1 Gravitation

Gravitation

Keplar's laws of planetary motion.The universal law of gravitation.
Acceleration due to gravity and its variation with altitude and depth.
Gravitational potential energy and gravitational potential. Escape velocity. Orbital velocity of a satellite. Geo-stationary satellites.

MIND MAP : LEARNING MADE SIMPLE

Gravitation

Satellite
Heavenly object that revolves around a planet

- **Geostationary satellite**
  Height from surface of earth =36000km
  Radius of orbit = 42,400km
  Time periods = 24 hours
  Orbital velocity = 3.1km/s
- **Polar satellite**
  Height from earth's surface = 880km
  Time period = 84min
  Orbital velocity = 7.92km/s
- Escape speed $v_{esc} = \sqrt{2GM/R} = \sqrt{2gR}$
  Earth 's v_{esc} = 11.2km/s
  Orbitals speed $v_{orb} = \sqrt{gR} = \frac{v_e}{\sqrt{2}}$
  Total Energy of a satellite
  E = K.E + P.E
  $= \left(\frac{GMm}{2r}\right) + \left(\frac{-GMm}{r}\right) = -\frac{1}{2}G\frac{Mm}{r}$
- **Weightlessness**
  During free fall under gravity inside a spacecraft or satellite a body is weightless i.e., effective weight becomes zero.

Acceleration due to gravity (g)
Acceleration possessed by an object during free fall due to earth's gravitational pull,

$g = \frac{G M_e}{R_e^2}$

Variation in acceleration due to gravity (g)
(i) with height $g' = g\left(1 - \frac{2h}{R_E}\right)$,
i.e. g decreases with height
(ii) with depth $g' = g\left(1 - \frac{d}{R_E}\right)$,
i.e. g decreases with depth
(iii) with rotation of earth about its own axis
$g' = g - R\omega^2 \cos^2 \lambda$,
At poles, $\lambda = 90^0$, g maximum
At equator, $\lambda = 0^0$, g minimum

Characteristics of gravitational force
(i) Weakest force in Nature.
(ii) Central as well as conservative.
(iii) Always attractive in nature.
(iv) Applicable for all bodies irrespective of their shape, size and position.

Newton's universal law of Gravitation
When two mass bodies are separted by a distance, they experience an attractive force which is directly proportional to the product of their masses and inversaly proportional to the square of their separation.

$F = \frac{Gm_1m_2}{r^2}$, $G = 6.67 \times 10^{-11} Nm^2 kg^{-2}$

Gravitational Field and potential
- Gravitational field Intensity
  $I = \frac{Gm}{r^2}$
- Gravitational potential
  $V_g = \frac{work\ done}{mass} = \frac{-Gm}{r}$
- Gravitational Potential Energy
  $U = \frac{-GMm}{r}$

Kepler's Law-of planetary motion
(i) Law of Orbit: Every planet revolves around the Sun in an elliptical orbit and Sun is at its one focus.
(ii) Law of Area: The radius vector drawn from the Sun to a planet sweeps out equal areas in equal intervals of time.
$\frac{dA}{dt} = \frac{L}{2m}$ = Constant
(iii) Law of Periods: $T^2 \propto a^3$
where, a = length of semi-major axis

GRAVITATION

1. INTRODUCTION

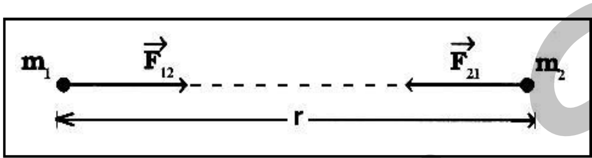
The constitutents of the universe are galaxy, stars, planets, comets, asteriods, meteroids. The force which keeps them bound together is called gravitational force. Gravitation is a nature phenomenon by which material objects attract towards one another.

In 1687 A.D. English Physicist, Sir Isaac Netwon published principia Mathematica, which explains the inverse-square law of gravitation.

2. NEWTON'S LAW OF GRAVITATION

2. 1 Defintion

Every particle of matter attracts every other particle of matter with a force which is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.



2.2 Mathematical Form

If m_1 and m_2 are the masses of the particles and r is the distance between them, the force of attraction F between the particles is given by

$$F \propto \frac{m_1 m_2}{r^2}$$

$$\therefore \quad F = G\frac{m_1 m_2}{r^2}$$

Where G is the universal constant of gravitation.

2.3 Vector Form

In vector form, Newton's law of gravitation is represented in the following manner. The force $\left(\vec{F}_{21}\right)$ exerted on particle m_2 by particle m_1 is given by,

$$\vec{F}_{21} = -G\frac{m_1 m_2}{r^2}\left(\hat{r}_{12}\right) \qquad ...(i)$$

Where $\left(\hat{r}_{12}\right)$ is a unit vector drawn from particle m_1 to particle m_2.

Similarly, the force $\left(\vec{F}_{12}\right)$ exerted on particle m_1 by particle m_2 is given by

$$\vec{F}_{12} = +G\frac{m_1 m_2}{r^2}\left(\hat{r}_{12}\right) \qquad ...(ii)$$

Where $\left(\hat{r}_{12}\right)$ is a unit vector drawn from particle m_1 to particle m_2

From (i) and (ii)

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

3. UNIVERSAL CONSTANT OF GRAVITATION

Universal gravitation constant is given as, $G = \frac{Fr^2}{m_1 m_2}$

Suppose that, $m_1 = m_2 = 1$, and $r = 1$ then $G = F$

$\therefore$ Universal gravitation constant is numerically equal to the force of attraction between two unit masses placed at unit distance apart.

3.1 Unit

$$\text{SI unit : } \frac{\text{newton}(\text{metre})^2}{(\text{kilogram})^2} = \frac{Nm^2}{kg^2}$$

CGS Unit : dyne cm^2/gm^2

3.2 Value of G

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

Dimensions of G

$$[G] = \frac{[F][r^2]}{[m_1 m_2]} = \frac{[M^1L^1T^{2}][M^0L^2T^0]}{[M^2L^0T^0]}$$

$$= [M^{-1}L^3T^{-2}]$$

Note...

1. The gravitational force is independent of the intervening medium.
2. The gravtional force is a conservative force.
3. The force exerted by the first particle on the second is exactly equal and opposite to the force exerted by the second particle on the first.
4. The gravitational force between two particles act along the line joining the two particles and they from an action-reaction pair.

4. VARIATION IN 'g'

4.1 The Acceleration due to Gravity at a height h above the Earth's surface

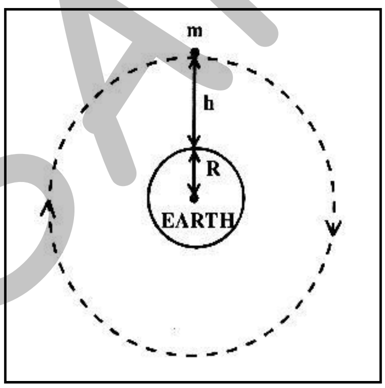
Let M and R be the mass and radius of the earth and g be the acceleratio due to gravity at the earth's surface. Suppose that a body of mass m is placed on the surface of the earth.

The weight 'mg' of the body is equal to the gravitational force acting on it.

$$\therefore \quad mg = \frac{GMm}{R^2}$$

$$\therefore \quad g = \frac{GM}{R^2} \qquad \text{...(i)}$$

Now suppose that the body is raised to a height h, above the earth's surface, the weight of the body is now mg_h and the gravitational force acting on it is $\frac{GMm}{(R+h)^2}$



$$\therefore \quad mg_h = \frac{GMm}{(R+h)^2}$$

$$\therefore \quad g_h = \frac{GM}{(R+h)^2} \qquad \text{...(ii)}$$

Dividing eq (ii) by eq (i), we get,

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

$$\therefore \quad g_h = \left[\frac{R^2}{(R+h)^2}\right]g$$

4.2 Acceleration due to gravity at a very small height

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

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

$$= g\left(1-\frac{2h}{R}+\frac{h^2}{R^2}........\right)$$

If h << R, then neglecting high power's of 'h' we get,

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

4.3 Effect of depth on a acceleration due to Gravity

Also g in terms of ρ

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

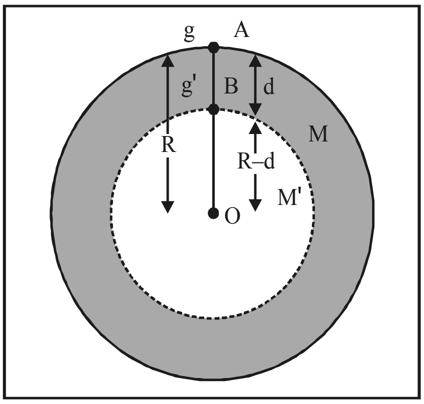
If ρ is density of the material of earth, then

$$M = \frac{4}{3}\pi R^3 \rho$$

$$\therefore \quad g = \frac{G \times \frac{4}{3}\pi R^3 \rho}{R^2}$$

$$\therefore \quad g = \frac{4}{3}\pi G R \rho \qquad \text{...(i)}$$

Let g_d be acceleration due to gravity at the point B at a depth x below the surface of earth. A body at the point B will experience force only due to the portion of the earth of radius OB (R – d). The outer spherical shell, whose thickness is d, will not exert any force on body at point B. Because it will acts as a shell and point is inside.



Now, $M' = \frac{4}{3}\pi(R-x)^3\rho$

or $g_d = \frac{4}{3}\pi G(R-d)\rho$ ...(ii)

Dividing the equation (ii) by (i), we have

$$\frac{g_d}{g} = \frac{\frac{4}{3}\pi G(R-d)\rho}{\frac{4}{3}\pi GR\rho} = \frac{R-d}{R} \quad \text{or} \quad g_d = g\left(1-\frac{d}{R}\right) \quad ...(iii)$$

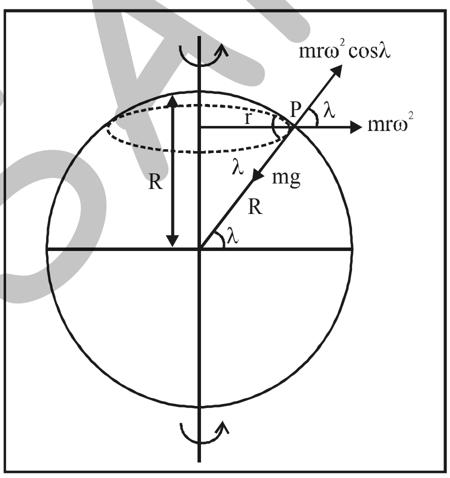
Therefore, the value of acceleration due to gravity decreases with depth.

4.4 Variation of 'g' with latitude due to Rotational motion of Earth

Due to the rotational of the earth the force $mr\omega^2 \cos\lambda$ acts radially outwards. Hence the net force of attraction exerted by the earth of the particle and directed towards the centre of the earth is given by

$mg' = mg - mr\omega^2\cos\lambda$

where g' is the value of the acceleration due to gravity at the point P.



$\therefore$ $g' = g - r\omega^2\cos\lambda$

Now, $r = R\cos\lambda$ (where R is the radius of the earth)

Then $g' = g - (R\cos\lambda)\,\omega^2\cos\lambda$

$\therefore$ $g' = g - R\omega^2\cos^2\lambda$

The effective acceleration due to gravity at a point 'P' is given by,

$g' = g - R\omega^2\cos^2\lambda$.

Thus value of 'g' changes with 'λ' and 'ω'

1. At poles,

$\lambda = 90$,

$g' = g - R\omega^2\cos^2 90$.

$g' = g$

This is maximum acceleration due to gravity.

2. At equator

$\lambda = 0$,

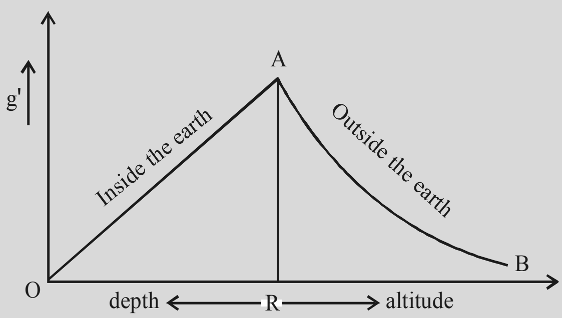
$g' = g - R\omega^2\cos^2 0$

$g' = g - R\omega^2$

This is minimum acceleration due to gravity.

Note...

The variation of acceleration due to gravity according to the depth and the height from the earth's surface can be expressed with help of following graph.



5. SATELLITE

5.1 Definition

Any smaller body which revolves around another larer body under the influence of its gravitation is called a **satellite.** The satellite may be natural or artificial.

1. The moon which revolves around the earth, is a satellite of the earth. There are sixteen satellites revolving around the planet Jupiter. These satellite are called natural satellites.

2. A satellite made and launched into circular orbit by man is called an artificial satellite. The first satellite was launched by USSR named SPUTNIK–I and the first Indian satellite was 'ARYABHATTA'.

5.2 Minimum two stage rocket is used to project a satellite in a cirular orbit round a planet

Suppose that a single stage launching system (i.e. a rocket), carrying satellite at its tip, is used to project the satellite from the surface of the earth. When the fuel in the rocket is ignited, the rocket begins to move upwards. The rocket attains maximum velocity when all the fule is exhausted.

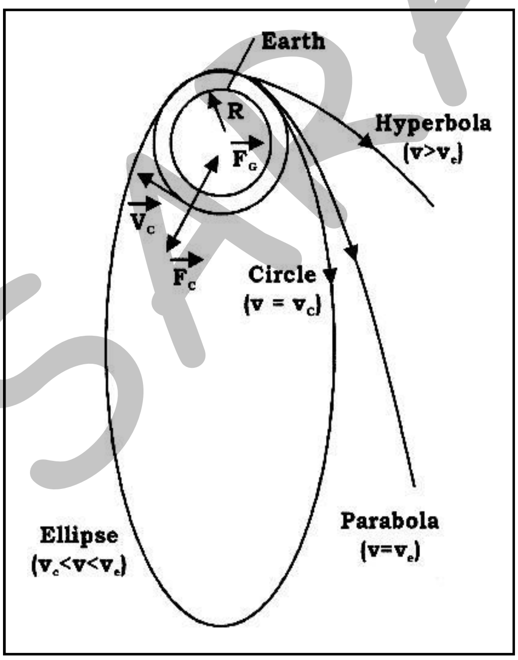
1. If the maximum velocity attained by the rocket is equal to or greater than the escape velocity, the rocket overcomes the eath's gravitational influence and escapes into space alogn with the satellite.

3. If the maximum velocity attained by the rocket is less escape velocity, the rocket cannot overcome the earth's gravitational influence and both the rocket and the satellite eventually fall on the earth's surface due to gravity.

Thus a single stage rocket is unable to launch a satellite in a circular orbit round the earth. Therefore a launching system (i.e. a rocket) having two or more stages must be used to launch a satellite in a circular orbit round the earth.

5.3 Different cases of Projection

When a satellite is taken to some height above the earth and then projected in the horizontal direction, the following four cases may occur, depending upon the magnitude of the horizontal velocity.



1. If the velocity of the projection is less than the critical velocity then the satellite moves in elliptical orbit, but the point of projection is apogee and int he orbit, the satellite comes closer to the earth with its perigee point lying at 180°. If it enters the atmosphere while coming towards perigee it will loose energy and spirally comes down. If it does not enters the atmosphere it will contiune to move in elliptical orbit.

2. If the velocity of the projection is equal to the critical velocity then the satellite moves in circular orbit round the earth.

3. If the velocity of the projection is greater than the critical velocity but less than the escape velocity, then the satellite moves in elliptical orbit and its apoagee, or point of greatest distance from the earth, will be greater than projection height.

4. If the velocity of the projection is equals to the escape velocity, then the satellite moves in parabolic path.

5. It the velocity of the projection is greater than the escape velocity, then orbit will hyperbolic and will escape the gravitational pull of the earth and continue to travel infinitely.

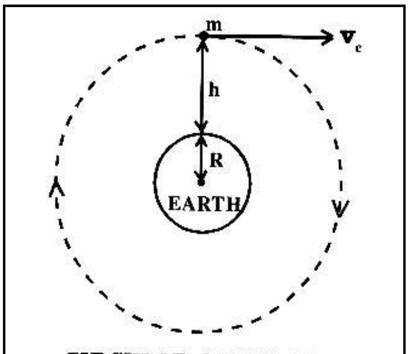
6. ORBITAL VELOCITY

6.1 Definition

The horizontal velocity with which a satellite must be projected from a point above the earth's surface, so that it revolves in a circular orbit round the earth, is called the **orbital velocity** of the satellite.

6.2 An Expression for the Critical Velocity of a Satellite revolving round the Earth

Suppose that a satellite of mass m is raised to a height h above the earth's surface and then projected in a horizontal direction with the orbital velocity v_c. The satellite begins to move round the earth in a circular orbit of radius, R + h, where R is the radius of the earth.



CIRCULAR ORBIT OF A SATELLITE

The gravitational force acting on the satellite is $\frac{GMm}{(R+h)^2}$,

where M is the mass of the earth and G is the constant of gravitation.

For circular motion,

Centrifugal force = Centripetal force

$$\therefore \quad \frac{mv_c^2}{(R+h)} = \frac{GMm}{(R+h)^2},$$

$$\therefore \quad v_c = \sqrt{\frac{GM}{(R+h)}}$$

This expression gives the critical velocity of the satellite.

From the expression, it is clear that the critical velocity depends upon.

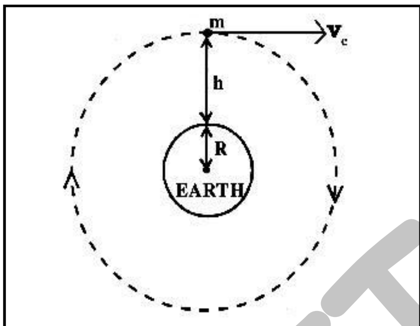
1. Mass of the earth
2. Radius of earth and
3. Height of the satellite above the surface of the earth.

7. PERIOD OF REVOLUTION OF A SATELLITE

The time taken by a satellite to complete one revolution round the earth is called its **period or periodic time** (T).

Consider a satellite of mass m revolving in a circular orbit at a height h above the surface of the earth. Let M and R be the mass and the radius of the earth respectively. The radius (r) of the circular orbit of the satellite is r = R + h.

For the circular motion,



CIRCULAR ORBIT OF A SATELLITE

$$\therefore \quad v_c = \sqrt{\frac{GM}{r}} \qquad \text{...(i)}$$

If T is the period of revolution of the satellite,

$$\text{Period (T)} = \frac{\text{circumference of orbit}}{\text{critical velocity}} = \frac{2\pi r}{v_c}$$

$$T = \frac{2\pi r}{\sqrt{\frac{GM}{r}}} \qquad \text{...(From i)}$$

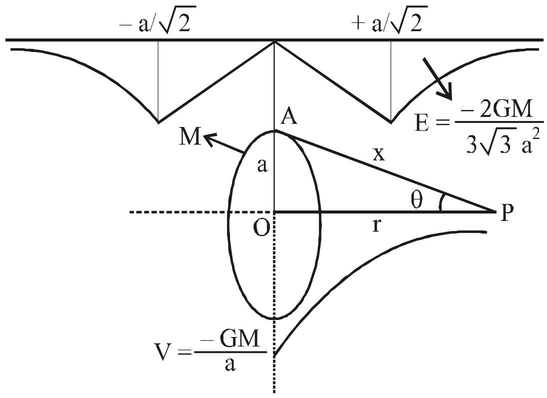
$$\therefore \quad T = 2\pi\sqrt{\frac{r^3}{GM}}$$

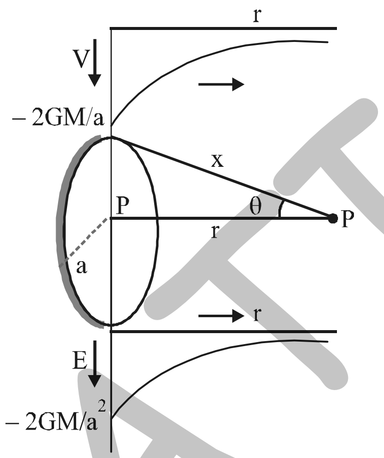
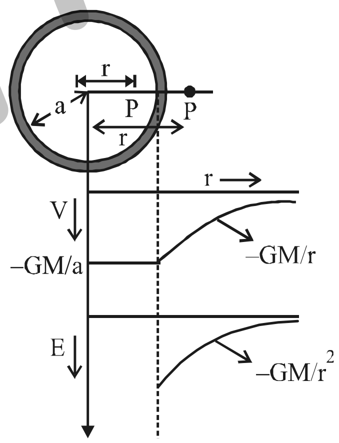
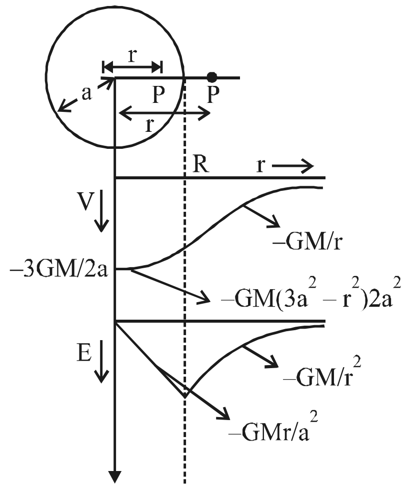
This expression gives the periodic time of the satellite. Squaring the expression, we get

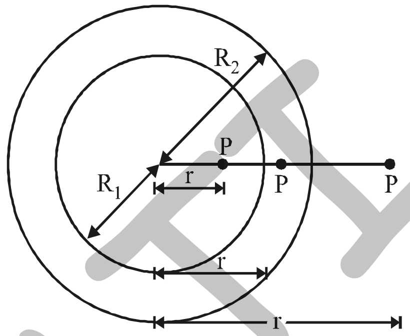
$$\therefore \quad T^2 = \frac{4\pi^2 r^3}{GM}$$

$$\therefore \quad T^2 \propto r^3 \qquad \text{...(since G and M are constants)}$$

Thus, the square of the period of revolution of a satellite is directly proportional to the cube of the radius of its orbit.

Object	Potential (V)	Electric Field (E)	Figure
Ring	$V = \frac{-GM}{(a^2+r^2)^{1/2}}$	$\vec{E} = \frac{-GMr}{(a^2+r^2)^{3/2}}\hat{r}$	

Object	Potential (V)	Electric Field (E)	Figure
Thin Circular	$V = \frac{-2GM}{a^2}\left[\sqrt{a^2+r^2} - r\right]$	$\vec{E} = -\frac{2GM}{a^2}\left[1 - \frac{r}{\sqrt{r^2+a^2}}\right]\hat{r}$	
Uniform Thin Spherical Shell **(a) Point P inside the shell (r ≤ a)** **(b) Point P outside the shell (r ≥ a)**	$V = \frac{-GM}{a}$ $V = \frac{-GM}{r}$	$E = 0$ $\vec{E} = \frac{-GM}{r^2}\hat{r}$	
Uniform Solid Sphere **(a) Point P inside the sphere (r ≤ a)** **(b) Point P outside the sphere (r ≥ a)**	$V = -\frac{Gm}{2a^3}\left(3a^2 - r^2\right)$ $V = -\frac{GM}{r}$	$\vec{E} = \frac{-GMr}{a^3}\hat{r}$ $\vec{E} = \frac{-GM}{r^2}\hat{r}$	

Object	Potential (V)	Electric Field (E)	Figure
Uniform Thick Spherical Shell			
(a) Point outside the shell	$V=-G\frac{M}{r}$	$\vec{E}=-G\frac{M}{r^2}\hat{r}$	
(b) Point inside the shell	$V=\frac{-3}{2}GM\left(\frac{R_2+R_1}{R_2^2+R_1R_2+R_1^2}\right)$	$\vec{E}=0$	
(c) Point between the two surfaces	$V=\frac{-GM}{2r}\left(\frac{3rR_2^2-r^3-2R_1^3}{R_2^3-R_1^3}\right)$	$\vec{E}=\frac{-GM}{r^2}\left(\frac{r^3-R_1^3}{R_2^3-R_1^3}\right)\hat{r}$	

8. GRAVITATIONAL FIELD

The space surrounding any mass is called a gravitational feld. If any other mass is brought in this space, it is acted upon by a gravitational force. In short, the space in which any mass experiences a gravitational force, is called a **gravitational field.**

9. GRAVITATIONAL INTENSITY

The **gravitational intensity** at any point in a gravitational field is defined as the force acting on a unit mass placed at that point.

1. The gravitational intensity (E) at a point at distrance r from a point mass M is given by

$$E=\frac{GM}{r^2}$$ (Where G is the constant of gravitation.)

2. If a point mass m is placed in a gravitational field of intensity E, the force (F) acting on the mass m is given by

$F = mE.$

10. GRAVITATIONAL POTENTIAL

The **gravitational potential** at any point in a gravitational field is defined as the work done to bring a unit mass from infinity to that point.

1. The gravitational potential (V) at a point at distance r from a point mass M is given by,

$$V=-\frac{GM}{r}$$ (Where G is the constant of gravitation)

2. The work done on a unit mass is converted into its potential energy. Thus, the gravitational potential at any point is equal to the potential energy of a unit mass placed at that point.

3. If a small point mass m is placed in a gravitational field at a point where the gravitational potential is V, the gravitational potential energy (P.E.) of the mass m is given by.

P.E. = mass × gravitational potential

$=mV$

$$P.E.=-\frac{GMm}{r}$$

10.1 Gravitational Potential Energy

Gravitational potential energy of a body at a point is defined as the work done in bringing the body from infinity to that point.

Let a body of mass m is displaced through a distance 'dr' towards the mass M, then work done given by,

$$dW=F\,dr=\frac{GMm}{r^2}dr \Rightarrow \int dW=\int_{\infty}^{r}\frac{GMm}{r^2}dr$$

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

(i) From above equation, it is clear that gravitational potential energy increases with increase in distance (r) (i.e. it becomes less negative).

(ii) Gravitational P.E. becomes maximum (or zero) at $r=\infty$.

10.2 Expressions for different Energies of Satellite

1. Potential Energy
2. Kinetic Energy

3. Total Energy and

4. Binding energy

Let M = mass of the earth

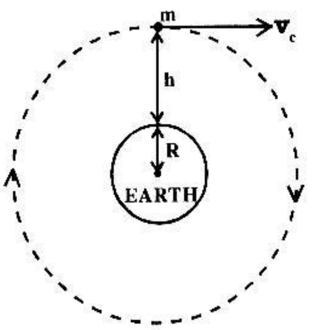
R = radius of the earth

m = mass of the satellite

G = constant of gravitation

h = height of satellite

1. **Potential energy (P.E.) :** The satellite is at a distance (R + h) from the centre of the earth.



CIRCULAR ORBIT OF A SATELLITE

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

$$-\frac{GMm}{R+h} = U$$

2. **Kinetic energy (K.E.) :** The satellite is revolving in a circular orbit with the critical velocity (v_c). Hence its kinetic energy is given by,

$$K.E. = \frac{1}{2}mv_c^2$$

But $v_c = \sqrt{\frac{GM}{R+h}}$

$$\therefore \quad K.E. = \frac{1}{2}m\left(\frac{GM}{R+h}\right) = \frac{GMm}{2(R+h)}$$

3. **Total energy (T.E.)**

T. E = P.E. + K.E.

$$= -\frac{GMm}{R+h} + \frac{GMm}{2(R+h)} = -\frac{GMm}{2(R+h)}$$

The –ve sign indicates that the satellite is bound to the earth.

4. **Binding energy (B.E.) :** From the expression for the total energy, it is clear that if the satellite is given energy equal to $+\frac{GMm}{2(R+h)}$ the satellite will escape to infinity where its total energy is zero.

$$\therefore \quad B.E. = -(T.E.) = -\left[-\frac{GMm}{2(R+h)}\right] = +\frac{GMm}{2(R+h)}$$

5. **Binding Energy of a satellite**

The minimum energy which must be supplied to a satellite, so that it can escape from the earth's gravitation field, is called the **binding energy of a satellite.**

When the body of mass m is at rest on the earth's surface, its gravitational potential energy is given by,

$$U = -\frac{GMm}{R}$$

If the body is give an energy equal to $+\frac{GMm}{R}$, it will escape to infinity.

$\therefore$ Binding energy of the body = $+\frac{GMm}{R}$

11. ESCAPE VELOCITY OF A BODY

11.1 Expression for the escape velocity of a body at rest on the earth's surface

The minimum velocity with which a body should be projected from the surface of the earth, so that it escapes from the earth's gravitational field, is called the escape velocity. Thus, if a body or a satellite is given the escape velocity, its kinetic energy of projection will be equal to its binding energy.

Kinetic Energy of projection = Binding Energy.

$$\therefore \quad \frac{1}{2}mv_e^2 = \frac{GMm}{R}$$

$$\therefore \quad v_e = \sqrt{\frac{2GM}{R}}$$

11.2 Expression for 'V_e' in terms's of 'g'

The escape velocity for any object on the earth's surface is given by.

$$v_e = \sqrt{\frac{2GM}{R}}$$

If m is the mass of the object, its weight mg is equal to the gravitational force acting on it.

$$\therefore \quad mg = \frac{GMm}{R^2}$$

$$\therefore \quad GM = gR^2$$

Substituting this value in the expression for v_e we get,

$$v_e = \sqrt{2gR}$$

11.3 Expression for the escape velocity of a body from Earth in terms of mean density of the planet

1. Derive expression for

$$v_e = \sqrt{\frac{2GM}{R}}$$

2. Let ρ be the mean density of the planet. Then,

$$M = \frac{4}{3}\pi R^3 \rho$$

$$v_e = \sqrt{\frac{2G}{R} \times \frac{4}{3}\pi R^3 \rho}$$

$$v_e = 2R\sqrt{\frac{2\pi G\rho}{3}}$$

11.4 The escape velocity of a body from the surface of the earth is $\sqrt{2}$ times its critical velocity when it revolves close to the earth's surface

Let M and R be the mass and radius of the earth and m be the mass of the body. When orbiting close to the earth's surface, the radius of the orbit is almost equal to R. If v_c is the critical velocity of the body, then for a circular orbit.

Centripetal force = Gravitational force

$$\therefore \quad mv_c^2 = \frac{GMm}{R^2}$$

$$\therefore \quad v_c = \sqrt{\frac{GM}{R}} \quad \text{...(i)}$$

If v_e is the escape velocity from the earth's surface,

K.E. of projection = Binding energy

$$\therefore \quad \frac{1}{2}mv_e^2 = \frac{GMm}{2}$$

$$\therefore \quad v_e = \sqrt{\frac{2GM}{R}} \quad \text{...(ii)}$$

From Eq (i) and Eq. (ii), we get,

$$v_e = \sqrt{2}\, v_c$$

12. COMMUNICATION SATELLITE

An artificial satellite revolving in a circular obrit round the earth in the same sense of the rotational of the earth and having same period of revolution as the period of rotation of the earth (i.e. 1 day = 24 hours = 86400 seconds) is called as geo-stationary or communication satellite.

As relative velocity of the satellite with respective to the earth is zero it appears stationary from the earth's surface. Therefore it is know as geo-stationary satellite or geosynchronous satellite.

1. The height of the communication satellite above the earth's surface is about 36000 km and its period of revolution is 24 hours or 24 × 60 × 60 seconds.
2. The satellite appears to be at rest, because its speed relative to the earth is zero, hence it is called as geostationary or geosynchronous satellite.

12.1 Uses of the communication satellite

1. For sending TV signals over large distances on the earth's surface.
2. Telecommunication.
3. Weather forescasting.
4. For taking photographs of astronomical objects.
5. For studying of solar and cosmic radations.

13. WEIGHTLESSNESS

1. The gravitational force with which a body is attracted towards the centre of earth is called the weight of body. Weightlessness is a moving satellite is a feeling. It is not due to weight equal to zero.
2. When an astronaut is on the surface of earth, gravitational force acts on him. This gravitational force is the weight of astronaut and astronant exerts this force on the surface of earth. The surface of earth exerts an equal and opposte reaction and due to this reaction he feels his weight on the earth.
3. for an astronaut in an orbiting satellite, the satellite and astronaut both have same acceleration towards the centre

of earth and this acceleration is equal to the acceleration due to gravity of earth.

4. Therefore astronaunt does not produce any action on the floor of the satellite. Naturally the floor does not exert any force of reaction on the astronaut. As there is no reaction, the astronaut has a feeling of weightlessness. (i.e. no sense of his own weight).

Note...

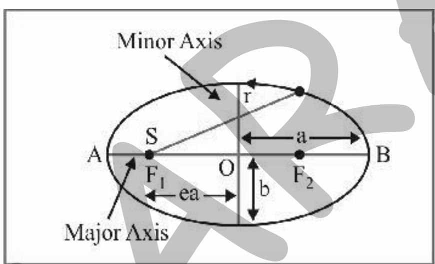
1. The sensation of weightlessness experienced by an aastronaut is not the result of there being zero gravitational acceleration, but of there being zero difference between the acceleration of the spacecraft and the acceleration of the astronaut.
2. The most common problem experienced by astronauts in the initial hours of weightlessness is known as space adaptation snydrome (space sickness).

14. KEPLER'S LAWS

14.1 Law of Orbit

Each Planet move surround the sun in an elliptical orbit with the sun at one of the foci as shown in figure. The eccentricity of an ellipse is defined as the ratio of the distance SO and AO i.e. $e = \frac{SO}{AO}$

$\therefore \quad e = \frac{SO}{a} \qquad SO = ea$



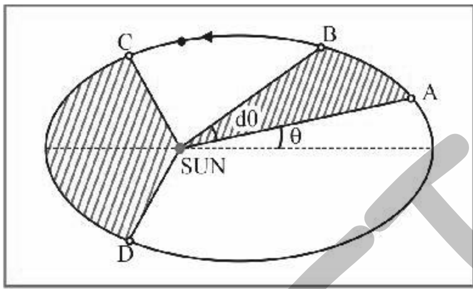
The distance of closest approach with sun at F_1 is AS. This distance is called perigee. The greatest distance (BS) of the planet from the sun is called apogee.

Perigee (AS) = AO – OS = a – ea = a (1 – e)

apogee (BS) = OB + OS = a + ea = a (1 + e)

14.2 Law of Area

The line joining the sun and a planet sweeps out equal areas in equal intervals of time. A planet takes the same time to travel from A to B as from C to D as shown in figure. (The shaded areas are equal). Naturally the planet has to move faster from C to D.



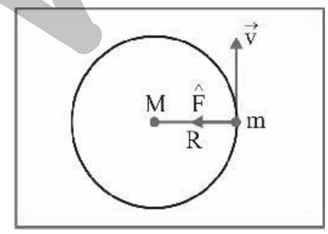
$$\text{Areal velocity} = \frac{\text{area swept}}{\text{time}}$$

$$= \frac{\frac{1}{2}r(rd\theta)}{dt} = \frac{1}{2}r^2\frac{d\theta}{dt} = \text{cosntant}$$

Hence $\frac{1}{2}r^2\omega$ = constant.

14.3 Law of Periods

The square of the time for the planet to complete a revolution about the sun is proportional to the cube of semimajor axis of the elliptical orbit.



i.e. Centripetal force = Gravitational force

$$\frac{mv^2}{R} = \frac{GMm}{R^2} \Rightarrow \frac{GM}{R} = v^2$$

Now, velocity of the planet is

$$v = \frac{\text{Circumference of the circular orbit}}{\text{Time period}} = \frac{2\pi R}{T}$$

Substituting Value in above equation

$$\Rightarrow \frac{GM}{R} = \frac{4\pi^2R^2}{T^2} \text{ or } T^2 = \frac{4\pi^2R^3}{GM}$$

Since $\left(\frac{4\pi^2}{GM}\right)$ is constant,

$$\therefore T^2 \propto R^3 \text{ or } \frac{T^2}{R^3} = \text{constant}$$

14.4 Gravity

Gravity is the force of attraction exerted by earth towards is centre on a body lying on or near the surface of earth. Gravity is merely a special case of gravitation and is also called earth's gravitational pull.

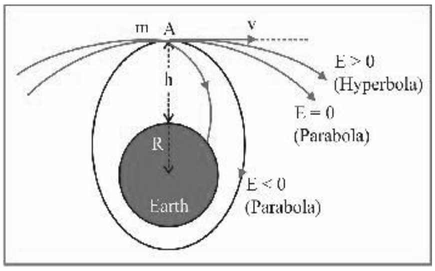
Weight of a body is defined as the force of attraction exerted by the earth on the body towards its centre.

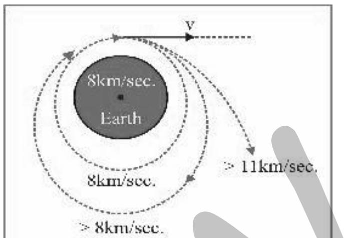
The units and dimenstions of gravity pull or weight are the same as those of force.

Astronomical Data

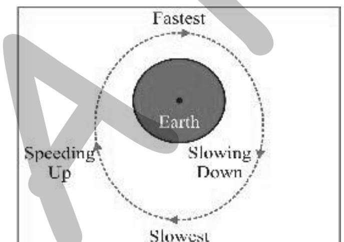
Body	Sun	Earth	Moon
Mean radius, m	6.95×10^{8}	6.37×10^{6}	1.74×10^{6}
Mass, kg	1.97×10^{30}	5.96×10^{24}	7.30×10^{22}
Mean density, 10^3 kg/m^3	1.41	5.52	3.30
Period of rotation about axis, days	25.4	1.00	27.3

LAUNCHING OF AN ARTIFICIAL SATELLITE AROUND EARTH





(a)



(b)

The satellite is placed upon the rocket which is launched from the earth. After the rocket reaches its maximum vertical height h, a spherical mechanism gives a thrust to the satellite at point A (figure) producing a horizontal velocity v. The total energy of the satellite at A is thus,

$$E = \frac{1}{2}mv^2 - \frac{GMm}{R+h}$$

The orbit will be an ellipse (closed path), a parabola, or an hyperbola depending on whether E is negative, zero, or positive. In all cases the centre of the earth is at one focus of the path. If the energy is too low, the elliptical orbit will intersect the earth and the satellite will fall back. Otherwise it will keep moving in a closed orbit, or will escape from the earth, depending on the values of v and R.

Hence a satellite carried to a height h (<< R) and given a horizontal velocity of 8 km/sec will be placed almost in a circular orbit around the earth (figure). If launched at less than 8 km/sec, it would get closer and closer to earth until it hits the ground. Thus 8 km/sec is the critical (minimum) velocity.

14.5 Intertial mass

Inertial mass of a body is related to its inertia in linear motion; and is defined by Newton's second law of motion.

Let a body of mass m_i move with acceleration a under the action of an external force F. According to Newton's second law of motion, $F = m_i a$ or $m_i = F/a$

Thus, inertial mass of a body is equal to the magnitude of external force required to produce unit acceleration in the body.

14.6 Gravitational mass

Gravitational mass of a body is related to gravitational pull on the body, and is defined by Newton's law of gravitational.

$$F = \frac{GM\,m_G}{R^2} \quad \text{or} \quad m_G = \frac{F}{\left(GM/R^2\right)} = \frac{F}{I}$$

The mass m_G of the body in this sence is the gravitational mass of the body. The intertia of the body has no effect on the gravitational mass of the body.

$m_G = F$

Thus, **Gravitational mass** of a body is defined as the magnitude of gravitational pull experienced by the body in a gravitational field of unit intensity.

14.7 Centre of Gravity

Centre of gravity of a body placed in the gravitational field is that point where the net gravitational force of the field acts.

QUESTION ALIKE

Very Short Answer Type Questions :

1. What is the value of *G* at the centre of the earth?

Sol. 6.67×10^{-11} Nm^2/kg^2.

2. What is the apparent weight of an astronaut in a satellite revolving around the earth?

Sol. Zero.

3. What is the time period of geostationary satellite?

Sol. 24 hours

4. Write any two applications of Newton's law of gravitation.

Sol. (i) It helps to determine mass of the earth, the sun and the planets.

(ii) It helps to discover new stars and planets.

5. How does orbital velocity of a satellite vary with the mass of the satellite?

Sol. $V_0 = \sqrt{\dfrac{GM}{R+h}}$, where M = mass of planet.

It is independent of the mass of the satellite.

6. How far from the earth does the gravitational potential energy due to earth become zero?

Sol. At infinity.

7. What is the effect of rotation of the earth on the acceleration due to gravity?

Sol. It decreases due to rotation. This effect is maximum at equator and zero at poles.

8. Why does a rubber ball bounce higher on a hill than on ground?

Sol. At higher altitudes *g* decreases so the gravitational pull is less on hills.

9. Why is it not possible to place an artificial satellite in an orbit such that it is always visible over New Delhi?

Sol. Because a satellite remains always visible only if it is revolving around the earth in the equatorial plane with the period of revolution of 24 hours.

10. Why does a body weigh more at the poles than at the equator?

Sol. Because $g' = g - \omega^2 R\cos^2\phi$, and also earth is not of uniform radius

$\therefore \quad g_p > g_e$

Short Answer Type Questions :

11. Which is more fundamental, mass or weight of a body? Why?

Sol. Mass of a body is more fundamental because the value of weight changes from place to place as it depends on acceleration due to gravity but mass remains constant everywhere in the universe.

12. Why do the astronauts landing on the surface of moon tie heavy weights at their back before landing on moon?

Sol. The value of g is small on moon so the astronauts feel less weight hence to compensate for the loss in weight the astronauts tie heavy weights at their back.

13. Comment "Earth has atmosphere but moon has not"

Sol. Earth has atmosphere because the r.m.s velocity of air molecules is less than the escape speed from the surface of earth but at moon the r.m.s. velocity of air molecules is larger than the escape speed from the surface of moon. So moon does not have atmosphere.

14. To what factor does the time period of revolution of a planet be increased so that its distance from sun is increased 100 times?

Sol. $\frac{T_1^2}{T_2^2} = \frac{R_1^3}{R_2^3}$

$\therefore \quad \frac{T_1^2}{T_2^2} = \frac{R_1^3}{(100R_1)^3}$

$\therefore \quad T_2^2 = T_1^2(100)^3$

$\therefore \quad T_2 = T_1 \; 1000$

So time period of revolution of a planet increases to 1000 times.

15. Define orbital speed of satellite. What is its value for a satellite close to earth surface?

Sol. It is the speed of satellite with which it orbits around the earth.

Its value in the orbit close to earth is 7.92 km/s.

16. Two bodies of masses 10^{10} kg and 10^{20} kg are separated by a distance of 10^{15} m. What is the force of attraction between them?

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

$\therefore \quad F = \frac{6.67 \times 10^{-11} \times 10^{10} \times 10^{20}}{(10^{15})^2}$

$= 6.67 \times 10^{-11} \times \frac{10^{30}}{10^{30}}$

$\therefore \quad F = 6.67 \times 10^{-11}$ N

17. Two point mass having equal mass m are separated by a distance of 100 m. What is the value of m if the gravitational force of attraction between them is 66.7 N?

Sol. As $F = \dfrac{Gm_1m_2}{r^2}$

$$\therefore \quad 66.7 = \frac{6.67\times10^{-11}\ \text{m}^2}{(100)^2}$$

$$\therefore \quad m^2 = \frac{100000}{10^{-11}}$$

$$\therefore \quad m^2 = 10^{16}$$

$$\therefore \quad m = 10^8\ \text{kg}$$

18. What will be the value of g at a height 0.75 times that of radius of the earth?

Sol. $g_h = g\left[\dfrac{R}{R+h}\right]^2$

$$\therefore \quad g_h = g\left[\frac{R}{R+0.75R}\right]^2$$

$$= g\left[\frac{R}{1.75R}\right]^2$$

$$= g\left[\frac{4}{7}\right]^2$$

$$g_h = 9.8 \times \frac{16}{49} = 3.2\ \text{m/s}^2$$

19. Write any four properties of gravitational force.

Sol. (i) It is independent of the medium between the particles.

(ii) It is always attractive.

(iii) It is weakest force in nature.

(iv) It is conservative force.

20. The ratio of masses of two planets is 3 : 7 and the ratio of their radii is 9 : 7. What will be the ratio of the escape speed on both the planets?

Sol. $v_1 = \sqrt{\dfrac{2GM_1}{R_1}}$

$$v_2 = \sqrt{\frac{2GM_2}{R_2}}$$

$$\therefore \quad \frac{v_1}{v_2} = \sqrt{\frac{M_1}{M_2}\times\frac{R_2}{R_1}} = \sqrt{\frac{3}{7}\times\frac{7}{9}} = \sqrt{\frac{3}{9}} = \sqrt{\frac{1}{3}}$$

Hence, the ratio of their escape speed will be $1:\sqrt{3}$.

21. A body weighs 100 N at the surface of earth. At what height will it weigh 36 N?

[Take R_e = 6400 km]

Sol. mg = 100 N, mg_h = 36 N

$$\therefore \quad \frac{g_h}{g} = \frac{36}{100}$$

$$g_h = g\left[\frac{R_e}{R_e + h}\right]^2$$

$$\therefore \quad \frac{g_h}{g} = \left[\frac{R_e}{R_e + h}\right]^2$$

$$\therefore \quad \frac{36}{100} = \frac{R_e^2}{(R_e + h)^2}$$

$$\frac{6}{10} = \frac{R_e}{R_e + h}$$

$$\therefore \quad 6R_e + 6h = 10R_e$$

$$\therefore \quad h = \frac{2R_e}{3} = \frac{2 \times 6400}{3}$$

$$\therefore \quad h = 4266.6 \text{ km}$$

22. How deep a mine should be dug so that the weight of a body decreases by 75% as that on surface of the earth?

[Take R_e = 6400 km]

Sol. $$g_d = g\left[1 - \frac{d}{R_e}\right]$$

$$\therefore \quad 25\% \text{ of } g = g\left[1 - \frac{d}{R_e}\right]$$

$$\therefore \quad \frac{25}{100} = 1 - \frac{d}{R_e}$$

$$\therefore \quad \frac{d}{R_e} = 1 - \frac{25}{100}$$

$$d = \frac{75}{100} \times R_e$$

$$\therefore \quad d = \frac{75 \times 6400}{100}$$

$$\therefore \quad d = 4800 \text{ km}$$

23. What is the value of escape speed on a planet whose mass is four times that of earth and radii double that of earth?

Sol. $v_e = \sqrt{\dfrac{2GM_e}{R_e}}$

$v_p = \sqrt{\dfrac{2GM_p}{R_p}}$

$\therefore \quad \dfrac{v_p}{v_e} = \sqrt{\dfrac{M_p}{M_e} \times \dfrac{R_e}{R_p}}$

$\therefore \quad v_p = 11.2\sqrt{\dfrac{4}{1} \times \dfrac{1}{2}}$

$= 11.2 \times 1.414$

$\simeq 15.8$ km/s

24. What are the uses of geostationary satellites?

Sol. (i) They are used in communicating radio, T.V. and telephone signals across the world.

(ii) In weather forecasting.

(iii) In studying meteorites and cosmic radiations.

(iv) In studying upper region of atmosphere.

25. Deduce the relation between the orbital velocity of satellite close to earth's surface and escape velocity from earth surface.

Sol. $V_e = \sqrt{2gR_e}$

$\therefore \quad V_e = \sqrt{2}\sqrt{gR_e}$

As $\quad V_0 = \sqrt{gR_e}$

$\boxed{\therefore \ V_e = \sqrt{2}V_0}$

26. The radii of two planets are R and $2R$ respectively and their densities are ρ and $\dfrac{\rho}{2}$. What is the ratio of acceleration due to gravity at their surface?

Sol. As $g = \dfrac{GM}{R^2}$

Also as $M = \dfrac{4}{3}\pi R^3 \rho$

$\therefore \quad g = \dfrac{G4}{3}\dfrac{\pi R^3 \rho}{R^2}$

$\therefore \quad g = \frac{4G\pi R\rho}{3}$

Now, $g_1 = \frac{4}{3}G\pi R\rho$

$g_2 = \frac{4}{3}G\pi 2R \times \frac{\rho}{2}$

$\therefore \quad \frac{g_1}{g_2} = \frac{1}{1}$

27. What will be the escape velocity from a point 3200 km above earth's surface? (Take R_e = 6400 km, g_e = 9.8 m/s^2)

Sol. $V_e = \sqrt{2g_h(R+h)}$

$\therefore \quad V_e = \sqrt{\frac{2gR^2}{(R+h)^2} \times (R+h)}$

$\therefore \quad V_e = \sqrt{\frac{2gR^2}{(R+h)}}$

$\therefore \quad V_e = \sqrt{\frac{2 \times 9.8 \times (6.4 \times 10^6)^2}{6.4 \times 10^6 + 3.2 \times 10^6}}$

$= \sqrt{83.62 \times 10^6}$

$= 9.1 \times 10^3$ m/s

= 9.1 km/s

28. Mention some necessary conditions for a geostationary satellite.

Sol. (i) It should revolve in an orbit concentric and coplanar with equatorial plane of the earth.

(ii) Its sense of rotation should be same as that of the earth.

(iii) It should have period of revolution of 24 hours and revolve at height of nearly 36,000 km.

29. Mention the conditions under which the weight of a body can become zero.

Sol. (i) When the body is kept at the centre of earth

(ii) At its free fall

(iii) When a body is orbiting around the earth

30. Prove that the weight at the centre of the earth is zero.

Sol. As weight = mg

but $g_d = g\left[1 - \frac{d}{R_e}\right]$

Now, $d = R_e$

$\therefore \quad g_d = g\left[1 - \frac{R_e}{R_e}\right]$

$\therefore \quad g_d = 0$

$\therefore$ Weight at centre $= m \times 0$

$= 0$

Long Answer Type Questions :

31. State and prove Kepler's 2[nd] law.

Sol. Law of areas : The line that joins any planet to the sun sweeps out equal areas in equal intervals of time.

It means that the area covered by the planet around the sun in given time intervals is constant *i.e.*, areal velocity is constant. This law comes from the observations that planets appear to move slower when they are farther from the sun than when they are nearer.

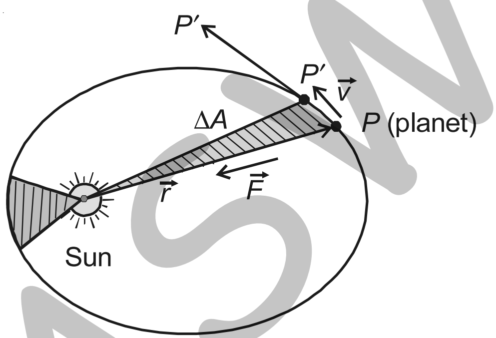


Fig : The plant *P* moves around the sun in an elliptical orbit. The shaded area is the area Δ*A* swept out in a small interval of time Δ*t*.

This law can be considered as a consequence of conservation of angular momentum which is valid for any force that is always directed towards or away from a fixed point *i.e.*, the central force. This area swept out by the planet of mass m in the time interval Δt is $\Delta\vec{A}$.

$\Delta\vec{A}$ is given by $\Delta\vec{A} = \frac{1}{2}(\vec{r} \times \vec{v}\Delta t)$

$$\therefore \quad \frac{\Delta\vec{A}}{\Delta t} = \frac{1}{2}\vec{r} \times \vec{v}$$

$$= \frac{1}{2}\vec{r} \times \frac{\vec{p}}{m} \qquad \ldots\left(\vec{v} = \frac{\vec{p}}{m}\right)$$

$$\therefore \quad \frac{\Delta\vec{A}}{\Delta t} = \frac{\vec{L}}{2m}$$

Where $\vec{L} = \vec{r} \times \vec{p}$ = angular momentum, $\vec{p}$ = momentum and $\vec{r}$ is the position vector where sun is taken as the origin.

The torque acting on a planet due to the central force is clearly zero; *i.e.*, because $\vec{F}$ is parallel to $\vec{r}$.

Since, $\vec{\tau} = \vec{r} \times \vec{F} = rF \sin\theta$

$\therefore \quad \vec{\tau} = 0$

As $\vec{\tau} = \frac{d\vec{L}}{dt}$

$\therefore \quad \frac{d\vec{L}}{dt} = 0$

This implies that $\vec{L}$ is constant as the planet goes around.

Hence, $\frac{\Delta\vec{A}}{\Delta t}$ is a constant.

32. Draw and explain the setup made by Henry Cavendish to find the value of *G*.

Sol. The value of universal gravitational constant *G* was first determined experimentally by English scientist Henry Cavendish in 1798. The apparatus used by him is schematically shown in figure.

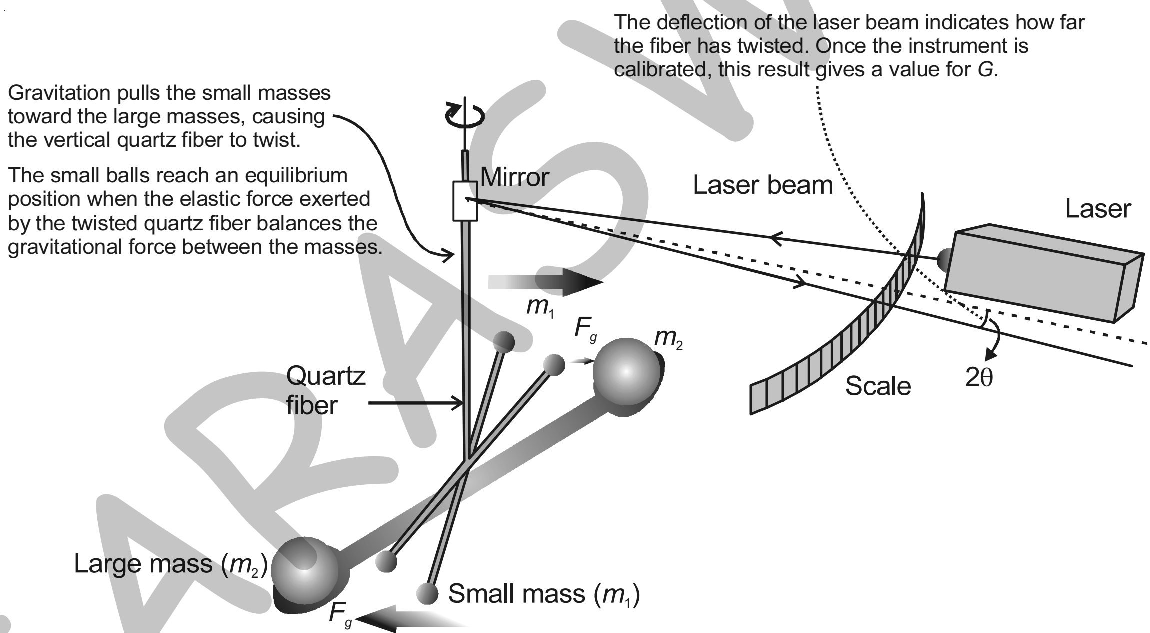


Fig : Experimental set up for finding the value of *G*

A light rod of length *L* is suspended from a rigid support by a thin quarty fibre. Two small identical lead spheres of mass *m* are attached at its ends to form a dumb-bell. Two large lead spheres of mass *M* are placed near the ends of the dumb-bell on opposite sides such that all the four spheres lie horizontally. The small spheres get attracted towards the large ones due to which torque arises and the suspended wire gets twisted till such time as the restoring torque of the wire equals the gravitational torque. The angle of rotation 'θ' is measured by the deflection of a light beam reflected from a mirror attached to the vertical suspension.

Now, gravitational torque = $F \times L = \frac{GMmL}{r^2}$

and restoring torque = $k\theta$

Where, k is the restoring torque per unit angle of twist also known as torsion constant.

$$\therefore \quad \frac{GMmL}{r^2} = k\theta$$

$$\text{or } G = \frac{k\theta r^2}{MmL}$$

By knowing all the quantities, we can easily find the value of G. Since the time of Cavendish's experiment, the measurement of G has been refined and currently accepted value is

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

33. Define gravitational potential. Write its expression. Also mention its relation with gravitational potential energy.

Sol. It is the potential energy associated with a unit mass at a point due to its position or we may say that the gravitational potential due to the gravitational force of the earth is defined as the potential energy of a particle of unit mass at that point.

$$V = \frac{\text{Work done}}{\text{Mass}}$$

$$\therefore \quad V = \frac{\frac{-GMm}{r}}{m}$$

$$\therefore \quad V = \frac{-GM}{r}$$

or simply we may also write that

Gravitational potential energy = Mass × gravitational potential

34. Define the time period of a satellite. Obtain its expression and hence show that it obeys Kepler's 3rd law.

Sol. It is the time taken by an earth satellite to complete one revolution around the earth.

Circumference of the orbit of satellite = $2\pi(R_e + h)$

$$V_0 = \text{orbital speed} = \frac{\text{Circumference}}{\text{Time period}}$$

$$\therefore \quad T = \frac{2\pi(R_e + h)}{V_0}$$

$$\therefore \quad T = \frac{2\pi(R_e + h)}{\sqrt{\frac{GM}{R_e + h}}} \quad \ldots\left(V_0 = \sqrt{\frac{GM}{R_e + h}}\right)$$

$$\therefore \quad T = \frac{2\pi(R_e + h)^{3/2}}{\sqrt{GM_e}} \quad \ldots\text{(iv)}$$

By squaring both sides we get

$$T^2 = \frac{4\pi^2}{GM_e}(R_e + h)^3$$

or $T^2 = k(R_e + h)^3$ …(v)

Where, $k = \frac{4\pi^2}{GM_e}$ = a constant

$\therefore\ T^2 \propto R^3$

35. What do you mean by weightlessness? Explain it with any one practical illustration.

Sol. Weight of a body is the force with which it is attracted towards the centre of the earth.

According to Newton's second law $F = ma$

$\therefore$ $F = mg = W$ as $a = g$. SI unit of weight is newton.

Now, let us take a case of spring balance attached to a ceiling to weigh any object. If the spring balance is pulled from one side or say anything is attached to its free end then it would be stretched by certain amount. Suppose its top end suddenly breaks from the ceiling then in its free fall both ends of spring balance will move with identical acceleration g, hence the spring is not stretched and does not exert any upward force on the object which is moving down with acceleration g due to gravity. So, the reading becomes zero and we may say that the object in its free fall is weightless and this phenomenon is called weightlessness.

36. (i) State Kepler's 3rd law of planetary motion.

(ii) What is the time period in days of a planet at a distance 4 times that of earth from the sun.

Sol. (i) **Kepler's III law :** The square of the period of revolution of a planet around the sun is proportional to the cube of the semi-major axis of its elliptical path.

(ii) Here,

T_1 = 365 days , $R_1 = R$

T_2 = ? , $R_2 = 4R$

Now, $\frac{T_1^2}{T_2^2} = \frac{R_1^3}{R_2^3}$

$\therefore \frac{(365)^2}{T_2^2} = \frac{R^3}{(4R)^3}$

$\therefore$ $T_2^2 = 64 \times 365 \times 365$

$\therefore$ T_2 = 2920 days

37. Write some uses of

(i) Geostationary satellites

(ii) Polar satellites

Sol. (i) Uses of geostationary satellites

(a) They are used in communicating radio, T.V. and telephone signals across the world.

(b) In weather forecasting.

(c) In studying meteorites and cosmic radiations.

(d) In studying upper region of atmosphere.

(ii) Uses of polar satellites

(a) For spying work for military purposes.

(b) For weather forecasting (even better than geostationary satellites).

38. What will be the minimum energy required to lift a body from earth's surface to an altitude five times the radius of earth?

Sol. Let the mass of satellite be m kg.

At earth's surfaces

$$U_i = -\frac{GMm}{R}$$

At altitude of $5R$

$$U_f = -\frac{GMm}{R+5R} = -\frac{GMm}{6R}$$

$\therefore$ Required energy $= U_f - U_i$

$$= \frac{GMm}{R}\left[1-\frac{1}{6}\right]$$

$$= \frac{5}{6}\cdot\frac{GMm}{R}$$

$$= \frac{5}{6}\frac{gR^2m}{R}$$

$$= \frac{5}{6}mgR$$

39. A planet has its mass 4 times that of earth and radius thrice that of earth. What will be the weight of a block on its surface which weighs 100 N at earth's surface? [Take g = 10 ms^{-2}]

Sol. $g_p = \dfrac{GM_p}{R_p^2}$

$$g_e = \frac{GM_e}{R_e^2}$$

$$\therefore \quad \frac{g_p}{g_e} = \frac{M_p}{M_e}\frac{R_e^2}{R_p^2} = \frac{4}{1}\times\frac{1}{9}$$

$$\therefore \quad g_p = \frac{4}{9}g_e$$

Now, weight at earth = mg

$\therefore$ 100 = m × 10

$\therefore$ m = 10 kg

$\therefore$ Weight at a planet = mg_p

$$= 10\times\frac{4}{9}$$

$$= \frac{40}{9} = 4.44 \text{ kg}$$

40. If the mass of earth is doubled by keeping its size unchanged, what will be the acceleration due to gravity at height 3200 km above earth's surface? [R_e = 6400 km and g = 9.8 m/s^2]

Sol. $g_2 = \frac{GM_2}{R^2}$

$g_1 = \frac{GM_1}{R^2}$

$\therefore \quad g_2 = 2g_1$

$\therefore \quad g_2 = 19.6$ m/s^2

Now,

$$g_h = g_2\left[\frac{R}{R+h}\right]^2$$

$$\therefore \quad g_h = 19.6\left[\frac{6400}{6400+3200}\right]$$

$$= 19.6 \times \frac{6400}{9600}$$

$$\therefore \quad g_h = 19.6 \times \frac{64}{96}$$

$\therefore \quad g_h = 13.06$ m/s^2

41. (i) Earth is continuously pulling the moon towards its centre, still it does not fall to the earth. Why?

(ii) Why gravitational force is considered as the long range force?

Sol. (i) Gravitational force of attraction due to earth provides the necessary centripetal force, which keeps the moon in orbit around the earth. Moon will fall if its orbital velocity becomes zero.

(ii) As this force exists between the sun and planets, stars and our planet earth, different stars, even between each galaxies.

42. Calculate the work required in raising a body of mass m to a height h from the surface of the earth.

Sol. Let mass of earth be M and its radius be R.

As we know that, the acceleration due to gravity at earths surface is g.

Work done = change in P.E.

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

$$= GMm\left[\frac{1}{R} - \frac{1}{R+h}\right]$$

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

$$= \frac{gR^2mh}{R[R+h]} \quad \ldots\left[\because GM = gR^2\right]$$

$\therefore$ Work done = $\dfrac{mgh}{1+\dfrac{h}{R}}$

43. A rocket is launched vertically from the surface of the earth with an initial velocity of 8 km/s. How far above the surface of the earth would it go? (Ignore the air resistance, take $R_e = 6.4 \times 10^6$ m and $g = 9.8$ m/s^2)

Sol. Initial K.E. = gain in gravitational potential energy of rocket

$$\therefore \quad \frac{1}{2}mV^2 = -\frac{GMm}{(R+h)} - \left[-\frac{GMm}{R}\right]$$

$$\therefore \quad \frac{1}{2}V^2 = \frac{gR^2h}{R(R+h)} = \frac{gRh}{(R+h)}$$

$$\therefore \quad \frac{R+h}{h} = \frac{2gR}{V^2}$$

$$\therefore \quad \frac{R}{h} + 1 = \frac{2gR}{V^2}$$

$$\therefore \quad h = R\left[\frac{2gR}{V^2} - 1\right]^{-1}$$

$$\therefore \quad h = 6.4 \times 10^6 \left[\frac{2 \times 9.8 \times 6.4 \times 10^6}{(8 \times 10^3)^2} - 1\right]^{-1}$$

$\therefore$ h = 6666.66 km

44. Mention some properties of gravitational force.

Sol. Properties of Gravitational Force

(i) It is independent of the medium between the particles.

(ii) It is always attractive in nature.

(iii) It is true from inter atomic distances to interplanetary distance.

(iv) It is weakest force in nature.

(v) It is conservative force, i.e., work done by it doesn't depend on its path or work done in moving a particle round a closed path under the action of gravitational force is zero.

(vi) It is an action reaction pair i.e., the force with which one body (say earth) attracts the second body (say apple) is equal to the force with which apple attracts the earth (in accordance with Newtons 2nd law).

(vii) It is a two-body interaction i.e., gravitational force between two particles is independent of the presence or absence of other particles.

(viii) It is a central force i.e., acts along the line joining the two particles or centres of the interacting bodies.

45. A satellite is launched into a circular orbit close to the earth's surface. What additional velocity is now to be imparted to the satellite in the orbit to overcome the gravitational pull? [Take R_e = 6400 km, g = 9.8 m/s^2]

Sol. Orbital velocity near the earth's surface ; $V_0 = \sqrt{gR_e}$

while, escape velocity = $\sqrt{2}V_0$

$\therefore$ Additional velocity required $= V_e - V_0$

$= (1.414 - 1)\sqrt{gR_e}$

$= 0.414\sqrt{9.8 \times 6400 \times 10^3}$

$= 3.278 \times 10^3$ m/s

$= 3.278$ km/s

Multiple Choice Questions

1. The acceleration due to gravity is g at a point r distant from the centre of earth of radius R .if $r < R$, then

(a) $g \propto r$ (b) $g \propto r^2$

(c) $g \propto r^{-1}$ (d) $g \propto r^{-2}$

2. The height of the point vertically above the earth's surface at which the acceleration due to gravity becomes 1% of its value at the surface is (R is the radius of the earth)

(a) $8R$ (b) $9R$

(c) $10R$ (d) $20R$

3. The change in the value of g at a height h above the surface of the earth is the same as at a depth d below the surface of earth. When both d and h are much smaller than the radius of earth, then which of the following is correct?

(a) $d=2h$ (b) $d=h$

(c) $d=h/2$ (d) $d=3h/2$

4. The radii of two planets are respectively R_1 and R_2 and their densities are respectively p_1 and p_2 .The ratio of the accelerations due to gravity (g_1/g_2) at their surfaces is

(a) $\frac{R_1 p_2}{R_2 p_1}$ (b) $\frac{R_1 p_1}{R_2 p_2}$

(c) $\frac{p_1 R^2{}_2}{p_2 R^2{}_1}$ (d) $\frac{R_1 R_2}{p_1 p_2}$

5. If the radius of the earth was to shrink by 1% , the density remaining constant, the acceleration due to gravity on the surface of earth will be

(a) less than g (b) greater than g

(c) g (d) infinite

6. How high can a man be able to jump on surface of a plan of radius 320 km, but having density same as that of earth if he jumps 5m on the surface of the earth?

(Radius of earth = 6400 km)

(a) 60 m (b) 80 m

(c) 100 m (d) 120 m

7. The escape Velocity for a body projected vertically upwards from the surface of earth is 11 km/sec. If the body is projected at an angle of $45°C$ with the vertical, the escape velocity will be

(a) $11/\sqrt{2}\, km/\sec$ (b) $11\sqrt{2}\, km/\sec$

(c) 2 km/sec (d) 11 km/sec

8. A body is projected up with a velocity equal to $\frac{3}{4}$ of the excape velocity from the surface of the earth. The height it reached is (Radius of the earth $= R$

(a) $\frac{10R}{9}$ (b) $\frac{9R}{7}$

(c) $\frac{9R}{8}$ (d) $\frac{10R}{3}$

9. The escape velocity corresponding to a planet of mass m and radius R is 50 km/s. If the planet's mass and radius were $4M$ and R respectively, then the corresponding escape velocity would be

(a) $100 km/s$ (b) $50 km/s$

(c) $200 km/s$ (d) $25 km/s$

10. The escape velocity of an object from the earth depends upon the mass of the earth (R) ,its mean density (ρ) ,its radius (R) and gravitational constant (G) .Thus the formula for escape velocity is

(a) $V_e = R\sqrt{\frac{8\pi}{3}G\rho}$ (b) $V_e = M\sqrt{\frac{8\pi}{3}GR}$

(c) $V_e = \sqrt{2GMR}$ (d) $V_e = \sqrt{\frac{2GM}{R^2}}$

11. The escape velocity of a particle of mass m varies as

(a) m^2 (b) m

(c) m^0 (d) m^{-1}

12. If the escape velocity of a planet is 3 times that of the earth and its radius is 4 times that of the earth, then the mass of the planet is (Mass of the earth $= 6X10^{24} kg$)

(a) $1.62X10^{22} kg$ (b) $0.72X10^{22} kg$

(c) $2.16X10^{26} kg$ (d) $1.22X10^{22} kg$

13. The mass of the earth is $6.0X10^{24}$ kg. The potential energy of a body of mass 50kg at a distance of $6.3X10^9 m$ from the centre of the earth is

(a) $-3.23X10^9 J$ (b) $-3.19X10^6 J$

(c) $-2.5X10^6 J$ (d) $-4.0X10^{11} J$

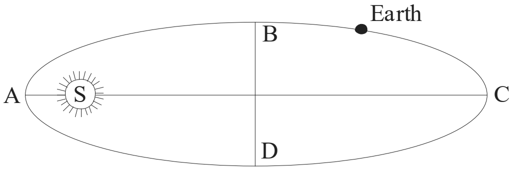
14. The work done in shifting a particle of mass m

from centre of earth to the surface of the earth is (where R is the radius of the earth)

(a) $-mgR$ (b) $+\frac{mgR}{2}$

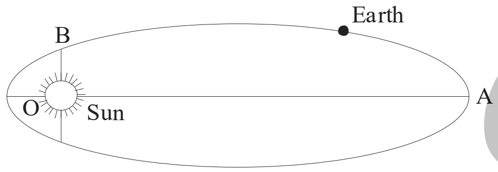
(c) *zero* (d) $\frac{-mgR}{2}$

15. The earth rotates around the sun (see figure) in an elliptical orbit. At which point will velocity be maximum?



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

16. The earth moves around the sun in an elliptical orbit as shown in the figure. The ratio $\frac{OA}{OB} = x$. The ratio of the speed of the earth at B and at A is



(a) $\sqrt{x}$ (b) x
(c) x^2 (d) $x\sqrt{x}$

17. The mean distance of mars from sun is 1.5 times that of earth from sun. What is approximately the number of years required by mars to make one revolution about sun?
(a) 2.35 Years (b) 1.84 Years
(c) 3.65 Years (d) 2.75 Years

18. Two satellities A and B go around the earth in circular orbits at height of R_A and R_B respectively from the surface of the earth. Assuming earth to be a uniform sphere of radius R_e, the ratio of the magnitudes of their orbital velocity is

(a) $\sqrt{\frac{R_B}{R_A}}$ (b) $\frac{R_B + R_e}{R_A + R_e}$

(c) $\sqrt{\frac{R_B + R_e}{R_A + R_e}}$ (d) $\left(\frac{R_A}{R_B}\right)$

19. Two Satellities of masses M and $9M$ are or biting a planet in a circular orbit of radius r. Their frequency of revolution will be in the ratio of
(a) $1:9$ (b) $1:3$
(c) $1:1$ (d) $3:1$

20. The time period of an earth satellite in circular orbit is independent of
(a) the mass of the satellite
(b) radius of its orbit
(c) both the mass of satellite and radius of the orbit
(d) neither the mass of satellite nor the radius of its orbit

21. A satellite is launched into a circular orbit of radius R around earth while a second satellite is launched into an orbit of radius $1.02R$. The percentage difference in the time period is
(a) 0.7% (b) 1.0%
(c) 1.5% (d) 3.0%

22. In a satellite if the time of revolution is T, then kinetic energy is proportional to
(a) T^{-1} (b) $T^{-2/3}$
(c) T^{-2} (d) $T^{-1/3}$

23. An earth satellite is moving around the earth in circular orbit. In such case, what is conserved?
(a) Velocity
(b) Linear momentum
(c) Angular momentum
(d) None of these

24. The orbit of geostationary satellite is circular, the time period of satellite depends on
(i) Mass of the satellite
(ii) Mass of the earth
(iii) Radius of the orbit
(iv) height of the satellite from the surface of the earth
(a) (i) only (b) (i) and (ii)
(c) (i),(ii) and (iii) (d) (ii),(iii) and (iv)

25. An artificial satellite is orbiting at a height of 180 km from earth's surface. The earth's radius is 6300 km and $g = 10\,m\,s^{-2}$ on its surface. What is the radial acceleration?
(a) $6\,m\,s^{-2}$ (b) $7\,m\,s^{-2}$
(c) $8\,m\,s^{-2}$ (d) $9\,m\,s^{-2}$

26. 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) gx (b) $\frac{gR}{R-x}$

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

27. A geostationary satellite is orbiting the earth at a height of $6R$ above the surface of earth R being the radius of earth. The time period of another satellite at a height of from the surface of earth , is

(a) $10\,hour$ (b) $\left(6/\sqrt{2}\right)hour$

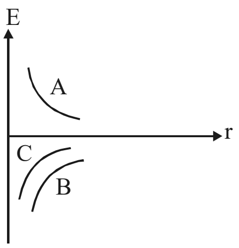
(c) $6\,hour$ (d) $6\sqrt{2}\,hour$

28. The kinetic energy of a satellite is 2 MJ. What is the total energy of the satellite?

(a) $-2MJ$ (b) $-1MJ$

(c) $-\frac{1}{2}MJ$ (d) $-4MJ$

29. Figure shows the variation of energy with the orbital radius of a satellite in a circular motion. Mark the correct statement.



(a) A shows the kinetic energy, B shows the total energy and c the potential energy of the satellite.
(b) A and B are the kinetic energy and potential energy respectively and C the total energy of the satellite.
(c) A and B are the potential energy and kinetic energy respectively and C the total energy of the satellite.
(d) C and A are the kinetic and potential energies respectively and B the total energy of the satellite.

30. The height of a geostationary satellite is

(a) 1000 km (b) 32000 km

(c) 36000 km (d) 850 km

31. The universal law of gravitation is the force law also known as the

(a) triangle law
(b) square law
(c) inverse square law
(d) parallelogram law

32. Three equal masses of 1 kg each are placed at the vertices of an equilateral triangle PQR and a mass of 2 kg is placed at the centroid of the triangle which is at a distance of $\sqrt{2}\,m$ from each of the vertices of the triangle. Force, in newton, acting on the mass of 2 kg is

(a) 2 (b) $\sqrt{2}$

(c) 1 (d) Zero

33. A mass M of is divided into two parts m and $(M-m)$, which are separated by a certain distance. The ratio m/M which maximizes the gravitational force between the parts is

(a) 1:4 (b) 1:3

(c) 1:2 (d) 1:1

34. Three particles each of mass m are placed at the vertices of an equilateral triangle of side r as shown in given figure.
The magnitude of the gravitational force on any one particle due to others two is

(a) $\frac{\sqrt{3}Gm^2}{2r^2}$ (b) $\frac{\sqrt{3}Gm^2}{r^2}$

(c) $\frac{Gm^2}{r^2}$ (d) $\frac{Gm^2}{2r^2}$

35. The magnitudes of the gravitational field at distances r_1 and r_2 from the centre of a uniform sphere of radius R and mass M are F_1 and F_2 respectively. Then

(a) $\frac{F_1}{F_2}=\frac{r_1}{r_2}, if\ r_1 < R\ and\ r_2 < R$

(b) $\frac{F_1}{F_2}=\frac{r_2}{r_1}, if\ r_1 < R\ and\ r_2 < R$

(c) $\frac{F_1}{F_2}=\frac{r_1^3}{r_2^3}, if\ r_1 > R\ and\ r_2 > R$

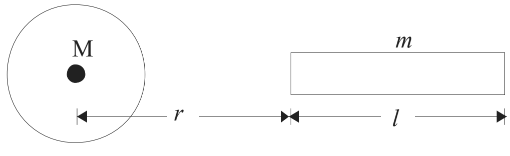
(d) $\frac{F_1}{F_2}=\frac{r_1^2}{r_2^2}, if\ r_1 < R\ and\ r_2 < R$

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

(a) $2.5R$ (b) $4.5R$

(c) $7.5R$ (d) $1.5R$

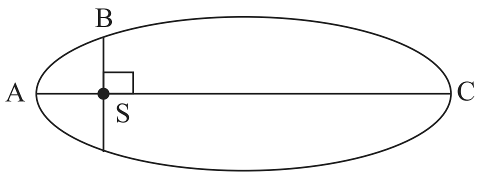
37. The gravitational force of attraction between a uniform sphere of mass M and a uniform rod of length L and mass m as shown in figure is



(a) $\frac{GMm}{r(r+1)}$ (b) $\frac{GM}{r^2}$

(c) Mmr^2 (d) $(r^2+1)mM$

38. 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) $K_B < K_A < K_C$ (b) $K_A > K_B > K_C$
(c) $K_A < K_B < K_C$ (d) $K_B > K_A > K_C$

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

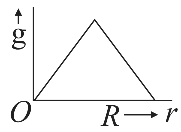
40. The acceleration due to gravity at a height 1 km above the earth is the same as at a depth d below the surface of earth. Then
(a) $d = \frac{1}{2}$ km (b) d = 1 km
(c) $d = \frac{3}{2}$ km (d) d = 2 km

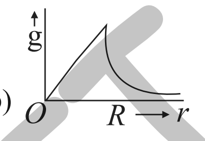
41. Two astronauts are floating in gravitational free space after having lost contact with their spaceship. The two will
(a) keep floating at the same distance between them
(b) move towards each other
(c) move away from each other
(d) will become stationary

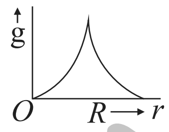
42. At what height from the surface of earth the gravitation potential and the value of g are -5.4×10^7 J kg^{-2} and 6.0 ms^{-2} respectively? Take, the radius of earth as 6400 km.
(a) 1600 km (b) 1400 km
(c) 2000 km (d) 2600 km

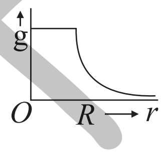
43. The ratio of escape velocity at earth (V_e) to the escape velocity at a planet (V_p) whose radius and mean density are twice as that of earth is
(a) $1:2\sqrt{2}$ (b) 1:4
(c) $1:\sqrt{2}$ (d) 1:2

44. Starting from the centre of the earth having radius R, the variation of g (acceleration due to gravity) is shown by

(a)


(b)


(c)


(d)


45. A satellite of mass m is orbiting the earth (of radius R) at a height h from its surface. The total energy of the satellite in terms of g_0, the value of acceleration due to gravity at the earth's surface is
(a) $\frac{mg_0R^2}{2(R+h)}$ (b) $-\frac{mg_0R^2}{2(R+h)}$
(c) $\frac{2mg_0R^2}{R+h}$ (d) $-\frac{2mg_0R^2}{R+h}$

46. 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 the sun and planet i.e. $T^2 = Kr^3$, here K is constant. If the masses of the 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) $GK = 4p^2$ (b) $GMK = 4p^2$
(c) K = G (d) $K = \frac{1}{G}$

47. Two spherical bodies of masses M and 5M and radii R and 2R are 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) 2.5 R (b) 4.5 R
(c) 7.5 R (d) 1.5R

48. 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) $7.76\ kms^{-1}$ (b) $8.56\ kms^{-1}$
(c) $9.13\ kms^{-1}$ (d) $6.67\ kms^{-1}$

49. A satellite S is moving in an elliptical orbit around the earth. The mass of the satellite is very small as compared to the mass of the earth. Then,
(a) the angular momentum of S about the centre of the earth changes in direction, but its magnitude remains constant
(b) the total mechanical energy of S varies periodically with time
(c) the linear momentum of S remains constant in magnitude
(d) the acceleration of S is always directed towards the centre of the earth

50. 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) 100m

Answer Key

1. A	2. B	3. A
4. B	5. A	6. C
7. D	8. B	9. A
10. A	11. C	12. C
13. B	14. B	15. A
16. B	17. B	18. C
19. C	20. A	21. D
22. B	23. C	24. D
25. A	26. D	27. D
28. A	29. B	30. C
31. C	32. D	33. C
34. B	35. A	36. C
37. A	38. B	39. D
40. D	41. B	42. D
43. A	44. B	45. B
46. B	47. C	48. A
49. D	50. C	

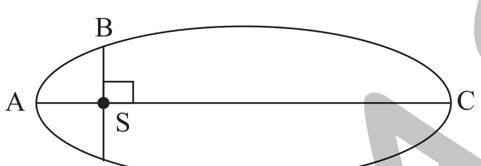
JEE & NEET Previous Year

NEET & AIPMT

1. 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? **[NEET 2019]**
(a) 250 N (b) 100 N
(c) 150 N (d) 200 N

2. 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: **[NEET 2019]**
(a) $\frac{1}{2}$mgR (b) $\frac{3}{2}$mgR
(c) mgR (d) 2mgR

3. 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 **[NEET 2018]**



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

4. 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? **[NEET 2018]**
(a) Time period of a simple pendulum on the Earth would decrease
(b) Walking on the ground would become more difficult
(c) Raindrops will fall faster
(d) 'g' on the Earth will not change

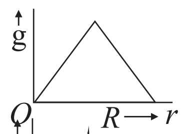
5. The acceleration due to gravity at a height 1 km above the earth is the same as at a depth d below the surface of earth. Then **[NEET 2017]**
(a) d = $\frac{1}{2}$ km (b) d = 1 km
(c) d = $\frac{3}{2}$ km (d) d = 2 km

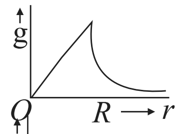
6. Two astronauts are floating in gravitational free space after having lost contact with their spaceship. The two will **[NEET 2017]**
(a) keep floating at the same distance between them
(b) move towards each other
(c) move away from each other
(d) will become stationary

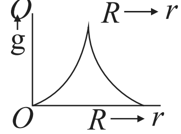
7. At what height from the surface of earth the gravitation potential and the value of g are –5.4 × 10^7 J kg^{-2} and 6.0 ms^{-2} respectively? Take, the radius of earth as 6400 km. **[NEET 2016]**
(a) 1600 km (b) 1400 km
(c) 2000 km (d) 2600 km

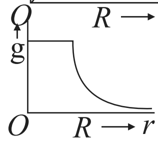
8. The ratio of escape velocity at earth (V_e) to the escape velocity at a planet (V_p) whose radius and mean density are twice as that of earth is **[NEET 2016]**
(a) $1:2\sqrt{2}$ (b) 1:4
(c) $1:\sqrt{2}$ (d) 1:2

9. Starting from the centre of the earth having radius R, the variation of g (acceleration due to gravity) is shown by **[NEET 2016]**

(a)


(b)


(c)


(d)


10. A satellite of mass m is orbiting the earth (of radius R) at a height h from its surface. The total energy of the satellite in terms of g_0, the value of acceleration due to gravity at the earth's surface is **[NEET 2016]**
(a) $\frac{mg_0R^2}{2(R+h)}$ (b) $-\frac{mg_0R^2}{2(R+h)}$
(c) $\frac{2mg_0R^2}{R+h}$ (d) $-\frac{2mg_0R^2}{R+h}$

11. 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 the sun and planet i.e. $T^2 = Kr^3$, here K is constant. If the masses of the sun and planet are M and m respectively, then as per Newton's law of gravitation force of attraction between them is **[AIPMT 2015]**
$F = \frac{GMm}{r^2}$ here G is gravitational constant. The

relation between G and K is described as

(a) $GK = 4\pi^2$ (b) $GMK = 4\pi^2$

(c) K = G (d) $K = \frac{1}{G}$

12. Two spherical bodies of masses M and 5M and radii R and 2R are 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 **[AIPMT 2015]**

(a) 2.5 R (b) 4.5 R

(c) 7.5 R (d) 1.5R

13. 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 **[AIPMT 2015]**

(a) 7.76 kms^{-1} (b) 8.56 kms^{-1}

(c) 9.13 kms^{-1} (d) 6.67 kms^{-1}

14. A satellite S is moving in an elliptical orbit around the earth. The mass of the satellite is very small as compared to the mass of the earth. Then, **[AIPMT 2015]**

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

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

(c) the linear momentum of S remains constant in magnitude

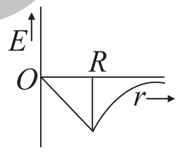
(d) the acceleration of S is always directed towards the centre of the earth

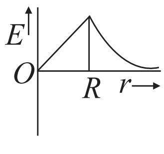
15. A black hole is an object whose gravitational field is so strong that even light cannot escape from it. To what approximate radius would earth (mass = 5.98×10^{24} kg) have to be compressed to be a black hole? **[AIPMT 2014]**

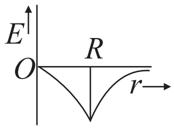
(a) 10^{-9}m (b) 10^{-6}m

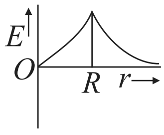
(c) 10^{-2}m (d) 100m

16. Dependence of intensity of gravitational field (E) of the earth with distance (r) from centre of the earth is correctly represented by **[AIPMT 2014]**

(a) 

(b) 

(c) 

(d) 

17. Infinite number of bodies, each of mass 2 kg are situated on X-axis at distances lm, 2 m, 4 m and 8 m, respectively from the origin. The resulting gravitational potential due to this system at the origin will be **[NEET 2013]**

(a) –G (b) $-\frac{8}{3}G$

(c) $-\frac{4}{3}G$ (d) – 4G

18. The height at which the weight of a body becomes 1/16th, its weight on the surface of the earth (radius R), is **[AIPMT 2012]**

(a) 5 R (b) 15 R

(c) 3R (d) 4 R

19. A compass needle which is allowed to move in a horizontal plane is taken to a geomagnetic pole. It **[AIPMT 2012]**

(a) will become rigid showing no movement

(b) will stay in any position

(c) will stay in North-South direction only

(d) will stay in East-West direction only

20. A spherical planet has a mass M_p and diameter D_p. A particle of mass m falling freely near the surface of this planet will experience an acceleration due to gravity, equal to **[AIPMT 2012]**

(a) $4GM_p / D_p^2$ (b) $GM_p m / D_p^2$

(c) GM_p / D_p^2 (d) $4GM_p m / D_p^2$

21. A geostationary satellite is orbiting earth at a height of 5 R above that surface of the earth, R being the radius of the earth. The time period of another satellite in hour at a height of 2 R from the surface of the earth is **[AIPMT 2012]**

(a) 5 (b) 10

(c) $6\sqrt{2}$ (d) $6/\sqrt{2}$

22. A planet moving along an elliptical orbit is closest to the sun at a distance r_1 and farthest away at a distance of r_2. If v_1 and v_2 are the linear velocities at these points respectively, then the ratio $\frac{V_1}{V_2}$ is **[AIPMT 2011]**

(a) r_2/r_1 (b) $(r_2/r_1)^2$

(c) r_1/r_2 (d) $(r_1/r_2)^2$

23. A body projected vertically from the earth reaches a height equal to earth's radius before returning to the earth. The power exerted by the gravitational force is greatest **[AIPMT 2011]**

(a) at the instant just before the body hits the earth

(b) it remains constant all through

(c) at the instant just after the body is projected

(d) at the highest position of the body

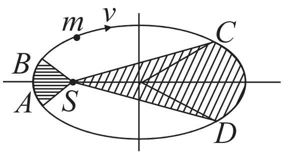
24. The radii of circular orbits of two satellites A and B of the earth are 4R and R, respectively. If the peed of satellite A is 3 v, then the speed of satellite B will be **[AIPMT 2010]**

(a) 3v/4 (b) 6v
(c) 12v (d) 3v/2

25. A particle of mass M is situated at the centre of a spherical shell of same mass and radius a. The gravitational potential at a point situated at a/2 distance from the centre, will be **[AIPMT 2010]**

(a) $-\frac{3GM}{a}$ (b) $-\frac{2GM}{a}$
(c) $-\frac{GM}{a}$ (d) $-\frac{4GM}{a}$

26. The figure shows elliptical orbit of a planet m about the sun S. The shaded area SCD is twice the shaded area SAB. If t_1 is the time for the planet to move from C to D and t_2 is the time to move from A to B, then **[AIPMT 2009]**



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

27. 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 **[AIPMT 2008]**

(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

28. Two satellites of the earth, S_1 and S_2 are moving in the same orbit. The mass of S_1 is four times the mass of S_2. Which one of the following statements is true? **[AIPMT 2007]**

(a) The time period of S_1 is four times that of S_2
(b) The potential energies of the earth and satellite in the two cases are equal
(c) St and S_2 are moving with the same speed
(d) The kinetic energies of the two satellites are equal

29. 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_e, where v_e is its escape velocity from the surface of the earth. The value of f is **[AIPMT 2006]**

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

30. For a satellite moving in an orbit around the earth, the ratio of kinetic energy to potential energy is **[AIPMT 2005]**

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

31. Imagine a new planet having the same density as that of the earth but it is 3 times bigger than the earth in size. If the acceleration due to gravity on the surface of the earth is g and that on the surface of the new planet is g', then **[AIPMT 2005]**

(a) g' = 3g (b) g' = $\frac{g}{9}$
(c) g' = 9g (d) g' = 27g

32. The density of newly discovered planet is twice that of the earth. The acceleration due to gravity at the surface of the planet is equal to that at the surface of the earth. If the radius of the earth is R, the radius of the planet would be **[AIPMT 2004]**

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

33. 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 **[AIPMT 2003]**

(a) $\frac{F}{3}$ (b) $\frac{F}{9}$
(c) 3 F (d) F

34. The acceleration due to gravity on the planet A is 9 times the acceleration due to gravity on the 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? **[AIPMT 2003]**

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

35. A body of mass m is placed on the earth's surface. It is then taken from the earth's surface to a height h = 3 R, then the change in gravitational potential energy is **[AIPMT 2002]**

(a) $\frac{mgh}{R}$ (b) $\frac{2}{3}mgR$

(c) $\frac{3}{4}mgR$ (d) $\frac{mgR}{2}$

36. A body attains a height equal to the radius of the earth. The velocity of the body with which it was projected is **[AIPMT 2001]**

(a) $\sqrt{\frac{GM}{R}}$ (b) $\sqrt{\frac{2GM}{R}}$

(c) $\sqrt{\frac{5}{4}\frac{GM}{R}}$ (d) $\sqrt{\frac{3GM}{R}}$

37. Escape velocity from the earth is 11.2 km/s. Another planet of same mass has radius 1/4 times that of the earth. What is the escape velocity from another planet? **[AIPMT 2000]**

(a) 11.2 km/s (b) 44.8 km/s
(c) 22.4 km/s (d) 5.6 km/s

JEE & AIEEE

1. A box weights 196 N on a spring balance at the north pole. Its weight recorded on the same balance if it is shifted to the equator is close to (Take g = 10 ms^{-2} at the north pole and the radius of the earth = 6400 km) **[JEE Mains 2020]**

(a) 194.66 N (b) 195.66 N
(c) 195.32 N (c) 194.32 N

2. The kinetic energy needed to project a body of mass m from the earth surface (radius R) to infinity is **[AIEEE 2002]**

(a) $mgR/2$ (b) $2mgR$
(c) $mg R$ (d) $mgR/4$

3. If g is the acceleration due to gravity on the Earth's surface, the gain in the given potential energy of object of mass m raised form the surface of the Earths to a height equal to the radius R of theEarth is **[AIEEE 2003]**

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

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

4. Suppose the gravitation force varies inversely as the nth power of distance. Then the time period planet is circular orbit of radius R around will be the proportional **[AIEEE 2004]**

(a) $R^{\left(\frac{n+1}{2}\right)}$ (b) $R^{\left(\frac{n-1}{2}\right)}$

(c) R^{n} (d) $R^{\left(\frac{n-2}{2}\right)}$

5. Aparticleof mass 10 g is kept on the surface of a uniform sphere 100 kg and radius 10 cm. find the work to be done against the gravitational force between them to take the particle far away from the sphere (you may take G = 6.67 × 10^{-11} N m^2/kg^2) **[AIEEE 2005]**

(a) 13.34 × 10^{-10} J (b) 3.33 × 10^{-10} J
(c) 6.67 × 10^{-9} J (d) 6.67 × 10^{-10} J

6. If g_E and g_M are the accelerations due to gravity on the surface of the Earths and the moon, respectively, and if Millikan's oil drop experiment could be reformed on the two surface, one will find the ratio $\frac{\text{electric charge on the moon}}{\text{electric charge on the Earth}}$ to be **[AIEEE 2007]**

(a) 1 (b) 0
(c) g_E / g_M (d) g_M / g_E

7. Aplanetin a distant solar system is 10 times more massive than the earth and its radius is 10 times smaller. Give that the escape velocity from the Earth is 11 km s^{-1}, the escape velocity from the surface of the planet would be **[AIEEE 2008]**

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

8. The height (in terms of R, the radius of the earth), at which the acceleration due to gravity becomes $\frac{g}{9}$, is (where g = acceleration due to gravity on the surface of the earth) **[AIEEE 2009]**

(a) 2R (b) $\frac{R}{\sqrt{2}}$

(c) $\frac{R}{2}$ (d) $\sqrt{2}R$

9. Twobodies of mass m and 4$m$are placed at a distance r. The gravitational potential at a point the line joining them where the gravitational field is zero is **[AIEEE 2011]**

(a) $-\frac{4gM}{r}$ (b) $-\frac{6gM}{r}$

(c) $-\frac{9Gm}{r}$ (d) Zero

10. The mass of a spaceship is 1000 kg. It is to be launched from the Earth's surface out into free space. The value of g and R. (radius of Earth's) are 10 m/s^2 and 6400 km, respectively. The required energy for this work will be **[AIEEE 2012]**

(a) 6.4×10^{11} J (b) 6.4×10^{8} J
(c) 6.4×10^{9} J (d) 6.4×10^{10} J

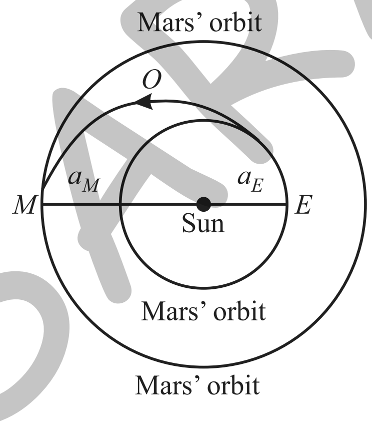
11. What is the minimum energy required to launch a satellite of mass *m* from the surface of a planet of mass *M* and radius *R* in a circular orbit at an altitude of 2*R*? **[JEE Main 2013]**

(a) $\frac{5GmM}{3R}$ (b) $\frac{GmM}{2R}$
(c) $\frac{GmM}{3R}$ (d) $\frac{5GmM}{6R}$

12. Four particles, each of mass *M* and equidistant from each other, move along a circle of radius *R* under the action of their mutual gravitational attraction. The speed of each particle is **[JEE Main 2014]**

(a) $\sqrt{\frac{GM}{R}}$ (b) $\sqrt{2\sqrt{2}\frac{GM}{R}}$
(c) $\sqrt{\frac{GM}{R}(1+2\sqrt{2})}$ (d) $\frac{1}{2}\sqrt{\frac{GM}{R}(1+2\sqrt{2})}$

13. India's Mangalyan was sent to the Mars by launching it into a transfer orbit EOM around the sun. It leaves the Earth at *E* and meets Mars at *M*. If the semi-major axis of Earth's orbit is $a_E = 1.5\times10^{11} m$, that of Mar's orbit $a_M = 2.28\times10^{11}$ m, taken Kepler's laws give the estimate of time for Mangalyan to reach Mars from Earth to be close to **[JEE Main 2015]**



(a) 500 days (b) 320 days
(c) 260 days (d) 220 days

NEET & AIPMT Answer Key

1. B	2. A	3. B
4. D	5. D	6. B
7. D	8. A	9. B
10. B	11. B	12. C
13. A	14. D	15. C
16. A	17. D	18. C
19. C	20. A	21. C
22. A	23. A	24. B
25. A	26. C	27. A
28. C	29. B	30. B
31. A	32. D	33. D
34. D	35. C	36. A
37. C		

JEE Answer Key

1. C	2. C	3. B
4. A	5. D	6. A
7. C	8. A	9. A
10. D	11. D	12. D
13. C		