Reg. No. \_\_\_\_\_\_\_\_\_\_\_\_\_



**End Semester Examination – Nov / Dec – 2019**

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| **Code :** | **17AE2022** | **Duration :** | **3hrs** |
| **Sub. Name :** | **SPACE DYNAMICS** | **Max. Marks :** | **100** |

**ANSWER ALL QUESTIONS (5 x 20 = 100 Marks)**

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| **Q. No.** | **Sub Div.** | **Questions** | **Course**  **Outcome** | **Marks** |
| 1. | a. | Write Kepler laws of motion. Use third law of motion to calculate the orbital period of Jupiter if its distance from Sun is 5.2 Astronomical Units (AU). | CO2 | **6** |
| b. | Find the orbital period of an Earth satellite in minutes whose semi-major axis (*a*) is 7800 km. Gravitational constant (µ) for Earth =398600 km3/s2. | CO2 | 4 |
| c. | Given cos θ = (cos E – e) /(1 – e cos E),  sin θ = (1- e2)1/2 sin E/(1 – e cos E),  if E = 85 degrees, e = 0.3, find the true anomaly θ. | CO2 | **5** |
| d. | Compute the eccentric anomaly E from the true anomaly θ and the eccentricity e using the following relations.  cos E = ( e + cos θ) / (1 + e cos θ),  sin E = (1-e2)1/2 sin θ / (1 + e cos θ),  for e = 0.2 and θ = 110 degrees. | CO2 | **5** |
| **(OR)** | | | | |
| 2. | a. | Draw a neat diagram to show the six orbital elements of a satellite moving in an elliptic orbit. | CO4 | 4 |
| b. | If the position and velocity of a satellite are (2600, 15500, 4250) km and (-2.8, -0.8, 4.95) km/s, respectively; find the angular momentum and the orbital elements: eccentricity (e), inclination (i), argument of perigee (ω), right ascension of ascending node (Ω) and true anomaly (θ) of the satellite. | CO4 | 16 |
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| 3. | a. | Find the solution of Kepler’s equation up to second approximation as E = M + e sin M + e2 sin 2M / 2 +…, where the eccentricity e is small. | CO4 | 7 |
| b. | From the Kepler’s equation M = E – e sin E, where e is the eccentricity of an elliptic orbit and E and M are eccentric and mean anomaly, respectively, if M = 55 degrees and e = 0.15, calculate the eccentric anomaly E in radians and degrees. | CO4 | 9 |
| c. | Prove that r = a (1 – e cos E); r, a, e and E are radial distance, semi-major axis, eccentricity and eccentric anomaly, respectively. | CO4 | 4 |
| **(OR)** | | | | |
| 4. | a. | Define vernal equinox. Explain geocentric-inertial coordinate system. | CO3 | 5 |
| b. | Define Sun-synchronous orbit. Calculate the orbital inclination for an elliptic Sun-synchronous orbit, whose semi-major axis is 7100 km and eccentricity is 0.01. Earth’s gravitational constant (μ) = 398600 km3s-2, J2= 0.00108263 and Earth’s radius is 6378 km. | CO5 | 11 |
| c. | From the Kepler’s equation M = E – e sin E, where e is the eccentricity of an elliptic orbit and E and M are eccentric and mean anomaly, respectively, if E = 120 degrees and e = 0.2, Calculate the mean anomaly M in radian and degrees. | CO4 | 4 |
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| 5. | a. | Find the additional velocity required for a Hohmann transfer from a  circular Earth satellite orbit of radius 8000 km to a circular Earth  satellite orbit of radius 16000 km. | CO4 | 8 |
| b. | Calculate the velocity change required to transfer a satellite from a circular orbit of 400 km altitude with an inclination of 30° to an orbit of the same size at an inclination of 10°. Earth’s gravitational constant = 398600 km3s-2. | CO4 | 5 |
| c. | Calculate the synodic period of Venus relative to the Earth. The orbital periods of Earth and Venus are 365.26 days and 224.7 days, respectively. | CO6 | 4 |
| d. | Prove that the radial velocity vr = µ e sin θ / h. | CO4 | 3 |
| **(OR)** | | | | |
| 6. | a. | Name four important perturbing forces acting on an Earth satellite.  Explain briefly any two of the perturbing forces. | CO5 | 8 |
| b. | Explain Cowell’s and Encke's methods. Give their advantages and disadvantages. | CO5 | 12 |
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| 7. | a. | For the Kepler’s equation for hyperbolic orbits:  Mh= e sinh F – F, where Mh, e and F are mean anomaly, eccentricity and eccentric anomaly, respectively; if e = 3 and F is 5 radians, find the value of mean anomaly Mh. | CO6 | 4 |
| b. | Calculate the radius of sphere of influence of the Earth. The mass of the Earth and the Sun are 5.974x1024 kg and 1.989 x1030 kg, respectively. The radius of Earth’s orbit about Sun is 149.6x106km. | CO6 | 4 |
| c. | At a given point of a spacecraft’s geocentric trajectory, the radius is 17000 km, the speed is 8.2 km/s, and the flight path angle is 50 degrees. Show that the path is a hyperbola. Calculate the hyperbolic excess velocity, angular momentum, true anomaly and eccentricity of the orbit. Earth’s gravitational constant = 398600 km3s-2. | CO6 | 12 |
| **(OR)** | | | | |
| 8. | a. | A geocentric trajectory has perigee velocity of 13 km and perigee altitude of 322 km. Find its eccentricity. Find the radius vector when the true anomaly is 65 degrees. Earth’s gravitational constant is 398600 km3s-2. | CO4 | 7 |
| b. | An earth satellite has the following position and velocity vectors at a given instant:  **r** = 7100 **p** + 8900 **q**, (km),  **v** = - 5 **p** + 7 **q**, (km/s).  Calculate the angular momentum (h), the true anomaly (θ) and the eccentricity (e). | CO6 | 8 |
| c. | Using Kepler’s third law, estimate the trip time T from the Earth to Jupiter along the Hohmann transfer orbit by assuming the orbits of Earth and Jupiter around the Sun to be circular with radii of  149.6 x 106 and 778.6 x106 km, respectively. The value of the Sun’s gravitational constant (µ) = 1.32715 x 1011 km3s-2. | CO6 | 5 |
|  | | **Compulsory**: |  |  |
| 9. | a. | From the first principles, derive the rocket equation:  Vb = g0Isp ln(Mi/Mf),  where Vb is the burnout velocity, g0 is the acceleration due to gravity at sea level, Isp is specific impulse and Mi/Mf is the mass ratio. If the Isp of a rocket is 410s, and Vb is 9500 metres/s, calculate its mass ratio (g0=9.8 m/s2). | CO1 | 10 |
| b. | A two-stage rocket has the following design characteristics:  First stage: propellant mass = 32000 kg, structural mass = 10000 kg.  Second stage: propellant mass = 15000 kg, structural mass = 4000 kg. The payload mass is 100 kg. The specific impulse for first stage is 280s and for the second stage is 370s. Calculate the final burnout velocity (g0=9.8 m/s2). | CO1 | 10 |