2024

UPDATED SYLLABUS

PHYSICS

NCERT - 11

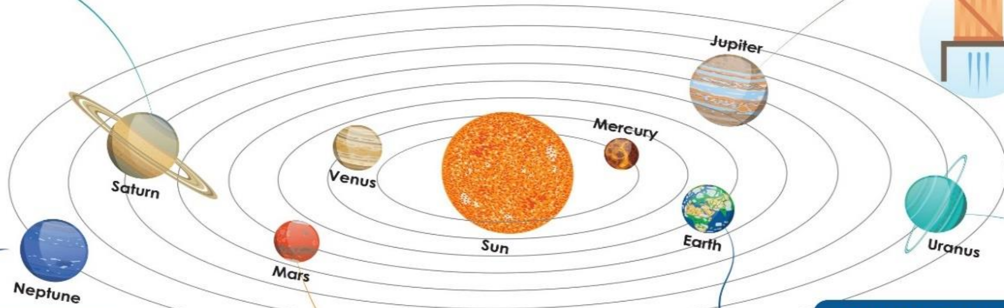
- Useful for CBSE, JEE & NEET exams
- Each topic contains Detailed Theory with images
- Every topic contains Exercises and Detailed solutions

8. Gravitation

Physics Smart Booklet

Theory + NCERT MCQs + Topic Wise Practice MCQs + NEET PYQs

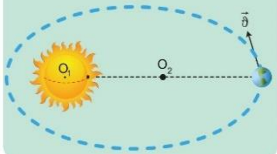
GRAVITATION



KEPLER'S LAW OF PLANETARY MOTION

LAW OF ORBIT

Every planet revolves around the sun in an elliptical orbit and sun is at it's one of the foci points.

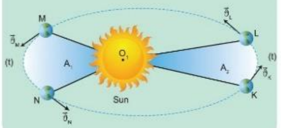


LAW OF AREA

(i) The line joins any planet to the sun sweeps equal area in equal intervals of time

(ii) $\frac{dA}{dt} = \frac{L}{2m}$

(iii) Areal velocity is constant

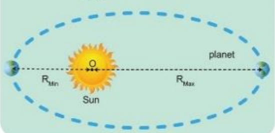


LAW OF PERIODS

(i) The square of time period of revolution of a planet is proportional to cube of semi – major axis of an ellipse

(ii) $T^2 \propto R^3$

(iii) $T^2 = \frac{4\pi^2 R^3}{Gm}$



NEWTON'S LAW OF GRAVITATION

THE gravitational force acting between two bodies separated by distance 'r' is directly proportional to product of their masses and inversely proportional to square of distance between them

$$F = \frac{Gm_1m_2}{r^2}$$

$$\Rightarrow G = 6.67 \times 10^{-11}\ \frac{Nm^2}{Kg^2}$$

$\vec{r_1}$ = position of first particle

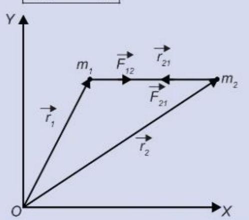
$\vec{r_2}$ = position of second particle

$\vec{r_{12}}$ = Force between them.

$$\vec{F_{12}} = \frac{Gm_1m_2}{|\vec{r_1} - \vec{r_2}|^2}\hat{r}_{12}$$

$$\vec{F_{12}} = \frac{Gm_1m_2\,(\vec{r_1} - \vec{r_2})}{|\vec{r_1} - \vec{r_2}|^3}$$

$$\boxed{\vec{F_{12}} = -\vec{F_{21}}}$$



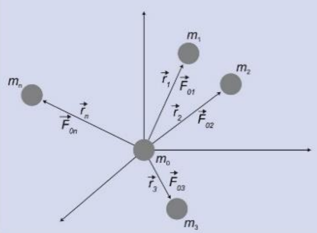
SUPERPOSITION PRINCIPLE IN VECTOR FORM

$$\vec{F_1} = \vec{F_{12}} + \vec{F_{13}} + \ldots\ldots + \vec{F_{1n}}$$

SUPERPOSITION PRINCIPLE IN SCALAR FORM

Resultant force acting on a particle due to other particles is vector sum of forces exerted by individual particle in it

F1 = F12 + F13 + ……. + F1N

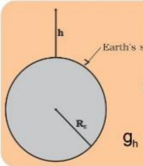


GRAVITATIONAL ACCELERATION

At surface of earth, $F_{gravitational}$ = weight

$$Mg = \frac{GMMe}{R_c^2}$$

$$gs = \frac{Gme}{R_c^2}$$

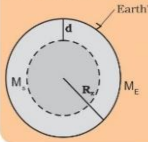


$g_h = g_s\left(\frac{1+h}{Rc}\right)^{-2}$ (i)

if h <<<< Rc (ii)

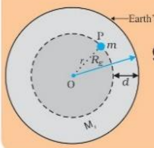
$g_h = g_s\left(1 - \frac{2h}{Rc}\right)$ (iii)

Variation of 'g' with depth



$$g_d = g_s\left(1 - \frac{d}{Rc}\right)$$

Variation of 'g' from equator to pole



$$g = g - Rw^2\cos^2$$

GRAVITATIONAL POTENTIAL & GRAVIATATION POTENTIAL

- Energy required to bring a mass from an infinite position to point under gravitational field of earth with constant velocity

$$U = \frac{Gm_1m_2}{r}$$

- Generally, infinite is reference point

Amount of work done in moving a unit test mass from ∞ - position to point under gravitational field of earth

$$V = \frac{Gm}{r} = \frac{U}{M}$$

(i) $r < R \rightarrow v = -GM\frac{(3R^2 - r^2)}{2R^3}$

(ii) $r = R \rightarrow v = -\frac{GM}{R}$

(iii) $r > R \rightarrow v = -\frac{GM}{r}$

Strength of Gravitational field applied per unit test mass is defined as Gravitational field intensity

$$\vec{E} = \frac{-GM}{r^2}\hat{r}$$

Relation between Gravitational potential & intensity

(i) $E = \frac{dv}{dr}$

(ii) $\Delta V = \int \vec{E} \cdot d\vec{r}$

WEIGHTLESSNESS

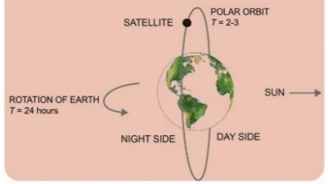
(1) During free fall under gravity in side a spacecraft or satellite, body is weightless.

(2) Effective weight of body becomes zero.

GEOSTATIONARY & POLAR SATELLITE

(1) GEOSTATIONARY SATELLITE
Height from earth's surface = 36,000 km
RADIUS = 42,400 Km
Time Period = 24 hours.

(2) POLAR SATELLITE
Height from earth's surface = 330 Km
Time Period = 84 Min
Orbital Velocity = 7.92 Km/s

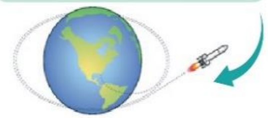


ESCAPE SPEED & ENERGY CONSERVATION

Minimum speed required by an object to escape Gravitational field of Earth

$$V_e = \sqrt{\frac{2GM}{R}} = \sqrt{2gR}$$

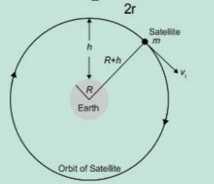
Ve = 11.2 Km/s



(i) orbital velocity = $\sqrt{\frac{GM}{r}}$

(ii) Total energy of satellite = constant
K.E + P.E = constant

(iii) Total energy = $\frac{GMM}{2r} - \frac{GMM}{r}$
$= -\frac{GMM}{2r}$



Gravitation

Kepler's laws of planetary motion

Based on the regularities in the motion of the planets, Kepler formulated a set of three laws known as Kepler's laws of planetary motion.

I Law (Law of orbits)

All planets move round the Sun in elliptical orbits with Sun at one of the foci.

II Law (Law of areas)

A line joining any planet and the Sun sweeps out equal areas in equal intervals of time.

Areal velocity: The area swept by the radius vector of a planet around the sun, per unit time is called areal velocity of the planet. Areal velocity of a planet remains constant.

III Law (Law of periods)

The square of the period of any planet about the Sun is proportional to the cube of the semi-major axis of its orbit. $T^2 \propto a^3$

where T is the period and a is the semi major axis.

If T_1 and T_2 are the periods of any two planets and r_1 and r_2 are their mean distances from the Sun, then

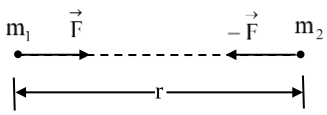
$$\frac{T_1^2}{T_2^2} = \frac{r_1^3}{r_2^3}$$

Nearer planets move faster. For example the orbital speed of Earth is about 30 km s^{-1}. The speed of Jupiter is about 13.2 km s^{-1} with a period of 11.86 years and that of Saturn is 9.7 km s^{-1} with a period of 29.46 years.

- Out of planets known before 18th century, Saturn is the slowest. Infact, the Sanskrit name 'shani' refers to slowly moving object. Saturn is seen for about 2½ years in each constellation $\left(\frac{T}{12} = \frac{29.46}{12} \approx 2.5 \text{ years}\right)$ and passes through 3 constellations in 7½ years, commonly known as 'saade-sath'.

Newton's Law of Gravitation: Every particle attracts every other particle with force that is proportional to the product of the masses and inversely proportional to the square of their separation and acts along the straight line joining them.

$$F = G\left(\frac{m_1 m_2}{r^2}\right)$$



Newton's law of universal gravitation

G is a universal constant, called the constant of gravitation.

$G = 6.67 \times 10^{-11}\ N m^2 Kg^{-2}$

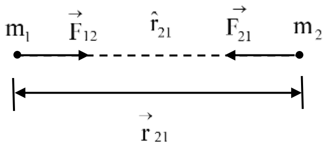
The dimensional formula for G is $[M^{-1}L^3T^{-2}]$

- The gravitational force is the weakest known force of nature.
- The value of G is the same for two particles, two celestial objects and two terrestrial objects.
- A spherical shell of matter attracts a particle that is outside the shell as if all the shell's mass were concentrated at its centre.
- A uniform shell of matter exerts no gravitational force on a particle located inside it. It is a gravitational shield for particles within it.
- The net gravitational force on a particle due to one or more particles is determined using the principle of superposition.

- The gravitational force on a particle would first increase slightly, eventually reach a maximum and finally decrease to zero at the centre of the earth as the particle is lowered down the centre. The reason for the initial increase is the predominance of the effect of decrease in r over that of the shell of the earth's crust that lies outside the radial position of the particle. As the centre is approached, the effect of the outer shell predominates.
- If the earth were uniformly dense, the gravitational force would decrease to zero as the particle is lowered to the centre of the earth.

Newton's law in vector form

$$\vec{F}_{21} = \left(\frac{Gm_1m_2}{r^3}\right)\vec{r}_{12} = \left(\frac{Gm_1m_2}{r^2}\right)\hat{r}_{12}$$



$\vec{F}_{12} = -\vec{F}_{21}$

where $\vec{F}_{12} \rightarrow$ force exerted on particle of mass m_2 by particle of mass m_1

$\vec{r}_{12} \rightarrow$ position vector of m_2 relative to m_1

$\hat{r}_{12} \rightarrow$ unit vector in the direction of $\vec{r}_{12}$

Gravity: It is the term used to describe the force on a body near the surface of a celestial body. The earth's gravity is given by

$F = \frac{GMm}{(R+h)^2}$ where $M \rightarrow$ mass of the earth, $R \rightarrow$ average radius of the earth

$h \rightarrow$ height of a body of mass m above the surface of the earth.

Acceleration due to gravity (g): It is the acceleration of a body due to gravity. On the surface of the earth $g = \frac{GM}{R^2}$

- The value of g is independent of the mass of the body.
- In the absence of air resistance, heavy and light bodies released from the same height reach the ground simultaneously.
- The average density of the earth is given by $\rho = \frac{3g}{4\pi GR}$.
- Acceleration due to gravity on the surface of the moon is about one-fifth of that on the surface of the earth.

Variation of g

(i) Due to altitude: Acceleration due to gravity at a height 'h' above surface of earth is

$$g_h = \frac{GM}{(R+h)^2}$$

$g_h = g\left[1 - \frac{2h}{R}\right]$ (for h << R) $R \rightarrow$ radius of earth

Thus g decreases with altitude.

(ii) Due to depth: Acceleration due to gravity at a depth 'd' below the surface of earth is

$g_d = g\left[1 - \frac{d}{R}\right]$ for (d << R)

at d = R, i.e., centre of earth

$g_d = 0$

$\therefore$ g decreases with depth

(iii) Due to rotation of earth: Acceleration due to gravity at a latitude λ is given by

$g_\lambda = g - R\omega^2 \cos^2\lambda$ $\omega \rightarrow$ angular velocity of earth

(a) At poles: $\lambda = \frac{\pi}{2}$

$$\therefore g_p = g - R\omega^2 \cos\frac{\pi}{2} = g_{max}$$

Thus g is maximum at poles.

(b) At equator: $\lambda = 0$

$\therefore\ g_{eq} = g - R\omega^2 \cos 0$

$= g - R\omega^2$

$= g_{min}$

(c) If earth stops rotating about its axis, the value of g at the equator will increase by 0.38 %, but at poles it remains constant.

(d) If angular speed (ω) increases by 17 times present value, there will be weightlessness on the equator. But g at the poles do not change. Earth's duration of day reduces to 84 minutes.

(iv) Due to nonspherical shape of earth

Polar radius (R_p) > equatorial radius and $g \propto \frac{1}{R^2}$

Value of g increases from poles to radius.

g is maximum at poles and minimum at non spherical shape of earth.

☞

- Latitude is the angle made by the line joining the centre of the earth and a point on the surface of the earth with the equator.
- If h is not small enough compared to R, $g = g\left[1+\frac{h}{R}\right]^{-2}$.
- The weight of an object decreases with altitude as well as depth. On the other hand, it increases with latitude.
- The free-fall acceleration g measured on the equator of the real, rotating earth is slightly, less than the gravitational acceleration (a_g) due strictly to the gravitational force $a_g - g = 0.03\,\text{m s}^{-2}$.

Gravitational field and potential

Gravitational field

The strength of a **gravitational field at any point is defined as the gravitational force experienced by unit mass at that point.**

If $\vec{f}$ is the force acting on a mass m at a point, the gravitational field at that point is

$$\vec{F}_G = \frac{\vec{f}}{m}. \qquad \dots (1)$$

Gravitational field due to a point mass at a distance 'r' is given by

$$\vec{F}_G = \frac{\vec{f}}{m} = -\frac{GM}{r^2}\hat{r} \qquad \dots (2)$$

The gravitational field at a point due to an object is inversely proportional to its distance from the object and it is a vector directed towards the object. SI unit of gravitational field is N kg^{-1}.

Gravitational potential energy

The concept of potential energy is already introduced. The potential energy of a system corresponding to a conservative force is defined as $U_f - U_i = -\int_i^f \vec{F}.d\vec{r}$

The change in the potential energy of a system is equal to the negative of the work done by the internal conservative forces.

For the small displacements of a body near the earth's surface, we have used the equation $U_f - U_i = mgh$

But the idea of gravitational potential energy is not confined to earth-particle system. In general, for a two particle system, we can write

$$U_f - U_i = -\int_i^f \vec{F}.\vec{dr} = -\int_{r_1}^{r_2} \frac{Gm_1m_2}{r^2}\, dr = Gm_1m_2\left[\frac{1}{r_1} - \frac{1}{r_2}\right]$$

We choose gravitational potential energy of this system equal to zero when the separation between the particles is infinity. Then potential energy of the system for any separation r is $U(r) = -\frac{Gm_1m_2}{r}$

For a system of n particles, the potential energy is the sum of the potential energy of every pair of particles in the system. In other words, the potential energy is additive.

Gravitational potential

The gravitational potential at any point is defined the negative of the work done by the gravitational force to bring unit mass from infinity to that point.

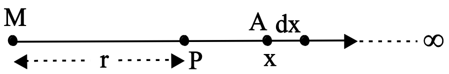
Or

The gravitational potential at any point is the negative of the work done by a force in displacing a unit mass from that point to infinity.

If V is the gravitational potential at any point, the potential energy U of a mass m at that point is given by U = mV.

Gravitational potential at a point due to a point mass

Let P be a point at a distance r, along the x-axis, from a point mass M kept at the origin O.



By definition of potential given earlier, the potential at the point P is

$$V_p = -\frac{GM}{r} \qquad \ldots (3)$$

The following table gives potential due to various regular bodies.

	Body	Position	Potential
1.	Uniform ring of radius a	At a point on its axis at a distance r from its center	$\frac{-GM}{\sqrt{a^2 + r^2}}$
2.	Uniform thin spherical shell of radius a	At a distance r from its center such that r ≥ a	$-\frac{GM}{r}$
		At a distance r from its center such that r < a	$-\frac{GM}{a}$
3.	Uniform solid sphere of radius a	At a distance r from its center such that r ≥ a	$-\frac{GM}{r}$
		At a distance r from its center such that r < a	$-\frac{GM}{2a^3}(3a^2 - r^2)$

☞	Negative potential energy indicates that the gravitational force is attractive. Kinetic energy is always positive. But potential energy can either be positive or negative. As long as the total energy (KE + PE) is negative, the object is bound within the system.

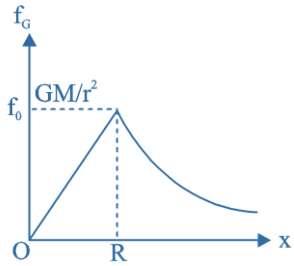
Earth's gravitational field

The gravitational force on a particle of mass m held at a distance h from the surface of the earth is $F = \frac{GMm}{(R+h)^2}$, towards the centre of the earth.

Hence gravitational field produced at a height h is $f_G = \frac{F}{m} = \frac{GM}{(R+h)^2}$, towards the earth.

At the surface of the earth, $f_G = \frac{GM}{R^2}$, … (5)

towards the centre of the earth. We see that **the gravitational field due to earth is numerically equal to the acceleration due to gravity of the earth**. The variation of gravitational field due to earth with distance x from its centre is shown in the figure.



distance from the centre of earth

Gravitational potential due to earth at a height h is $V = -\frac{GM}{R+h}$

At the surface $V = -\frac{GM}{R} = gr \left(\because g = \frac{GM}{R^2}\right)$ … (6)

For convenience in special cases potential at the surface is taken to be zero. Anyhow it is only the difference in potential is that significant.

As the height above the surface increases potential increases and the gravitational field is in the direction of decreasing potential, that is towards the surface. $F = -\frac{dV}{dr}$. … (7)

☞ Gravitational field due to a spherical shell at any point inside it is zero. Potential is constant equal to $-\frac{GM}{R}$ at all points on it. Hence gravitational field due to a shell is zero $\left(\frac{dV}{dr} = 0\right)$. However, even inside the spherical shell there will be gravitational field due to other objects. There is no gravitational shielding.

The following table gives intensity of field due to various objects.

	Object	Position	Field intensity
1.	Point mass	At a distance r from it	$\frac{GM}{r^2}$
2.	Uniform ring of radius a	At a point on its axis at a distance r from center	$\frac{GMr}{(a^2+r^2)^{3/2}}$
3.	Uniform disc of radius a	At a point on its axis at a distance r from center	$\frac{2GMr}{a^2}\left[\frac{1}{r} - \frac{1}{\sqrt{r^2+x^2}}\right]$
4.	Uniform thin spherical shell of radius a	At a distance r outside the shell	$\frac{GM}{r^2}$
		At a distance r inside the shell	Zero
5.	Uniform solid sphere of radius a	At a distance r outside the sphere	$\frac{GM}{r^2}$
		At a distance r inside the sphere	$\frac{GMr}{a^3}$

Escape velocity

The minimum velocity with which an object must be projected from the earth's surface so that it escapes from the earth's gravitational attraction is called escape velocity.

It is given by $v_0 = \sqrt{\frac{2GM}{R}} = \sqrt{2gR}$

where $g = \frac{GM}{R^2}$ is the acceleration due to gravity at the surface of the earth.

The escape velocity from earth's surface is 11.2 km s^{-1}.

Black hole: In the final stages of a massive star it consists of only attractive gravitational forces acting on its particles. Hence it continues to contract in size, increasing the density of matter in it. The negative potential $-\frac{GM}{R}$ and hence escape velocity increases. When the velocity becomes equal to the speed of light c, light also cannot escape from it. Hence no information about the object can be obtained from light coming out of it. Hence such an object is called a black hole. The maximum radius R_0 of a black hole is given by $c = \sqrt{\frac{2GM}{R_0}}$.

Inertial and gravitational mass

(a) **Inertial mass:** The mass of an object is that property of the object that causes it to resist a change in its velocity.

The mass that appears in **Newton's** second law, $\sum \vec{F} = m\vec{a}$, is often called, for this reason, the inertial mass.

(b) **Gravitational mass:** The mass of an object is that property of the object that causes it to be attracted to another object by the gravitational force.

The mass that appears in Newton's law of gravitation, $F = \frac{Gm_1m_2}{r^2}$, is often called, for this reason, the gravitational mass.

(c) It is obvious that mass characterised two different properties of matter. The inertial mass of an object is a measure of its resistance to change of velocity. For example, the difficulty one encounters in stopping a runaway cart has nothing to do with its gravitational mass. The gravitational mass is a measure of its attraction to other objects in its environment. For example, the effort one expends in holding a book has nothing to do with its inertial mass. Experiments show that the inertial mass m_i object is proportional to its gravitational mass m_g and the units are so chosen that $m_i = m_g$

Satellite

(a) A satellite is a celestial object rotating around a planet. For example, the moon is the satellite of the earth.

(b) An artificial satellite is one that is made to rotate around the earth. There are hundreds of artificial satellites.

(c) **Orbital speed** (v_0) **:** It is the speed of a satellite around the earth.

$$v_0 = \sqrt{\frac{GM}{r}} = \sqrt{gr} = \sqrt{g(R+h)}$$

where $r \to$ radius of the orbit of the satellite , $h \to$ height above the surface of the earth

$R \to$ average radius of the earth.

Its period of rotation is $T = 2\pi\sqrt{\frac{r^3}{GM}} = 2\pi\sqrt{\frac{r}{g}} = 2\pi\sqrt{\frac{R+h}{g}}$. If h << R, we can write $T = 2\pi\sqrt{\frac{R}{g}}$

(d) **Escape speed** (v_e) **:** It is the minimum speed with which an object is projected from the surface of the earth so that it escapes from the earth's gravity.

$v_e = \sqrt{2GM/R} = \sqrt{2gR} = \sqrt{2}v_e$. It is about 11.2 $Km s^{-1}$ for earth.

(e) **Energy of a satellite**

Consider a satellite of mass m in an orbit of radius r.

We have, the centripetal force $\frac{mv^2}{r} = \frac{GMm}{r^2}$

$\therefore$ Kinetic energy is $K = \frac{1}{2}mv^2 = \frac{GMm}{2r}$ … (1)

Potential energy $U = -\frac{GMm}{r}$ … (2)

$U = -2K$

Total energy of the satellite $E = K + U = \frac{GMm}{r}\left[\frac{1}{2} - 1\right] = -\frac{GMm}{2r}$ … (3)

Close to the earth, $E = -\frac{GMm}{2R} = -\frac{mgR}{2}$

As height increases, the kinetic energy decreases, potential energy increases.

(f) **Rocket launching:** It is a multistage process. Initially at the lift off, the launching rocket rises vertically to pass through denser atmospheric layer with least fuel consumption. The first stage rocket falls off at about 60 km height, and the second stage rocket is fired. The second stage rocket is gradually fitted by the guidance system. When it reaches the desired height, the tracking system guides the rocket to move horizontally. At this stage, small rockets are fired to separate the capsule from the second stage rocket and project it into space with the speed required to follow a predetermined orbit.

Communication and Indian remote sensing (IRS) satellites

The artificial satellites are broadly classified into two types.

(i) Communication satellites and

(ii) Remote sensing satellites.

Communication satellites

1. Communication satellites are mainly used for communication.
2. They link remote areas of earth with telephone and television.
3. With a network of geostationary satellites a radio/TV program can be broadcasted all over the world simultaneously.
4. These satellites are also used to take photographs of clouds around earth which help in weather forecasting.
5. INSAT series of satellites launched by India are communication satellites.

Remote sensing satellites

1. Remote sensing satellites are used to estimate the natural resources.
2. They are usually placed in low flying polar orbits.
3. These can take photograph of large areas of land. Hence they can be used to study resources such as forest, river, water resources, mineral deposits, agricultural crops etc.
4. These are also used for military purposes.

☞

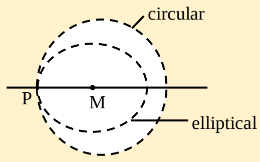
- The geostationary circular orbit (also called the Clarke geosynchronous orbit or Clark Arc, after the famous science fiction writer Arthur C. Clarke who proposed the idea of a communication satellite in 1945) is in the equatorial plane of the earth. Its direction of angular motion coincides with that of the earth about its polar axis.
- All communication satellites are geostationary. TV programs are relayed live via these satellites
- The escape speed does not depend on the direction of projection
- It can be shown that the escape speed in terms of radius and density of a planet is given by

$$v_e = \sqrt{\frac{8\pi G}{3}} R\sqrt{\rho} \Rightarrow v_e \propto R\sqrt{\rho}$$

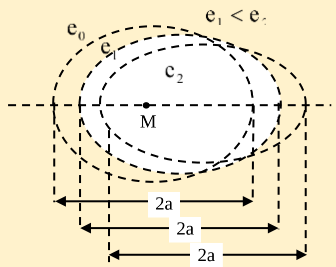
- An orbiting satellite has both potential energy U and kinetic energy K.

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

- It can be shown that $E = -\dfrac{GMm}{2r}$ holds for an elliptical orbit of semi major axis ‘a’ if r is replaced by a. So, total mechanical energy of a satellite remains the same if it is put in different elliptical orbits with the same a, but different values of eccentricity e (including 2000)
- To change the speed and orbit of a satellite, a burn is executed in it. The values of K and E at P, the location of the burn, are less than their corresponding values in the circular orbit. W = –2K and E = –K for a circular orbit do not apply for the new elliptical orbit.



Changing the orbit of a satellite



Three elliptical orbits with the same semimajor axis a, but e values (e = 0 for circular orbit of r = a)

- Once the satellite is placed in the required orbit by burning small orbital engines, no engines are required to keep it in the orbit since gravity takes care of that
- **Physiological effects in weightlessness :** (i) Astronaut’s face becomes puffy. (ii) Astronaut grows a little temporarily (iii) Cardiovascular system of an astronaut does not need to work hard to pump blood around the body (iv) There is no preferred direction, no upside down or right side up. All orientations of an astronaut are equally comfortable.
- **Physical effects in weightlessness :** (i)A liquid column has no weight, no hydrostatic pressure, no buoyant effects, no sedimentation. (ii) There is no convection. (iii) A column of air expands on heating but stays where it is. (iii) Surface tension is much more evident. It is because of surface tension that near normal dinning is possible in space. Space shuttle straws come with small clamps to pinch them closed and keep the drinks from climbing.

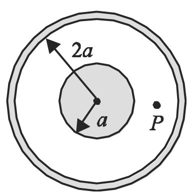
Illustrations

1. A uniform solid sphere of mass M and radius ‘a’ is surrounded symmetrically by a uniform thin spherical shell of equal mass and radius 2a. Find the gravitational field at a distance $\frac{3}{2}a$ from the centre.

(A) $\frac{4}{9}\frac{GM}{a^2}$ (B) $\frac{4}{16}\frac{GM}{a^2}$ (C) $\frac{2}{3}\frac{GM}{a^2}$ (D) $\frac{21}{25}\frac{GM}{a^2}$

Ans (A)

The point P is at a distance $\frac{3}{2}a$ from the centre.



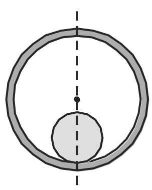
As P is inside the cavity of the thin spherical shell, the field here due to the shell is zero.

The field due to the solid sphere is $g = \dfrac{GM}{\left(\frac{3}{2}a\right)^2} = \dfrac{4}{9}\dfrac{GM}{a^2}$

2. A solid sphere of mass *m* and radius *r* is placed inside a hollow thin spherical shell of mass *M* and radius *R* as shown. A particle of mass m_1 is placed on the line joining the two centres at a distance *x* from the point of contact of the sphere and the shell [if $r < x < 2r$]. The magnitude of gravitational force due to sphere and shell on this particle is

(A) $\dfrac{Gmm_1x}{r^3}$ (B) $\dfrac{Gmm_1(x-r)}{r^3}$

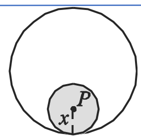
(C) $\dfrac{Gmm_1}{(x-r)^2}$ (D) $\dfrac{GMm_1}{(x-r)^2}$



Ans (B)

The distance of point p from the centre of the sphere is $(x - r)$.

The field due to shell at P is zero.



So field at point P is $\frac{Gm}{r^3}(x-r)$.

So force on m_1 kept at this point is $\frac{Gmm_1}{r^3}(x-r)$

3. The time taken by a particle to move down a straight tunnel from the surface of earth to its centre is _____ [R is radius of earth]

(A) $\frac{\pi}{2}\sqrt{\frac{R}{g}}$ (B) $\pi\sqrt{\frac{R}{g}}$ (C) $\frac{\pi}{4}\sqrt{\frac{R}{g}}$ (D) $\frac{2}{\sqrt{3}}\pi\sqrt{\frac{R}{g}}$

Ans (A)

Force on the particle when it is at distance x from centre is

$$F = mg' = mg\left(1 - \frac{R-x}{R}\right) = \frac{mgx}{R}$$

As it is of restoring nature $F = -\frac{mg}{R}x$ or $a = -\frac{g}{R}x$

Comparing it with $a = -\omega^2 x$, we have $\omega = \sqrt{\frac{g}{R}}$

$\therefore T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{R}{g}}$ Required time is $\frac{T}{4} = \frac{\pi}{2}\sqrt{\frac{R}{g}}$

4. A small mass m is transferred from the centre of a hollow sphere of mass M to infinity. Find the work done in this process. [Radius of sphere is R]

(A) $\frac{3}{2}\frac{GMm}{R}$ (B) zero (C) $\frac{GMm}{R}$ (D) $\frac{GMm}{2R}$

Ans (C)

At infinity $V = 0$, at the centre $V_C = -\frac{GM}{R}$

$$W = m(0 - V_C) = m\left[0 - \left(\frac{-GM}{R}\right)\right] = \frac{GMm}{R}$$

5. An artificial satellite is moving in a circular orbit around the earth with a speed equal to half the magnitude of escape velocity from the earth. The height of the satellite above the earth's surface is

[R = Radius of earth]

(A) $\frac{R}{2}$ (B) $\frac{R}{3}$ (C) R (D) $\frac{3}{2}R$

Ans (C)

$$v_e = \sqrt{\frac{2GM}{R}} \Rightarrow v_0 = \frac{1}{2}\sqrt{\frac{2GM}{R}} \text{ (given)}$$

Also, $v_0 = \sqrt{\frac{GM}{R+h}}$

$$\therefore \sqrt{\frac{GM}{R+h}} = \frac{1}{2}\sqrt{\frac{2GM}{R}} \Rightarrow R + h = 2R \Rightarrow h = R$$

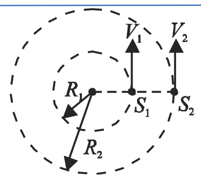
6. Two satellites S_1 and S_2 revolve round a planet in coplanar circular orbits in the same sense. Their periods of revolution are 1h and 8h respectively. The radius of orbit of S_1 is 10^4 km. The speed of S_2 relative to S_3 when S_2 is closest to S_1, is _____ km h^{-1}.

(A) 2×10^4 (B) $\pi \times 10^4$ (C) $2\pi \times 10^4$ (D) 10^4

Ans (B)

$T^2 \alpha r^3$

$$\left(\frac{T_1}{T_2}\right)^2 = \left(\frac{R_1}{R_2}\right)^3 \text{ or } \left(\frac{1}{8}\right)^2 = \left(\frac{R_1}{R_2}\right)^3$$



$$\therefore\ R_2 = 4R_1 = 4\times 10^4 \text{ km}$$

$$v_1 = \frac{2\pi R_1}{T_1} = 2\pi\times 10^4 \text{ km h}^{-1}$$

$$\text{and } v_2 = \frac{2\pi R_2}{T_2} = \pi\times 10^4 \text{ km h}^{-1}$$

In the given situation $|v_1 - v_2| = \pi \times 10^4$ km h^{-1}

7. A body is projected vertically upwards from the surface of the earth with a velocity sufficient to carry it to infinity. If the radius of the earth is R, the velocity of the body at a height h is

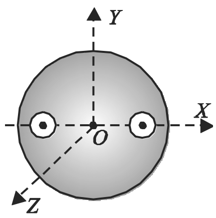
(A) $\sqrt{gR}$ (B) $\sqrt{\frac{2gR^2}{3(R+h)}}$ (C) $\sqrt{\frac{gR^2}{R+h}}$ (D) $\sqrt{\frac{2gR^2}{R+h}}$

Ans (D): From conservation of energy

$$-\frac{GMm}{R} + \frac{m}{2}\left(\sqrt{\frac{2GM}{R}}\right)^2 = -\frac{GMm}{R+h} + \frac{1}{2}mv^2$$

$$\frac{GM}{R+h} + \frac{GM}{R} - \frac{GM}{R} = \frac{1}{2}v^2 \Rightarrow v = \sqrt{\frac{2GM}{R+h}} = \sqrt{\frac{2gR^2}{R+h}}$$

8. A solid sphere of uniform density and radius 4 m is located with its centre at the origin 'O' of coordinates. Two spheres of equal radius 1 m with their cavities at $A(-2, 0, 0)$ and $B(2, 0, 0)$ respectively are taken out, leaving behind spherical cavities. The mass of each sphere taken out is M. The gravitational field at B is



(A) GM (B) $\frac{21GM}{5}$

(C) $\frac{31}{16}GM$ (D) $\frac{31}{8}GM$

Ans (C)

Mass of whole sphere of radius 4 M (without cavities) is $M_0 = \frac{M\times\frac{4}{3}\pi(4)^3}{\frac{4}{3}\pi(1)^3} = 64\,M$

The gravitational field at B = field due to whole sphere – field due to sphere A

$$= \frac{GM_0 r}{R^3} - \frac{GM}{AB^2}$$

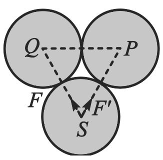
$$= \frac{G(64M)\times 2}{4^3} - \frac{GM}{4^2} = \frac{31}{16}GM$$

9. Three uniform spheres each having a mass m and radius R are kept in such a way that each touches the other two. Find the magnitude of the gravitational force on any of the spheres due to the other two.

(A) $\frac{\sqrt{3}Gm^2}{4R^2}$ (B) $\frac{\sqrt{3}Gm^2}{2\sqrt{2}R^2}$ (C) $\frac{\sqrt{3}Gm^2}{4\sqrt{2}R^2}$ (D) $\frac{Gm^2}{2\sqrt{2}R^2}$

Ans (A)

$\theta = 60°$, ΔPQS is an equilateral triangle of side $2R$.



Forces on S: $F = \frac{Gm^2}{(2R)^2} = \frac{Gm^2}{4R^2}$ and $F' = F$

$$F_{net} = \sqrt{F^2 + F^2 + 2F^2\cos 60} = \sqrt{3}F$$

$$F_{net} = \frac{\sqrt{3}Gm^2}{4R^2}$$

10. The distance between two bodies A and B is r. Taking the gravitational force according to the law of inverse square of r, the acceleration of body A is a. If the gravitatinal force follows an inverse fourth power law, then what will be the acceleration of the body A?

(A) $\frac{a}{r^3}$ (B) $\frac{a}{r}$ (C) $\frac{a}{\sqrt{r}}$ (D) $\frac{a}{r^2}$

Ans (D)

$$F=\frac{Gm_Am_B}{r^2}\Rightarrow a_A=a=\frac{F}{m_A}=\frac{Gm_B}{r^2} \qquad ...(i)$$

$$F'=\frac{Gm_Am_B}{r^4}\Rightarrow a_A=a'=\frac{F'}{m_A}=\frac{Gm_B}{r^4} \qquad ...(ii)$$

From (i) and (ii) $\frac{a'}{a}=\frac{1}{r^2}\Rightarrow a'=\frac{a}{r^2}$

11. Value of g on the surface of earth is 9.8 ms^{-2}. Find its value on the surface of a planet whose mass and radius both are two times that of earth.

(A) 9.8 ms^{-2} (B) 19.6 ms^{-2} (C) 4.9 ms^{-2} (D) 10.32 ms^{-2}

Ans (C)

$$g=\frac{GM}{R^2}=9.8\text{ ms}^{-2}; \quad g'=\frac{G.(2M)}{(2R)^2}=\frac{GM}{R^2}.\frac{1}{2}=4.9\text{ ms}^{-2}$$

12. Calculate the change in the value of g at latitude 45° (when compared with g at equator). The radius of earth = 6.37 × 10^3 km.

(A) 0.021 ms^{-2} (B) 0.0013 ms^{-2} (C) 0.043 ms^{-2} (D) 0.017 ms^{-2}

Ans (D)

$$g_{equator}=g-R\omega^2\cos^2 0=g-R\omega^2$$

$$g_{45°}=g-R\omega^2\cos^2 45°=g-\frac{R\omega^2}{2}$$

$$\Delta g=\left(g-\frac{R\omega^2}{2}\right)-(g-R\omega^2)=\frac{R\omega^2}{2}=\frac{6.37\times10^6}{2}\times\left(\frac{2\pi}{24\times60\times60}\right)^2=0.017\text{ ms}^{-2}$$

13. A body is weighed by a spring balance, 1000 N at the north pole. If only the rotation of earth is accounted for, how much will it weigh at the equator?

(A) 1002 N (B) 997 N (C) 995 N (D) 999 N

Ans (B)

$$g_{pole}=g-R\omega^2\cos^2 90°=g\Rightarrow mg=1000$$

$$g'=g_{equator}=g-R\omega^2\cos^2 0°=g-R\omega^2$$

$$\Rightarrow mg'=\frac{1000}{g}(g-R\omega^2)=1000\left(1-\frac{R\omega^2}{g}\right)=997\text{ N}$$

14. A particle of mass 20 g experiences a gravitational force of 4N along + ve X-direction. Find the gravitational field at that point (magnitude)

(A) 50 N kg^{-1} (B) 100 N kg^{-1} (C) 200 N kg^{-1} (D) 150 N kg^{-1}

Ans (C)

$$m=20g=20\times10^{-3}\text{ kg}; \ F=4N$$

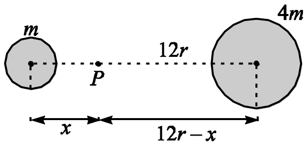
$$E=\frac{F}{m}=\frac{4}{20\times10^{-3}}=0.2\times10^3=200\text{ N kg}^{-1}$$

15. Two spheres one of mass m has radius r. Another sphere has mass 4m and radius 2r. The centre to centre distnace betwen them is 12r. Find the distance from the centre of smaller sphere where net graviational field is zero.

(A) 2r (B) 4r (C) 5r (D) 3.5 r

Ans (B)

Let at point P net gravitational field is zero. So fields due to spheres are equal and opposite.

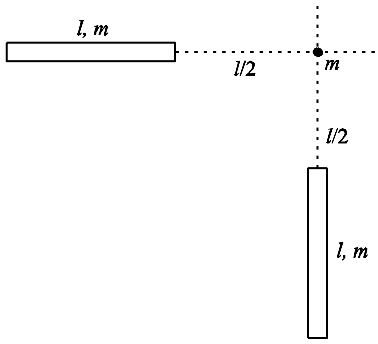


$$E_1 = E_2 \Rightarrow \frac{Gm}{x^2} = \frac{G.4m}{(12r-x)^2} \Rightarrow 144r^2 + x^2 - 24xr = 4x^2$$

$$3x^2 + 24rx - 144r^2 = 0$$

$$x^2 + 8rx - 48r^2 = 0 \Rightarrow x = 4r$$

16. Figure shows two uniform rods each of mass m and length l placed on two perpendicular lines. A small point mass m is placed on the point of intersection of two lines. Find the net gravitational force experienced by m.



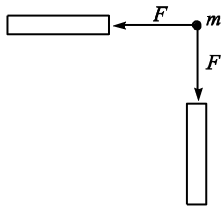
(A) $\frac{2\sqrt{2}Gm^2}{3l^2}$

(B) $\frac{\sqrt{2}Gm^2}{3l^2}$

(C) $\frac{4\sqrt{2}Gm^2}{3l^2}$

(D) $\frac{\sqrt{2}Gm^2}{l^2}$

Ans (C)



The formula of illustration (1) can be used here

$$F = \frac{Gm^2}{(l/2)\,[(l/2)+l)} = \frac{4Gm^2}{3l^2}$$

$$\therefore\ F_{net} = F\sqrt{2} = \frac{4\sqrt{2}Gm^2}{3l^2}$$

17. The period of a satellite in a circular orbit around a planet is independent of

(A) the mass of the planet (B) the radius of the planet

(C) the mass of the satellite (D) all the three parameters (A), (B) and (C)

Ans (C)

The period of a satellite in a circular orbit is independent of mass of the satellite.

18. The time period of a satellite in a circular orbit of radius R is T. The radius of the orbit in which the time period is 8T is

(A) 2 R (B) 3 R (C) 4 R (D) 5 R

Ans (C)

From the Kepler's law, we have $T^2 = R^3 \Rightarrow \left(\frac{T_2}{T_1}\right)^2 = \left(\frac{R_2}{R_1}\right)^3$

$$R_2 = R_1\left(\frac{T_2}{T_1}\right)^{2/3} = R\left(\frac{8T}{T}\right)^{2/3} = 4R.$$

19. If the distance between the sun and the earth is increased by three times, the attraction between the two will

(A) remain constant (B) decrease by 63 %

(C) decrease by 83 % (D) decrease by 89 %

Ans (D)

We have $F = \frac{Gm_1m_2}{r^2}$

$$\frac{F_1}{F_2} = \frac{\left(\frac{Gm_1m_2}{r^2}\right)}{\left(\frac{Gm_1m_2}{(3r)^2}\right)} = 9 \qquad F_2 = \frac{F_1}{9}$$

$\therefore$ % decrease in force = $\frac{F_1 - F_2}{F_1} \times 100$ = 89 %

20. The ratio between masses of two planets is 2 : 3 and the ratio between their radii is 3 : 2. The ratio between acceleration due to gravity on these two planets is

(A) 4 : 9 (B) 8 : 27 (C) 9 : 4 (D) 27 : 8

Ans (B)

We know that $g = \frac{GM}{R^2}$ $\quad \therefore \frac{g_1}{g_2} = \frac{\frac{GM_1}{R_1^2}}{\frac{GM_2}{R_2^2}} = \frac{M_1}{M_2}\frac{R_2^2}{R_1^2} = \frac{2}{3}\times\left(\frac{2}{3}\right)^2 = \frac{8}{27}$

21. If the change in the value of g at a height h above the surface of the earth is same as at a depth d below it, then (both d and h are much smaller than the radius of the earth)

(A) $d = \frac{h}{2}$ (B) d = h (C) d = 2h (D) $d = h^2$

Ans (C)

The acceleration due to gravity at height h is $g' = g\left(1 - \frac{2h}{R}\right)$

The acceleration due to gravity at a depth d is $g'' = g\left(1 - \frac{d}{R}\right)$

Given that, $g' = g''$

$g'\left(1 - \frac{2h}{R}\right) = g''\left(1 - \frac{d}{R}\right)$ $\qquad$ 2h = d

22. If R is the radius of the earth and g is acceleration due to gravity on the earth's surface, the mean density of earth is

(A) $\frac{4\pi G}{3gR}$ (B) $\frac{3\pi G}{4gR}$ (C) $\frac{3g}{4\pi RG}$ (D) $\frac{\pi Rg}{12G}$

Ans (C)

We have, $g = \frac{GM}{R^2} = \frac{G}{R^2}\times\frac{4}{3}\pi R^3\rho \Rightarrow \rho = \frac{3g}{4\pi RG}$

NCERT LINE BY LINE QUESTIONS

1. The escape speed of a body from the earth depends on

(1) Mass of the body

(2) The direction of projection

(3) The height of location from where the body is launched

(4) All of these

2. A planet of mass *m* revolved around the sun of mass Min an elliptical orbit. The maximum and minimum distance of the planet form the Sun are *r* and 3r respectively. The time period of the planet is proportional to

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

3. Two point masses *m* and 9m are separated by a distance don a line. A third point mass of **1** kg is to be placed at a point on the line such that the net gravitational force on it is zero. The distance of 1 kg mass from mass *m* is

1) $\frac{d}{4}$ 2) $\frac{d}{2}$ 3) $\frac{d}{3}$ 4) $\frac{d}{6}$

4. The force of gravitation between two masses is 10 mN in vacuum. If both the masses are placed in a liquid at the same distance, then new force of gravitation will be

(1) 10mN (2) $\frac{40}{3}$mN (3) $\frac{30}{4}$mN (4) Can't say

5. Three equal masses of 3 **kg** each are fixed at the vertices of an equilateral triangle ***ABC.*** The gravitational force acting on mass 2 kg placed at the centroid of triangle is

(1) Zero (2) 6.67×10^{-3}N (3) 9×10^{-9}N (4) Data is insufficient

6. An object is projected from earth's surface, with speed half of the escape speed of earth, then maximum height attained by it is

1) $\frac{R_E}{2}$ 2) $\frac{R_E}{3}$ 3) R_E 4) $2R_E$

7. The change in gravitational potential energy when a body of mass m is raised to height $4R_E$ from the earth surface is $4R_E$ is radius of earth)

(1) $\frac{4}{3}mgR_E$ (2) mgR_E (3) $\frac{mgR_E}{5}$ (4) $\frac{4}{5}mgR_E$

8. The potential energy of a system of four particles each of mass *m*, placed at vertices of a square of side a is

(1) $-(4+\sqrt{2})\frac{Gm^2}{a}$ (2) $-4\frac{Gm^2}{a}$ (3) $-4\sqrt{2}\frac{Gm^2}{a}$ (4) $-\frac{4Gm}{a}$

9. A satellite of mass *m* is in a circular orbit of radius $2R_E$ around the earth. The energy required to transfer it to a circular orbit of radius $4R_E$ is

(1) $\frac{mgR_E}{2}$ (2) $\frac{7}{8}mgR_E$ (3) $\frac{mgR_E}{8}$ (4) $\frac{mgR_E}{4}$

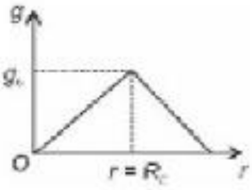
10. If the gravitational potential at the surface of earth is V_o, then potential at a point at height equal to radius of earth is

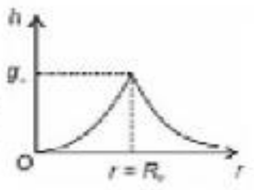
(1) V_0 (2) $\frac{V_0}{2}$ (3) $\frac{V_0}{3}$ (4) $\frac{V_0}{4}$

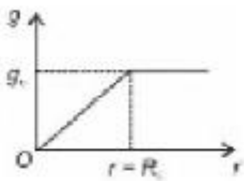
11. A satellite revolving around earth has potential energy - 2 MJ, then the binding energy of the satellite is

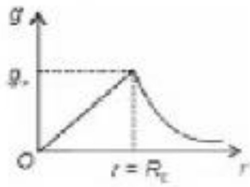
(1) 1 MJ (2) 2MJ (3) – 1 MJ (4) 8 MJ

12. Starting from the centre of earth having radius R_E , the variation is acceleration due to gravity is best represented by the curve

(1) 

(2) 

(3) 

(4) 

13. A body weighs 90 N on the surface of earth. The gravitational force on it due to earth at a height equal to half the radius of earth is

(1) 81 N   **(2)** 40 N   (3) 45 N   (4) 30 N

14. The escape speed of a projectile on the earth surface is 11.2 km/s. A body is projected out with three times of escape speed. The speed of body far away from the earth is (Ignore the presence of sun and other planets)

(1) 31.7 km/s   (2) 24 km/s   (3) 22.4 km/s   (4) Zero

15. The density of a newly invented planet is twice that of earth. The acceleration due to gravity at the surface of the planet is double that at the surface of earth, If radius of earth is R_E then the radius of the planet would be

1) R_E 2) $\frac{R_E}{2}$ 3) $2R_E$ 4) $4R_E$

16. For a satellite moving in a circular orbit around the earth, the ratio of kinetic energy to the magnitude of potential energy is

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

17. A point mass m is placed inside a spherical shell of mass M and radius R. The gravitational force experienced by the point

(1) $\frac{GMm}{R^2}$ (2) $\frac{GMm}{2R^2}$ (3) $\frac{2GMm}{R^2}$ (4) Zero

18. A Geostationary satellite is orbiting at a height of $6R_E$ above the surface of earth. The time period of another satellite at a height $2.5R_E$ above the surface of earth is (R_E is radius of earth)

(1) 6 hours   (2) $6\sqrt{2}$ hours   (3) $\frac{6}{\sqrt{2}}$ hours   (4) 12 hours

19. A particle is projected vertically up with velocity $v = \sqrt{\frac{5}{4}gR_E}$ from earth surface.

The velocity of particle at height equal to the maximum height reached by it is

(1) $\sqrt{\frac{gR_E}{4}}$ (2) $\sqrt{\frac{gR_E}{3}}$ (3) $\sqrt{\frac{gR_E}{5}}$ (4) Zero

20. When energy of a satellite-Earth system is non-zero positive, then satellite will

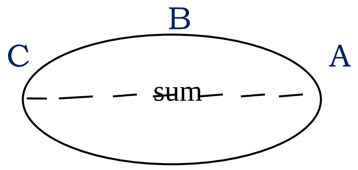
(1) Move around the earth in circular orbit
(2) Just escape out
(3) Move around the earth in elliptical orbit

(4) Escape out with speed some interstellar speed

NCERT BASED PRACTICE QUESTIONS

1. "All planets move i elliptical orbits with the sun situated at one of the foci". This law was given by
(a) Newton (b) keplar (c) Archimedesc (d) Pascal
2. Planet revolving round sun swept out equal area in equal time because
(a) Its linear momentum remain constant
(b) It angular momentum remain constent
(c) Its (linear + angular) momentum remain constant
(d) None of these

3. Planet revolving around the sun is shown in figure its speed will be maximum at
(a) A
(b) B
(c) C
(d) same at all points



4. A planet revolving round the sun has time perid T and semi major axis R then which of the following relation is correct
(a) $T^2 \times R^3$ (b) $T \times R^2$ (c) $T \times R^3$ (d) $T^2 \times R$
5. A planet revolving around the sun has angular momentum L and mass m then areal velocity of the planet is
(a) $\frac{L}{2m}$ (b) $\frac{L}{m}$ (c) $\frac{2m}{L}$ (d) 2 mL
6. Which of the following is not correct for gravitation force?
(a) It is a conservation force
(b) It is a central force
(c) It depends on the medium between two particles
(d) all of the above
7. Two particles of mass m_1 and m_2 are laced at distance r has a force of attraction F if a third mass m_3 is placed near these two particles then force of attraction between them will be F' then
(a) F' > F (b) F' < F (c) F' = F (d) can not be said

8. If earth pall moon with force F the moon pull the earth with force
(a) greater than F (b) less than F
(c) equal to F (d) none of these
9. If a body is at a height h from the surface of earth than the value of acceleration due to gravity at that height if acceleration due to gravity at earth surface is g is
(a) $g\left(1-\frac{2h}{R}\right)$ (b) $g\left(1-\frac{h}{R}\right)$
(c) $g\left(1-\frac{h}{2R}\right)$ (d) None of these
10. A planet has radius half the radius of earth and mass double than that of earth then value of acceleration due to gravity at the surface of that planet is (g = 10 m/s^2)
(a) 40 m/s^2 (b) 160 m/s^2
(c) 80 m/s^2 (d) 90 m/s^2
11. The value of acceleration due to gravity at a depth of d from the earth surface is
(a) $g\left(1-\frac{2d}{R}\right)$ (b) $g\left(1-\frac{d}{2R}\right)$

(c) $g\left(1-\frac{d}{R}\right)$ (d) None of these

12. If value of acceleration due to gravity at a height h from the earth surface is same as at a depth d the which of the following is correct

(a) h = 2d (b) d = 2h (c) $d = \frac{h}{4}$ (d) d = 4h

13. The value of acceleration due to gravity ----------when one move from equator to pole

(a) increases (b) decreases

(c) remains same (d) can not be said

14. Acceleration due to gravity at the centre of earth is

(a) ∞ (b) 0 (c) g (d) None of these

15. Two particles of mass m_1 and m_2 are placed at distance & then gravitational potential energy of to particle system is

(a) $-\frac{Gm_1m_2}{r}$ (b) $\frac{Gm_1m_2}{r}$ (c) $-\frac{Gm_1m_2}{r^2}$ (d) $\frac{Gm_1m_2}{r^2}$

16. Potential energy of a system of four particles placed at the vertices of a square of side l is

(a) $-\frac{2Gm^2}{l}$ (b) $-\frac{2Gm^2}{l}\left(2+\frac{1}{\sqrt{2}}\right)$

(c) $-\frac{2Gm^2}{l}\left(2+\sqrt{2}\right)$ (d) $\frac{-Gm^2}{l}\left(2+\frac{1}{\sqrt{2}}\right)$

17. Escape velocity of a body at the earth surface is

(a) $\sqrt{gR_E}$ (b) $\sqrt{2gR_E}$ (c) $\sqrt{\frac{gR_E}{2}}$ (d) $\sqrt{\frac{GM_E}{R_E}}$

18. Kinetic energy of a satellite of mass M revolving in orbit of radius R is

(a) $\frac{GM_Em}{R^2}$ (b) $\frac{GM_Em}{2R}$ (c) $\frac{GM_Em}{R}$ (d) $-\frac{GM_Em}{2R}$

19. If kinetic energy of a satellite revolving around the sun is k then total energy of the satellite is

(a) 2k (b) – k (c) $\frac{k}{2}$ (d) – 2k

20. Weight of a person at the surface of earth is w then weight of the person in a satellite revolving around the earth is

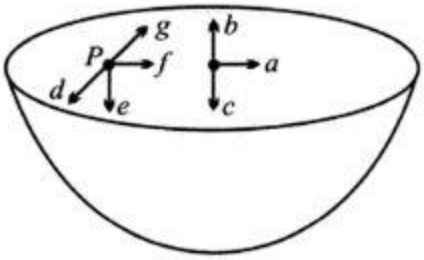
(a) 0 (b) w (c) $\frac{w}{2}$ (d) 2w

21. Which of the following symptoms is not likely to afflict an astronaut in space?

(a) swollen feet (b) swollen face

(c) headache (d) orientational problem

22. The gravitational intensity at the centre of hemispherical shell of uniform mass density has the direction



(a) a (b) b (c) c (d) zero

23. A rocket is fired the earth towards the sun at what distance from the earth's centre is the gravitational force the rocket is zero (mass of sun = 2 $\times 10^{30}$ kg. Mass of earth = 6$\times 10^{24}$kg) orbital radius = 1.5 $\times 10^{11}$m)
(a) 1.3$\times 10^8$m (b) 5.2 $\times$ 10^8
(c) 2.6$\times 10^8$m (d) 3.6$\times 10^8$m

24. Two stars each of one solar mass (- 2$\times 10^{30}$kg) are approaching each other for a head on collision. When they are a distance 10^9, their speeds are negligible. What is the speed with which they collide? (radius of star = 10^4km)
(a) 2.6$\times 10^6$m/s (b) 1.3$\times 10^6$m/s (c) 5.2$\times 10^6$ m/s (d) 3.6$\times 10^6$m/s

25. A body weighs 63N on the surface of the earth. What is the gravitational force it due to the earth at a height equal to half the radius of earth
(a) 63 N (b) 36 N (c) 28 N (d) 56N

26. The escape speed of a projectile on the earth's surface is 11.2 km/s A body is projected out with thrice of this speed of the body far away from the earth is
a) 31.7 km/s (b) 11.2 km/s (c) 22.7 km/s (d)22.4km/s

27. The earth is a sphere of uniform mass density how much would the body weigh half way down to the centre of the earth if its weighed 250 N on the surface
(a) 500 N (b) 100N (c) 125 N (d) 150N

28. At what height from the surface of the earth will the value of g be reduced by 36% from the value at the surface of earth (R = 6400km)
(a) 3200 km (b) 16000 km (c) 800km (d) 400km

29. The radii of the planets are respectively R_1 and R_2 and their densities are respectively P_1 and P_2. The ratio of acceleration due to gravity at their surface is
(a) $\frac{R_1P_2}{R_2P_1}$ (b) $\frac{R_2P_2}{R_1P_1}$ (c) $\frac{R_1P_1}{R_2P_2}$ (d) $\frac{R_2P_1}{R_1P_2}$

30. Two planets of radii r_1 and r_2 are made from the same material . The ratio of the acceleration of gravity $\frac{g_1}{g_2}$ at the surfaces of the planets is
(a) r_1/r_2 (b) r_1/r_2 (c) $\left(\frac{r_1}{r_2}\right)^2$ (d) $\left(\frac{r_2}{r_1}\right)^2$

31. If mass of a body is M on the earth surface then mass of the same body on the moon surface is
(a) $\frac{M}{6}$ (b) zero (c) M (d) none of these

32. If υ be the orbital velocity of a satellite in a circular orbit close to the earth's surface and υ_e is the escape velocity from the earth then relation between the two is

(a) $\upsilon_e = \upsilon$ (b) $\upsilon_e = \sqrt{2}\ \upsilon$

(c) $\upsilon = \sqrt{3}\ \upsilon_e$ (d) $\upsilon = \sqrt{3}\ \upsilon_e$

33. The amount of work required to send a body of mass m from earth's surface to a height $\frac{R}{2}$ Where R is redius of earth is

(a) $\frac{mgR}{2}$ (b) $\frac{mgR}{3}$ (c) $\frac{mgR}{4}$ (d) $\upsilon_e = 2\upsilon$

34. For a satellite, if the time of revolution is T, then kinetic energy is proportional to

(a) $\frac{1}{T}$ (b) $\frac{1}{T^2}$ (c) $\frac{1}{T^3}$ (d) $T^{2/3}$’

35. The atmosphere is held to the earth by

(a) winds (b) gravity (c) clouds (d) the rotation of earth

36. The time period of a satellite in a circular orbit of radius R is T. The period of another satellite in a circular orbit of radius 4R is

(a) 4 T (b) T/4 (c) 8 T (d) 8/T

37. A ball takes t second to fall from height h_1 and 2t seconds to fall from a height h_2 then h_1/h_2 is

(a) 0.5 (b) 0.25 (c) 2 (d) 4

38. Where is the intensity of a gravitational field of the earth maximum?

(a) centre of earth (b) equator

(c) poles (d) same every where

TOPIC WISE PRACTICE QUESTIONS

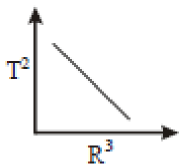
Topic 1: Kepler's Laws of Planetary Motion

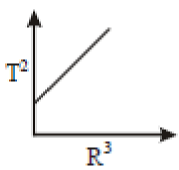
1. Kepler's second law regarding constancy of areal velocity of a planet is a consequence of the law of conservation of

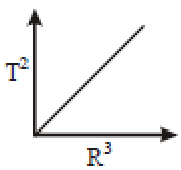
(a) energy (b) angular momentum

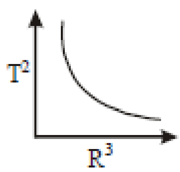
(c) linear momentum (d) None of these

2. Which of the following graphs represents the motion of a planet moving about the sun ?

(a)


(b)


(c)


(d)


3. Two satellites revolve round the earth with orbital radii 4R and 16R, if the time period of first satellite is T then that of the other is

(a) 4 T (b) $4^{2/3}$ T (c) 8 T (d) None of these

4. A comet moves in an elliptical orbit with an eccentricity of e = 0.20 around a star. The distance between the perihelion and the aphelion is 1.0×10^8 km. If the speed of the comet at perihelion is 81 km/s, then the speed of the comet at the aphelion is:

(a) 182 km/s (b) 36 km/s (c) 121.5 km/s (d) 54 km/s

5. The period of moon's rotation around the earth is nearly 29 days. If moon's mass were 2 fold its present value and all other things remain unchanged, the period of moon's rotation would be nearly

(a) 29 2 days (b) 29/ 2 days (c) 29 × 2 days (d) 29 days

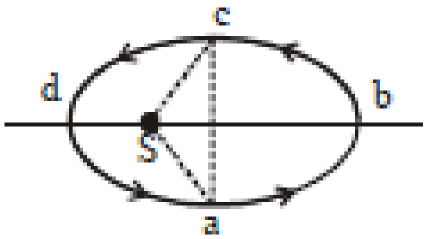
6. A planet of mass m moves around the sun of mass M in an elliptical orbit. The maximum and minimum distance of the planet from the sun are r_1 and r_2 respectively. The time period of planet is proportional to

(a) $r_1^{2/5}$ (b) $(r_1+r_2)^{3/2}$ (c) $(r_1-r_2)^{3/2}$ (d) $r^{3/2}$

7. 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

(a) 8 R (b) 4 R (c) 2 R (d) R

8. Figure shows elliptical path abcd of a planet around the sun S such that the area of triangle cSa is1/4 the area of the ellipse. (See figure) With db as the semimajor axis, and ca as the semi minor axis. If t_1 is the time taken for planet to go over path abc and t_2 for path taken over cda then:



(a) $t_1 = 4t_2$ (b) $t_1 = 2t_2$ (c) $t_1 = 3t_2$ (d) $t_1 = t_2$

9. A planet moves around the sun. At a point P it is closest from the sun at a distance d_1 and has a speed v_1. At another point Q, when it is farthest from the sun at a distance d_2 its speed will be

(a) $d_1^2 v_1 / d_2^2$ (b) $d_2 v_1 / d_1$ (c) $d_1 v_1 / d_2$ (d) $d_2^2 v_1 / d_1^2$

10. The planet mercury is revolving in an elliptical orbit around the sun as shown in fig. The kinetic energy of mercury will be greatest at

(a) A (b) B (c) C (d) D

11. The distance of Neptune and Saturn from the sun is nearly 10^{13} and 10^{12} meter respectively. Assuming that they move in circular orbits, their periodic times will be in the ratio

(a) 10 (b) 100 (c) $10\sqrt{10}$ (d) 1000

12. A satellite is revolving round the earth in an orbit of radius r with time period T. If the satellite is revolving round the earth in an orbit of radius $r + \Delta r$ ($\Delta r << r$) with time period $T + \Delta T$ then,

(a) $\frac{\Delta T}{T} = \frac{3}{2}\frac{\Delta r}{r}$ (b) $\frac{\Delta T}{T} = \frac{2}{3}\frac{\Delta r}{r}$ (c) $\frac{\Delta T}{T} = \frac{\Delta r}{r}$ (d) $\frac{\Delta T}{T} = -\frac{\Delta r}{r}$

13. The time period of a satellite of earth is 5 hours. If the separation between the earth and the satellite is increased to 4 times the previous value, the new time period will become

(a) 10 hours (b) 80 hours (c) 40 hours (d) 20 hours

14. 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 in m/s when it is farthest

(a) 12 (b) 60 (c) 112 (d) 6

Topic 2: Newton's Universal Law of Gravitation

15. Two masses m_1 and m_2 ($m_1 < m_2$) are released from rest from a finite distance. They start moving under their mutual gravitational attraction, then

(a) acceleration of m_1 is more than that of m_2 (b) acceleration of m_2 is more than that of m_1

(c) centre of mass of system will remain at rest in all the reference frame

(d) total energy of system does not remains constant

16. Two bodies of masses 4 kg and 9 kg are separated by a distance of 60 cm. A 1 kg mass is placed in between these two masses. If the net force on 1 kg is zero, then its distance from 4 kg mass is

(a) 26 cm (b) 30 cm (c) 28 cm (d) 24 cm

17. A body weighs 72 N on the surface of the earth. What is the gravitational force on it due to earth at a height equal to half the radius of the earth from the surface?

(a) 32 N (b) 28 N (c) 16 N (d) 72 N

18. If masses of two point objects is doubled and distance between them is tripled, then gravitational force of attraction between them will nearly

(a) increase by 225% (b) decrease by 44% (c) decrease by 56% (d) increase by 125%

19. The distance of the centres of moon and earth is D. The mass of earth is 81 times the mass of the moon. At what distance from the centre of the earth, the gravitational force will be zero?

(a) $\frac{D}{2}$ (b) $\frac{2D}{3}$ (c) $\frac{4D}{3}$ (d) $\frac{9D}{10}$

20. Six stars of equal mass are moving about the centre of mass of the system such that they are always on the vertices of a regular hexagon of side length *a*. Their common time period will be

(a) $4\pi\sqrt{\frac{a^3}{Gm}}$ (b) $2\pi\sqrt{\frac{4\sqrt{3}a^3}{Gm(5\sqrt{3}+4)}}$ (c) $4\pi\sqrt{\frac{3a^3}{Gm}}$ (d) None of these

21. Two stars of mass m_1 and m_2 are parts of a binary system. The radii of their orbits are r_1 and r_2 respectively, measured from the C.M. of the system. The magnitude of gravitational force m_1 exerts on m_2 is

(a) $\frac{m_1 m_2 G}{(r_1+r_2)^2}$ (b) $\frac{m_1 G}{(r_1+r_2)^2}$ (c) $\frac{m_2 G}{(r_1+r_2)^2}$ (d) $\frac{(m_1+m_2)}{(r_1+r_2)^2}$

22. The percentage change in the acceleration of the earth towards the sun from a total eclipse of the sun to the point where the moon is on a side of earth directly opposite to the sun is

(a) $\frac{M_s}{M_m}\frac{r_2}{r_1}\times 100$ (b) $\frac{M_s}{M_m}\left(\frac{r_2}{r_1}\right)^2\times 100$ (c) $2\left(\frac{r_1}{r_2}\right)^2\frac{M_s}{M_m}\times 100$ (d) $\left(\frac{r_1}{r_2}\right)^2\frac{M_s}{M_m}\times 100$

23. There are two bodies of masses 10^3 kg and 10^5 kg separated by a distance of 1 km. At what distance from the smaller body, the intensity of gravitational field will be zero

(a) 1/9 km (b) 1/10 km (c) 1/11 km (d) 10/11 km

24. Two spheres of masses m and M are situated in air and the gravitational force between them is F. The space around the masses is now filled with a liquid of specific gravity 3. The gravitational force will now be

(a) *F*/9 (b) 3*F* (c) *F* (d) *F*/3

Topic 3: Acceleration due to Gravity

25. The weight of an object in the coal mine, sea level and at the top of the mountain, are respectively W_1, W_2 and W_3 then

(a) $W_1 < W_2 > W_3$ (b) $W_1 = W_2 = W_3$ (c) $W_1 < W_2 < W_3$ (d) $W_1 > W_2 > W_3$

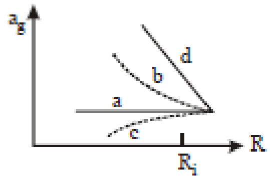
26. The ratio between the values of acceleration due to gravity at a height 1 km above and at a depth of 1 km below the Earth's surface is (radius of Earth is R)

(a) $\frac{R-2}{R-1}$ (b) $\frac{R}{R-1}$ (c) $\frac{R-2}{R}$ (d) 1

27. The angular velocity of the earth with which it has to rotate so that acceleration due to gravity on 60° latitude becomes zero is (Radius of earth = 6400 km, at the poles g = 10 ms^{-2})

(a) 2.5×10^{-3} rad/s (b) 5.0×10^{-1} rad/s (c) 10×10^{1} rad/s (d) 7.8×10^{-2} rad/s

28. A (nonrotating) star collapses onto itself from an initial radius R_i with its mass remaining unchanged. Which curve in figure best gives the gravitational acceleration a_g on the surface of the star as a function of the radius of the star during the collapse



(a) a (b) b (c) c (d) d

29. What should be the velocity of rotation of earth due to rotation about its own axis so that the weight of a person becomes 3/5 of the present weight at the equator. Equatorial radius of the earth is 6400 km

(a) 8.7×10^{-7} rad/s (b) 7.8×10^{-4} rad/s (c) 6.7×10^{-4} rad/s (d) 7.4×10^{-3} rad/s

30. If the density of a small planet is the same as that of earth, while the radius of the planet is 0.2 times that of the earth, the gravitational acceleration on the surface of the planet is

(a) 0.2 g (b) 0.4 g (c) 2 g (d) 4 g

31. As we go from the equator to the poles, the value of g

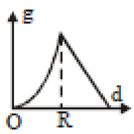
(a) remains the same (b) decreases

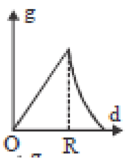
(c) increases (d) decreases upto latitude of 45°

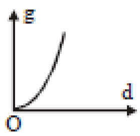
32. The radius of a planet is n times the radius of earth (R). A satellite revolves around it in a circle of radius $4nR$ with angular velocity w. The acceleration due to gravity on planet's surface is

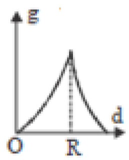
(a) $R\omega^2$ (b) $16\,R\omega^2$ (c) $32\,nR\omega^2$ (d) $64\,nR\omega^2$

33. The variation of acceleration due to gravity g with distance d from centre of the earth is best represented by (R = Earth's radius):

(a) 

(b) 

(c) 

(d) 

34. The acceleration due to gravity on the planet A is 9 times the acceleration due to gravity on planet B. A man jumps to a height of 2m on the surface of A. What is the height of jump by the same person on the planet B?

(a) $\frac{2}{3}$m (b) $\frac{2}{9}$m (c) 18 m (d) 6 m

35. A roller coaster is designed such that riders experience "weightlessness" as they go round the top of a hill whose radius of curvature is 20 m. The speed of the car at the top of the hill is between:

(a) 14 m/s and 15 m/s (b) 15 m/s and 16 m/s (c) 16 m/s and 17 m/s (d) 13 m/s and 14 m/s

36. If earth is supposed to be a sphere of radius R, if g30 is value of acceleration due to gravity at lattitude of 30° and g at the equator, the value of $g - g_{30}$ is

(a) $\frac{1}{4}\omega^2 R$ (b) $\frac{3}{4}\omega^2 R$ (c) $\omega^2 R$ (d) $\frac{1}{2}\omega^2 R$

37. In order to make the effective acceleration due to gravity equal to zero at the equator, the angular velocity of rotation of the earth about its axis should be (g = 10 ms^{-2} and radius of earth is 64000 km)

(a) Zero (b) $\frac{1}{800}$ rad sec^{-1} (c) $\frac{1}{80}$ rad sec^{-1} (d) $\frac{1}{8}$ rad sec^{-1}

38. If the mass of earth is eighty times the mass of a planet and diameter of the planet is one fourth that of earth, then acceleration due to gravity on the planet would be

(a) 7.8 m/s_2 (b) 9.8 m/s^2 (c) 6.8 m/s^2 (d) 2.0 m/s^2

39. Explorer 38, a radio-astronomy satellite of mass 200 kg, circles the Earth in an orbit of average radius 3R/2 where R is the radius of the Earth. Assuming the gravitational pull on a mass of 1 kg at the earth's surface to be 10 N, calculate the pull on the satellite

(a) 889 N (b) 89 N (c) 8889 N (d) 8.9 N

40. How many hours would make a day if the earth were rotating at such a high speed that the weight of a body on the equator were zero?

(a) 6.2 h (b) 1.4 h (c) 28 h (d) 5.6 h

41. Let *g* be the acceleration due to gravity at earth's surface and *K* be the rotational kinetic energy of the earth. Suppose the earth's radius decreases by 2% keeping all other quantities same, then

(a) g decreases by 2% and K decreases by 4%

(b) g decreases by 4% and K increases by 2%

(c) g increases by 4% and K decreases by 4%

(d) g decreases by 4% and K increases by 4%

42. Let w be the angular velocity of the earth's rotation about its axis. Assume that the acceleration due to gravity on the earth's surface has the same value at the equator and the poles. An object weighed at the equator gives the same reading as a reading taken at a depth d below earth's surface at a pole (d << R). The value of d is

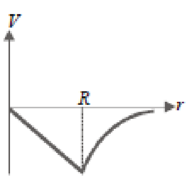
(a) $\frac{\omega^2 R^2}{g}$ (b) $\frac{\omega^2 R^2}{2g}$ (c) $\frac{2\omega^2 R^2}{g}$ (d) $\frac{\sqrt{Rg}}{g}$

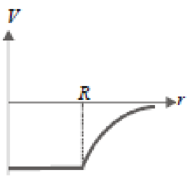
Topic 4: Gravitational Field, Potential and Potential Energy

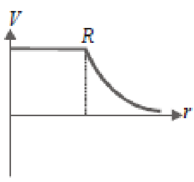
43. The magnitude of gravitational potential energy of earth-moon system is U which is zero at infinite separation. If K is the K.E. of the moon with respect to earth, then

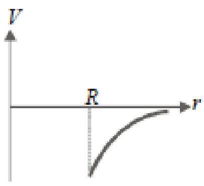
(a) |U| = K (b) |U| < K (c) |U| > K (d) either B or C

44. The gravitational potential due to a hollow sphere (mass *M*, radius *R*) varies with distance *r* from centre as

(a) 

(b) 

(c) 

(d) 

45. A planet is moving in an elliptical orbit around the sun. If T, V, E and L stand respectively for its kinetic energy, gravitational potential energy, total energy and magnitude of angular momentum about the centre of force, then which of the following is correct ?

(a) T is conserved (b) V is always positive (c) E is always negative

(d) L is conserved but direction of vector L changes continuously

46. If '*g*' is the acceleration due to gravity on the earth's surface, the gain in the potential energy of an object of mass '*m*' raised from the surface of the earth to a height equal to the radius '*R*' of the earth is

(a) $\frac{1}{4}$mgR (b) $\frac{1}{2}$mgR (c) 2 mgR (d) mgR

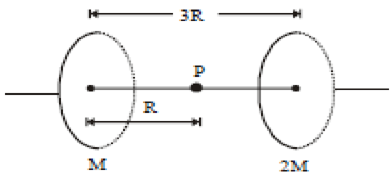
47. In a certain region of space, gravitational field is given by $I = -(K/r)$. Taking the reference point to be at $r = r_0$ with $V = V_0$, find the potential.

(a) $K\log\frac{r}{r_0}+V_0$ (b) $K\log\frac{r_0}{r}+V_0$ (c) $K\log\frac{r}{r_0}-V_0$ (d) $\log\frac{r_0}{r}-V_0r$

48. Taking the gravitational potential at a point infinite distance away as zero, the gravitational potential at a point A is –5 unit. If the gravitational potential at point infinite distance away is taken as + 10 units, the potential at point A is

(a) – 5 unit (b) + 5 unit (c) + 10 unit (d) + 15 unit

49. Two rings having masses M and 2M, respectively, having the same radius are placed coaxially as shown in the figure. If the mass distribution on both the rings is non – uniform, then the gravitational potential at point P is



(a) $-\frac{GM}{R}\left[\frac{1}{\sqrt{2}}+\frac{2}{\sqrt{5}}\right]$ (b) $-\frac{GM}{R}\left[1+\frac{2}{\sqrt{2}}\right]$ (c) zero (d)cannot be determined from the given information

Topic 5: Motion of Satellites, Escape Speed and Orbital Velocity

50. A satellite revolves around the earth of radius R in a circular orbit of radius 3R. The percentage increase in energy required to lift it to an orbit of radius 5R is

(a) 10 % (b) 20 % (c) 30 % (d) 40 %

51. The mean radius of earth is R, its angular speed on its own axis is ω and the acceleration due to gravity at earth's surface is g. What will be the radius of the orbit of a geostationary satellite?

(a) $\left(R^2g/\omega^2\right)^{1/3}$ (b) $\left(Rg/\omega^2\right)^{1/3}$ (c) $\left(R^2\omega^2/g\right)^{1/3}$ (d) $\left(R^2g/\omega\right)^{1/3}$

52. The moon has a mass of 1/81 that of the earth and a radius of 1/4 that of the earth. The escape speed from the surface of the earth is 11.2 km/s. The escape speed from the surface of the moon is:

(a) 1.25 km/s (b) 2.5 km/s (c) 3.7 km/s (d) 5.6 km/s

53. A planet in a distant solar system is 10 times more massive than the earth and its radius is 10 times smaller. Given that the escape velocity from the earth's surface is 11 km s^{-1}, the escape velocity from the surface of the planet would be

(a) 1.1 km s^{-1} (b) 11 km s^{-1} (c) 110 km s^{-1} (d) 0.11 km s^{-1}

54. What is the minimum energy required to launch a satellite of mass m from the surface of a planet of mass M and radius R in a circular orbit at an altitude of 3R?

(a) $\frac{7GmM}{8R}$ (b) $\frac{2GmM}{3R}$ (c) $\frac{GmM}{2R}$ (d) $\frac{GmM}{R}$

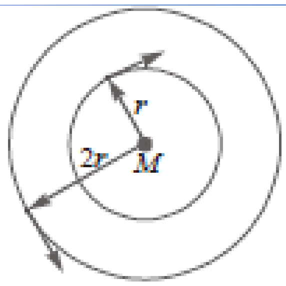
55. The orbital velocity of an artificial satellite in a circular orbit just above the centre's surface is v_0. For a satellite orbiting at an altitude of half of the earth's radius, the orbital velocity is

(a) $\left(\sqrt{\left(\frac{2}{3}\right)}\right)v_0$ (b) $\frac{2}{3}v_0$ (c) $\frac{3}{2}v_0$ (d) $\sqrt{\left(\frac{3}{2}\right)}v_0$

56. A satellite of mass m revolves around the earth of radius R at a height 'x' from its surface. If g is the acceleration due to gravity on the surface of the earth, the orbital speed of the satellite is

(a) $\frac{gR^2}{R+x}$ (b) $\frac{gR}{R-x}$ (c) gx (d) $\left(\frac{gR^2}{R+x}\right)^{1/2}$

57. Two satellites of masses *m* and 2*m* are revolving around a planet of mass *M* with different speeds in orbits of radii *r* and 2*r* respectively. The ratio of minimum and maximum forces on the planet due to satellites is



(a) $\frac{1}{2}$ (b) $\frac{1}{4}$ (c) $\frac{1}{3}$ (d) None of these

58. A satellite is revolving round the earth in a circular orbit of radius 'a' with velocity v_0. A particle of mass m is projected from the satellite in forward direction with relative velocity $V = \left[\sqrt{\frac{5}{4}} - 1\right]V_0$ .During subsequent motion of the particle total energy is

(a) $-3G M_e m/8a$ (b) zero (c) $-5G M_e m/6a$ (d) ∞

59. Two particles of equal mass '*m*' go around a circle of radius *R* under the action of their mutual gravitational attraction. The speed of each particle with respect to their centre of mass is

(a) $\sqrt{\frac{Gm}{4R}}$ (b) $\sqrt{\frac{Gm}{3R}}$ (c) $\sqrt{\frac{Gm}{2R}}$ (d) $\sqrt{\frac{Gm}{R}}$

60. The Earth is assumed to be a sphere of radius R. A platform is arranged at a height *R* from the surface of the Earth. The escape velocity of a body from this platform is *fv*, where *v* is its escape velocity from the surface of the Earth. The value of *f* is

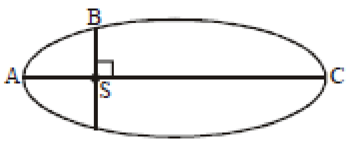
(a) $\frac{1}{3}$ (b) $\frac{1}{2}$ (c) $\sqrt{2}$ (d) $\frac{1}{\sqrt{2}}$

NEET PREVIOUS YEARS QUESTIONS

1. If the mass of the Sun were ten times smaller and the universal gravitational constant were ten times larger in magnitude, which of the following is not correct?

(a) Raindrops will fall faster (b) Walking on the ground would become more difficult
(c) 'g' on the Earth will not change (d) Time period of a simple pendulum on the Earth would decrease

2. The kinetic energies of a planet in an elliptical orbit about the Sun, at positions A, B and C are K_A, K_B and K_C, respectively. AC is the major axis and SB is perpendicular to AC at the position of the Sun S as shown in the figure. Then



(a) $K_A < K_B < K_C$ (b) $K_A > K_B > K_C$ (c) $K_B > K_A > K_C$ (d) $K_B < K_A < K_C$

3. The acceleration due to gravity at a height 1 km above the earth is the same as at a depth d below the surface of earth. Then

(a) d = 1 km (b) $d = \frac{3}{2}$ km (c) d = 2 km (d) $d = \frac{1}{2}$ km

4. Two astronauts are floating in gravitation free space after having lost contact with their spaceship. The two will **[2017]**

(a) move towards each other. (b) move away from each other.
(c) become stationary (d) keep floating at the same distance between them.

5. At what height from the surface of earth the gravitational potential and the value of g are $-5.4 \times 10^7 Jkg^{-1}$ and $6.0\ ms^{-2}$ respectively? Take the radius of earth as 6400 km:

(a) 2600 km (b) 1600 km (c) 1400 km (d) 2000 km

6. The ratio of escape velocity at earth (v_e) to the escape velocity at a planet (v_p) whose radius and mean density are twice as that of earth is :

(a) 1 : 2 (b) $1 : 2\sqrt{2}$ (c) 1 : 4 (d) 1 : 2

7. Kepler's third law states that square of period of revolution (T) of a planet around the sun, is proportional to third power of average distance r between sun and planet i.e. $T^2 = Kr^3$ here K is constant. If the masses of sun and planet are M and m respectively then as per Newton's law of gravitation force of attraction between them is $F = \frac{GMm}{r^2}$, here G is gravitational constant. The relation between G and K is described as

(a) $GMK = 4\pi^2$ (b) K = G (c) $K = \frac{1}{G}$ (d) $GK = 4\pi^2$

8. Two spherical bodies of mass M and 5 M and radii R and 2R released in free space with initial separation between their centres equal to 12 R. If they attract each other due to gravitational force only, then the distance covered by the smaller body before collision is

(a) 4.5 R (b) 7.5 R (c) 1.5 R (d) 2.5 R

9. A satellite S is moving in an elliptical orbit around the earth. The mass of the satellite is very small compared to the mass of the earth. Then,

(a) the total mechanical energy of S varies periodically with time.

(b) the linear momentum of S remains constant in magnitude.

(c) the acceleration of S is always directed towards the centre of the earth.

(d) the angular momentum of S about the centre of the earth changes in direction, but its magnitude remains constant.

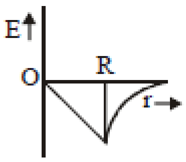
10. A remote - sensing satellite of earth revolves in a circular orbit at a height of 0.25×10^6 m above the surface of earth. If earth's radius is 6.38×10^6 m and g = 9.8 ms^{-2}, then the orbital speed of the satellite is:

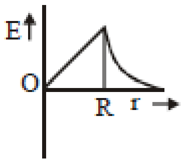
(a) 8.56 km s^{-1} (b) 9.13 km s^{-1} (c) 6.67 km s^{-1} (d) 7.76 km s^{-1}

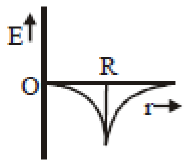
11. A black hole is an object whose gravitational field is so strong that even light cannot escape from it. To what approximate radius would earth (mass = 5.98×10^{24} kg) have to be compressed to be a black hole?

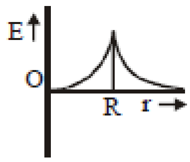
(a) 10^{-9} m (b) 10^{-6} m (c) 10^{-2} m (d) 100 m

12. Dependence of intensity of gravitational field (E) of earth with distance (r) from centre of earth is correctly represented by:

(a) 

(b) 

(c) 

(d) 

13. A projectile is fired from the surface of the earth with a velocity of 5 ms^{-1} and angle q with the horizontal. Another projectile fired from another planet with a velocity of 3 ms^{-1} at the same angle follows a trajectory which is identical with the trajectory of the projectile fired from the earth. The value of the acceleration due to gravity on the planet is (in ms^{-2}) given g = 9.8 m/s^2

(a) 3.5 (b) 5.9 (c) 16.3 (d) 110.8

14. A body weighs 200 N on the surface of the earth. How much will it weigh half way down to the centre of the earth?

(1) 150 N (2) 200 N (3) 250 N (4) 100 N

15. At a point A on the earth's surface the angle of dip, $\delta = +25°$. At a point B on the earth's surface the angle of dip, $\delta = -25°$. We can interpret that :

(1) A and B are both located in the northern hemisphere.

(2) A is located in the southern hemisphere and B is located in the northern hemisphere.

(3) A is located in the northern hemisphere and B is located in the southern hemisphere.

(4) A and B are both located in the southern hemisphere

16. The work done to raise a mass m from the surface of the earth to a height h, which is equal to the radius of the earth, is

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

17. The time period of a geostationary satellite is 24 h, at a height $6R_E$ (R_E is radius of earth) from surface of earth. The time period of another satellite whose height is 2.5 R_E from surface will be,

1) $6\sqrt{2}h$ 2) $12\sqrt{2}h$ 3) $\frac{24}{2.5}h$ 4) $\frac{12}{2.5}h$

18. Assuming that the gravitational potential energy of an object at infinity is zero, the change in potential energy (final – initial) of an object of mass m, when taken to a height h from the surface of earth (of radius R), is given by,

1) $-\frac{GMm}{R+h}$ 2) $\frac{GMmh}{R(R+h)}$ 3) mgh 4) $\frac{GMm}{R+h}$

19. What is the depth at which the value of acceleration due to gravity becomes 1/n times the value that at the surface of earth? (radius of earth = R**)**

(1) R/n^2 (2) R(n . 1)/n (3) Rn/(n . 1) (4) R/n

20. A body weight 72N on the surface of the earth. What is the gravitational force on it at a height equal to half the radius of the earth?

1) 24N 2) 48 N 3) 32 N 4) 30 N

21. The escape velocity from the Earth's surface is υ.The escape velocity from the surface of another planet having a radius , four times that of Earth and same mass density is :

1. 2υ 2. 3υ 3. 4υ 4. υ

22. A particle of mass 'm' is projected with a velocity $u = kV_e$ (k < 1) from the surface of the earth. (V_e = escape velocity) The maximum height above the surface reached by the particle is

1) $R\left(\frac{k}{1+k}\right)^2$ 2) $\frac{R^2k}{1+k}$ 3) $\frac{Rk^2}{1-k^2}$ 4) $R\left(\frac{k}{1-k}\right)^2$

23. A body of mass 60 g experiences a gravitational force of 3.0 N, when placed at a particular point. The magnitude of the gravitational field intensity at that point is:

1) 0.5 N/kg 2) 50 N/kg 3) 20 N/kg 4) 180 N/kg

NCERT LINE BY LINE QUESTIONS – ANSWERS

1. (c) 2. (b) 3. (a) 4. (a) 5. (a) 6. (b) 7. (d) 8. (a) 9. (c) 10. (b)

11. (a) 12. (d) 13. (b) 14. (a) 15. (a) 16. (b) 17. (d) 18. (b) 19. (d) 20. (d)

NCERT BASED PRACTICE QUESTIONS - ANSWERS

1	b	2	b	3	c	4	a	5	a
6	c	7	c	8	c	9	a	10	b
11	c	12	b	13	a	14	b	15	a
16	b	17	b	18	b	19	b	20	a
21	a	22	d	23	c	24	a	25	c
26	a	27	c	28	b	29	c	30	a
31	c	32	b	33	b	34	d	35	b
36	c	37	d	38	c				

TOPIC WISE PRACTICE QUESTIONS - ANSWERS

1) 2	**2)** 3	**3)** 3	**4)** 4	**5)** 4	**6)** 2	**7)** 2	**8)** 3	**9)** 3	**10)** 1
11) 3	**12)** 1	**13)** 3	**14)** 1	**15)** 2	**16)** 4	**17)** 1	**18)** 3	**19)** 4	**20)** 2
21) 1	**22)** 3	**23)** 3	**24)** 3	**25)** 1	**26)** 1	**27)** 1	**28)** 2	**29)** 2	**30)** 1
31) 3	**32)** 4	**33)** 2	**34)** 3	**35)** 1	**36)** 2	**37)** 2	**38)** 4	**39)** 1	**40)** 2
41) 3	**42)** 1	**43)** 3	**44)** 2	**45)** 3	**46)** 2	**47)** 1	**48)** 2	**49)** 1	**50)** 2
51) 1	**52)** 2	**53)** 3	**54)** 1	**55)** 1	**56)** 4	**57)** 3	**58)** 1	**59)** 1	**60)** 4

NEET PREVIOUS YEARS QUESTIONS-ANSWERS

1) 3	**2)** 2	**3)** 3	**4)** 1	**5)** 1	**6)** 2	**7)** 1	**8)** 2	**9)** 3	**10)** 4
11) 3	**12)** 1	**13)** 1	**14)** 4	**15)** 3	**16)** 3	**17)** 1	**18)** 2	**19)** 2	**20)** 3
21) 3	**22)** 3	**23)** 2							

TOPIC WISE PRACTICE QUESTIONS - SOLUTIONS

1. **(b)** Since areal velocity $\vec{A}$ & angular momentum $\vec{L}$ of a planet are related by equation $\vec{A} = \frac{\vec{L}}{2M}$, where M is the mass of planet. Since in planetary motion $\vec{L}$ is $\left(\vec{\tau}_{ext} = 0\right)$, hence $\vec{A}$ is also constant

2. **(c)**

3. **(c)** $\frac{T_1}{T_2} = \left(\frac{R_1}{R_2}\right)^{3/2} \Rightarrow \frac{T}{T_2} = \left(\frac{4R}{16R}\right)^{3/2} \Rightarrow T_2 = 8T$

4. **(d)** $\frac{v_p}{v_a} = \frac{1+e}{1-e} = \frac{1+0.20}{1-0.20} = \frac{3}{2}$

5. **(d)** Time period does not depend upon the mass of satellite

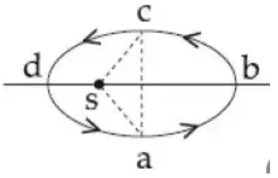
6. **(b)** $T^2 \,\alpha\, r^3$, where r = mean radius $= \frac{r_1 + r_2}{2}$

7. **(b)** Given that $T_1 = 1$ day and $T_2 = 8$ days

$$\therefore \frac{T_2}{T_1} = \left(\frac{r_2}{r_1}\right)^{3/2}$$

$$\Rightarrow \frac{r_2}{r_1} = \left(\frac{T_2}{T_1}\right)^{2/3} = \left(\frac{8}{1}\right)^{2/3} = 4 \Rightarrow r_2 = 4r_1$$

8. (c) Since area of triangle csa is 41 of total area of ellipse, therefore:



Area of cdas = $\frac{1}{3}$ Area of abcs

Now that from Kepler's second law areal velocities of the planets are constant which essentially means planets cover equal area in equal time interval.

Hence,

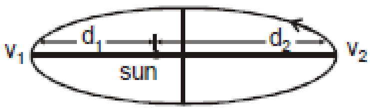
Time taken in covering path abc and path cda will be in proportion to their respective enclosed areas.

$\Rightarrow t_1 = 3t_2$

9. **(c)** In planetary motion $\vec{\tau}_{ext} = 0 \Rightarrow \vec{L} = \text{constant}$

$$\vec{L} = \vec{r} \times \vec{p}\left(= m\vec{v}\right) = mrv\left(\because \theta = 90^0\right)$$

So $m_1 d_1 v_1 = m_2 d_2 v_2$ (here r = d)



$$\Rightarrow v_2 = \frac{v_1 d_1}{2}$$

10. **(a)** Angular momentum is conserved. At A, the moment of inertia is least and hence angular speed is maximum. Thus the K.E. at A is maximum.

11. **(c)** $T^2 \propto R^3$ (According to Kepler's law)

$$T_1^2 \propto \left(10^{13}\right)^3 \text{ and } T_2^2 \propto \left(10^{12}\right)^3$$

$$\therefore \frac{T_1^2}{T_2^2} = (10)^3 \text{ or } \frac{T_1}{T_2} = 10\sqrt{10}$$

12. **(a)** Since, $T^2 = kr^3$

Differentiating the above equation

$$\Rightarrow 2\frac{\Delta T}{T} = 3\frac{\Delta r}{r} \Rightarrow \frac{\Delta T}{T} = \frac{3}{2}\frac{\Delta r}{r}$$

13. **(c)** According to Kepler's law of planetary motion,

$$\therefore T_2 = T_1\left(\frac{R_2}{R_1}\right)^{3/2} = 5 \times \left[\frac{4R}{R}\right]^{3/2} = 40 \text{ hours}$$

14. **(a)** By law of conservation of angular momentum,

mvr = constant

$$v_{min} \times r_{max} = v_{max} \times r_{min}$$

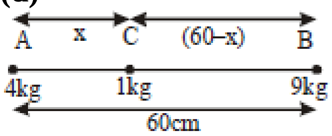
$$\therefore v_{max} = \frac{60 \times 1.6 \times 10^{12}}{8 \times 10^{12}} = \frac{60}{5} = 12 \text{ m/s}$$

15. **(b)** Same force acts on both masses

Hence $a \propto \frac{1}{m}\left(F = ma\right)$

In absence of external force (remember mutual gravitational force is an internal force for the system) total energy remains constant.

16. **(d)**



$$\therefore G\frac{4\times1}{x^2}=G\frac{9\times1}{(60-x)^2} \text{ or } \frac{2}{3}=\frac{x}{(60-x)}\Rightarrow x=24\text{cm}$$

17. **(a)** Weight of body on the surface of the earth =mg=72N

Acceleration due to gravity at height h is $g_h=\frac{gR_E^2}{(R_E+h)^2}$

Substitute $h=\frac{R_E}{2}$ in above expression:

$$g_h=\frac{gR_E^2}{\left(R_E+\frac{R_E}{2}\right)^2}=\frac{4}{9}g$$

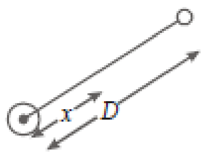
Gravitational force on body at height h is $F=mgh$

$$=m\times\frac{4}{9}g=\frac{4}{9}\times mg \qquad =\frac{4}{9}\times72N=32N$$

18. **(c)** $\% \text{ change}=\frac{\left[\frac{G(2m_1)(2m_2)}{(3r)^2}-\frac{Gm_1m_2}{r^2}\right]}{\frac{Gm_1m_2}{r^2}}\times100$; $=\frac{\frac{4}{9}-1}{1}\times100=-56\%$

–ve sign indicates that force of attraction decreases

19. **(d)** $\frac{Gm_e}{x^2}=\frac{Gm_m}{(D-x)^2}$



or $\frac{G(81m)}{x^2}=\frac{m}{(D-x)^2}$

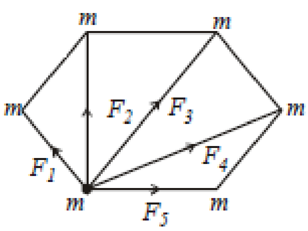
$$\therefore x=\frac{9D}{10}$$

20. **(b)** $\overline{F}=\overline{F_1}+\overline{F_2}+\overline{F_3}+\overline{F_4}+\overline{F_5}$

$|\overline{F}_2|=|\overline{F}_5|$ and $|\overline{F}_2|=|\overline{F}_4|$

$\overline{F}_1=\overline{F}_3+2F_2\cos30^\circ+2F_1\cos60^\circ$

$F_3=\frac{Gm^2}{4a^2}; F_2=\frac{Gm^2}{3a^2}; F_1=\frac{Gm^2}{a^2}$



$$F=\frac{Gm^2}{a^2}\left(\frac{5}{4}+\frac{1}{\sqrt{3}}\right)=m\omega^2 a$$

$$\omega=\sqrt{\frac{Gm}{a^3}\left(\frac{5}{4}+\frac{1}{\sqrt{3}}\right)}$$

21. **(a)** $F=\frac{Gm_1m_2}{r^2}=\frac{Gm_1m_2}{(r_1+r_2)^2}$

22. (c) During total eclipse:
Total attraction due to sun and moon,

$$F_1=\frac{GM_sM_e}{r_1^2}+\frac{GM_mM_e}{r_2^2}$$

When moon goes on the opposite side of earth effective force of attraction

$$F_2=\frac{GM_sM_e}{r_1^2}-\frac{GM_mM_e}{r_2^2}$$

Change in force, $\Delta F=F_1-F_2=\frac{2GM_mM_e}{r_2^2}$

Change in acceleration of earth $\Delta a=\frac{\Delta F}{M_e}=\frac{2GM_m}{r_2^2}$

Average force on earth, $F_{av}=\frac{F_{av}}{M_e}=\frac{GM_s}{r_1^2}$

Percentage change in acceleration

$$=\frac{\Delta a}{a_{av}}\times 100=\frac{2GM_m}{r_2^2}\times\frac{r_1^2}{GM_s}\times 100=2\left(\frac{r_1}{r_2}\right)^2\frac{M_m}{M_s}\times 100$$

23. **(c)** $\frac{G\times 10^3}{(r)^2}=\frac{G\times 10^5}{(1-r)^2}$ **;** $\frac{1}{r^2}=\frac{10^2}{(1-r)^2}$ **;** $\frac{1}{r}=\frac{10}{1-r}\Rightarrow 10r=1-r$ **;** $\therefore r=\frac{1}{11}km$

24. **(c)** Gravitational force is independent of medium, Hence, this will remain same.

25. **(a)** At the surface of earth, the value of g = 9.8m/sec^2. If we go towards the centre of earth or we go above the surface of earth, then in both the cases the value of g decreases.
Hence $W_1=mg_{mine}$, $W_2=mg_{sea\ level}$, $W_3=mg_{moun}$
So $W_1 < W_2 > W_3$ (g at the sea level = g at the surface of earth)

26. **(a)** We know that,
variation in g with height "h"

$$g^| = g\left(\frac{R}{R+h}\right)^2$$

$g^| \rightarrow$ gravity at height h from surface of earth.
$r \rightarrow$ Radius of earth
$h \rightarrow$ height above surface

Therefore, $g^| \propto \frac{1}{r^2}$

Acceleration due to gravity above the earth

$$(g_1)=g_0\left(1-\frac{2h}{r}\right) \text{------------(i)}$$

Since h<<R acceleration due to gravity below earth surface

$$g_2=g_0\left(1-\frac{d}{R}\right) \text{--------------(ii)}$$

Now, put d = h = 1 km Thus, $\frac{g_1}{g_2}=\frac{R-2}{R-1}$

27. **(a)** $g^{|} = g - \omega^2 cos^2\lambda \Rightarrow 0 = g - \omega^2 R\cos^2 60^0$

$$0 = g - \frac{\omega^2 R}{4} \Rightarrow \omega = 2\sqrt{\frac{g}{R}} = \frac{1}{400}\frac{rad}{\sec} = 2.5\times10^{-3}\frac{rad}{\sec}$$

28. **(b)** $g \propto \frac{1}{R^2}$

R decreasing g increase hence, curve b represents correct variation

29. (b) True weight at equator, W=mg

Observed weight at equator, $W^{|} = mg^{|} = \frac{3}{5}mg$

At equator, latitude λ=0 ; Using the formula, $mg^{|} = mg - mR\omega^2\cos^2\lambda$

$$= \frac{3}{5}mg = mg - mR^2\omega^2\cos^2\theta = mg - mR\omega^2 \Rightarrow mR\omega^2 = mg - \frac{3}{5}mg = \frac{2}{5}mg$$

$$\therefore \omega = \left(\frac{2}{5}\frac{g}{R}\right)^{1/2} = \left(\frac{2\times9.8}{5\times6.4\times10^6}\right)^{1/2} = 7.8\times10^{-4} rad/s$$

30. **(a)** We know that,

$$g = \frac{GM}{R^2} = \frac{G\left(\frac{4}{3}\pi R^3\right)\rho}{R^2} = \frac{4}{3}\pi GR\rho$$

$$\frac{g^{|}}{g} = \frac{R^{|}}{R} = \frac{0.2R}{R} = 0.2 \quad \therefore g^{|} = 0.2g$$

31. **(c)** Since $g = \frac{GM_e}{R_e^2}$ for earth.

At poles the earth is slightly flattened. It means that the radius of earth at poles is slightly less in comparison to radius at equator. So from the above expression, the value of 'g' at poles is greater in comparison to value of 'g' at equator.

32. **(d)** $mr\omega^2 = \frac{GMm}{r^2}$

$$GM = r^3\omega^2 \qquad \left(GM = gR^2\right)$$

$$g = \frac{r^3.\omega^2}{R^2}$$

$$g^{|} = \frac{\left(4nR\right)^3.\omega^2}{n^2.R^2} \; g^{|} = 64nR\omega^2$$

33. **(b)** With depth $g_1 = g\left(1 - \frac{d}{R}\right)$

As depth d goes on increasing g1 goes on decreasing, it remains maximum at the surface of Earth .The above equation is in the form of straight line.
With height

$$g_2 = g\left(1 - \frac{2h}{R}\right) = g - \frac{2gh}{R}$$

$$g_2 \propto \frac{1}{R} \text{ (Hyperbola)}$$

Acceleration due to gravity goes on decreasing as the h above Earth surface increases.

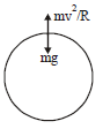
34. **(c)** Applying conservation of total mechanical energy principle

$$\frac{1}{2}mv^2 = mg_A h_A = mg_B h_B$$

$$\Rightarrow g_A h_A = mg_B h_B$$

$$\Rightarrow h_B = \left(\frac{g_A}{g_B}\right) h_A = 9 \times 2 = 18\,m$$

35. **(a)** For the riders to experience weightlessness at the top of the hill, the weight of the rider must be balanced by the centripetal force.



i.e., $mg = \frac{mv^2}{R} \Rightarrow v = \sqrt{gR}$

$= \sqrt{10 \times 20} = 14.1\,ms^{-1}$

Hence, the speed of the car should be between 14 ms^{-1} and 15 ms^{-1}.

36. **(b)** Acceleration due to gravity at lattitude' λ ' is given by

$g_\lambda = g_e - R_e\omega^2 \cos^2\lambda$

At equator, $\lambda = 90^0 \Rightarrow \cos\lambda = \cos 90^0 = 0$

$g_\lambda = g_e = g$ (as given in question)

$$\text{At } 30^0, g_{30} = g - R\omega^2\cos^2 30 = g - \frac{3}{4}R\omega^2$$

or $g - g_{30} = \frac{3}{4}R\omega^2$

37. **(b)** $g^| = g - \omega^2 R\cos^2\lambda$

To make effective acceleration due to gravity zero at equator $\lambda = 0$ and $g' = 0$

$$\therefore 0 = g - \omega^2 R \Rightarrow \omega = \sqrt{\frac{g}{R}} = \frac{1}{800}\frac{rad}{s}$$

38. **(d)** Since gravitational acceleration on earth is defined as

$g_e = \frac{GM_e}{R_e^2}$ ----------------(i)

mass of planet is $M_p = \frac{M_e}{80}$ & radius $R_p = \frac{R_e}{4}$

So, $g_p = \frac{GM_p}{R_p^2}$ -----------(ii)

From (i) & (ii), we get

$$g_p = g_e\frac{M_p}{R_p^2} \times \frac{R_e^2}{M_e} = \frac{g_e}{5} = 2m/sec^2 \text{ (as g=10m/sec}^2\text{)}$$

39. **(a)** $g_h = g\left(1 - \frac{2h}{R}\right) = \frac{4g}{h}$ (since $h = R + \frac{3R}{2}$)

Force on the satellite $= mgh = \frac{4}{9}mg$

$= \frac{4}{9} \times 200 \times 10 \approx 889N$

40. **(b)** mg = mR ω^2

$$\omega = \sqrt{\frac{g}{R}} \Rightarrow T = 2\pi\sqrt{\frac{R}{g}} = 2\pi\sqrt{64000}$$

$$= 2\pi \times 800s = \frac{2\pi \times 800}{3600}h = 1.36 = 1.4h$$

41. **(c)** $g = \frac{GM}{R^2} = GMR^{-2}$

$\therefore \frac{\Delta g}{g} \times 100 = -2\frac{\Delta R}{R} \times 100 = -2 \times (-2\%)$
$= 4\%$

Also $K = \frac{1}{2} I\omega^2$, $\therefore \frac{\Delta K}{K} = \frac{\Delta I}{I}$,

As $I = KR^2$, so $\frac{\Delta I}{I} = \frac{2\Delta R}{R}$

$\therefore \frac{\Delta K}{K} \times 100 = 2\left(\frac{\Delta R}{R} \times 100\right) = 2(-2\%) = -4\%.$

42. **(a)** $g\left(1-\frac{d}{R}\right) = g - \omega^2 R;\ d = \frac{\omega^2 R^2}{g}$

43. **(c)** The orbital velocity of moon is

$v_{0m} = \sqrt{\frac{GM_e}{r}}$ --------------(i)

$\frac{GM_e M_m}{2r}$ --------------(ii)

$U = -\frac{GM_e M_m}{r}$ -----------(iii)

So kinetic energy of moon is $K = \frac{1}{2} M_m v_{0m}^2$

where r is distance between the centres of earth & moon.
It is clear from (ii) & (iii) that U>K (in magnitudes term)

44. **(b)** $v_g = -\frac{GM}{R}$ for $r \le R$ and $v_g = -\frac{GM}{r}$, for $r > R$, and so option (*b*) is correct.

45. **(c)** In a circular or elliptical orbital motion, torque is always acting parallel to displacement or velocity. So, angular momentum is conserved. In attractive field, potential energy is negative. Kinetic energy changes as velocity increase when distance is less. So, option (c) is correct.

46. **(b)** Gravitational potential energy on the earth surface $U_r = \frac{-GMm}{R}$

Gravitational potential energy at a height h above the earth's surface, $U_h = \frac{-GMm}{R+h}$

$U_h = \frac{-GMm}{R+R} = \frac{-GMm}{2R}$

Gain in gravitational potential energy $= U_h - U_r$

$= \frac{-GMm}{2R} - \left(\frac{-GMm}{R}\right) = \frac{GMm}{R} - \frac{GMm}{2R}$

$= \frac{GMm}{2R} = \frac{1}{2} mgR$

47. **(a)** We know that intensity is negative gradient of potential,
i.e., $I = -(dV/dr)$ and as here $I = -(K/r)$, so

$\frac{dV}{dr} = \frac{K}{r}$, i.e., $\int dV = K$

or $V - V_0 = K \log \frac{r}{r_0}$

so $V = K \log \frac{r}{r_0} + V_0$

48. (b) The gravitational potential V at a point distance 'r' from a body a mass m is equal to the amount of work done in moving a unit mass from infinity to that point

$$V_r - V_\infty = -\int_\infty^r \vec{E}.d\vec{r} = -GM(1/r - 1/\infty) \qquad = -\frac{GM}{r}\left[\text{As } \vec{E} = -\frac{dV}{dr}\right]$$

(i) In the first case

When $V_\infty = 0, V_r = \frac{-GM}{r} = -5\,\text{unit}$

(ii) In the second case $V_\infty = +10\,\text{unit}$

$V_r - 10 = -5$ or $V_r = +5\,\text{unit}$

49. **(a)** As all the points on the periphery of either ring are at the same distance from point P, the potential at point P due to the whole ring can be calculated as $V = -(GM)/\left(\sqrt{R^2 + x^2}\right)$ where x is the axial distance from the centre of the ring. This expression is independent of the fact whether the distribution of mass of uniform or non- uniform.

So, at P, $V = -\frac{GM}{\sqrt{2}R} - \frac{G \times 2M}{\sqrt{5}R} = -\frac{GM}{R}\left[\frac{1}{\sqrt{2}} + \frac{2}{\sqrt{5}}\right]$

50. **(b)** Conceptual

51. **(a)** $T = \frac{2\pi r}{v_0} = \frac{2\pi r}{(gR^2/r)^{1/2}} = \frac{2\pi r^{3/2}}{\sqrt{gR^2}} = \frac{2\pi}{\omega}$

Hence, $r^{3/2} = \frac{\sqrt{gR^2}}{\omega}$ or $r^3 = \frac{gR^2}{\omega^2}$

or $r = (gR^2/\omega^2)^{1/3}$

52. **(b)** $v_e = \sqrt{\frac{2GM_e}{R_e}}$; $v_m = \sqrt{\frac{2G\frac{M_e}{81}}{\frac{R_e}{4}}} = \frac{2}{9}v_e \qquad = 2/9 \times 11.2\,kms^{-1} = 2.5\,kms^{-1}$

53. **(c)** $\frac{(v_e)_p}{(v_e)_e} = \frac{\sqrt{\frac{2GM_p}{R_p}}}{\sqrt{\frac{2GM_e}{R_e}}} = \sqrt{\frac{M_p}{M_e} \times \frac{R_e}{R_p}} = \sqrt{\frac{10M_e}{M_e} \times \frac{R_e}{R_e/10}} = 10$

$\therefore (v_e)_p = 10 \times (v_e)_e = 10 \times 11 = 110\,\text{km/s}$

54. **(a)** As we know,

Gravitational potential energy $= \frac{-GMm}{r}$

and orbital velocity, $v_0 = \sqrt{GM/R+h}$

$E_f = \frac{1}{2}mv_0^2 - \frac{GMm}{3R} = \frac{1}{2}m\frac{GM}{4R} - \frac{GMm}{4R}$

$= \frac{GMm}{4R}\left(\frac{1}{2} - 1\right) = \frac{-GMm}{8R}$

$E_i = \frac{-GMm}{R} + K$; $E_i = E_f$

Therefore minimum required energy, $K = \frac{7GMm}{8R}$

55. **(a)** $v = \sqrt{\left(\frac{GM}{r}\right)}$ where r is radius of the orbit of the satellite

Here $r = R_e + h = R_e + \frac{R_e}{2} = \frac{3}{2}R_e$

So, $v = \sqrt{\frac{2GM}{3R_e}} = v_0\sqrt{\frac{2}{3}}$

where v_0 is the orbital velocity of the satellite, which is moving in circular orbit of radius, $r = R_e$

56. **(d)** $\frac{mv^2}{(R+x)} = \frac{GmM}{(R+x)^2}$ also $g = \frac{GM}{R^2}$

$\therefore \frac{mv^2}{(R+x)} = m\left(\frac{GM}{R^2}\right)\frac{R^2}{(R+x)^2}$

$\therefore \frac{mv^2}{(R+x)} = mg\frac{R^2}{(R+x)^2}$

$\therefore v^2 = \frac{gR^2}{R+x} \Rightarrow v = \left(\frac{gR^2}{R+x}\right)^{1/2}$

57. **(c)** $F_{min} = \frac{GMm}{r^2} - \frac{GM(2m)}{(2r)^2} = \frac{GMm}{2r^2}$

and $F_{max} = \frac{GMm}{r^2} + \frac{GM(2m)}{(2r)^2} = \frac{3}{2}\frac{GMm}{r^2}$

$\therefore \frac{F_{min}}{F_{max}} = \frac{1}{3}$

58. (a) Angular momentum of particle=m(v_0+v)a where $v_0 = \sqrt{\frac{GM_e}{a}}$

Total energy of particle $= \frac{1}{2}m(v_0 + v^2) - \frac{GM_e m}{a}$

$= \frac{5}{8}\frac{GM_e m}{a} - \frac{GM_e m}{a} = \frac{-3}{8}\frac{GM_e m}{a}$

At any distance 'r', total energy= $= \frac{1}{2}mu^2 - \frac{GM_e m}{r}$

But angular momentum conservation gives,

$mur = m\sqrt{\frac{5GM_e}{4a}}a \Rightarrow u = \sqrt{\frac{5}{4}\frac{GM_e a}{r^2}}$

Therefore total energy= $\frac{1}{2}m\frac{5}{4}\frac{GM_e a}{r^2} - \frac{GM_e m}{r}$

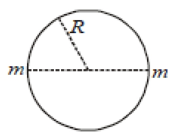
According to conservation of energy this is equal to the initial enegy.

Hence, $\frac{1}{2}m\frac{5}{4}\frac{GM_e a}{r^2} - \frac{GM_e m}{r} = -\frac{3GM_e m}{8a}$

Solving this gives $r = a, \frac{5}{3}a$

59. **(a)** Here, centripetal force will be given by the gravitational force between the two particles.

$\frac{Gm^2}{(2R)^2} = m\omega^2 R$



$$\Rightarrow \frac{Gm}{4R^3} = \omega^2 \Rightarrow \omega = \sqrt{\frac{Gm}{4R^3}}$$

If the velocity of the two particles with respect to the centre of gravity is v then $v = \omega R$

$$v = \sqrt{\frac{Gm}{4R^3}} \times R = \sqrt{\frac{Gm}{4R}}$$

60. **(d)** $v_e = \sqrt{\frac{2GM}{R}}$ and $v_e^{|} = \sqrt{\frac{2GM}{R+h}} = \sqrt{\frac{2GM}{R+R}} = \frac{v_e}{\sqrt{2}}$ $\quad \therefore f = \frac{1}{\sqrt{2}}$

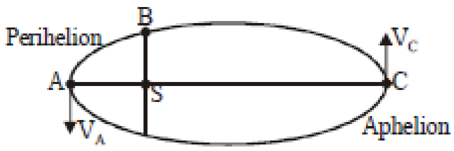
NEET PREVIOUS YEARS QUESTIONS-EXPLANATIONS

1. **(c)** If universal gravitational constant becomes ten times, then $G^{|} = 10G$

Acceleration due to gravity, $g = \frac{GM}{R^2}$

So, acceleration due to gravity increases.

2. **(b)** Speed of the planet will be maximum when its distance from the sun is minimum as *mvr* = constant.



Point A is perihelion and C is aphelion.

Clearly, $V_A > V_B > V_C$

So, $K_A > K_B > K_C$

3. (c) Acceleration due to gravity at height h, $g_n = g_0\left(1 - \frac{2h}{R}\right) h = 1km$

Acceleration due to gravity at depth d, $d_d = g_0\left(1 - \frac{d}{R}\right)$

$$g_h = g_d \;; \qquad g_0\left(1 - \frac{2h}{R}\right) = g_0\left(1 - \frac{d}{R}\right) \Rightarrow d = 2h\,; = 2 \times 1km \Rightarrow d = 2km$$

4. **(a)** Both the astronauts are in the condition of weightlessness. Gravitational force between them pulls towards each other. Hence Astronauts move towards each other under mutual gravitational force.

5. **(a)** As we know, gravitational potential (v) and acceleration due to gravity (g) with height

$$V = \frac{-GM}{R+h} = -5.4 \times 10^7 \text{ ----------(1)}$$

and $g = \frac{GM}{(R+h)^2} = 6$ -----------(2)

Dividing (1) by (2) $\quad \dfrac{\frac{-GM}{R+h}}{(R+h)^2} = \frac{-5.4 \times 10^7}{6} \Rightarrow \frac{5.4 \times 10^7}{(R+h)} = 6$

$\Rightarrow$ R + h = 9000 km so, h = 2600 km

6. **(b)** As we know, escape velocity,

$$V_e = \sqrt{\frac{2GM}{R}} = \sqrt{\frac{2G}{R}.\left(\frac{4}{3}\pi R^3 \rho\right)} \propto R\sqrt{\rho}$$

$$\therefore \frac{V_e}{V_p} = \frac{R_e}{R_p}\sqrt{\frac{\rho_e}{\rho_p}} \Rightarrow \frac{V_e}{V_p} = \frac{R_e}{2R_e}\sqrt{\frac{\rho_e}{2\rho_e}} \;; \qquad \therefore \text{Ratio } \frac{V_e}{V_p} = 1 : 2\sqrt{2}$$

7. **(a)** As we know, orbital speed, $V_{orb} = \sqrt{\frac{GM}{r}}$

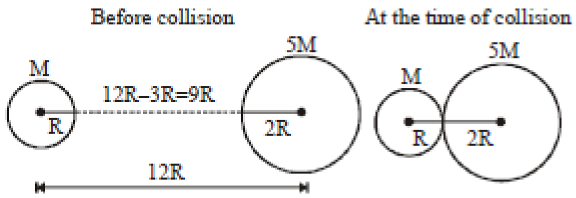
Time period $T = \frac{2\pi r}{v_{orb}} = \frac{2\pi r}{\sqrt{GM}}\sqrt{r}$

Squaring both sides,

$$T^2 = \left(\frac{2\pi r\sqrt{r}}{\sqrt{GM}}\right)^2 = \frac{4\pi^2}{GM}.r^3 \qquad \Rightarrow \frac{T^2}{r^3} = \frac{4\pi^2}{GM} = K$$

$\Rightarrow GMK = 4\pi^2$

8. **(b)**



Let the distance moved by spherical body of mass M is x_1 and by spherical body of mass 5m is x_2

As their C.M. will remain stationary

So, (M) (x_1) = (5M) (x_2) or, x1 = $5x_2$ and for touching $x_1 + x_2 = 9R$

So, $x_1 = 7.5$ R

9. **(c)** The gravitational force on the satellite will be aiming towards the centre of the earth so acceleration of the satellite will also be aiming towards the centre of the earth.

10. **(d) Given:** Height of the satellite from the earth's surface h= 0.25×10^6m

Radius of the earth R = 6.38×10^6m

Acceleration due to gravity g = 9.8 m/s^2

Orbital velocity, V_0 = ?

$$V_0 = \sqrt{\frac{GM}{(R+h)}} = \sqrt{\frac{GM}{R^2}.\frac{R^2}{(R+h)}} \qquad = \sqrt{\frac{9.8\times 6.38\times 6.38}{6.63\times 10^6}} = 7.76\,km/s \qquad \left[\because \frac{GM}{R^2} = g\right]$$

11. **(c)** From question,

Escape velocity

$$= \sqrt{\frac{2GM}{R}} = c = \text{speed of light} \quad \Rightarrow R = \frac{2GM}{c^2} \quad = \frac{2\times 6.6\times 10^{-11}\times 5.98\times 10^{24}}{(3\times 10^8)^2} m = 10^{-2} m$$

12. **(b)** First when (r < R) $E \propto r$ and then when $r > R$ $E \propto \frac{1}{r^2}$

Hence graph (b) correctly dipicts.

13. (a) Horizontal range $= \frac{u^2 \sin 2\theta}{g}$ so $g \propto u^2$

or $\frac{g_{planet}}{g_{earth}} = \frac{(u_{planet})^2}{(u_{earth})^2}$; Therefore $g_{planet} = \left(\frac{3}{5}\right)^2 (9.8 m/s^2) = 3.5 m/s^2$

14. g' = g (1-d/R)

$$g' = g\left(1 - \frac{R/2}{R}\right)$$

mg' = mg(1/2) ; W' = 200(1/2) = 100 N

15. In northern hemisphere dip is +ve and in southern hemisphere dip is .ve.

16.

$$W = \frac{mgh}{1+h/R}$$

at h = R, $W = \frac{mgR}{2}$

17. We know that square of time period is proportional to cube of the radius.

$$T^2 \propto r^3 \ ; \qquad T^2 \propto (R_E + h)^3 \ ; \qquad \frac{T_1^2}{T_2^2} = \frac{(R_E + 6R_E)^3}{(R_E + 2.5R_E)^3}$$

$$\frac{T_1^2}{T_2^2} = \frac{7^3}{\left(\frac{7}{2}\right)^3} \ ; \qquad \frac{T_1^2}{T_2^2} = 8; \ T_2 = \frac{T_1}{2\sqrt{2}}$$

$$T_2 = \frac{24}{2\sqrt{2}} \Rightarrow T_2 = 6\sqrt{2}h$$

18. Gravitational potential energy of the two particle system can be written as follows :

$U = \frac{Gm_1m_2}{r}$. Hence potential energies in two cases can be written as follows :

$$(P.E.)_A = \frac{GMm}{R}$$

$$(P.E.)_B = \frac{GMm}{R+h}$$

$$\therefore \Delta U = (P.E)_B - (P.E)_A$$

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

19. At depth: $g_{eff} = g\left(1 - \frac{d}{R}\right)$

$$\Rightarrow \frac{g}{n} = g\left(1 - \frac{d}{R}\right) \Rightarrow d = (n-1)R/n$$

20. $g_n = g\left[\frac{R}{R+h}\right]^2$

$$mg_h = mg\left[\frac{R}{R + \frac{R}{2}}\right]^2$$

$$W_h = 72\left(\frac{2}{3}\right)^2 = 32N$$

21.

$$V_e = \sqrt{\frac{2GM}{R}} \Rightarrow M = \frac{4}{3}\pi R^3 D$$

$$V_e = \sqrt{\frac{2G \times \frac{4}{3}\pi R^3 D}{R}}$$

$$V_e \alpha R; \frac{V_1}{V_2} = \frac{R_1}{R_2}; \frac{V}{V_2} = \frac{R}{4R}; V_2 = 4V$$

22

given v = kVe
where, k < 1
Thus, v < Ve
From conservation of mechanical energy,

$$\frac{1}{2}mV^2 - \frac{GmM}{R} = -\frac{GmM}{(R+h)}$$

$$\Rightarrow \frac{v^2}{2} = \frac{GM}{R} - \frac{(GM)}{(R+h)} = \frac{h}{R(R+h)}GM$$

$$\Rightarrow \frac{1}{2}k^2V_e^2 = \frac{GMh}{R(R+h)}$$

We know, $V_e = \sqrt{\frac{2GM}{R}} \Rightarrow \frac{1}{2}k^2\left(\frac{2GM}{R}\right) = \frac{GMh}{R(R+h)}$

$$k^2 = \frac{h}{(R+h)}$$

$Rk^2 + hk^2 = h$

$Rk^2 = h(1 - k^2)$

$$\therefore\ h = \frac{Rk^2}{(1-k^2)}$$

23. $E = \frac{F}{m} = \frac{30}{60\times10^{-3}} = 50\,N/kg$