# GRAVITATION

**1.** The energy required to take a satellite to a height 'h' above Earth surface (radius of Earth $= 6.4 \times 10^3$ km) is $E_1$ and kinetic energy required for the satellite to be in a circular orbit at this height is $E_2$. The value of h for which $E_1$ and $E_2$ are equal, is:

(1) $1.28 \times 10^4$ km (2) $6.4 \times 10^3$ km

(3) $3.2 \times 10^3$ km (4) $1.6 \times 10^3$ km

**2.** If the angular momentum of a planet of mass m, moving around the Sun in a circular orbit is L, about the center of the Sun, its areal velocity is :

(1) $\frac{4L}{m}$ (2) $\frac{L}{m}$ (3) $\frac{L}{2m}$ (4) $\frac{2L}{m}$

**3.** Two stars of masses $3 \times 10^{31}$ kg each, and at distance $2 \times 10^{11}$m rotate in a plane about their common centre of mass O. A meteorite passes through O moving perpendicular to the star's rotation plane. In order to escape from the gravitational field of this double star, the minimum speed that meteorite should have at O is : (Take Gravitational constant $G = 6.67 \times 10^{-11}$ Nm$^2$ kg$^{-2}$)

(1) $1.4 \times 10^5$ m/s (2) $24 \times 10^4$ m/s

(3) $3.8 \times 10^4$ m/s (4) $2.8 \times 10^5$ m/s

**4.** A satellite is moving with a constant speed v in circular orbit around the earth. An object of mass 'm' is ejected from the satellite such that it just escapes from the gravitational pull of the earth. At the time of ejection, the kinetic energy of the object is :

(1) $\frac{3}{2}mv^2$ (2) $mv^2$

(3) $2mv^2$ (4) $\frac{1}{2}mv^2$

**5.** The mass and the diameter of a planet are three times the respective values for the Earth. The period of oscillation of a simple pendulum on the Earth is 2s. The period of oscillation of the same pendulum on the planet would be :-

(1) $\frac{2}{\sqrt{3}}$s (2) $2\sqrt{3}$s

(3) $\frac{\sqrt{3}}{2}$s (4) $\frac{3}{2}$s

**6.** A satellite is revolving in a circular orbit at a height h from the earth surface, such that h << R where R is the radius of the earth. Assuming that the effect of earth's atmosphere can be neglected the minimum increase in the speed requried so that the satellite could escapte from the gravitational field of earth is:

(1) $\sqrt{gR}\left(\sqrt{2}-1\right)$ (2) $\sqrt{2gR}$

(3) $\sqrt{gR}$ (4) $\sqrt{\frac{gR}{2}}$

**7.** Two satellites, A and B, have masses m and 2m respectively. A is in a circular orbit of radius R, and B is in a circular orbit of radius 2R around the earth. The ratio of their kinetic energies, $T_A/T_B$, is:

(1) 2 (2) $\sqrt{\frac{1}{2}}$ (3) 1 (4) $\frac{1}{2}$

**8.** A straight rod of length L extends from x = a to x=L + a. The gravitational force is exerts on a point mass 'm' at x = 0, if the mass per unit length of the rod is $A + Bx^2$, is given by:

(1) $Gm\left[A\left(\frac{1}{a+L}-\frac{1}{a}\right)-BL\right]$

(2) $Gm\left[A\left(\frac{1}{a}-\frac{1}{a+L}\right)+BL\right]$

(3) $Gm\left[A\left(\frac{1}{a+L}-\frac{1}{a}\right)+BL\right]$

(4) $Gm\left[A\left(\frac{1}{a}-\frac{1}{a+L}\right)-BL\right]$

**9.** A satellite of mass M is in a circular orbit of radius R about the centre of the earth. A meteorite of the same mass, falling towards the earth, collides with the satellite completely inelastically. The speeds of the satellite and the meteorite are the same, just before the collision. The subsequent motion of the combined body will be :

(1) in a circular orbit of a different radius

(2) in the same circular orbit of radius R

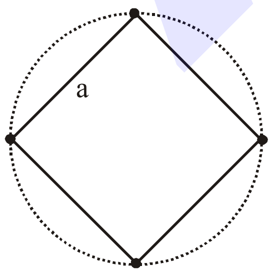
(3) in an elliptical orbit

(4) such that it escapes to infinity

**10.** A rocket has to be launched from earth in such a way that it never returns. If E is the minimum energy delivered by the rocket launcher, what should be the minimum energy that the launcher should have if the same rocket is to be launched from the surface of the moon ? Assume that the density of the earth and the moon are equal and that the earth's volume is 64 times the volume of the moon :-

(1) $\frac{E}{4}$ (2) $\frac{E}{16}$ (3) $\frac{E}{32}$ (4) $\frac{E}{64}$

**11.** Four identical particles of mass M are located at the corners of a square of side 'a'. What should be their speed if each of them revolves under the influence of other's gravitational field in a circular orbit circumscribing the square?




(1) $1.21\sqrt{\frac{GM}{a}}$ (2) $1.41\sqrt{\frac{GM}{a}}$

(3) $1.16\sqrt{\frac{GM}{a}}$ (4) $1.35\sqrt{\frac{GM}{a}}$

**12.** A test particle is moving in a circular orbit in the gravitational field produced by a mass density $\rho(r) = \frac{K}{r^2}$. Identify the correct relation between the radius R of the particle's orbit and its period T :

(1) $T/R^2$ is a constant

(2) TR is a constant

(3) $T^2/R^3$ is a constant

(4) T/R is a constant

**13.** A solid sphere of mass 'M' and radius 'a' is surrounded by a uniform concentric spherical shell of thickness 2a and mass 2M. The gravitational field at distance '3a' from the centre will be :

(1) $\frac{2GM}{9a^2}$ (2) $\frac{GM}{3a^2}$

(3) $\frac{GM}{9a^2}$ (4) $\frac{2GM}{3a^2}$

**14.** A spaceship orbits around a planet at a height of 20 km from its surface. Assuming that only gravitational field of the planet acts on the spaceship, what will be the number of complete revolutions made by the spaceship in 24 hours around the planet ?

[Given : Mass of planet = $8 \times 10^{22}$ kg ;

Radius of planet = $2 \times 10^6$ m,

Gravitational constant $G = 6.67 \times 10^{-11}$ $Nm^2/kg^2$]

(1) 9 (2) 11

(3) 13 (4) 17

**15.** The value of acceleration due to gravity at Earth's surface is 9.8 $ms^{-2}$. The altitude above its surface at which the acceleration due to gravity decreases to 4.9 $ms^{-2}$, is close to : (Radius of earth = $6.4 \times 10^6$ m)

(1) $1.6 \times 10^6$ m (2) $6.4 \times 10^6$ m

(3) $9.0 \times 10^6$ m (4) $2.6 \times 10^6$ m

**16.** The ratio of the weights of a body on the Earth's surface to that on the surface of a planet is 9 : 4. The mass of the planet is $\frac{1}{9}$th of that of the Earth. If 'R' is the radius of the Earth, what is the radius of the planet ? (Take the planets to have the same mass density)

(1) $\frac{R}{3}$ (2) $\frac{R}{2}$

(3) $\frac{R}{4}$ (4) $\frac{R}{9}$

## SOLUTION

**1. Ans. (3)**

$U_{surface} + E_1 = U_h$

KE of satelite is zero at earth surface & at height h

$$-\frac{GM_em}{R_e}+E_1=-\frac{GM_em}{(Re+h)}$$

$$E_1 = GM_em\left(\frac{1}{R_e}-\frac{1}{R_e+h}\right)$$

$$E_1 = \frac{GM_em}{(R_e+h)}\times\frac{h}{R_e}$$

Gravitational attraction $F_G = ma_C = \frac{mv^2}{(R_e+h)}$

$$E_2 \Rightarrow \frac{mv^2}{(R_e+h)}=\frac{GM_em}{(R_e+h)^2}$$

$$mv^2 = \frac{GM_em}{(R_e+h)}$$

$$E_2 = \frac{mv^2}{2}=\frac{GM_em}{2(R_e+h)}$$

$E_1 = E_2$

$$\frac{h}{R_e}=\frac{1}{2} \Rightarrow h = \frac{R_e}{2}=3200km$$

**2. Ans. (3)**

$$\frac{dA}{dt}=\frac{L}{2m}$$

**3. Ans. (4)**

By energy convervation between 0 & ∞.

$$-\frac{GMm}{r}+\frac{-GMm}{r}+\frac{1}{2}mV^2=0+0$$

[M is mass of star m is mass of meteroite)

$$\Rightarrow v=\sqrt{\frac{4GM}{r}}=2.8\times10^5 m/s$$

**4. Ans. (2)**

At height r from center of earth. orbital velocity

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

∴ By energy conservation

$$\text{KE of 'm'} + \left(-\frac{GMm}{r}\right)=0+0$$

(At infinity, PE = KE = 0)

$$\Rightarrow \text{KE of 'm'} = \frac{GMm}{r}=\left(\sqrt{\frac{GM}{r}}\right)^2 m = mv^2$$

**5. Ans. (2)**

$$\because g=\frac{GM}{R^2}$$

$$\frac{g_p}{g_e}=\frac{M_e}{M_e}\left(\frac{R_e}{R_p}\right)^2=3\left(\frac{1}{3}\right)^2=\frac{1}{3}$$

Also $T\propto\frac{1}{\sqrt{g}}$

$$\Rightarrow \frac{T_p}{T_e}=\sqrt{\frac{g_e}{g_p}}=\sqrt{3}$$

$$\Rightarrow T_p=2\sqrt{3}s$$

**6. Ans. (1)**

$$v_0 = \sqrt{g(R+h)} \approx \sqrt{gR}$$

$$v_e = \sqrt{2g(R+h)}\approx\sqrt{2gR}$$

$$\Delta v=v_e-v_0=\left(\sqrt{2}-1\right)\sqrt{gR}$$

**7. Ans. (3)**

$$\text{Orbital velocity} V = \sqrt{\frac{GMe}{r}}$$

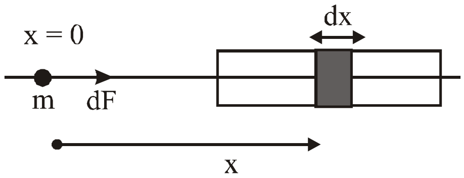
$$T_A = \frac{1}{2}m_AV_A^2$$

$$T_B = \frac{1}{2}m_BV_B^2$$

$$\Rightarrow \frac{T_A}{T_B}=\frac{m\times\frac{Gm}{R}}{2m\times\frac{Gm}{2R}}$$

$$\Rightarrow \frac{T_A}{T_B} = 1$$

**8. Ans. (2)**




dm= $(A + Bx^2)dx$

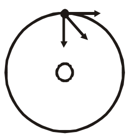
$$dF = \frac{GM\,dm}{x^2}$$

$$= F = \int_a^{a+L} \frac{GM}{x^2}\left(A + Bx^2\right)dx$$

$$= GM\left[-\frac{A}{x} + Bx\right]_a^{a+L}$$

$$= GM\left[A\left(\frac{1}{a} - \frac{1}{a+L}\right) + BL\right]$$

**9. Ans. (3)**



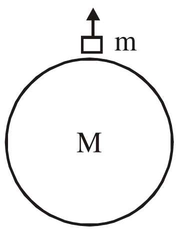
$$mv\hat{i} + mv\hat{j}$$

$$= 2m\vec{v}^1$$

$$\vec{v} = \frac{1}{\sqrt{2}} \times \sqrt{\frac{GM}{R}}$$

**10. Ans. (2)**

**Sol.**




minimum energy required (E) = – (Potential energy of object at surface of earth)

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

Now $M_{earth} = 64\ M_{moon}$

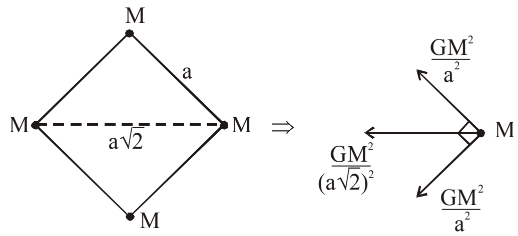
$$\rho.\frac{4}{3}\pi R_e^3 = 64.\frac{4}{3}\pi R_m^3 \Rightarrow R_e = 4R_m$$

$$\text{Now } \frac{E_{moon}}{E_{earth}} = \frac{M_{moon}}{M_{earth}}.\frac{R_{earth}}{R_{moon}} = \frac{1}{64} \times \frac{4}{1}$$

$$\Rightarrow E_{moon} = \frac{E}{16}$$

**11. Ans. (3)**

**Sol.**




Net force on particle towards centre of circle

$$\text{is } F_C = \frac{GM^2}{2a^2} + \frac{GM^2}{a^2}\sqrt{2}$$

$$= \frac{GM^2}{a^2}\left(\frac{1}{2} + \sqrt{2}\right)$$

This force will act as centripetal force. Distance of particle from centre of circle is $\frac{a}{\sqrt{2}}$.

$$r = \frac{a}{\sqrt{2}},\ F_C = \frac{mv^2}{r}$$

$$\frac{mv^2}{\frac{a}{\sqrt{2}}} = \frac{GM^2}{a^2}\left(\frac{1}{2} + \sqrt{2}\right)$$

$$v^2 = \frac{GM}{a}\left(\frac{1}{2\sqrt{2}} + 1\right)$$

$$v^2 = \frac{GM}{a}(1.35)$$

$$v = 1.16\sqrt{\frac{GM}{a}}$$

**12. Ans. (4)**

**Sol.** $m = \int_0^R \rho\ 4\pi r^2 dr$

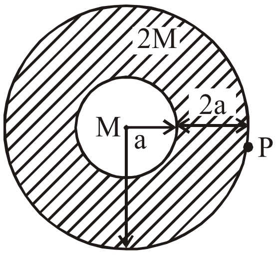
$m = 4\pi KR$

$v \propto \sqrt{4\pi K}$

$$\frac{T}{R} = \frac{2\pi}{\sqrt{4\pi K}}.$$

**13. Ans. (2)**

**Sol.**




We use gauss's Law for gravitation

$g \cdot 4\pi r^2 =$ (Mass enclosed) $4\pi G$

$$g = \frac{3M 4\pi G}{4\pi(3a)^2}$$

$$= \frac{MG}{3a^2}$$

Option (2)

**14. Ans. (2)**

**Sol.** $F_g = \frac{mv^2}{r}$

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

$$V = \sqrt{\frac{GM}{r}} = \sqrt{\frac{(6.67\times10^{-11})(8\times10^{22})}{2.02\times10^{6}}}$$

$V = 1.625 \times 10^3$

$$T = \frac{2\pi r}{V}$$

$n \times T = 24 \times 60 \times 60$

$$n\left[\frac{2\pi(2.02\times10^6)}{1.625\times10^3}\right] = 24\times3600$$

$$n = \frac{24\times3600\times1.625\times10^3}{2\pi(2.02\times10^6)}$$

$n = 11$

**15. Ans. (4)**

**Sol.** $$\frac{GM}{(R+h)^2} = \frac{GM}{2R^2}$$

$R + h = \sqrt{2}R$

$h = (\sqrt{2}-1)R$

$\simeq 2.6\times10^6$ m

**16. Ans. (2)**

**Sol.** Since mass of the object remains same

$\therefore$ Weight of object will be proportional to 'g' (acceleration due to gravity)

Given

$$\frac{W_{earth}}{W_{planet}} = \frac{9}{4} = \frac{g_{earth}}{g_{planet}}$$

Also, $g_{surface} = \frac{GM}{R^2}$ (M is mass planet, G is universal gravitational constant, R is radius of planet)

$$\therefore \frac{9}{4} = \frac{GM_{earth}\,R^2_{planet}}{GM_{planet}\,R^2_{earth}} = \frac{M_{earth}}{M_{planet}} \times \frac{R^2_{Planet}}{R^2_{earth}} = 9\frac{R^2_{Planet}}{R^2_{earth}}$$

$$\therefore R_{planet} = \frac{R_{earth}}{2} = \frac{R}{2}$$



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