Register Number:……..

KUMARAGURU
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B.E DEGREE EXAMINATIONS: MAY 2018

(Regulation 2015)

Sixth Semester

AERONAUTICAL ENGINEERING

U15AEE019**:** Space Mechanics

COURSE OUTCOMES

CO1: Estimate the trajectory/orbit of a space vehicle or a satellite in a suitable coordinate system.
CO2: Calculate the delta-v required for transferring a spacecraft from one orbit to another.
CO3: Perform orbit perturbation analysis for satellite orbits.
CO4: Design a trajectory and estimate the amount of propellant required for interplanetary and lunar missions.
CO5: Apply the orbital mechanics concepts to ballistic missiles.
CO6: Estimate the trajectory of ballistic missiles.

Time: Three Hours **Maximum Marks: 100**

Answer all the Questions:-

PART A (10 x 1 = 10 Marks)

1. Match **List I** (conic section orbits) with **List II** (its eccentricity, *e*) and select the correct answer using the codes given below. CO1 [K_2]

List I	List II
A. Circular path	i. e = 2.35
B. Elliptical path	ii. e = 0
C. Parabolic path	iii. e = 0.7
D. Hyperbolic path	iv. e = 1

	A	B	C	D
a)	ii	i	iv	iii
b)	iv	iii	i	ii
c)	ii	iii	iv	i
d)	iv	i	ii	iii

2. A satellite moves round the earth in a circular orbit of radius R making one revolution per day. A second satellite moving in a circular orbit, moves round the earth once in 8 days. The radius of the orbit of the second satellite is _____. CO1 [K_2]

a) 8R b) 4R

c) 2R d) R

3. Which of the following perturbations approach employ direct numerical integration to solve the two-body equation of motion with perturbed accelerations? CO3 [K_1]

(i) Cowell's method
(ii) Encke's method
(iii) Lagrangian method
(iv) Gaussian VOP method

a) (i) and (ii) only
b) (ii) and (iii) only
c) (i) and (iv) only
d) (iii) and (iv) only

4. A satellite moves around the earth in a circular orbit of radius r with speed v. If the mass of the satellite is M, its total energy is _____. CO1 [K_2]

a) $-\frac{1}{2}M v^2$
b) $\frac{1}{2}M v^2$
c) $\frac{3}{2}M v^2$
d) $M v^2$

5. Assertion (A): Even when orbit of a satellite is elliptical, its plane of rotation passes through the center of earth.
Reason (R): According to law of conservation of angular momentum, the plane of rotation of a satellite always remains same. CO1 [K_1]

a) Both A and R are Individually true and R is the correct explanation of A
b) Both A and R are Individually true but R is not the correct explanation of A
c) A is true but R is false
d) A is false but R is true

6. A satellite is revolving in a circular orbit at a height 'h' from the earth's surface (radius of earth R; h << R). The minimum increase in its orbital velocity required, so that the satellite could escape from the earth's gravitational field, is close to _____. (Neglect the effect of atmosphere) CO2 [K_2]

a) $\sqrt{2gR}$
b) $\sqrt{gR}$
c) $\sqrt{gR/2}$
d) $\sqrt{gR}\left(\sqrt{2}-1\right)$

7. A satellite is in geostationary orbit of radius R with orbital velocity V. It needs to be transferred to a circular polar orbit of the same radius through a single impulse out-of-plane maneuver. The magnitude of the change in velocity required is _____. CO2 [K_2]

a) 0.5V
b) 1.225V
c) 2V
d) $\sqrt{2}$ V

8. When a spacecraft passing behind a planet during its interplanetary travel, its kinetic energy CO4 [K_2]

a) increases with respect to sun
b) decreases with respect to sun
c) increases with respect to the planet
d) decreases with respect to the planet

9. The required *Q* value for a ballistic missile to follow a circular path around the earth from burnout to re-entry is _____. CO5 [K_2]

a) 0.5 b) 1

c) 1.5 d) 2

10. The maximum free-flight range of a ballistic missile with *Q* value of 0.6 is _____. (Circumference of earth is 111.317 km/deg) CO6 [K_2]

a) 3846 km b) 5649.7 km

c) 6871.5 km d) 7892.3 km

PART B (10 x 2 = 20 Marks)
(Answer not more than 40 words)

11. Differentiate between solar day and sidereal day. CO1 [K_1]

12. Name the six orbital elements of a Keplerian orbit. CO1 [K_1]

13. The maximum and minimum distances of a comet from the sun are 8×10^{12} m and 1.6×10^{12} m. If its velocity when nearest to the sun is 60 m/s what will be its velocity when it is farthest? CO1 [K_2]

14. Mention the primary perturbing forces for a satellite orbit. CO3 [K_1]

15. Compare Hohmann transfer and bi-elliptic transfer. CO2 [K_1]

16. The on-board rocket motor of a satellite of initial mass 2000 kg provides a specific impulse of 280 seconds. If this motor is fired to give a speed increment of 500 m/s along the direction of motion, find the mass of propellant consumed. (g_e = 9.81 m/s^2) CO4 [K_3]

17. What is sphere of influence? CO4 [K_1]

18. What is a need for gravity-assist maneuvers for an interplanetary spacecraft? CO4 [K_1]

19. Differentiate between low trajectory and high trajectory of a ballistic missile. CO6 [K_2]

20. What are the influence coefficients for a ballistic missile? CO6 [K_1]

Answer any FIVE Questions:-
PART C (5 x 14 = 70 Marks)
(Answer not more than 300 words)

Q.No. 21 is Compulsory.
Assume the following data wherever required:

Radius of earth = 6378 km; Earth's gravitational parameter = 398600.44 km^3/s^2; Radius of earth's moon = 1738 km; Moon's gravitational parameter = 4902.87 km^3/s^2; Radius of lunar sphere of influence = 66183 km; Velocity of moon relative to center of the earth = 1.023 km/s.

21. An earth orbit of a satellite is to be changed from a circle of radius 15000 km to a coplanar ellipse with perigee altitude of 500 km and apogee radius of 22000 km. CO2 [K_3]

(i) Calculate the magnitude of the required delta-v for a single delta-v maneuver. (8)

(ii) Calculate the minimum total delta-v if the orbit change is accomplished instead by a Hohmann transfer. (6)

22. State and prove Kepler's second law and third law of planetary motion. CO1 [K_3]

23. A satellite orbits the earth with a perigee radius of 7000 km and an apogee radius of 70000 km. Calculate the following:
    (a) semi-major axis and eccentricity of the orbit;
    (b) period of the orbit;
    (c) specific energy of the orbit;
    (d) true anomaly at which the altitude is 1000 km;
    (e) speed at perigee and apogee. CO1 [K_3]

24. Explain Encke's method of special perturbations with mathematical formulations. CO3 [K_2]

25. (i) Explain the patched conic approximation method with an example. (7)
    (ii) Explain the various steps involved in patched conic method for a realistic interplanetary mission. (7) CO4 [K_2]

26. A lunar probe is sent to earth's moon on a trajectory with the following injection conditions: Injection velocity at perigee = 10.75 km/s, Injection radius = 6800 km, and Arrival angle = 39°. Assume a coplanar transfer and the moon's orbit has a circular radius of 384400 km, calculate the elements ('*a*' and '*e*') of transfer trajectory and arrival trajectory. Also justify is this a lunar landing trajectory? CO4 [K_4]

27. Derive the free-flight range equation of a ballistic missile. Also show that for a ballistic missile with $Q = 1$ at burnout, the free-flight range (Ψ) is given by CO5 [K_3]

$$\cos\frac{\Psi}{2} = \sqrt{1-\cos^2\phi_{bo}}$$

where ϕ_{bo} = flight-path angle of the missile at burnout.

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