PHYSICS CLASS XI
CHAPTER – 8 GRAVITATION

Q.1. Can we determine the mass of a satellite by measuring its time period?

Ans. No, we cannot determine the mass of a satellite by measuring its time period.

Q.2. Why is the atmosphere much rarer on the moon than on the earth?

Ans. The value of escape velocity on the moon is small as compared to the value of the earth.

Q.3. What velocity will you give to a donkey and what velocity to a monkey so that both escape the gravitational field of the earth?

Ans. The escape velocity does not depend upon the mass of the body.

Q.4. How much energy is required by a satellite to keep it orbiting? Neglect air resistance.

Ans. No energy is required. This is because the work done by centripetal force is zero.

Q.5. Two satellites are at different heights. Which would have greater velocity?

Ans. $v_n \propto \frac{1}{\sqrt{r}}$; so the satellite at smaller height would possess greater velocity.

Q.6. What is a parking orbit?

Ans. Parking orbit is that in which the period of revolution of a satellite is equal to the period of revolution of a satellite is equal to the period of rotation the earth about its axis.

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Q.7. An artificial satellite revolving around the earth does not need any fuel. On the other hand, the aeroplane requires fuel to fly at a certain height. Why?

Ans. While the satellite moves in air-free region, the aeroplane has to overcome air resistance.

Q.8. A thief with a box is his hand jumps from the top of a building. What will be the load experienced by him during the state of free fall?

Ans. During the state of free fall, his acceleration is equal to the acceleration due to gravity. So, the thief will be in state of weightlessness. Hence, the load experienced by him will be zero.

Q.9. What is the weight of a body in a geostationary satellite?

Ans. The weight of a body is zero in a geostationary satellite.

Q.10. Is it possible to put an artificial satellite in an orbit such a way that it always remains visible directly over New Delhi?

Ans. It is not possible. This is because New Delhi is not in the equatorial plane.

Q.11. Does the speed of a satellite remain constant in a particular orbit?

Ans. Yes, as v = $\sqrt{\frac{GM}{r}}$, v depends only upon r. For a particular orbit, r is constant and so is v.

Q.12. Assume that an artificial satellite release a bomb. Would the bomb ever the strike the earth if the effect of air resistance is neglected?

Ans. The bomb would merely act as another satellite. It would never hit the earth.

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Q.13. Show that the orbital velocity of a satellite revolving the earth is 7.92 km s^{-1}?

Ans. Orbital velocity $v_o = \sqrt{gR}$

$= \sqrt{9.8 \times 6.4 \times 10^6}$ kms^{-1}

$= 7.92$ kms^{-1}

Q.14. The orbiting velocity of an earth – satellite is 8 kms^{-1}. What will be the escape velocity?

Ans. Escape velocity $v_e = \sqrt{2}\, v_o$

$V_e = \sqrt{2} \times 8 = 1.103$ kms^{-1}

Q.15. A satellite does not need any fuel to circle around the earth. Why?

Ans. The gravitational force between satellite and the earth provides the centripetal force required by the satellite to move in a circular orbit.

Q.16. If the kinetic energy of a satellite revolving around the earth in any orbit is doubled, what will happen to it?

Ans. The total energy of a satellite in any orbit, E = - k, where K is KE in that orbit. If its kinetic energy is doubled, i.e., an additional kinetic energy (K) is given to it, E = - K + K = 0 and the satellite will leave its orbit and go to infinity.

Q.17. On what factor does the escape speed from a surface depend?

Ans. Value of escape speed at the surface of a planet is given by the relation

$V_{es} = \sqrt{\frac{2GM}{R}} = \sqrt{2\,gR}$

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Thus, the value of escape speed from the surface of a planet depends upon (i) value of acceleration due to gravity g at the surface and (ii) the size (i.e., radius) R of the planet only. It is independent of all other factors e.g., the mass and size of the body to be projected, angle of projection etc.

Q.18. An astronaut, by mistake, drops jis food packet from an artificial satellite orbiting around the earth. Will it reach the surface of the earth? Why?

Ans. The food packet will not fall on the earth. As the satellite as well as astronaut were in a state of weightlessness, hence, the food packet, when dropped by mistake, will also start moving with the same velocity as that of satellite and will continue to move along with the satellite in the same orbit.

Q.19. If suddenly the gravitational force of attraction between the earth and a satellite revolving around it becomes zero, what will happen to the satellite?

Ans. If suddenly the gravitational force of attraction between the earth and a satellite revolving around it becomes zero, satellite will not be able to revolve around the earth. Instead, the satellite will start moving along a straight line tangentially at that point on its orbit. Where it is at the time of gravitational force becoming zero.

Q.20. The escape speed on the earth is 11.2 km/s. What is its value for a planet having double the radius and eight times the mass of the earth?

Ans. v_p (escape speed on a planet) = $\sqrt{\frac{GM_P}{R_P}}$

v_p (escape speed on the earth) = $\sqrt{\frac{GM_e}{R_e}}$

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Clearly, $\frac{v_p}{v_e} = \sqrt{\frac{M_P}{M_e} \times \frac{R_e}{R_P}} = \sqrt{8 \times \frac{1}{2}} = 2$

or $v_P = 2v_e = 22.4$ km/s

Q.21. The earth is acted upon by the gravitational attraction of the sun. Why don't the earth fall into the sun?

Ans. The earth is orbiting round the sun in a stable orbit (nearly circular) such that the gravitational attraction of the sun just provides the centripetal force to the earth for its orbital motion so, net force on the earth is zero consequently the earth does not fall into the sun.

Q.22. Does the change in gravitational potential energy of a body between two given points depend upon the nature of path followed, why?

Ans. The change in gravitational potential energy of a body between two given points depends only upon the position of the given points and is independent of the path followed.

It is due to the fact that the gravitational force is a conservative force and work done by a conservative force depends only on the position of initial and final points and is independent of path followed.

Q.23. The escape speed of a projectile on the earth's surface is 11.2 km/s. A body is projected out with thrice this speed. What is the speed of the body far away from the earth? Ignore the presence of the sun and other planets.

Ans. Let v_e be the escape velocity and v be the velocity of the body outside the gravitational field of the earth. According to law of conservation of energy.

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Initial KE of the body = energy spent by the body in crossing the earth's gravitational field + kinetic energy left with the body once outside the earth's gravitational field,

i.e., $\frac{1}{2}m(3v_e)^2 = \frac{1}{2}mv_e^2 + \frac{1}{2}mv^2$

or $\frac{9}{2}mv_e^2 = \frac{1}{2}mv_e^2 + \frac{1}{2}mv^2$ or $v^2 = 8v_e^2$

or $v = \sqrt{8v_e^2} = 2\sqrt{2v_e}$

As $v_e = 11.2$ km/s $\Longrightarrow$ $v = 2\sqrt{2} \times 11.2$ km/s

or $v = 31.7$ km/s

Q.24. Does the escape speed of a body from the earth depend on

(i) mass of the body

(ii) the location from it is projected

(iii) the direction of projection

(iv) the height of the location from where the body is launched?

Ans. (i) No, escape velocity is independent of the mass of the body.

(ii) Yes, escape velocity depends (through slightly on the location from where the body is projected because with location g changes and so should v_e (= $\sqrt{2gR}$) change.

(iii) No, escape velocity is independent of the direction of projection.

(iv) Yes, escape velocity depends (through slightly) on the height of location from where the body is projected as g depends on height.

Q.25. Viscous force increase the velocity of a satellite. Discuss?

Ans. Imagine a satellite of mass m moving with a velocity v in an orbit of radius r around a planet of mass M.

PE of the satellite, U = $-\frac{GMm}{r}$

KE of the satellite, K = $\frac{1}{2}mv^2 = \frac{GMm}{2r}$ (as v = $\sqrt{GM/r}$)

Total energy of the satellite, i.e.,

$$E = K + U = \frac{GMm}{2r} - \frac{GMm}{r}$$

$$= -\frac{GMm}{2r}$$

For the sake of clarity, take $\frac{GMm}{2r}$ = x

Clearly, U = - 2x, K = x, E = - x

The orbiting satellite loses energy due to viscous force acting on it due to atmosphere and as such it loses height.

Let the new orbital radius be $\frac{r}{2}$ (say)

Clearly, U' = - 4x

K' = 2x

E' = - 2x

Clearly, E' < E, U' < U and K' > K. Since, kinetic energy has increased, the velocity of the satellite increases.

Q.26. A satellite orbits the earth at a height of 400 km above the surface. How much energy must be expanded to rocket the satellite out of the earth's gravitational influence?

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Mass of the satellite = 200 kg, mass of the earth, M = 6.0 × 10^{24} kg, radius of the earth = 6.4 × 10^{6} m, G = 6.67 × 10^{-11} Nm^2/kg^2.

Ans. Mass of the earth, M = 6.0 × 10^{24} kg

Mass of the satellite, m = 200 kg

Radius of the earth, R = 6.4 × 10^{6} m

Height of the satellite above the earth's surface

h = 400 km = 0.4 × 10^{6} m

Radius of the orbit of the satellite r = R + h

= 6.8 × 10^{6} + 0.4 × 10^{6}

= 6.8 × 10^{6} m

Total energy of the satellite

$$E = -\frac{GMm}{2r} = \frac{6.67\times10^{-11}\times6.0\times10^{24}\times200}{26.8\times10^{6}}$$

= - 5.9 × 10^{9} J

Negative total energy denoted that the satellite is round to the earth.

Therefore, to pull the satellite out of the earth's gravitational influence, energy required = 5.9 × 10^{6} J.

Q.27. Define period of revolution. Derive an expression of period of revolution or time period of satellite.

Ans. Period of revolution of a satellite is the time taken by the satellite to complete one revolution round the earth. It is denoted by T.

$$\therefore \quad T = \frac{circumference\ of\ circular\ orbit}{orbital\ velocity}$$

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or $T = \frac{2\pi r}{v_0}$

or $T = \frac{2\pi(R+h)}{v_o}$ $\left(\because v_o = \sqrt{\frac{GM}{R+h}}\right)$

or $T = 2\pi\sqrt{\frac{(R+h)^3}{GM}}$

Also, $T = 2\pi\sqrt{\frac{(R+h)^2(R+h)}{GM}}$

or $T = 2\pi\sqrt{\frac{R+h}{g}}$

But $gR^2 = GM$

$\therefore$ $T = 2\pi\sqrt{\frac{(R+h)^3}{gR^2}}$

Q.28. Calculate the change in the energy of a 500 kg satellite when it falls from an attitude of 200 km to 199 km. if this change takes place during one orbit. Calculate the retarding force on the satellite.

Given, mass of the earth = 6 × 10^{24} kg and radius of the earth = 6400 km

Ans. Given, $M_e = 6 \times 10^{24}$ kg, r_e = 6400 km

$r_1 = 6400 + 200 = 6600$ km $= 6.6 \times 10^6$ m

$r_2 = 6400 + 199 = 6599$ km $= 6.599 \times 10^6$ m

change in energy = $GMm\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$

$= 6.67 \times 10^{-11} \times 6 \times 10^{24} \times 500$

$$\left(\frac{1}{6.6\times10^6} - \frac{1}{6.599\times10^6}\right)$$

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= 2 × $10^{17}(1.5152 \times 10^{-7}$- 1.5154 × $10^{7})J$

= - 4 × 10^{6} J

If this occurs during one orbit, then the energy lost

= force × distance. If we take the distance as being the circumference of one orbit.

Then,

Retarding force = $\frac{4\times10^{6}}{2\pi\times6.6\times10^{6}}$ = $\frac{4\times10^{6}}{2\times6.6\times3.14\times10^{6}}$ = 0.1 N

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