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Register Number:……………………..

B.E DEGREE EXAMINATIONS: APRIL 2015

(Regulation 2009)

Seventh Semester

AERONAUTICAL ENGINEERING

AER120**:** Space Mechanics and Missile Technology

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

Answer all the Questions:-

PART A (10 x 1 = 10 Marks)

1. The exact time difference between a solar day and a sidereal day is
   - a) 3 minutes
   - b) 3 minutes, 28 seconds
   - c) 3 minutes, 56 seconds
   - d) 4 minutes

2. A planet is observed to be at its slowest when it is at a distance r_1 from the sun and at its fastest when it is at a distance r_2 from the sun. The eccentricity e of the planet's orbit is given by
   - a) $e = \frac{r_1}{r_2}$
   - b) $e = \frac{r_1 - r_2}{r_1 + r_2}$
   - c) $e = \frac{r_2}{r_1}$
   - d) $e = \frac{r_1 + r_2}{r_1 - r_2}$

3. If two satellites S_1 and S_2 of different masses (with mass of S_1 > mass of S_2) were revolving in a same orbit, then which one of the following is true?
   - a) Angular momentum, h of $S_1 > h$ of S_2
   - b) Total energy, ξ of $S_1 > \xi$ of S_2
   - c) Total energy, ξ of $S_2 > \xi$ of S_1
   - d) Both S_1 and S_2 have same total energy

4. To transfer a satellite from an elliptical orbit to a circular orbit having radius equal to the apogee distance of the elliptical orbit, the speed of the satellite should be
   - a) increased at the apogee
   - b) decreased at the apogee
   - c) increased at the perigee
   - d) decreased at the perigee

5. The Hohmann ellipse used as Earth to Venus transfer orbit has
   - a) apogee at Earth and perigee at Venus
   - b) both apogee and perigee at Earth
   - c) apogee at Venus and perigee at Earth
   - d) both apogee and perigee at Venus

6. The two bodies in the cruise phase of a patched conic interplanetary trajectory from Earth to Mars are

a) Earth and spacecraft
b) Sun and spacecraft
c) Mars and spacecraft
d) Earth and Mars

7. A Q value required for a ballistic missile in order to escape from Earth's gravitational field is
a) 0.5
b) 1
c) 1.5
d) 2

8. An ionized gas in space environment composed of equal number of positively and negatively charged particles is termed as
a) plasma
b) neutral gas particles
c) cosmic rays
d) long-wave radiation

9. A type of missile in which the control surfaces in airframe are located at 180 degrees from each other is
a) cruciform missile
b) cross-form missile
c) planform missile
d) multiform missile

10. The pitch angle of a missile in its vertical motion is
a) 0°
b) 45°
c) 90°
d) > 90°

PART B (10 x 2 = 20 Marks)

11. What is meant by obliquity of the ecliptic?
12. Define ascending and descending nodes of a satellite orbit.
13. Show that the speed of a satellite on an elliptical orbit at either end of the minor axis is the same as local circular satellite speed at that point.
14. The Earth's radius is 6378 km and the acceleration due to gravity on its surface is 9.81 m/s^2. A satellite is in a circular orbit at a height of 630 km above the Earth's surface. Calculate the minimum additional speed it needs to escape from the Earth's gravitational field. (Earth's gravitational parameter is 398600.4418 km^3/s^2)
15. Mention the various steps involved in a realistic interplanetary mission with patched conic method.
16. What is meant by 'evection' in Earth-Moon system?
17. 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?
18. Mention the various sources of down-range error in a ballistic missile.
19. Differentiate between cruise missiles and ballistic missiles.
20. What is 'gravity drag' in missiles and rockets?

PART C (5 x 14 = 70 Marks)

(**Use the values given below for additional data wherever required:**

Radius of the Earth = 6378 km; Earth's gravitational parameter = 398600.4418 km^3/s^2; Sun's gravitational parameter = 1.327×10^{11} km^3/s^2; Radius of the 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. a) With a neat geometry describe the following coordinate systems for space applications:
    (i) Earth-centered inertial coordinate system
    (ii) Heliocentric ecliptic coordinate system
    (iii) Local horizontal coordinate system
    (iv) Earth-centered Earth-fixed coordinate system

(OR)

b) State Kepler's first law of planetary motion and prove Kepler's first law by using Newton's laws.

22. a) i) With a single delta-v maneuver, the earth orbit of a satellite is to be changed from a circle of radius 15,000 km to a coplanar ellipse with perigee altitude of 500 km and apogee radius of 22,000 km. Calculate the magnitude of the required delta-v. (8)

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

(OR)

b) i) An earth's spacecraft is in a 300 km circular parking orbit. It is desired to increase the altitude to 600 km and change the inclination by 20°. Find the total delta-v required if the plane change is made after insertion into the 600 km orbit (so that there are a total of three delta-v burns). (8)

ii) Explain the concept of 'osculating' orbit and the process of orbit rectification in Encke's method of special perturbations. (6)

23. a) Consider a type I mission to Mars for a launch on 22 March 2001 and arrival at Mars on 8 October 2001. The time of flight is the difference between these dates or 200 days. The ephemeris data of Earth at launch and Mars at arrival are shown in the following table:

Element	Earth	Mars
Longitude, *deg*	181.444	333.221
Eccentricity	0.0167084	0.0934025
Semi-major axis, *km*	149,598,020	227,939,133
Inclination, *deg*	0	1.8497
Long. of Perihelion, *deg*	102.958	336.093
Long. of Ascending Node, *deg*	0	49.572
Radius, *km*	149,905,909.7	206,671,197
Velocity, *km/s*	29.892	26.4964
True Anomaly, *deg*	78.4854	357.128
Flight Path Angle, *deg*	0.93486	–0.24524

Design the transfer ellipse and determine its eccentricity and semi major axis by performing the following trials:

Trial 1: Place the line of apsides through the Earth position at launch.

Trial 2: Rotate the line of apsides clockwise by 15°. (Increase θ by 15°)

Justify which one of the two trials will give a best possible transfer ellipse for the above mission?

(OR)

b) A lunar probe is sent to the 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?

24. a) i) A requirement exists for a ballistic missile with a total range of 13704.8 km where: powered flight range = 259.28 km, re-entry range = 111.12 km, r_{bo} = 6644.64 km, ϕ_{bo} = 15°. Assuming a symmetrical trajectory, calculate the time of free-flight in minutes. (8)

ii) Show that for maximum free-flight range of a ballistic missile: $Q_{bo} = 1 - e^2$ where '*e*' is the eccentricity.

(**Hint:** Use trigonometry relation $\cos^2\theta = \frac{1+\cos 2\theta}{2}$) (6)

(OR)

b) i) 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 4.8 km/s and at an angle of 30° to the local horizontal. Assume the submarine lies motionless in the water during the firing. Calculate the true speed and flight path angle of the missile relative to the center of the rotating Earth. (8)

ii) Discuss on solar environment in space and its effects on spacecraft components and spacecraft orbit. (6)

25. a) With mathematical equations, explain the various forces acting on a missile while passing through Earth's atmosphere.

(OR)

b) i) List out the classification of missiles based on propulsion system and explain any FOUR of them in detail. (8)

ii) Explain the various types of rocket staging and explain the need for staging in rockets. (6)

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