remember from geometry, that for a circle the distances a and b are equal, find the eccentricity of a circular orbit and give the relationship between the periapsis, apoapsis and semi-major axis distances. 	Understand	1
3	What do you mean by sidereal days? (i) 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. (ii) The moon is in slightly elliptical orbit around the earth (e = 0.055). Determine the moon's apogee and perigee distance in both kilometres and miles.	Remember	1

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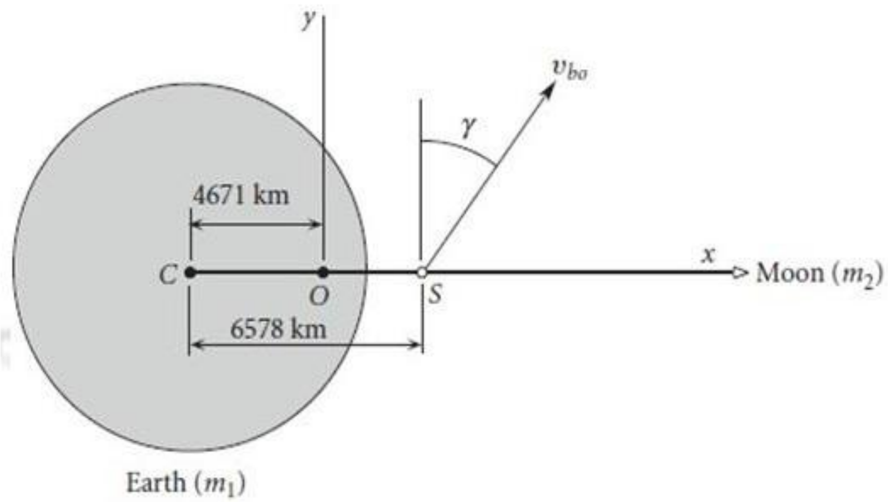
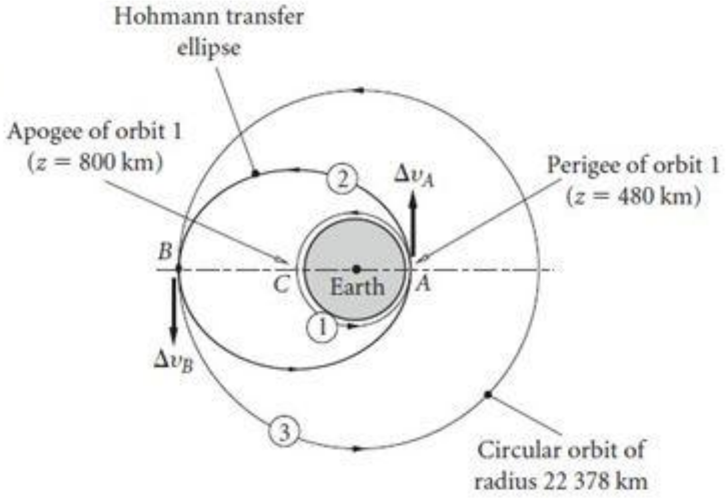
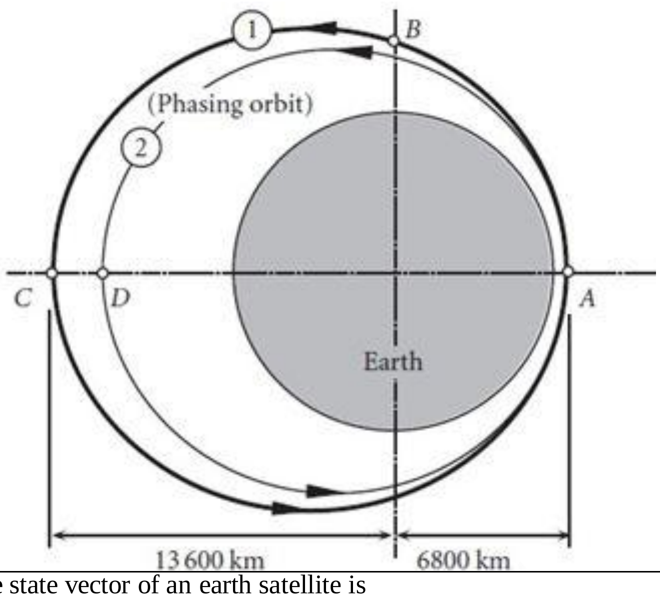
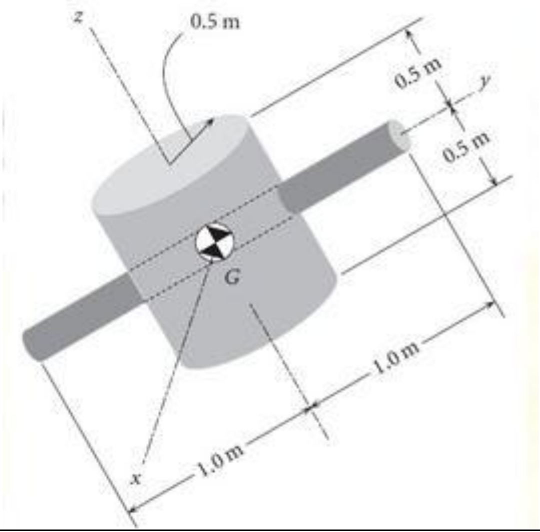
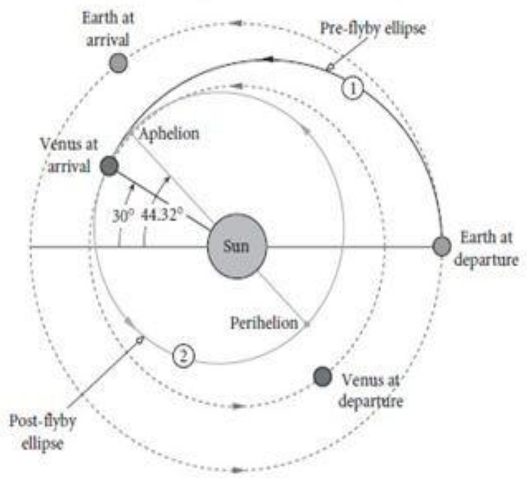
4	(i) Compare different types of coordinate system used in space mechanics. (ii) Due to thrust limitation and the reaches of atmosphere, the space shuttle is limited to operation between about 200km to 800km altitude. From this information, determine the orbital parameters associated with an elliptical orbit between these two altitudes.	Remember	1
5	Determine the Potential using Newton's law of gravitation. Using Newton's Law find out gravitational attraction of the Earth in a system of satellite rotate at 200km round the Earth.	Remember	1
6	Discuss various time system used in space mechanics. How it is related to geocentric reference frame?	Understand	1
7	At some specified time the position of a spacecraft is at a right ascension of 30.00^0 and a declination of 60.00^0. The obliquity (inclination) of the ecliptic is 23.45^0. (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 Euler angles.	Understand	2
8	An asteroid has the approximate shape of an ellipsoid of revolution. Its semi major axis is 6 km, its semi minor axis is 4 km. The average density is $2.70\ 10^3$ kg/m^3. Find the surface gravitational accelerations on the semi major and the semi minor axes. (Universal gravitational constant G = $6.673\ 10^{-11}$ m^3 kg^{-1} S^{-2}).	Remember	2
9	An inflated Mylar sphere of 5.00 m radius is on a low earth orbit at 500km altitude. The surface density of the skin is 0.70 kg/m^2. (The gravitational parameter of the Earth is $3.986\ 10^5$ km^3/s^2; the Earth's mean radius is 6378 km). Find the gravity gradient torque about the center of the sphere.	Remember	7
10	What do you mean by celestial sphere? Discuss the different coordinate system is used in space mechanics and identify its significance. Draw the celestial sphere for an observer in latitude 60°N, putting in the horizon, equator, zenith, north celestial pole and observer's meridian. If the local sidereal time is 9h put in the vernal equinox and the ecliptic. The artificial satellite 1960 iota 1 (Echo 1) is observed to have at this instance an altitude of 45° and an azimuth of 315° E of N. Insert the satellite's position in your diagram and estimate (i) Echo's topo-centric right ascension and declination, (ii) its topo-centric ecliptic longitude and latitude. If the date is March 21, insert the Sun in your diagram.	Create	1
ASSIGNMENT – II **UNIT-II**			
1	The position and velocity of a satellite at a given instant are described by r = 2I + 2J + 2K (Distance Units) v = 0.4I + 0.2J + 0.4K (Distance Units per Time Unit) where I, J, K is a nonrotating geocentric coordinate system. Find the specific angular momentum and total specific mechanical energy of the satellite.	Remember	4
2	Using the equations of motion find out why orbiting astronauts experience weightlessness.	Remember	1
3	An earth satellite is in an orbit with perigee altitude z_p =400 km and an eccentricity e =0.6. Find (a) the perigee velocity, v_p; (b) the apogee radius, r_a; (c) the semi-major axis, a; (d) the true-anomaly-averaged radius $.r\theta$; (e) the apogee velocity; (f) the period of the orbit; (g) the true anomaly when $r = .r\theta$; (h) the satellite speed when $r = .r\theta$; (i) the flight path angle γ when $r = .r\theta$; (j) the maximum flight path angle γ_{max} and	Understand	4

S. No	Question	Blooms Taxonomy Level	Course Outcome
	the true anomaly at which it occurs.		
4	The perigee of a satellite in a parabolic geocentric trajectory is 7000 km. Find the distance d between points P1 and P2 on the orbit which are 8000 km and 16000 km, respectively, from the center of the earth.	Remember	6
5	At a given point of a spacecraft's geocentric trajectory, the radius is 14 600 km, the speed is 8.6 km/s, and the flight path angle is 50◦. Show that the path is a hyperbola and calculate the following: (a) $C3$, (b) angular momentum, (c) true anomaly, (d) eccentricity,(e) radius of perigee, (f) turn angle, (g) semi major axis, and (h) aiming radius.	Remember	7
6	An earth satellite moves in the xy plane of an inertial frame with origin at the earth's Center. Relative to that frame, the position and velocity of the satellite at time t_0 are $\mathbf{r}_0 = 8182.4\hat{\mathbf{i}} - 6865.9\hat{\mathbf{j}}$ (km) (a) $\mathbf{v}_0 = 0.47572\hat{\mathbf{i}} + 8.8116\hat{\mathbf{j}}$ (km/s) Compute the position and velocity vectors after the satellite has traveled through a true anomaly of 120◦.	Remember	3
7	On January 10·0 1963, the heliocentric ecliptic rectangular coordinates of position and velocity of an interplanetary probe were $x = 0{\cdot}68$, $y = 0{\cdot}52$, $z = 0{\cdot}18$ and $\dot{x} = -2{\cdot}2$, y = 28·1, z = 2·6 respectively; the distance being measured in units of the Earth's semi-major axis, the velocity in km s-1. Find the elements of the Earth's orbit.	Understand	3
8	A spacecraft has a burnout velocity v_{bo} at a point on the earth–moon line with an altitude of 200 km. Find the value of v_{bo} for each of the scenarios depicted in Figure  	Remember	7
9	A meteoroid is first observed approaching the earth when it is 402 000 km from the center of the earth with a true anomaly of 150◦. If the speed of the meteoroid at that time is 2.23 km/s, calculate (a) the eccentricity of the trajectory; (b) the altitude at closest approach; (c) the speed at closest approach.	Understand	6
10	For the Sun–Earth system, find the distance of the $L1$, $L2$ and $L3$ Lagrange points from the center of mass of the Sun–Earth system.	Remember	1
ASSIGNMENT – III **UNIT-III**			
1	A satellite is orbiting the earth in a 500 nm circular orbit. The ascending node moves to the west, completing one revolution every 90 days.	Remember	6

S. No	Question	Blooms Taxonomy Level	Course Outcome
	a. What is the inclination of the orbit? b. It is desired that the ascending node make only one revolution every 1 35 days. Calculate the new orbital inclination required if the satellite remains at the same altitude.		
2	The space shuttle is in a 280 km by 400 km orbit with an inclination of 51.43^0. Find the rates of node regression and perigee advance.	Create	4
3	Determine the perigee and apogee for an earth satellite whose orbit satisfies all of the following conditions: it is sun-synchronous, its argument of perigee is constant, and its period is three hours.	Understand	3
4	A spacecraft is in a 480 km by 800 km earth orbit (orbit 1 in Figure). Find (a) the Δv required at perigee A to place the spacecraft in a 480 km by 16 000 km transfer orbit (orbit 2); and (b) The Δv (apogee kick) required at B of the transfer orbit to establish a circular orbit of 16 000 km altitude (orbit 3). 	Understand	7
5	Spacecraft at A and B are in the same orbit (1). At the instant shown, the chaser vehicle at A executes a phasing maneuver so as to catch the target spacecraft back at A after just one revolution of the chaser's phasing orbit (2). What is the required total Δv? 	Understand	7
6	At time t_0 the state vector of an earth satellite is $\mathbf{r}_0 = 1600\hat{\mathbf{I}} + 5310\hat{\mathbf{J}} + 3800\hat{\mathbf{K}}$ (km) (a) $\mathbf{v}_0 = -7.350\hat{\mathbf{I}} + 0.4600\hat{\mathbf{J}} + 2.470\hat{\mathbf{K}}$ (km/s) (b)	Understand	6

S. No	Question	Blooms Taxonomy Level	Course Outcome
	Determine the position and velocity 3200 seconds later and plot the orbit in three dimensions.		
7	A lunar vehicle arrives at the sphere of influence of the Moon with $\lambda_1 = 0^0$. The speed of the vehicle relative to the Earth is 200 m/sec and the flight-path angle relative to the Earth is 80°. The vehicle is in direct motion relative to the Earth. Find v2 relative to the Moon and ε_2. Is the vehicle in retrograde or direct motion relative to the Moon	Understand	6
8	Given the following state vector of a satellite in geocentric equatorial coordinates, **r** = $-3670\hat{\mathbf{I}} - 3870\hat{\mathbf{J}} + 4400\hat{\mathbf{K}}$ km $\mathbf{v} = 4.7\hat{\mathbf{I}} - 7.4\hat{\mathbf{J}} + 1\hat{\mathbf{K}}$ km/s find the state vector four days (96 hours) later, assuming that there are no perturbations other than the influence of the earth's oblateness on _ and ω.	Remember	6
9	A rigid spacecraft is modeled by the solid cylinder *B* which has a mass of 300 kg and the slender rod *R* which passes through the cylinder and has a mass of 30 kg. Which of the principal axes *x*, *y*, *z* can be an axis about which stable torque-free rotation can occur?  	Understand	7
10	Consider a spacecraft that costs on a minimum energy elliptic path in the gravitational field of the sun. The path starts at a point P1 in the vicinity of Jupiter. P_1 is at 75.00^0 ecliptic longitude, 1.00^0 ecliptic latitude, and at a radius from the sun's center of 5.150 AU. It ends at point P_2 in the vicinity of Pluto. P_2 is at 335.00^0 ecliptic longitude, -12.00^0 ecliptic latitude and at a radius of 38.00 AU. (1 AU = 1.495979×10^8 km; gravitational parameter of the sun = 1.32712×10^{11} km^3/s^2.) (a) Compute the semi major axis and eccentricity of the path. (b) Compute the time required to travel from P_1 to P_2.		2
	ASSIGNMENT – IV **UNIT-IV**		
1	A ballistic missile is launched from a submarine in the Atlantic (30^0N, 75^0W) on an azimuth of 1 35^0. Burnout speed relative to the submarine is 16,000 ft/sec and at an angle of 3 0^0 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 center of the rotating Earth?	Remember	4
2	During the test firing of a ballistic missile, the following measurements were made: h_{bo} = 1/5 (DU), v_{bo} = 2/3 (DU/TU), h_{apogee} = 0.5 (DU). Assuming a symmetrical trajectory, what was the free-flight range of the missile during this test in nautical miles? (DU = distance unit and TU = time unit)	Remember	4

S. No	Question	Blooms Taxonomy Level	Course Outcome
3	A missile's coordinates at burnout are: 30^0N, 60^0E. Re-entry is planned for 30^0S, 60^0W. Burnout velocity and altitude are 1.0817 (DU/TU) and .025 (DU) respectively. ψ is less than 180° . What must the flight-path angle be at burnout?	Remember	5
4	A ballistic missile was observed to have a burnout speed and altitude of 24,300 ft/sec and 258 nm respectively. What must be the maximum free-flight range capability of this missile?	Understand	5
5	It is desired to maximize the payload of a new ballistic missile for a free-flight range of 8,000 nm. The design burnout altitude has been fixed at 344 nm. What should be the design burnout speed?	Remember	5
6	A ballistic missile has the following nominal burnout conditions : V_{bo} = 0.905 DU/TU, r_{bo} = 1.1 DU, ϕ_{bo} = 30^0 The following errors exist at burnout : ΔV_{bo} = - 5 x 10^{-5} DU/TU, Δr_{bo} = 5 x 10^{-4} DU, ϕ_{bo}= -10^{-4} radians. How far will the missile miss the target? What will b e the direction of the miss relative to the trajectory plane?	Understand	5
7	A ballistic missile launched from 29°N, 79.3°W burns out at 30°N, 80^0W after developing an increase in velocity of 0.9 DU/TU. Its elevation and azimuth relative to the Earth are : $\Phi_e = 30^0$, $\beta_e = 330^0$, Assuming a rotating Earth and a r_{bo} of 1.1 DU, what are the coordinates of the re- entry point? Assume a symmetrical trajectory.	Remember	5
8	A ballistic missile's 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	5
9	A ballistic missile which burned out at 45^0N, 150^0E, at an altitude of 2.092574 x 10^6 ft will re-enter at 45^0N, 120^0W, at the same altitude, using a "backdoor" trajectory (ψ > 180^0). If the velocity at burnout was 28,530 ft/sec, what was the flight-path angle at burnout?	Remember	5
10	A rocket testing facility located at 30^0N, 100^0W launches a missile to impact at altitude of 70^0S. A lateral displacement ΔX in the launch causes the rocket to burn out east of the intended burnout point. In what direction will the error at impact be?	Understand	4
	ASSIGNMENT – V **UNIT-V**		
1	Define patched-conic. Calculate the heliocentric departure speed and time of flight for a Hohmann transfer from Earth to Mars. Assume both planets are in circular coplanar orbits. Neglect the phasing requirements due to their relative positions at the time of transfer.	Remember	6
2	What do you mean by phase angle? It is desired to send an interplanetary probe to Mars on a Hohmann ellipse around the Sun. The- launch vehicle burns out at an altitude of 0.05 DU. Determine the burnout velocity required to accomplish this mission.	Understand	6
3	A space probe can alter its flight path without adding propulsive energy by passing by a planet en route to its destination. Upon passing the planet it will be deflected some amount, called the turning angle. For a given planet, P, show that $\sin\delta = 1/(D_V^2/\mu_n)$	Understand	6
4	Define synodic period. 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. *If* μ_{sun} = 1.327 × 10^{11} km^3/s^2, μ_{earth} = 398 600 km^3/s^2, and the orbital radii of the earth and Mars, R_{earth} = 149.6 × 10^6 km, R_{Mars} = 227.9 × 10^6 km.	Understand	6
5	Classify the trajectory type and their classes. After a Hohmann transfer from earth, calculate the minimum delta-v required to place a spacecraft in Mars orbit with a period of seven hours. Also calculate the periapse radius, the aiming radius and the angle between periapse and Mars' velocity vector. If μ_{sun} = 1.327 × 10^{11} km^3/s^2, μ_{Mars} = 42830 km^3/s^2, R_{earth} = 149.6 × 10^6 km, R_{Mars} = 227.9 × 10^6 km, and r_{Mars} = 3396 km	Understand	6

S. No	Question	Blooms Taxonomy Level	Course Outcome
6	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 300 km. (a) For an approach from the dark side of the planet, show that the post-flyby orbit is as illustrated in Fig. (b) For an approach from the sunlit side of the planet, show that the post-flyby orbit is as illustrated in Fig.  $\mu_{sun} = 1.3271 \times 10^{11}\ km^3/s^2$ $\mu_{Venus} = 324\,900\ km^3/s^2$ $R_{earth} = 149.6 \times 10^6\ km$ $R_{Venus} = 108.2 \times 10^6\ km$ $r_{Venus} = 6052\ km$	Understand	7
7	With the use of Hohmann 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 in km/sec.	Understand	6
8	It is desired to return to an inferior (inner) planet at the earliest possible time from a superior (outer) planet. The return is to be made on an ellipse with the same value of p and e as was use d on the outbound journey. Derive an expression for the loiter time at the superior planet in terms of the phase angle, transfer time, and the angular rates of the planets. Assume circular, coplanar planet orbits.	Understand	7
9	On 1December 2005 a spacecraft leaves a 180 km altitude circular orbit around the earth on a mission to Venus. It arrives at Venus 121 days later on 1April 2006, entering a 300 km by 9000 km capture ellipse around the planet. Calculate the total delta-v requirement for this mission.		5
10	Calculate the propellant mass required to launch a 2000 kg spacecraft from a 180 km circular earth 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 300 s.	Understand	5

Prepared By: Dr. P K Mohanta, Associate Professor

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