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Class: XI
Subject: Physics
Topic: Gravitation
No. of Questions: 20

Q1. The acceleration due to gravity g on earth is 9.8 ms^{-2}. What would be the value of g for a planet whose size is the same as that of the earth but the density is twice that of the earth?

a. 19.6 ms^{-2}

b. 9.8 ms^{-2}

c. 4.9 ms^{-2}

d. 2.45 ms^{-2}

Sol: a

Volume of earth (V) = $\frac{4\pi}{3}R^3$. Therefore, density of earth is $\rho = \frac{M}{V}$ or $M = V\rho = \frac{4\pi}{3}R^3\rho$

Now $g = \frac{GM}{R^2} = \frac{4\pi G\rho R}{3}$. Since R is the same for both planets, if ρ is doubled, the value of g is also doubled. Hence the correct choice is (1).

Q2. If the radius of the earth suddenly decreases to 80% of its present value (the mass of the earth remaining the same), then the value of acceleration due to gravity will

a. remain unchanged

b. become (9.8 × 0.8) ms^{-2}

c. increase by 36%

d. increase by about 56%

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Sol: d

Now $g = \frac{GM}{R^2}$. If R reduces to $R' = 0.8\,R$, the value of g becomes

$$g' = \frac{GM}{R'^2} = \frac{GM}{0.64R^2}$$

$$= \frac{g}{0.64} = \frac{9.8\text{ ms}^{-2}}{0.64}$$

Increase in value of $g = \frac{g}{0.64} - g = \frac{0.36\,g}{0.64}$

$\therefore$ Percentage increase $= \frac{0.36\,g}{0.64\,g} \times 100 = 56.25\%$

Hence the correct choice is (4).

Q3. A small planet is revolving around a massive star in a circular orbit of radius R with a period of revolution T. If the gravitational force between the planet and the star is proportional to $R^{-5/2}$, then T will be proportional to

a. $R^{3/2}$

b. $R^{3/5}$

c. $R^{7/2}$

d. $R^{7/4}$

Sol: d

Since the gravitational force provides the necessary centripetal force for circular motion, we have

$$\frac{mv^2}{R} \propto R^{-5/2}$$

or $\frac{mv^2}{R} = kR^{-5/2}$, where k is a constant.

Therefore $v = \sqrt{\frac{kR^{-3/2}}{m}}$

Period of revolution $T = \frac{2\pi R}{v} = 2\pi\sqrt{\frac{m}{k} \times R^{7/2}}$ or

$T \propto R^{7/4}$. Hence the correct choice is (4).

Q4. A satellite is orbiting the earth in a circular orbit of radius r. Its period of revolution varies as

a. $\sqrt{r}$

b. r

c. $r^{3/2}$

d. r^2

Sol: c

The speed of the satellite is given by

$$v = \sqrt{\frac{GM}{r}}$$

Therefore, its period of revolution is

$$T = \frac{2\pi r}{v} = \frac{2\pi}{\sqrt{GM}} \cdot r^{3/2}$$

Hence the correct choice is (3).

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Q5. The angular momentum of the earth revolving around the sun is proportional to R^n, where R is the distance between the earth and the sun. The value of n is

a. 0.5

b. 1.0

c. 1.5

d. 2.0

Sol: a

We know that

$$\frac{mv^2}{R} = \frac{GMm}{R^2}$$

which gives $v = \sqrt{\frac{GM}{R}}$

Now, angular momentum $L = mvR = m \times \sqrt{\frac{GM}{R}} \times R$

$= m\sqrt{GM}\ R^{1/2}$.

or $L \propto R^{1/2}$. Hence the correct choice is (1).

Q6. A satellite orbiting the earth is kept moving by the centripetal force provided by

a. the burning of fuel in its engine

b. the ejection of hot gases from its exhaust

c. the gravitational attraction of the sun

d. the gravitational attraction of the earth

Sol: d

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Q7. Two satellites A and B are orbiting around the earth in circular orbits of the same radius. The mass of A is 16 times that of B. The ratio of the period of revolution of B to that of A is

a. 1 : 16

b. 1 : 4

c. 1 : 2

d. 1 : 1

Sol: d

The period of revolution of a satellite in a given orbit is independent of its mass.
Hence, the correct choice is (4).

Q8. A satellite is moving around the earth in a stable circular orbit. Which one of the following statements will be wrong for such a satellite?

a. It is moving at a constant speed.

b. Its angular momentum remains constant.

c. It is acted upon by a force directed away from the centre of the earth which counter-balances the gravitational pull of the earth.

d. It behaves as if it were a freely falling body.

Sol: c

Choices (1), (2) and (4) are correct. Hence, choice (3) is the correct answer.

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Q9. The escape velocity from Earth is v_e. What is the escape velocity from a planet whose radius is twice that of the Earth and mean density is the same as that of Earth?

a. $v_e/2$

b. v_e

c. $2v_e$

d. $4v_e$

Sol: c

For earth : $v_e = \sqrt{\dfrac{2M_eG}{R_e}}$

For planet : $v_p = \sqrt{\dfrac{2M_pG}{R_p}}$

Therefore, $\dfrac{v_p}{v_e} = \sqrt{\dfrac{M_p}{M_e} \cdot \dfrac{R_e}{R_p}}$ (i)

If ρ_p and ρ_e are the respective average densities of the planet and the earth, then

$$M_P = \frac{4\pi}{3} R_p^3 \rho_p$$

and $M_e = \dfrac{4\pi}{3} R_e^3 \rho_e$

Therefore, $\dfrac{M_p}{M_e} = \dfrac{R_p^3}{R_e^3}$ $(\because \rho_p = \rho_e)$ (ii)

Using (ii) in (i) we get

$$\frac{v_p}{v_e} = \frac{R_p}{R_e} = 2 \qquad (\because R_p = 2R_e)$$

or $v_p = 2v_e$. Hence the correct choice is (3).

Q10. Choose the wrong statement. The escape velocity of a body from a planet depends upon

a. the mass of the body

b. the mass of the planet

c. the average radius of the planet

d. the average density of the planet

Sol: a

The escape velocity depends on the mass of the planet, its radius and its density.

Q11. A rocket is fired from the earth to the moon. The distance between the earth and the moon is r and the mass of the earth is 81 times the mass of the moon. The gravitational force on the rocket will be zero, when its distance from the moon is

a. $\frac{r}{20}$

b. $\frac{r}{15}$

c. $\frac{r}{10}$

d. $\frac{r}{5}$

Sol: c

Let the rocket be at a distance x from the moon when the gravitational force on it is zero. Its distance from earth = $r - x$. Gravitational force on the rocket due to earth is

$$F_e = \frac{GmM_e}{(r-x)^2}$$

where m is the mass of the rocket. Gravitational force on the rocket due to moon is

$$F_m = \frac{GmM_m}{x^2}$$

Since the two forces are in opposite directions, the net force on the rocket will be zero if $F_e = F_m$. Equating the two we get

$$\frac{r-x}{x} = \sqrt{\frac{M_e}{M_m}} = \sqrt{81} = 9$$

which gives $x = \frac{r}{10}$. Hence the correct choice is (3).

Q12. Two spheres, each of mass M, are placed at a distance r apart on a horizontal surface. The gravitational field intensity at the midpoint of the line joining the centres of the spheres is

a. zero

b. $\frac{GM^2}{r^2}$

c. $\frac{GM^2}{2r^2}$

d. $\frac{GM^2}{4r^2}$

Sol: a

Gravitational field intensity at a point is defined as the gravitational force experienced by a unit mass placed at that point. Since, the spheres have the same mass, the gravitational forces exerted by each sphere on a unit mass placed at the midpoint will be equal and opposite. Hence, the gravitational field intensity at the mid-point is zero. Thus the correct option is 1.

Q13. The escape velocity of a body on the earth's surface is v_e. A body is thrown with a speed 3 v_e. Assuming that the sun and the planets do not influence the motion of the body, its speed at infinity will be

a. zero

b. v_e

c. $\sqrt{2}\, v_e$

d. $2\sqrt{2}\, v_e$

Sol: d

If v_i and v_f are respectively the initial and final speeds of the body, we have, from the law of conservation of energy,

$$\frac{1}{2} mv2 - \frac{GmM}{R} = \frac{1}{2} mv_f^2 \qquad \text{(i)}$$

where m is the mass of the body and M is the mass of the earth and R its radius. The escape velocity is given by

$$\frac{1}{2} mv_e^2 = \frac{GmM}{R} \qquad \text{(ii)}$$

Using (ii) in (i) gives

$$\frac{1}{2} mv_i^2 - \frac{1}{2} mv_e^2 = \frac{1}{2} mv_f^2$$

or $$v_f = (v_i^2 - v_e^2)^{1/2} \qquad \text{(iii)}$$

Given $v_i = 3v_e$. Therefore, $v_f = 2\sqrt{2}\, v_e$. Hence the correct choice is (4).

Q14. The radius of the earth is R. For a satellite to appear stationary, it must be placed in orbit around the earth at a height of about (given R = 6380 km)

a. 5.6 R

b. 6.6 R

c. 7.6 R

d. 8.6 R

Sol: a

For a geostationary satellite, h = 35870 km

$\therefore \quad \frac{h}{R} = \frac{35870}{6380} = 5.6,$ which is choice (1).

Q15. Choose the only incorrect statement from the following

a. The equivalence of inertial and gravitational mass has provided a clue to the deeper understanding of gravitation.

b. At poles, the effect of rotation of the earth on the value of g is the minimum.

c. Massive rockets and extremely tiny particles, such as the molecules of a gas, require the same initial velocity to escape from the earth.

d. A geostationary satellite, if imparted the necessary velocity, can be put in orbit at any height above the earth.

Sol: d

The only incorrect statement is (4). A geostationary satellite can be put in orbit only at a height of 35,870 km above the earth.

Q16. Infinite number of masses, each of mass m, are placed along a straight line at distances of r, 2r, 4r, 8r, etc. from a reference point O. The gravitational field intensity at point O will be

a. $\frac{5\ Gm}{4r^2}$

b. $\frac{4\ Gm}{3r^2}$

c. $\frac{3\ Gm}{2r^2}$

d. $\frac{2\ Gm}{r^2}$

Sol: b

The gravitational field intensity at point O will be

$$I = Gm\left[\frac{1}{r^2}+\frac{1}{(2r)^2}+\frac{1}{(4r)^2}+\frac{1}{(8r)^2}+\cdots\right]$$
$$= \frac{Gm}{r^2}\left[1+\frac{1}{2^2}+\frac{1}{4^2}+\frac{1}{8^2}+\cdots\right]$$
$$= \frac{Gm}{r^2}\left[\frac{1}{2^0}+\frac{1}{2^2}+\frac{1}{2^4}+\frac{1}{2^6}+\cdots\right]$$
$$= \frac{Gm}{r^2}\left(\frac{1}{1-\frac{1}{2^2}}\right) = \frac{Gm}{r^2}\left(\frac{1}{1-\frac{1}{4}}\right) = \frac{4Gm}{3r^2}$$

Hence the correct choice is (2).

Q17. A body of mass m is raised to a height h above the surface of the earth of mass M and radius R until its gravitational potential energy increases by $\frac{1}{3}$ mgR.
The value of h is

a. $\frac{R}{3}$

b. $\frac{R}{2}$

c. $\frac{mR}{(M+m)}$

d. $\frac{mR}{M}$

Sol: b

PE on the surface of earth $= -\dfrac{GMm}{R}$

PE at a height h above the surface of earth

$$= -\frac{GMm}{(R+h)}$$

$$\therefore \text{Increase in PE} = -\frac{GMm}{(R+h)} - \left(-\frac{GMm}{R}\right)$$

$$= GMm\left(\frac{1}{R} - \frac{1}{R+h}\right)$$

$$= GMm\left[\frac{h}{R(R+h)}\right]$$

$$= \frac{gRmh}{(R+h)} \qquad \left(\because g = \frac{GM}{R^2}\right)$$

$\therefore$ PE will increase by $\dfrac{1}{3}mgR$ at a value of h given by

$$\frac{gRmh}{(R+h)} = \frac{1}{3}mgR$$

or $\dfrac{h}{R+h} = \dfrac{1}{3}$ or $h = \dfrac{R}{2}$, which is choice (2).

Q18. The change in the gravitational potential energy when a body of mass m is raised to a height nR above the surface of the earth is (here R is the radius of the earth)

a. $\left(\dfrac{n}{n+1}\right)mgR$

b. $\left(\dfrac{n}{n-1}\right)mgR$

c. nmgR

d. $\dfrac{mgR}{n}$

Sol: a

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Change in PE $= \frac{GMm}{R} - \frac{GMm}{(n+1)R} = \left(\frac{n}{n+1}\right)mgR$

Hence the correct choice is (1).

Q19. Two solid spheres of radii r and 2r, made of the same material are kept in contact. The mutual gravitational force of attraction between them is proportional to

a. $\frac{1}{r^4}$

b. $\frac{1}{r^2}$

c. r^2

d. r^4

Sol: d

If ρ is the density of the material of each sphere, then the mass of the sphere of radius r is $M_1 = \frac{4\pi}{3} r^3 \rho$ and the mass of the sphere of radius $2r$ is

$M_2 = \frac{4\pi}{3}(2r)^3 \rho$.

Distance between their centres is $d = r + 2r = 3r$.

$$\text{Now } F = \frac{GM_1M_2}{d^2} = \frac{G \times \left(\frac{4\pi}{3}\right) r^3 \rho \times \frac{4\pi}{3}(2r)^3 \rho}{9r^2}$$

which gives $F \propto r^4$, which is choice (4).

Q20. A comet is moving in a highly elliptical orbit around the sun. When it is closest to the sun, its distance from the sun is r and its speed is v. When it is farthest from the sun, its distance from the sun is R and its speed will be

a. $v\left(\frac{r}{R}\right)^{1/2}$

b. $v\left(\frac{r}{R}\right)$

c. $v\left(\frac{r}{R}\right)^{3/2}$

d. $v\left(\frac{r}{R}\right)^{2}$

Sol: b

The angular momentum of the planet is constant over the entire orbit. Hence vr = VR or V = $v\left(\frac{r}{R}\right)$, which is choice (2).