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GRAVITATION

GRAVITATIONALAND INTERNAL MASS

- **(a) Inertial mass :** When mass is defined on the property of inertia, it is termed as inertial mass.
- **(b) Gravitational mass :** When mass is defined on the property of gravity, it is called gravitational mass.
- **(c) Properties of inertial mass :** It is equal to the ratio of magnitude of external force applied on the body to the acceleration produced in it by that force. $m = F/a$

NEWTON'S LAW OF GRAVITATION

On the basis of Kepler's laws of planetary motion, Newton stated his famous law of gravitation.

According to this law - Every two objects in the universe attract each other. The force of attraction is directly proportional to the

product of masses and inversely proportional to the square of distance between the two masses, i.e., if two masses m_1 and m_2 are separated from each other by a distance r then

$$
F \propto \frac{m_1 m_2}{r^2} \quad \text{or} \quad F = G \frac{m_1 m_2}{r^2}
$$

where
$$
G
$$
 = universal gravitational constant

$$
G = 6.67 \times 10^{-11} \text{ N} \cdot \text{m}^2/\text{kg}^{-2} \, (\text{unit}) \, \text{M}^{-1} \text{L}^3 \text{T}^{-2} \, (\text{dim.})
$$

$$
G = 6.67 \times 10^{-8} \, \text{dyne cm}^{-2} \, \text{gm}^{-2}
$$

Gravitation force is a mutual force hence it is action -

reaction force i.e.
$$
\vec{F}_{12} = -\vec{F}_{2}
$$

It acts along the line joining two masses. It is a weak intensity force but its range is infinite. This force is independent of charge etc., it depends only on mass. The motion of a satellite and motion of planets around the sun are consequences of this force. force is a mutual force hence it is action -

e.i.e. $\vec{F}_{12} = -\vec{F}_{21}$

the line joining two masses. It is a weak

cce but its range is infinite. This force is

of charge etc., it depends only on mass. The

attellite a form of gravitational force is $\vec{F} = \frac{S_{\text{un}} - R}{12} \vec{r}$ gravitational field is the force
 $=$ universal gravitational constant \vec{r} to placed at that point. It is d
 $5.67 \times 10^{-11} \text{ N-m}^2/\text{kg}^{-2} \text{ (unit)} \text{M}^{-1} \text{$

Example 1 :

Two particles of masses 1 kg and 2 kg are placed at a separation of 50 cm. Assuming that the only forces acting on the particles are their mutual gravitation, find the initial acceleration of heavier particle.

Sol. Force exerted by one particle on another

$$
F = \frac{Gm_1m_2}{r^2} = \frac{6.67 \times 10^{-11} \times 1 \times 2}{(0.5)^2} = 5.3 \times 10^{-10} \text{ N}
$$

Acceleration of heavier particle

$$
= \frac{\mathrm{F}}{\mathrm{m}_2} = \frac{5.3 \times 10^{-10}}{2} = 2.65 \times 10^{-10} \,\mathrm{ms}^{-2}
$$

EXECUTE 2
 EXECUTE:
 $\frac{F}{n_2} = \frac{5.3 \times 10^{-10}}{2} = 2.65 \times 10^{-10} \text{ ms}^{-2}$

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ep bind our solar system and also this universe,

and other interstellar system. **SPONSADVANCED LEARNING**
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eep bind our solar system and also this universe,

and other inte This example shows that gravitation is very weak but only this force keep bind our solar system and also this universe, all galaxies and other interstellar system.

Example 2 :

Two particles of equal mass (m) each move in a circle of radius (r) under the action of their mutual gravitational attraction. Find the speed of each particle.

GRAVITATIONAL FIELD

The gravitational field is the space around a mass or an assembly of masses over which it can exert gravitational forces on other masses. It is characterised by –

 $\frac{3}{\pi}$ $\frac{3}{\pi}$ is experiment of the particle state in the particle state of the pa $F = \frac{G.m_1m_2}{T}$ gravitational field is the force experienced by a unit mass (a) gravitational field intensity (b) Gravitational potential. **Gravitational field strength or gravitational field intensity:** Gravitational field strength at a point in the producing the field.

> The gravitational field intensity is given by $\vec{E} = \frac{\vec{F}}{m}$ m \vec{r}

Acceleration due to gravity \vec{g} is also $\frac{F}{m}$. Hence, for the m^2 . There is, for the same $\frac{1}{2}$. Hence, for the

Earth's gravitational field \vec{g} and \vec{E} are same (Neglecting \vec{E} are same (Neglecting earth rotation).

Gravitational field due to a point mass :

Suppose, a particle of mass M is placed at point O. We

want to find the intensity of gravitational field E at a \mathbf{a} point P, at distance r from O. Magnitude of force F acting on a particle of mass m placed at P is, P

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

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Fraction of the force F and hence of E is from P to O as

in figure.

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 $E=0$ For

Fraction of the force F and hence of E is from P to O as

in figure.

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This stat The direction of the force F and hence of E is from P to O as shown in figure.

Gravitational field due to a uniform solid sphere :

Let mass of the solid sphere is M and its radius is R. **Field at an external point :** For calculating the gravitational field at an external point an uniform solid sphere may be treated as a single particle of same mass placed at its centre. Let $r =$ distance of the external point from the centre of the sphere. **EXECUTE AT AND STUDY**
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 Example 10

$$
\vec{E}(r) = -\frac{GM}{r^2} \hat{r} \text{ or } E(r) \propto \frac{1}{r^2} \text{ for } r \ge R \text{ mass}
$$

given

Field at an internal point : For calculating the gravitational field at an internal point at a distance $r (r \le R)$ from centre imagine a sphere of radius r, mass M' (uniform density) then value of gravitational field intensity

i.e. it is proportional to the distance of the point from the centre of the sphere.

In vector notation :

$$
\overrightarrow{E}(r) = -\frac{GM}{R^3} \cdot \overrightarrow{r} \qquad \text{for} \qquad r \le R
$$

or $E(r) \propto r$. Hence, E versus r graph is as shown in fig.

Field due to a uniform spherical shell At an External Point

For an external point the shell may be treated as a single particle of same mass placed at its centre. Thus, at an external point the gravitational field is given by,

$$
= \frac{GM}{r^2} = \frac{GM}{r^2}
$$

\n
$$
= \frac{GM}{R^3}r = G\rho \frac{4}{3}\pi r
$$

\ni.e. it is proportional to the distance of the point from
\nthe centre of the sphere.
\nIn vector notation :
\n $\vec{E}(r) = -\frac{GM}{R^3} \cdot \vec{r}$ for $r \le R$
\nor $E(r) \propto r$. Hence, E versus r graph is as shown in fig.
\n**Field due to a uniform spherical shell**
\n $\vec{E}(r) = -\frac{GM}{r^2} \hat{r}$ for an external point
\npoint the gravitational field is given by,
\n $\vec{E}(r) = -\frac{GM}{r^2} \hat{r}$ \vec{E}
\nFor $r \ge R$
\n $\vec{E}(r) = -\frac{GM}{r^2} \hat{r}$ \vec{E}
\nFor $r \ge R$
\n $\vec{E}(r) = -\frac{GM}{r^2} \hat{r}$ \vec{E}
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\n $\vec{E} = -\frac{GM}{R^2} \hat{r}$ For $r = R$
\n $\vec{E} =$

At an Internal Point

The field inside a uniform spherical shell $E=0$ For $r < R$

STU

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

direction of the force F and hence of E is from P to O as

the field inside a uniform split and the force F and hence of E is from P to O as

vir in figure.

The field inside a uniform spli **Newton's shell theorem :** A uniform shell of matter exerts no net gravitational force on a particle located inside it. This statement does not mean that the gravitational forces on the particle from the various elements of the shell magically disappear. Rather, it means that the sum of the force vectors on the particle from all the elements is zero. **STUDY MATERIAL: PHYSICS**
 Internal Point

Id inside a uniform spherical shell

¹⁰ For $r < R$
 I's shell theorem: A uniform shell of matter exerts
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particular fo **STUDY MATERIAL: PHYSICS**
 Enternal Point

Id inside a uniform spherical shell

Id inside a uniform spherical shell
 $\frac{1}{10}$ or Form F A uniform shell of matter exerts

reaviational force on a particle located inside

GRAVITATIONAL POTENTIAL (V)

 $\propto \frac{1}{r^2}$ for $r \ge R$ mass from some reference point (usually at infinity) to the At a point in a gravitational field potential V is defined as negative of the work done per unit mass in shifting a rest given point, somewhereases that the sum of the shell

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\text{as } \frac{F}{m} = \frac{\rightarrow}{E}\n\end{array}\right]$ dr

i.e.,
$$
V = -\frac{W}{m}
$$
 [dimensions [L² T⁻²] and unit J/kg.]

It is a scalar quantity. As by definition potential energy

$$
U = -W.\quad So,\quad V = \frac{U}{m},\quad i.e., U=mV
$$

i.e., physically potential at a point represents potential energy of a unit point mass at that point.

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on the particle from the various elements of the shell
\nmagically disappear. Rather, it means that the sum of the
\nforce vectors on the particle from all the elements is zero.
\n**NTIATIONALPOTENTIAL(V)**
\nAt a point in a gravitational field potential V is defined as
\nnegative of the work done per unit mass in shifting a rest
\nmass from some reference point (usually at infinity) to the
\ngiven point,
\ni.e.,
$$
V = -\frac{W}{m}
$$
 [dimensions [L² T⁻²] and unit J/kg.]
\nIt is a scalar quantity. As by definition potential energy
\nU=-W. So, $V = \frac{U}{m}$, i.e., U=mV
\ni.e., physically potential at a point represents potential
\nenergy of a unit point mass at that point.
\nAs by definition of work W = $\int \vec{F} \cdot d\vec{r}$
\nSo $V = -\frac{1}{m} \int \vec{F} \cdot d\vec{r} = -\int \vec{E} \cdot d\vec{r}$
\ni.e., $dV = -E dr$ or $E = -\frac{dV}{dr}$
\n**Gravitational potential due to a point mass**
\nSuppose a point mass M is situated at a point O.

i.e.,
$$
dV = -E dr
$$
 or $E = -\frac{dV}{dr}$

Gravitational potential due to a point mass

Suppose a point mass M is situated at a point O. The gravitational potential due to this mass at point P any distance r from O. P

a scalar quantity. As by definition potential energy
\n-W. So,
$$
V = \frac{U}{m}
$$
, i.e., $U = mV$
\nphysically potential at a point represents potential
\ngy of a unit point mass at that point.
\nby definition of work $W = \int \vec{F} \cdot d\vec{r}$
\n $V = -\frac{1}{m} \int \vec{F} \cdot d\vec{r} = -\int \vec{E} \cdot d\vec{r}$
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\n $dV = -Edr$ or $E = -\frac{dV}{dr}$
\n**virtual potential due to a point mass**
\nsoes a point mass M is situated at a point O.
\ngravitational potential due to this mass at point P any
\nmore r from O.
\n $V = -\int_{\infty}^{r} \vec{E} \cdot d\vec{r} = -\int_{\infty}^{r} -\frac{GM}{r^2} \vec{r} \cdot d\vec{r}$
\n $= \int_{\infty}^{r} \frac{GM}{r^2} dr$; $V = -\frac{GM}{r}$
\n**virtual potential due to a uniform solid sphere:**
\n**initial at an external point :** The gravitational potential
\nto a unique particle of same mass placed at its centre.
\nso, $V(r) = -\frac{GM}{r}$ $r \ge R$
\nne surface, $r = R$ and $V = -\frac{GM}{R}$
\nalculated potential at a point distant r from the centre of
\nsphere (r < R) we can use $E = -dV/dr$

Gravitational potential due to a uniform solid sphere: Potential at an external point : The gravitational potential due to a uniform sphere at an external point is same as that due to a single particle of same mass placed at its centre.

Thus,
$$
V(r) = -\frac{GM}{r} \quad r \ge R
$$

At the surface, $r = R$ and $V = -\frac{GM}{R}$ R_{and}

To calculate potential at a point distant r from the centre of the sphere $(r < R)$ we can use $E = -dV/dr$

$$
V = \frac{-GM(3R^2 - r^2)}{2R^3}
$$
. At centre, r = 0, V = $-\frac{3GM}{2R}$

Potential due to a Uniform Thin Spherical Shell

For an external point, spherical shell behave as whole of its mass is concentrated at the centre, i.e.,

For an internal point $(r < R)$ as gravitational intensity is zero the potential everywhere is same and equal to its

value at the surface, i.e.,
$$
V = -\frac{GM}{R} = \text{constant}
$$
 [for $r < R$]

GRAVITATIONAL POTENTIALENERGY

Assume a mass m_1 is fixed at a point and bring m_2 from The n infinity at a distance r from m_1 then work done in bringing m_2 will be stored in form of potential energy.

$$
U = -W = m_2 V = m_2 \left(\frac{-Gm_1}{r}\right) = \frac{-Gm_1m_2}{r}
$$

Hence, the gravitational potential energy of two particles of masses m_1 and m_2 separated by a distance r is given by,

$$
U = -\frac{Gm_1m_2}{r}
$$
(1)

This is actually the negative of work done in bringing those masses from infinity to a distance r by the gravitational forces between them.

R³ sum of the gravitational potential energies of all three pairs **Gravitational potential energy of a three particle system** The gravitational potential energy of the system is the of particles.

 $V = -\frac{3GM}{3R}$ each pair of particles in turn, calculate the gravitational $2R$. The contract of the contract of $\frac{n}{2}$. If a system contains more than two particles, we consider p or the n t i all extends the n e n . (1) as if the other particles were not there, and then algebraically sum gives the results.

> Applying eqⁿ. (1) to each of the three pairs (m_1, m_2) , (m_1, m_3) and (m_2, m_3) gives the potential energy of the

system as
$$
U = -\left(\frac{Gm_1m_2}{r_{12}} + \frac{Gm_1m_3}{r_{13}} + \frac{Gm_2m_3}{r_{23}}\right)
$$

Gravitational potential energy of a body on earth's surface: The gravitational potential energy of mass m in the gravitational field of mass M at a distance r from it is, (r is greater than radius of the Earth i.e. $r > R$)

C =
$$
-\frac{3GM}{2R}
$$
 Put in eq. (1)
\n $=\frac{-GM(3R^2-r^2)}{2R}$. A centre, r = 0, V = $-\frac{3GM}{2R}$
\n $=\frac{-GM(3R^2-r^2)}{R}$. A centre, r = 0, V = $-\frac{3GM}{2R}$
\n $=\frac{GM(3R^2-r^2)}{R}$. A centre, r = 0, V = $-\frac{3GM}{2R}$
\n $=\frac{GM}{R}$ particles were not there, and then algebraically sum gives
\nthe results on uniform **Pini** spherical shell
\nthe result of the centre, i.e.,
\n $=-\frac{GM}{r}$ r $\ge R$
\n $=\frac{GM}{r}$ G $=\frac{GM}{r}$
\n $\frac{GM}{r}$ G $=\frac{GM}{r}$ G $=\frac{GMm_1m_3}{r^2}$ + $\frac{Gm_1m_3}{r^2}$ + $\frac{Gm_2m_3}{r^2}$
\n $=\frac{GM}{R}$
\n $\frac{Gm_1m_2}{r}$ G $=\frac{GMm_1}{r^2}$ f $\frac{Gm_1m_3}{r^2}$ + $\frac{Gm_2m_3}{r^2}$
\n $\frac{Gm_1m_3}{r}$ + $\frac{Gm_2m_3}{r^2}$
\n $\frac{Gm_1m_3}{r}$ + $\frac{Gm_2m_3}{r^2}$
\n $\frac{Gm_1m_3}{r}$ + $\frac{Gm_2m_3}{r^2}$
\n $\frac{Gm_1m_3}{r}$ + $\frac{Gm_2m_3}{r^2}$
\n $\frac{Gm_1m_2}{r}$ G $=\frac{Gm_1m_1}{R}$
\n $\frac{Gm_1m_2}{r}$ = $\frac{Gm_1m_1}{R}$

R
Were concentrated at its centre. Therefore, a mass m near The Earth behaves for all external points as if its mass M Earth's surface may be considered at a distance R (the radius of earth) from M. = GMm $\left(\frac{r^{-2+1}}{-2+1}\right)_{\infty}^{r}$ or $U_P = -\frac{GMm}{r}$
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 $U = -\$ GMm $\left(\frac{r^{-2+1}}{-2+1}\right)_{\infty}^{r}$ or $U_{P} = -\frac{GMm}{r}$
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 or $U_P = -\frac{GMm}{r}$

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at the surface of the Earth is

1 energy of mass m at a height h

is

The potential energy of m at the surface of the Earth is

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

The gravitational potential energy of mass m at a height h above the surface of Earth is given by

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

[: The distance between the mass m and the centre of Earth is $(R + h)$]

$$
\therefore U = -\frac{GMm}{R\left(1 + \frac{h}{R}\right)} = -\frac{GMm}{R}\left(1 + \frac{h}{R}\right)^{-1}
$$
(For any height h)

So, expanding the right hand side of the above equation by Binomial theorem and neglecting squares and higher

EXAMPLE 21.1
\nSo, expanding the right hand side of the above equation
\nby Binomial theorem and neglecting squares and higher
\npowers of
$$
\frac{h}{R}
$$
, we get $U = -\frac{GMm}{R} \left(1 - \frac{h}{R}\right)$ For $h \ll R$
\nor $U = -\frac{GMm}{R} + \frac{GMmh}{R^2}$
\n $U = -\frac{GMm}{R} + \frac{GMm}{R^2}$
\n

or
$$
U = -\frac{3m}{R} + \frac{3m}{R^2}
$$

But
$$
\frac{GM}{R^2} = g
$$
 (acc. due to gravity) $\therefore U = -\frac{GMm}{R} + mgh$ (A) Zero
(C) 1.47 Jou

But $-\frac{GMm}{R}$ = gravitational potential energy of mass m at **Sol. (D).** V₂ $-\frac{G N n}{R}$ = gravitational potential energy of mass m at So

the surface of Earth.

If we set a reference such the gravitational potential energy at the surface of Earth is zero then $U = mgh$

BINDING ENERGY

Total mechanical energy (potential $+$ kinetic) of a closed system is negative. The modulus of this total mechanical energy is known as the binding energy of the system. This is the energy due to which system is closed or different parts of the system are bound to each other. $\frac{GM_{\rm m}}{R} = \frac{1}{2}$ gravitational potential energy of mass m at Sol. (D). $V_g = V_{g1} + V_{g2}$ or $V_g = -\frac{G}{N}$

urface of Earth.

set a reference such the gravitational potential energy

energie of Earth is zero then U =

Suppose the mass m is placed on the surface of earth. The radius of the earth is R and its mass is M.

Then, the kinetic energy of the particle $K = 0$

and potential energy of the particle is $U = -\frac{GMm}{R}$.

$$
E = K + U = 0 - \frac{GMm}{R}
$$
 or
$$
E = -\frac{GMm}{R}
$$
 The value of g depend on the following fac
(a) Height above the earth surface

$$
\therefore \text{ Binding energy} = |E| = \frac{GMm}{R}
$$
 (c) {

It is due to this energy, the particle is attached with the earth. If this much energy is supplied to the particle in any form (normally kinetic) the particle no longer remains bound to the earth. It goes out of the gravitational field of earth.

Example 3 :

Find the gravitational potential energy of a system of four particles, each having mass m, placed at the vertices of a square of side ℓ . Also obtain the gravitational potential at the centre of the square. m m

Sol. The system has four pairs with distance ℓ and two diagonal pairs

with distance $\sqrt{2} \ell$.

$$
\Delta \mathcal{L} = \{ \mathcal{L} \in \mathcal{L} \mid \mathcal{L} \in \mathcal{L} \}
$$

$$
U = -4 \frac{Gm^{2}}{\ell} - 2 \frac{Gm^{2}}{\sqrt{2} \ell} = -\frac{2Gm^{2}}{\ell} \left(2 + \frac{1}{\sqrt{2}} \right) = -5.41 \frac{Gm^{2}}{\ell}
$$

The gravitational potential at the centre of the square is

 $V =$ Algebraic sum of potential due to each particle

$$
\Rightarrow V = -\frac{4\sqrt{2}Gm}{\ell}
$$

Example 4 :

STUDY MATERIAL: PHYSICS

the right hand side of the above equation

eorem and neglecting squares and higher

, we get $U = -\frac{GMm}{R} \left(1 - \frac{h}{R}\right)$ For $h \ll R$
 $\frac{Lm}{R^2} + \frac{GMm}{R^2}$
 $= -\frac{GMm}{R} \left(1 - \frac{h}{R}\right)$ For $h \ll R$ **STUDYMATERIAL: PHYSICS**

le of the above equation
 $V = Algebraic$ sum of potential due to each particle

ting squares and higher
 $\frac{Mm}{R} \left(1 - \frac{h}{R}\right)$ For h << R
 Example 4:

Two bodies of mass 10² Kg and 10³ kg are **STUDY MATERIAL: PHYSICS**

and side of the above equation
 $V =$ Algebraic sum of potential due to each particle
 $= -\frac{GMm}{R} \left(1 - \frac{h}{R}\right)$ For $h \ll R$

Example 4:

Two bodies of mass 10² Kg and 10³ kg are lying 1m apa R^2 The gravitational potential at the mid-point of the line **STUDYMATERIAL: PHYSICS**

e above equation
 $V = \text{Algebraic sum of potential due to each particle}$

uares and higher
 $-\frac{h}{R}$ For h << R

Example 4:

Two bodies of mass 10² Kg and 10³ kg are lying 1m apart.

The gravitational potential at the mid-poin **STUDY MATERIAL: PHYSICS**
Algebraic sum of potential due to each particle
 $V = -\frac{4\sqrt{2}Gm}{\ell}$
 \therefore
bodies of mass 10² Kg and 10³ kg are lying 1m apart.
gravitational potential at the mid-point of the line
no them is Two bodies of mass 10^2 Kg and 10^3 kg are lying 1m apart. joining them is -

(A) Zero (B) –1.47 Joule/Kg (C) 1.47 Joule/Kg (D) – 1.47 × 10–7 Joule /Kg

EXAMPLE RAL
\nSo, expanding the right hand side of the above equation
\nby Binomial theorem and neglecting squares and higher
\npowers of
$$
\frac{h}{R}
$$
, we get $U = -\frac{GMm}{R} \left(1 - \frac{h}{R}\right)$ For $h < R$
\nor $U = -\frac{GMm}{R} + \frac{GMmh}{R^2}$
\n $U = -\frac{GMm}{R} + \frac{$

ACCELERATION DUETO GRAVITY

The acceleration produced in a body due to earth's gravitational force is called acceleration due to gravity.

$$
g = \frac{GM_e}{R_e^2} = \frac{4}{3}\pi GR_e d \text{ m/s}^2 \text{ (unit) } M^0 L^1 T^{-2} \text{ (dim.)}
$$

 $U = -\frac{GMm}{R}$. Is called its weight. It a body of mass m experiences an acceleration due to gravity g, then weight of the body is **Weight** : The gravitational force that a body experiences is called its weight. If a body of mass m experiences an $W = mg$

Variation of g :

 $E = -\frac{GMm}{r}$ The value of g depend on the following factors.

-
- (b) Depth below the earth surface
- (c) Shape of the earth
- (d) Axial rotation of the earth.
- **(a) Height above the earth surface -** If value of gravity at surface of earth is g and gravity at a height 'h' above the surface of earth is g' then -

system is negative. The modulus of this total mechanical
energy is known as the binding energy of the system. The acceleration produced in a body due to earth's
This is the energy due to which system is closed or different
approx of the system are bound to each other.
Suppose the mass m is placed on the surface of earth.
Then, the kinetic energy of the particle
$$
K = 0
$$

Using a constant of the particle is $U = -\frac{GMm}{R}$.
Then, the kinetic energy of the particle $K = 0$
Using the particle is $U = -\frac{GMm}{R}$.
Therefore, the total mechanical energy of the particle is $U = -\frac{GMm}{R}$.
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Therefore, the total mechanical energy of the particle is $U = -\frac{GMm}{R}$.
Therefore, the total mechanical energy of the particle is $U = -\frac{GMm}{R}$.
Therefore, the square is $U = -\frac{$

of g on going up a height 'h' above the surface of earth.

$$
\Delta g = \frac{2gh}{R_e}
$$

(b) Depth below the earth surface - if the value of gravity at surface of earth is g and the value of gravity at a distance h below earth surface is g' then

 ℓ

 2ℓ

(c) Shape of the earth - The earth is elliptical in shape. It is flatter at the poles and bulged out at the equator. Now, we know that $g \propto 1/R^2$, $R_p < R_e$; $g_E < g_p$

therefore the value of g at the equator is minimum and the value of g at the poles is maximum.

(d) Axial rotation of the earth - If the observed value of g at the latitude λ is represented by g_{λ} , then

Example 5 :

On a planet whose size is the same and mass 4 times as that of the earth, find the amount of energy needed to lift a 2kg mass vertically upwards through 2 m distance on the planet. Value of g on the surface of the earth is 10 m/s^2 . **EXECUTE 10**
 EXECUTE:

Example 1 is the same and mass 4 times as

ind the amount of energy needed to lift

Illy upwards through 2 m distance on the

on the surface of the earth is 10 m/s².

The earth $g = (GM/r^2)$
 $\frac{$

Sol. On the surface of the earth $g = (GM/r^2)$

On the planet g' =
$$
\frac{G \times 4M}{R^2}
$$
 : $\frac{g'}{g} = 4$ or $g' = 4$ g = 40 m/s²
Energy needed = mg'h = 2 × 40 × 2 = 160 Joule.

Example 6 :

If the radius of the earth be increased by a factor of 5, by what factor its density be changed to keep the value of g the same?

Example 5:
\nOn a planet whose size is the same and mass 4 times as that of the earth, find the amount of energy needed to lift a 2kg mass vertically upwards through 2 m distance on the planet. Value of g on the surface of the earth is 10 m/s².
\n**Sol.** On the surface of the earth g =
$$
(GM/r^2)
$$

\nOn the planet g' = $\frac{G \times 4M}{R^2}$ $\therefore \frac{g'}{g} = 4$ or g' = 4 g = 40 m/s²
\nEnergy needed = mg'h = 2 × 40 × 2 = 160 Joule.
\n**Example 6:**
\nIf the radius of the earth be increased by a factor of 5, by what factor its density be changed to keep the value of g the same?
\n**Sol.** $g = \frac{GM}{R^2} = \frac{Gp \times \frac{4}{3} \pi R^3}{R^2} = \frac{4}{3} \pi GRp$ (1)
\n $g' = \frac{4}{3} \pi G (5R) p'$ (2)
\nGiven that, g = g', so p' = p/5
\n**Example 7:**
\nAt what altitude will the acceleration due to gravity be 25% of that at the earth's surface (given radius of earth is

Given that, $g = g'$, so $\rho' = \rho/5$

Example 7 :

At what altitude will the acceleration due to gravity be 25% of that at the earth's surface (given radius of earth is R) ?

Example 6:
\nIf the radius of the earth be increased by a factor of 5, by what factor its density be changed to keep the value of g the same?
\n**Sol.**
$$
g = \frac{GM}{R^2} = \frac{Gp \times \frac{4}{3} \pi R^3}{R^2} = \frac{4}{3} \pi GRp
$$
(1)
\n $g' = \frac{4}{3} \pi G (5R) p'$ (2)
\nGiven that, $g = g'$, so $p' = p/5$
\n**Example 7:**
\nAt what altitude will the acceleration due to gravity be 25% of that at the earth's surface (given radius of earth is R)?
\n(A) R/4 (B)R
\n(C) 3R/8 (D) R/2
\n**Sol.** (B). $g = \frac{GM}{r^2} \Rightarrow g_0 = \frac{GM}{R^2}$ (1); $g_h = \frac{GM}{(R+h)^2}$
\n $\frac{g_h}{g_0} = (\frac{R}{R+h})^2 \Rightarrow \frac{1}{4} = (\frac{R}{R+h})^2 \Rightarrow \frac{R}{R+h} = \frac{1}{2}$
\nR + h = 2R $\Rightarrow h = R$
\n**TRY IT YOURSELF-1**
\n**Q.1** Two small balls of mass m each are suspended side by side by two equal threads of length L as shown in the

TRY IT YOURSELF-1

Q.1 Two small balls of mass m each are suspended side by side by two equal threads of length L as shown in the figure. If the distance between the upper ends of the threads be a, the angle θ that the threads will make with the vertical due to attraction between the balls is –

- **Q.2** In a spherical region, the density varies inversely with the distance from the centre. Gravitational field at a distance r (i) from the centre is –
	- (A) proportional to r (B) proportional to $1/r$
	- (C) proportional to r^2 (D) same everywhere
- **Q.3** In the above question, the gravitational potential is (A) linearly dependent on r (B) proportional to $1/r$

(C) proportional to r^2 (D) same every where.

- **Q.4** A meteorite 80,000 km from the earth is moving towards the earth at 2000m/s. Ignoring air friction what will be its velocity on impact?
- **Q.5** A uniform ring of mass m and radius a is placed directly above a uniform sphere of mass M and of equal radius.

of the sphere. Find the gravitational force exerted by the (iv) sphere on the ring.

Q.6 Assuming that the moon is a sphere of the same mean **Q.6** Assuming that the moon is a sphere of the same mean density as that of the earth and one quarter of its radius, the length of a seconds pendulum on the moon (its length on the earth's surface is 99.2 cm) is

(A) 24 8 cm (B) 49.6 cm

(C) 99.2 cm (D)
$$
\frac{99.2}{\sqrt{2}}
$$
 cm

- **Q.7** Calculate the height above the Earth's surface at which the value of acceleration due to gravity reduces to half its value on the Earth's surface. Assume the Earth to be a sphere of radius 6400 km.
- **Q.8** Find the potential energy of gravitational interaction of a point mass m and a thin uniform rod of mass M and length ℓ , if they are located along a straight line at a distance a from each other
- **Q.9** Three particles each of mass m, are situated at the vertices of an equilateral triangle of side length a. The only forces $\frac{K}{2}$ acting on the particles are their mutual gravitational forces. It is desired that each particle moves in a circle while maintaining the original separation a. Find the initial velocity that should be given to each particle for the circular motion. Son Final and point mass mand a thin uniform red of mass M and length

(b) for the located along a straight line at a distance a

from each other

(for the concelated along a straight line at a distance a

of an equilizer Interparticles each of mass m, are suitable at the vertices

of an equilateral triangle of side length a. The only forces

acting on the particles are their mutual gravitational forces.

Let is desired that each particle
- **Q.10** In the above questions, find the time period.

- **(4)** 1.09×10^4 m/s. (5) F = Mg = $\frac{\sqrt{3}$ GMm
- **(6) (A). (7)** 2649.6 km

$$
\textbf{(8)} \qquad \textbf{U} = -\frac{\text{GmM}}{\ell} \log_e \left(\frac{\text{a} + \ell}{\text{a}} \right) \qquad \qquad \textbf{(9)} \quad \textbf{v} = \sqrt{\frac{\text{Gm}}{\text{a}}}
$$

(10)
$$
T = 2\pi \left(\frac{a^3}{3Gm}\right)^{1/2}
$$

ESCAPE VELOCITY

(i) Escape velocity is the minimum velocity that should be given to the body to enable it to escape away from the gravitational field of earth.

If the mass of the planet is M and its radius is R, then the escape velocity from its surface will be

$$
V_e = \sqrt{(2GM/R)} = \sqrt{(8\pi R^2 dG/3)} = \sqrt{(2gR)}.
$$

- **STUDY MATERIAI.: PHYSIC**

In a spherical region, the density varies inversely with the **ESCAPE VELOCITY**

Instance from the centre is –

distance from the centre. Gravitational field at a distance r (i) Escape velocity i **STUDY MATERIAL: PHYSICS**
 PEVELOCITY

Escape velocity is the minimum velocity that should be

given to the body to enable it to escape away from the

gravitational field of earth.

If the mass of the planet is M and it The value of escape velocity does not depend upon the mass of the projected body, instead it depends on the mass and radius of the planet from which it is being projected.
	- **(iii)** The value of escape velocity does not depend on the angle and direction of projection.
	- The minimum energy needed for escape is = GMm/R.
	- **(v)** If the velocity of a satellite orbiting the earth is increased by 41.4% , then it will escape away from the gravitational field of the earth.

Example 8 :

99.2 is n times the escape velocity then what will be the residual cm velocity at infinity. If velocity given to an object from the surface of the earth

²
Sol. Let residual velocity be v then from energy conservation

g gravitational potential is
\n
$$
r(f)
$$
 (B) proportional to 1/*f*
\n(1) proportional to 1/*f*
\n(2) same every where.
\n(3) superpointal to 1
\n(4) The equation of the graph
\n $r(f)$ is the value of escape velocity
\n $r(f)$ is the value of escape velocity
\n $r(f)$ is the value of escape velocity
\n $r(f)$ is the value of the slope of the plane
\n $r(f)$ is the value of the graph
\n $r(f)$ is the value of

KEPLER'S LAWS FOR PLANETARY MOTION

- **1. First Law -** All planets revolve in elliptical orbits around the sun and the sun is situated at the focus of the elliptical path.
- **2. Second law -** Areal velocity $\left(\frac{1}{\lambda t}\right)$ **c** dA dt) or a planet remain

constant, i.e. the line joining the sun to planet covers equal areas in same intervals of time.

$$
\frac{dA}{dt} = \text{constant} = \frac{mr^2}{2m} \frac{d\theta}{dt} = \frac{J}{2m}
$$

- (b) **3. Third law -** The square of the period of revolution of the planet is directly proportional to the cube of semi major axis of its orbit. T $2 \propto a^3$
- * **Perigee :** the position of a planet nearest to the sun is known as perigee. In this position the speed of planet is maximum.
- * **Apogee :** The position of a planet at the maximum distance from sun is known as apogee. In this position the speed of the planet is minimum.

Motion of planets in elliptical orbits - If r_1 is minimum $\begin{bmatrix} S/2 & R/2 \end{bmatrix}$ distance (perigee) and r_2 is maximum distance (apogee) from sun which is at the focus, then from the law of conservation of angular momentum mV $_{\text{max}} r_1 = mV_{\text{min}} r_2$ **law** - The square of the period of revolution of the

is directly proportional to the cube of semi major

its orbit. $T^2 \propto a^3$

e: the position of a planet nearest to the sum is

m.

m. is hown as period of planet at t **Find law** - The square of the period of revolution of the

planet is directly proportional to the cube of semi major

xis of its orbit.

Herigee: the position of a planet nearest to the sum is

nexis of its orbit and to **Example 11.**
 Example 18 directly proportional to the cube of semi major

Example 11.

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Example 11.

Statistic directly proportional to the cube of semi major

statis of its orbit.

In the speed of planet i

$$
\frac{V_{\text{max}}}{V_{\text{min}}} = \frac{r_2}{r_1}
$$

$$
\frac{1+e}{1-e} = \frac{\text{semi major axis}}{\text{semi minor axis}} \quad ; \quad e = \frac{a-b}{a+b} \quad \text{[e = eccentricity]} \quad \text{In dynamiccentricity} \quad \text{In dynamiccentricital for a certain point.}
$$

Semi-major axis a = $\frac{r_1 + r_2}{2}$ 2 a set of \sim 3 a set of \sim $+r₂$ Semi-minor axis $b = a(1-e^2)^{1/2}$ Area of orbit = π ab = $\pi a^2 (1 - e^2)^{1/2}$

Example 9 :

Imagine a light planet revolving around a very massive (b) star in a circular orbit of radius r with a period of revolution T. On what power of r, will the square of time period depend if the gravitational force of attraction between the planet and the star is proportional to $r^{-5/2}$.

$$
\frac{V_{max}}{V_{min}} = \frac{r_2}{r_1}
$$
\n
$$
\frac{1+e}{1-e} = \frac{\text{semi major axis}}{\text{semi-min or axis}}; e = \frac{a-b}{a+b} [e = \text{eccentricity}]
$$
\n(1.524)
\n1- $e = \frac{\text{semi major axis}}{\text{semi-min or axis}}; e = \frac{a-b}{a+b} [e = \text{eccentricity}]$ \n(201)
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\

Example 10 :

A satellite revolves round a planet in an elliptical orbit. Its maximum and minimum distances from the planet are 1.5×10^7 m and 0.5×10^7 m respectively. If the speed of the satellite at the farthest point be 5×10^3 m/s, calculate the speed at the nearest point. 1 2

Sol. From law of conservation of angular momentum

0:
\nellellite revolves round a planet in an elliptical orbit. Its
\nmum and minimum distances from the planet are
\n10⁷m and 0.5 × 10⁷m respectively. If the speed of the
\nhite at the farthest point be 5 × 10³m/s, calculate the
\nd at the nearest point.
\nlaw of conservation of angular momentum
\nL = mv₁r₁ = mv₂r₂ or
$$
\frac{v_1}{v_2} = \frac{r_2}{r_1}
$$

\nPERIGEE
\nPERIGEE
\n $\overrightarrow{v_2}$
\n \over

Substituting the given values, we get ,

$$
\frac{5 \times 10^3}{v_2} = \frac{0.5 \times 10^7}{1.5 \times 10^7}
$$
 or $v_2 = 1.5 \times 10^4$ m/sec

Example 11 :

The Mars-sun distance is 1.524 times the Earth-sun distance. The period of revolution of Mars around the sun will be tituting the given values, we get,
 $\frac{x10^3}{v_2} = \frac{0.5 \times 10^7}{1.5 \times 10^7}$ or $v_2 = 1.5 \times 10^4$ m/sec
 $\frac{x}{v_2} = \frac{0.5 \times 10^7}{1.5 \times 10^7}$ or $v_2 = 1.5 \times 10^4$ m/sec
 \therefore

External matrix expects in the Earth-sun

ce s-sun distance is 1.524 times the Earth-sun

The period of revolution of Mars around the sun

fears
(2) 1.88 Years

ears
(4) 3.88 Years

ording to third law of Kepler T² \propto r³
 $\frac{rs}{th} = \left(\frac{r_{mars}}{r_{Earth}}\right)^{3/2} = (1.5$ $\frac{5 \times 10^{3} \text{ g}}{\text{v}_2} = \frac{0.5 \times 10^{7}}{1.5 \times 10^{7}}$ or $\text{v}_2 = 1.5 \times 10^{4} \text{ m/sec}$

1:

Mars-sun distance is 1.524 times the Earth-sun

mcc. The period of revolution of Mars around the sun

88 Years

88 Years

88 Years
 524 times the Earth-sun

lution of Mars around the sun

(2) 1.88 Years

(4) 3.88 Years

f Kepler T² \propto r³

(1.524) ^{3/2} = 1.88 Years

e (v₀) :

ravitational force provides

= $\sqrt{\frac{GM_e}{r}} = \sqrt{\frac{GM_e}{R_e + h}}$

ace of t = 1.5 × 10⁴ m/sec

imes the Earth-sun

1 of Mars around the sun

1.88 Years

bler T² × r³

4) ^{3/2} = 1.88 Years

3.88 Years

4) ^{3/2} = 1.88 Years

GM_e = $\sqrt{\frac{GM_e}{R_e + h}}$

of the earth (h < < R_e), r.5 × 10 m/sec

es the Earth-sun

of Mars around the sun

88 Years

88 Years
 $r r T^2 \propto r^3$
 $3/2 = 1.88$ Years
 $\frac{3/2}{r} = 1.88$ Years
 $\frac{M_e}{r} = \sqrt{\frac{GM_e}{R_e + h}}$

the earth $(h < R_e)$,

the earth the surface of

$$
(1) 0.88 \text{ Years} \t(2) 1.88 \text{ Years}
$$

$$
(3) 2.88 \text{ Years} \t(4) 3.88 \text{ Years}
$$

Sol. (2). According to third law of Kepler $T^2 \propto r^3$

or
$$
\frac{T_{\text{mars}}}{T_{\text{Earth}}} = \left(\frac{r_{\text{mars}}}{r_{\text{Earth}}}\right)^{3/2} = (1.524)^{3/2} = 1.88 \text{ Years}
$$

SATELLITE

(a) Orbital velocity of a satellite (v_0) :

 $+ b$ ¹ cereminizity centripetal force. In dynamic equilibrium gravitational force provides

$$
\frac{GM_{e}m}{r^{2}} = \frac{mv_{0}^{2}}{r} \text{ or } v_{0} = \sqrt{\frac{GM_{e}}{r}} = \sqrt{\frac{GM_{e}}{R_{e} + h}}
$$

For a satellite near the surface of the earth $(h < R_e)$, neglecting h in comparison to R_e

$$
v = \sqrt{gR_e} = 7.92 \text{ km/s}.
$$

(b) Velocity of projection (v_{P}) **:**

To set up a satellite at a given height above the surface of earth it has to projected from the surface with a predetermined velocity, called velocity of projection.

Loss of $KE =$ Gain in PE

3/2 2 r mr T 2 r v K 1 2 mv^P 2 = – e e e e GM m GM m (R h) R v^p ⁼ 1/2 1/2 e e e e 2GM h 2gh R (R h) 1 h / R

(c) Period of revolution (T) :

The time interval during which the satellite completes one (i) revolution is called period of revolution of a satellite.

$$
T = \frac{\text{circumference of an orbit}}{\text{velocity in orbit}}
$$

$$
= \frac{2\pi r}{v_0} = \frac{2\pi r^{3/2}}{\sqrt{GM}} = \frac{2\pi (R_e + h)^{3/2}}{\sqrt{gR_e^2}} = 2\pi \sqrt{\frac{R_e}{g}} \left(1 + \frac{h}{R_e}\right)^{3/2}
$$
 (ii) The radius of orbit of Geostationary satellite is 42,400 km and its height above the surface of earth is 36000 km.
The relative amplitude is 42,400 km and its height above the surface of earth is 36000 km.

For a satellite revolving very close to the surface of earth

$$
(h \ll R_e): T = 2\pi \sqrt{\frac{R_e}{g}} = 84.4 \text{ min.}
$$
 (v)
Ex

(d) Energy of satellite :

(i) Potential energy of satellite (P.E or U) -

$$
U\!=\!-\,\frac{GM_em}{r}
$$

(ii) Kinetic energy of satellite (K.E.) -

$$
KE = \frac{1}{2} mV_0^2 = \frac{GM_em}{2r}
$$

(iii) Total energy of satellite (T.E.) -

$$
T.E. = K.E. + P.E. = -\frac{GM_e m}{2r}
$$

(iv) Binding energy of satellite (B.E.) - Binding energy is the energy given to satellite in order that the satellite escape away form its orbit.

B.E. = - Total Energy =
$$
\frac{1}{2} \frac{GM_{e}m}{r}
$$
 Sol. We

Note :

Effective weight in a satellite : Satellite is an accelerated reference frame, with acceleration $a = g$ towards centre of earth. \therefore W = m (g – a) = m (g – g) = 0

Bound and Unbound trajectories :

Imagine a very tall tower on the surface of earth from where a projectile is fired with a velocity v parallel to the surface of earth. The trajectory of the projectile depends on its velocity. E. = -Total Energy = $\frac{1}{2}$

ive weight in a satellite is and accelerated
 \therefore W = m (g - a) = m (g - g) = 0

and Unbound trajectories:

tile is fired with a velocity v parallel to the surface

exergent in the surfac B.E. = - Total Energy = $\frac{1}{2} \frac{GM_{e}m}{r}$

From energy consective weight in a satellite : Satellite is an accelerated

necessarily in a satellite is an accelerated

necessarily and the surface of earth from where
 $\frac{$

Velocity

$$
v < \frac{v_e}{\sqrt{2}}
$$
 Projectile does not orbit the earth

 $\frac{v_{e}}{\sqrt{2}}$ Projectile does not orbit the earth.

It falls back on the earth's surface.

$$
v = \frac{v_e}{\sqrt{2}}
$$

 $v = \frac{v_e}{\sqrt{2}}$ Projectile orbits the earth in a circular path.

 $\frac{v_e}{\sqrt{2}} < v < v_e$ Projectile orbits in an elliptic

$$
v = v_e
$$
 Projectile does not orbit. It escapes the gravitational field of earth in a parabolic path.

$$
v > v_e
$$
 Projectile does not orbit. It escape the

gravitational field of earth in a hyperbolic path.

GEOSTATIONARY SATELLITE (PARKING SATELLITE)

- **STUDY MATEE**
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do d f revolution (T):

time interval during which the satellite completes one

(i) If an artificial satellite revolves around

equatorial plane with a time period of 24 **EXECUTE (PARKI**
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E time interval during which the satellite completes one (i) If an artificial satellite revolves around

olution is called period of revolution o **STUDY MATE**
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 CEOSTATIONARY SATELLITE (PARKING:

time interval during which the satellite completes one (i) If an artificial satellite revolves around

lution is called period of revolution of a satellite. **EXECUTE (PARTICUS CONSTATIONARY SATELLITE (PA

Period of revolution (T):

The time interval during which the satellite completes one (i) If an artificial statellite revolution

evolution is called period of revolution of STUDY MATERIAL: PHYSICS**
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tellite completes one (i) If an artificial statellite revolves around the earth in an

equatorial plane with a time period of 24 hrs. in th **STUDY MATERIAL: PHYSICS**
 GEOSTATIONARY SATELLITE (PARKING SATELLITE)

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equatorial plane with a time period of 24 hrs. in the same

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mypletes one (i) If an artificial satellite revolves around the earth in an

equatorial plane with a time period of 24 hrs. in the same

sense as t **STUDY MATERIAL: PHYSICS**

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ution of a satellite. (i) if an artificial satellite revolves around the earth in an

equatorial plane wit **EVENTION ARY SATELLITE (PA**

For al during which the satellite completes one (i) If an artificial satellite revolve

called period of revolution of a satellite.

Example 12:
 $\frac{3\pi}{1M} = \frac{2\pi (R_e + h)^{3/2}}{g} = 2\pi \sqrt{\frac{R_e}{$ **STUDY**
 EXECUTE CARE
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 EXECUTE CAREE (1 + b)
 EXECUTE CAREE (1 (i) If an artificial satellite revolves around the earth in an equatorial plane with a time period of 24 hrs. in the same sense as that of earth, then it will appear stationary to the observer on earth. Such a satellite is known as Geostationary satellite or Parking satellite. **STUDY MATERIAL: PHYSICS**
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an artificial satellite revolves around the earth in an

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n artificial satellite revolves around the earth in an

nortificial satellite revolves around the earth in an

torial plane with a time period of 24 hrs. in the same

	- **(ii)** Time period of Geostationary satellite is 24 hrs.
	- $\frac{R_e}{g}$ $\left(1 + \frac{h}{R_e}\right)^{3/2}$ (iii) The radius of orbit of Geostationary satellite is 42,400 km
and its height above the surface of earth is 36000 Km.
		- **(iv)** The relative angular velocity of the geostationary satellite is zero.
		- **(v)** The orbit velocity of a Geostationary satellite is 3.08 km/s

Example 12 :

Two satellites have their masses in the ratio of 3 : 1. The radii of their circular orbits are in the ratio of 1 : 4. What is the ratio of total mechanical energy of A and B?

ution (T): GEOSTATIONARY SATULTE (PARKINGSTATEILITE)
and during which the satellite completes one (i) If an artificial satellite revolves around the earth in an
elled period of revolution of a satellite.
and the earth, such it will appear stationary to the
observed round the earth. Such a satellite is 24 hrs.

$$
= \frac{2\pi (R_e + h)^{3/2}}{\sqrt{\frac{R_e}{gR_c^2}}} = 2\pi \sqrt{\frac{R_e}{g}} (1 + \frac{h}{R_e})^{3/2}
$$

(ii) Time period of Geostationary satellite is 24 hrs.

$$
= \frac{2\pi (R_e + h)^{3/2}}{\sqrt{\frac{R_e}{gR_c^2}}} = 2\pi \sqrt{\frac{R_e}{g}} (1 + \frac{h}{R_e})^{3/2}
$$

(iii) The radius of orbit of Geostationary satellite is 24 hrs.
(iv) The radius of orbit of Geostationary satellite is 24 hrs.
(v) The orbit velocity of a Geostationary satellite is 24 hrs.
(v) The orbit velocity of a Geostationary satellite is 24 hrs.
(v) The orbit velocity of a Geostationary satellite is 24 hrs.
(v) The orbit velocity of a Geostationary satellite is 200 K.m.
(v) The orbit velocity of a Geostationary satellite is 3.08 km/s
example 12:
(v) The orbit velocity of a Geostationary satellite is 3.08 km/s
Example 12:
(v) The orbit velocity of a Geostationary satellite is 3.08 km/s
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(v) The orbit velocity of a Geostationary satellite is 3.08 km/s
the ratio of total mechanical energy of A and B?
(v) The orbit velocity of a Geostationary satellite is 3.08 km/s
the ratio of total mechanical energy of A and B?
(v) From it is not.
(v) From the ratio of 1:4. What is
the ratio of

Example 13 :

A satellite of mass m, initially at rest on the earth, is launched into a circular orbit at a height equal to the radius of the earth. Find the minimum energy required.

Sol. We know that,
$$
V_0 = \sqrt{\frac{GM}{r}}
$$
 & $g = \frac{GM}{R^2}$

From energy conservation,
$$
U_i + K_i = U_f + K_f
$$

12 :
\nsatellites have their masses in the ratio of 3 : 1. The
\nio f their circular orbits are in the ratio of 1 : 4. What is
\natio of total mechanical energy of A and B?
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-\frac{GMm}{2r}
$$
\n
$$
=\frac{m_1}{r_1} \times \frac{r_2}{m_2} = \left[\frac{m_1}{m_2}\right] \left[\frac{r_2}{r_1}\right] = \frac{3}{1} \times \frac{4}{1} = \frac{12}{1}
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Example 14 :

 $rac{I_2}{m_2} = \left[\frac{m_1}{m_2}\right] \left[\frac{I_2}{I_1}\right] = \frac{3}{1} \times \frac{4}{1} = \frac{12}{1}$
of mass m, initially at rest on the earth, is
o a circular orbit at a height equal to the radius
Find the minimum energy required.
at, $V_0 = \sqrt{\frac{GM}{r}}$ A satellite can be in a geostationary orbit around earth at a distance r from the the centre. If the angular velocity of earth about its axis doubles, a satellite can now be in a geostationary orbit around earth if its distance from the centre is – Let $\sinh \theta$ at a height equal to the Factures

e minimum energy required.
 $=\sqrt{\frac{GM}{r}}$ & $g = \frac{GM}{R^2}$
 $K_f = -\frac{GMm}{2R} + \frac{1}{2}mv_0^2$
 $\frac{1}{2}m\left(\sqrt{\frac{GM}{2R}}\right)^2 = \frac{3GMm}{4R} = \frac{3}{4}mgR$

a a geostationary orbit around earth a From energy conservation, $U_i + K_i = U_f + K_f$
 $-\frac{GMm}{R} + K_f = -\frac{GMm}{2R} + \frac{1}{2}mv_0^2$
 $K_i = \frac{GMm}{2R} + \frac{1}{2}m\left(\sqrt{\frac{GM}{2R}}\right)^2 = \frac{3GMm}{4R} = \frac{3}{4}mgR$

4:

dellite can be in a geostationary orbit around earth at

tance r from the t ervation, $U_i + K_i = U_f + K_f$
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 $m\left(\sqrt{\frac{GM}{2R}}\right)^2 = \frac{3GMm}{4R} = \frac{3}{4}mgR$

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 $\frac{\pi}{2}$ (C) $\frac{r}{(4)^{1/3}}$ (D) $K_1 = \frac{GMm}{2R} + \frac{1}{2} m \left(\sqrt{\frac{GM}{2R}} \right)^2 = \frac{3GMm}{4R} = \frac{3}{4} mgR$

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Hellite can be in a geostationary orbit around earth at

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about its axis doubles, a satellite can $\frac{Mm}{R} + K_f = -\frac{Gm}{2R} + \frac{1}{2}mv_0^2$
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from the the centre. If the angular velocity of

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 $=\frac{GMm}{2R} + \frac{1}{2} m \left(\sqrt{\frac{GM}{2R}} \right)^2 = \frac{3GMm}{4R} = \frac{3}{4} mgR$

dite can be in a geostationary orbit around earth at

dece r from the the centre. If the angular velocity of

sout its axis doubles, a satellite c

(A)
$$
\frac{r}{2}
$$
 \t(B) $\frac{r}{2\sqrt{2}}$ \t(C) $\frac{r}{(4)^{1/3}}$ \t(D) $\frac{r}{(2)^{1/3}}$

Sol. (C). Let angular velocity is
$$
\omega \Rightarrow \text{m} \omega^2 = \frac{\text{GMm}}{r^2}
$$

$$
\omega^{2} = \frac{GM}{r^{3}}, \text{ so } \omega_{1}^{2}r_{1}^{3} = \omega_{2}^{2}r_{2}^{3}
$$

$$
r_{2}^{3} = r_{1}^{3} \left(\frac{\omega_{1}}{\omega_{2}}\right)^{2} = \frac{r_{1}^{3}}{4} \Rightarrow r_{2} = \frac{r_{1}}{4^{1/3}}
$$

E_{control}

TRY IT YOURSELF-2

Q.1 A spherical uniform planet is rotating about its axis. The velocity of a point on its equator is V. Due to the rotation of planet about its axis the acceleration due to gravity g at equator is 1/2 of g at poles. The escape velocity of a particle on the pole of planet in terms of V.

(A)
$$
V_e = 2V
$$
 (B) $V_e = V$

(C)
$$
V_e = V/2
$$
 (D) $V_e = \sqrt{3}V$

Q.2 Satellites A and B are orbiting around the earth in orbits of radio R and 4R respectively. The ratio of their areal velocities is –

(A) $1:2$ (B) $1:4$

(C) $1:8$ (D) $1:16$

Q.3 Which of the following are Kepler's laws?

- (1) Each planet moves in an elliptical orbit, with the sun at the center of the ellipse.
- (2) Each planet moves in an elliptical orbit, with the sun at the focus of the ellipse.
- (3) A line from the sun to a given planet sweeps out equal 1 . areas in equal times.
- (4) Planets move equal distances in equal times.
- (5) The periods of the planets are proportional to the cube of the semi-major axis lengths of their orbits.
- (6) The periods of the planets are proportional to the 3/2 power of the semi-major axis lengths of their orbits.
- (A) $1, 3, 5$ (B) $1, 3, 6$
- (C) $1, 4, 5$ (D) $2, 3, 6$
- **Q.4** A satellite following an elliptical path around a planet has an angular velocity ω_{far} when at its maximum distance d units from the planet's center. At its closest point, the distance between the satellite and planet's center is $d/3$.
The satellite angle and planet that closed using in The satellite's angular velocity at that closest point is:

$$
(A) \omega_{\text{far}}/3 \tag{B} \omega_{\text{far}}
$$

- (A) ω_{far} (B) ω_{far}

(C) $3\omega_{\text{far}}$ (D) $9\omega_{\text{far}}$
- **Q.5** A planet orbits a sun in an elliptical orbit as shown. Which principles of physics most clearly and directly explain why the speed of the planet is the same at positions A and B?

- (A) Conservation of Energy
- (B) Conservation of Angular Velocity
- (C) Conservation of Angular Momentum
- (D) Conservation of Charge
- **Q.6** Find the period of the circular orbit of our sun around the center of our Galaxy (take as point mass 4×10^{41} kg) at a radius 3×10^4 light years.
- **Q.7** A satellite is in an elliptical orbit around the earth with altitudes ranging from 230 to 890 km. At the high point it is moving at 7.23 km/s. What is its speed at the low point?
- **Q.8** The planet Neptune travels around the Sun with a period of 165 year. Find the radius of Neptune orbit in terms of Earth's orbit, both being considered as circular.
- **Q.9** Suppose Earth's orbital motion around the Sun is suddenly stopped. What time will the Earth take to fall into the Sun?
- $\overline{Q} = \sqrt{3}V$ **Q.10** The period of lunar orbit around the Earth is 27.3 days and the radius of the orbit is 3.9×10^5 km. Using the measured value of $G = 6.67 \times 10^{-11}$ N m² kg⁻², estimate the mass of Earth.

ANSWERS

(1) (A) **(2)** (A) **(3)**(D) **(4)**(D) **(5)** (AC) **(6)** 200 Million years. **(7)** 7.95 km/s (8)

$$
30 R_1 \qquad (9) 2 months \qquad (10) 6.3 \times 10^{24} kg
$$

IMPORTANT POINTS

- The acceleration due to gravity.
	- (a) At a height h above the Earth's surface

tellite like is in an elliptical orbit around the earth with
ides ranging from 230 to 890 km. At the high point it is
ing at 7.23 km/s. What is its speed at the low point?
planet Neptune travels around the Sun with a period
65 year. Find the radius of Neptune orbit in terms of
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ped. What time will the Earth take to fall into the Sun?
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radius of the orbit is 3.9 × 10⁵ km. Using the measured
e of G = 6.67 × 10⁻¹¹ N m² kg⁻², estimate the mass of
h.
ANSWERS
(2)(A) (3)(D) (4)(D)
(6) 200 Million years. (7) 7.95 km/s
(9) 2 months (10) 6.3 × 10²⁴ kg
IMPORTANT POINTS
acceleration due to gravity.
At a height h above the Earth's surface

$$
g(h) = \frac{GM_E}{(R_E + h)^2} = \frac{GM_E}{R_E^2} \left(1 - \frac{2h}{R_E}\right)
$$
; for h $< R_E$
 $g(h) = g(0) \left(1 - \frac{2h}{R_E}\right)$ where $g(0) = \frac{GM_E}{R_E^2}$
At depth d below the Earth's surface is
 $g(d) = \frac{GM_E}{R_E^2} \left(1 - \frac{d}{R_E}\right) = g(0) \left(1 - \frac{d}{R_E}\right)$
ler's laws of planetary motion state that –
All planets move in elliptical orbits with the Sun at
one of the focal points
The radius vector drawn from the sun to a planet
follows from the fact that the force of gravitational. This
sublows even that fact that the force of gravitational. This

(b) At depth d below the Earth's surface is

$$
g(d) = \frac{GM_{\rm E}}{R_{\rm E}^2} \left(1 - \frac{d}{R_{\rm E}}\right) = g(0) \left(1 - \frac{d}{R_{\rm E}}\right)
$$

- **2.** Kepler's laws of planetary motion state that
	- (a) All planets move in elliptical orbits with the Sun at one of the focal points
- (b) The radius vector drawn from the sun to a planet sweeps out equal areas in equal time intervals. This follows from the fact that the force of gravitation on the planet is central and hence angular momentum is conserved. $\frac{1}{12}$
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 $\left(\$
	- (c) The square of the orbital period of a planet is proportional to the cube of the semimajor axis of the elliptical orbit of the planet.

The period T and radius R of the circular orbit of a

planet about the Sun are related by $T = \frac{1}{G}$ $2 \left\{ \right.$ GM_S)

where M_S is the mass of the Sun. Most planets have nearly circular orbits about the Sun.

For elliptical orbits, the above equation is valid if R is replaced by the semi-major axis, a.

3. Angular momentum conservation leads to Kepler's second law. However, it is not special to the inverse square law of gravitation. It holds for any central force.

In Kepler's third law and $T^2 = K_s R^3$. The constant K_S is the same for all planets in circular orbits. This applies to satellites orbiting the Earth.

4. The escape speed from the surface of the Earth is

$$
v_e = \sqrt{\frac{2GM_E}{R_E}} = \sqrt{2gR_E}
$$
 and has a value of 11.2 km s⁻¹.

- ANGEDIE ARRIVES

the escape speed from the surface of the Earth is
 $e = \sqrt{\frac{2GM_E}{R_E}} = \sqrt{2gR_E}$ and has a value of 11.2 km s⁻¹.

geostationary (geosynchronous communication)

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The escape speed from the surface of the Earth is
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A geostationary (geosynchronous communication)

A geostationary (geosynchronous communication)

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ESPENDING EXECUTE OF THE EXECUTE OF THE INTEREST **5.** A geostationary (geosynchronous communication) satellite moves in a circular orbit in the equatorial plane at a approximate distance of 4.22 \times 10⁴ km from the Earth's centre. **6.** If F α r^B then material and same radius r are touching

STIDDY MATERIAL: PHYSICS
 $v_e = \sqrt{\frac{2GM_E}{R_E}} = \sqrt{2gR_E}$ and has a value of 11.2 km s⁻¹.

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ADDITIONAL EXAMPLES

Example 1 :

Sphere of the same material and same radius r are touching each other. Show that gravitational force between them is directly proportional to r^4 . Let mass of both sphere are m_1 and m_2 respectively. The density of material is ρ .

Sol. $m_1 = m_2 = (volume)$ (density)

Example 2 :

Two hypothetical planets of masses m_1 and m_2 and radii r_1 and r_2 , respectively, are nearly at rest when they are an infinite distance apart Because of their gravitational attraction, they head toward each other on a collision course.

- (a) When their center-to-center separation is d, find expressions for the speed of each planet and their relative velocity.
- (b) Find the kinetic energy of each planet just before they collide, if $m_1 = 2.00 \times 10^{24}$ kg, $m_2 = 8.00 \times 10^{24}$ kg, $r_1 = 3.00 \times 10^6$ and $r_2 = 5.00 \times 10^6$ m.
	- (Note : Both energy and momentum are conserved.)

Sol. (a) At infinite separation, $U = 0$; and at rest, $K = 0$. Since energy is conserved, we have

$$
0 = \frac{1}{2}mv_1^2 + \frac{1}{2}m_2v_2^2 - \frac{Gm_1m_2}{d}
$$
(1)

The initial momentum is zero and momentum is conserved. Therefore,

0 = m ¹v¹ – m2v² (2)

Combine eq. (1) and eq. (2) tofind

1 2 1 2 2G v m d (m m) and 2 1 1 2 2G v m d (m m) 1 2 r 1 2 2G (m m) v v (v) ^d Therefore, 2 32 1 1 1 ¹ K m v 1.07 10 J ² and 2 31 2 2 2 ¹ K m v 2.67 10 J ²

The relative velocity is

$$
v_r = v_1 - (-v_2) = \sqrt{\frac{2G (m_1 + m_2)}{d}}
$$

(b) Substitute the given numerical values into the equation found for v_1 and v_2 in part (a) to find

 $v_1 = 1.03 \times 10^4$ m/s and $v_2 = 2.58 \times 10^3$ m/s.

Therefore,
$$
K_1 = \frac{1}{2} m_1 v_1^2 = 1.07 \times 10^{32} J
$$

and
$$
K_2 = \frac{1}{2} m_2 v_2^2 = 2.67 \times 10^{31} J
$$

Example 3 :

nchronous communication

3 3 $V_1 = m_2 \sqrt{\frac{2G}{d (m_1 + m_2)}}$ and $v_2 = m_1 \sqrt{\frac{2}{d (m_1 + m_2)}}$

3 $\frac{1}{d} \times 2 \times 10^4$ km from the Earth's

3 $V_1 = m_2 \sqrt{\frac{2G}{d (m_1 + m_2)}}$ and $v_2 = m_1 \sqrt{\frac{2G}{d (m_1 + m_2)}}$

3 EXAMPLES

3 EXAMPLES

3 An asteroid, whose mass is 2.0×10^{-4} times the mass of earth, revolves in a circular orbit around the Sun at a distance that is twice earth's distance from the Sun, (a) Calculate the period of revolution of the asteroid in years. (b) What is the ratio of the kinetic energy of the asteroid to that of Earth ? erical values into the equation

art (a) to find
 $v_2 = 2.58 \times 10^3$ m/s.
 $v_2 = 1.07 \times 10^{32}$ J
 2.67×10^{31} J
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r orbit around the Sun at a

si distance from the Sun, (a)

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An asteroid, whose mass is 2.0×10^{-4} times the mass of

An asteroid, whose in a circular orbit around the Sum at a

distance that is twice earth's distance from the S a steroid, whose mass is 2.0×10^{-4} times the mass of
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stance that is twice earth's distance from the Sun, (a)
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n's distance from the Sun, (a)

blution of the asteroid in years.

: inetic energy of the asteroid to

: $T^2 = \frac{4\pi^2}{GM} r^3$, where M is the
 (10^{30} kg) and r is the radius of

the orbit = 2.67 × 10³¹ J

s 2.0 × 10⁻⁴ times the mass of

lar orbit around the Sun at a

n's distance from the Sun, (a)

ollution of the asteroid in years.

sinetic energy of the asteroid to

: T² = $\frac{4\pi^2}{GM}$ T³, where $\frac{1}{2}$ m₂ v_2^2 = 2.67 × 10³¹ J

see mass is 2.0 × 10⁻⁴ times the mass of

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tio of th $a_2v_2^2 = 2.67 \times 10^{31} J$
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frevolution of the asteroid in years.
the kinetic energy of the asteroid to
iods: $T^$

Sol. (a) Use the law of periods : $T^2 =$ 2 \overline{a} GM³ $=\frac{4\pi^2}{\Omega M}r^3$, where M is the

mass of the Sun (1.99 \times 10³⁰ kg) and r is the radius of the orbit. The radius of the orbit is twice the radius of earth's orbit :

$$
r = 2r_e = 2 (150 \times 10^9 \text{ m}) = 300 \times 10^9 \text{ m}
$$
. Thus

$$
T = \sqrt{\frac{4\pi^2 r^3}{GM}} = \sqrt{\frac{4\pi^2 (300 \times 10^9 \text{ m})^3}{(6.67 \times 10^{-11} \text{ m}^3/\text{s}^2 \text{ kg}) (1.99 \times 10^{30} \text{ kg})}}
$$

= 8.96 × 10⁷ s

Divide by $(365 \frac{d}{v})(24 \frac{h}{d})(60 \frac{min}{h})(60 \frac{s}{min})$

to obtain $T = 2.8$ y.

eir center-to-center separation is d, find

where the Sum (1.99 × 10³⁰ kg) and r is the respective.

Nelocity.

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We herebot the readius of the orbit is twist the readius of the orbit is twist the readius (b) The kinetic energy of any asteroid or planet in a circular orbit of radius r is given by $K = GMm/2r$, where m is the mass of the asteroid or planet. Notice that it is proportional to m and inversely proportional to r. The ratio of the kinetic energy of the asteroid to the kinetic energy of earth is $K/K_e = (m/m_e) (r_e/r)$. The radius of the orbit is twice the radius of
it :
 $(150 \times 10^9 \text{ m}) = 300 \times 10^9 \text{ m}$. Thus
 $\sqrt{\frac{4\pi^2 (300 \times 10^9 \text{ m})^3}{(6.67 \times 10^{-11} \text{ m}^3/\text{s}^2 \text{ kg})} (1.99 \times 10^{30} \text{ kg})}}$
 $(365 \text{ d/y}) (24 \text{ h/d}) (60 \text{ min/h}) (60 \text{s/min})$
 be Sun $(1.99 \times 10^{30} \text{ kg})$ and r is the radius of
The radius of the orbit is twice the radius of
The radius of the orbit is twice the radius of
thit:
2 $(150 \times 10^9 \text{ m}) = 300 \times 10^9 \text{ m}$. Thus
 $= \sqrt{\frac{4\pi^2 (300 \times 10^9 \text$

Substitute m = 2.0×10^{-4} m_e and r = $2r_e$ to obtain

$$
\frac{K}{K_e} = 1.0 \times 10^{-4} .
$$

Example 4 :

A satellite moves eastwards very near the surface of the earth in equatorial plane with speed (v_0) . Another satellite moves at the same height with the same speed in the equatorial plane but westwards. If $R =$ radius of the earth and ω be its angular speed of the earth about its own axis. Then find the approximate difference in the two time period S as observed on the earth. **NITATION**
 Example 7:
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 Example 7:

te moves eastwards very near the surface of the

A twhat height from the surface of the

te same height with the same speed in the

te same height with the same speed in the

(A) 5.76×10^6 m

its a **Example 7:**
 Example 7:

moves eastwards very near the surface of the

durational plane with speed (v₀). Another satellite

the same beight with the same speed in the

(A) 5.76×10^6 m

angular speed of the earth **EXEIDINERENTION**
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Example 7:

al plane with speed (v₀). Another satellite due to gravity 1000 of its value on

alme height with the same speed in the (A) 5.76 × 10⁶ m

but westwards. If R = radius of the earth

(C) 0.576 m **Example 7:**

Subsequent with speed of the surface of the At what height from the surface of earth is trial plane with speed (v_0). Another satellite the due to gravity 1/100 of its value on earth stars are height with **Example 7:**

Example 7:

Example 7:

Example 7:

Separate by the surface of the

At what height from the surface of earth is

stagged in the surface of the carth (A) 5.76 m

e but westwards. If R = radius of the earth (C **Example 7:**

Example 7:

res eastwards very near the surface of the

relation the surface of earth is trial plane with speed (v₀). Another sachilite

same height with the same speed in the

e but westwards. If R = radi

Sol.
$$
T_{\text{west}} = \frac{2\pi R}{v_0 + R\omega}
$$
 and $T_{\text{east}} = \frac{2\pi R}{v_0 - R\omega}$ or $\frac{R}{R + h} = \frac{1}{10}$
\n $\Rightarrow \Delta T = T_{\text{east}} - T_{\text{west}}$
\n $= 2\pi R \left[\frac{2R\omega}{v_0^2 - R^2 \omega^2} \right] = \frac{4\pi \omega R^2}{v_0^2 - R^2 \omega^2}$
\n**Example 8:**

Example 5 :

If the satellite is stopped suddenly in its orbit and allowed to fall freely onto the earth, find the speed with which it hits the surface of the earth. Height of satellite above the earth's surface is equal to radius of earth.

Sol. From conservation of energy

Total energy at height $h =$ Total energy at earth's surface

i.e., 0 – GMm – GMm **Sol. (BD).** Escape velocity = R h ⁼ ¹ 2 mv² R or 1 2 mv² ⁼ GMm GMm GMm GMm R R h R 2R **Example 9 :** { h = R} 1 2 mv² 2R This gives v = ² GM R g R R ⁼ (Rg)⁼ ³ 6400 10 9.8 = 7.919 × 10³ m/s. (R h) ^h ^e ^F R h ¹⁰ F 9 ^R

Example 6 :

At what height from the surface of earth the gravitational force will be reduced by 10% if the radius of earth is 6370 km.

Sol. Gravitational force on earth surface, $F_S = \frac{P}{R_e^2}$ the gravitational field of t

Gravitational force at height h

This gives
$$
v = \sqrt{\frac{GM}{R}} = \sqrt{\frac{R^2 g}{R}} = \sqrt{\frac{R^2 g}{R}}
$$

\nThis gives $v = \sqrt{\frac{GM}{R}} = \sqrt{\frac{R^2 g}{R}} = 7.919 \times 10^3$ m/s.
\n $\rho = 6$:
\nAt what height from the surface of earth the gravitational
\nforce will be reduced by 10% if the radius of earth is 6370
\n
\nGravitational force on earth surface, $F_S = \frac{GMm}{R_e^2}$
\nGravitational force at height h
\n $F_h = \frac{GMm}{(R_e + h)^2}$ $\therefore \frac{F_s}{F_h} = \frac{(R_e + h)^2}{R_e^2} = \frac{10}{9}$
\n $\therefore h = \frac{0.162 \times 6370}{3}$ or $h = 344$ Km
\n
\n $\frac{11}{1}$
\

Example 7 :

At what height from the surface of earth is the acceleration due to gravity 1/100 of its value on earth surface ?

Examples	Example 7:
\n words very near the surface of the \n with speed (v ₀). Another satellite \n depth of the \n end of the earth about its own axis.\n	\n At what height from the surface of earth is the acceleration \n due to gravity 1/100 of its value on earth surface? \n (A) 5.76 × 10 ⁶ m \n (B) 5.76 × 10 ⁶ m \n (C) 0.576 m \n (D) 57.6 × 10 ⁶ \n
\n The ratio of the earth about its own axis. \n The ratio of the earth about its own axis.\n	\n Sol. (A) $\frac{g}{g} = \left(\frac{R}{R+h}\right)^2 = \frac{1}{100}$ \n or $R = \frac{1}{R+h} = \frac{1}{10}$ \n or $R = 57.6 \times 10^6$ m \n density r, masses M _p and N _Q , and surface areas A and \n 4A, respectively. A spherical planet R also has uniform \n density r and its mass is (M _p + M _Q). The escape velocities \n earth, find the speed with which it \n from the planets P, Q and R, are V _p , V _Q and V _R , \n at the time of the system is given by a specific system.\n

or
$$
\frac{R}{R + h} = \frac{1}{10}
$$

or $h = 9R = 57.6 \times 10^6$ m

Example 8 :

Two spherical planets P and Q have the same uniform density r, masses M_p and M_Q , and surface areas A and 4A, respectively. A spherical planet R also has uniform density r and its mass is $(M_P + M_Q)$. The escape velocities from the planets P, Q and R, are V_p , V_Q and V_R , respectively. Then Q have the same uniform

Q, and surface areas A and

planet R also has uniform
 $-M_Q$). The escape velocities
 R , are V_p , V_Q and V_R ,
 $(B) V_R > V_Q > V_p$
 $(B) V_p / V_Q \stackrel{\frown}{=} 1/2$
 $\frac{GM}{R} \propto \sqrt{\frac{\frac{4}{3} \pi R^3}{R}} \propto \sqrt{Area}$

an 57.6 m

57.6 × 10⁶

57.6 × 10⁶

and surface areas A and

net R also has uniform

0. The escape velocities

are V_p, V_Q and V_R,

V_R>V_Q>V_p
 $\sqrt{V_Q} = 1/2$
 $\propto \sqrt{\frac{\frac{4}{3}\pi R^3}{R}} \propto \sqrt{Area}$

is same]

(A)
$$
V_Q > V_R > V_P
$$

\n(C) $V_R/V_P = 3$
\n(B) $V_R > V_Q > V_P$
\n(D) $V_P/V_Q = 1/2$

 $\frac{4}{3} \pi R^3$ $\frac{2GM}{R} \propto \sqrt{\frac{3}{2}} = \infty$ $\sqrt{\text{Area}}$

[since density of each planet is same]

 $=\frac{GMm}{2R}$ and two bodies, each of mass M, are kept fixed with a separation 2L. A particle of mass m is projected from the Two bodies, each of mass M, are kept fixed with a midpoint of the line joining their centres, perpendicular to the line. The gravitational constant is G. The correct statement(s) is (are) – bodies, each of mass M, are kept fixed with a
tion 2L. A particle of mass m is projected from the
int of the line joining their centres, perpendicular
line. The gravitational constant is G. The correct
ent(s) is (are) –
n bodies, each of mass M, are kept fixed with a
ation 2L. A particle of mass m is projected from the
oint of the line joining their centres, perpendicular
eline. The gravitational constant is G. The correct
ment(s) is (are) each of mass M, are kept fixed with a
A particle of mass m is projected from the
e line joining their centres, perpendicular
e gravitational constant is G. The correct
(are) –
num initial velocity of the mass m to escape

(A) The minimum initial velocity of the mass m to escape

the gravitational field of the two bodies is
$$
4\sqrt{\frac{GM}{L}}
$$

(B) The minimum initial velocity of the mass m to escape

the gravitational field of the two bodies is $2\sqrt{\frac{GM}{L}}$.

(C) The minimum initial velocity of the mass m to escape

$$
\frac{GMm}{R_e^2}
$$
 the gravitational field of the two bodies is $\sqrt{\frac{2GM}{L}}$

 \mathbf{L} and \mathbf{L} and \mathbf{L} and \mathbf{L}

.

(D) The energy of the mass m remains constant.

$$
\therefore \frac{F_s}{F_h} = \frac{(K_e + H)}{R_e^2} = \frac{10}{9}
$$
 Sol. (B). $\frac{-2GMm}{L} + \frac{1}{2}mv^2 = 0 \Rightarrow v = 2\sqrt{\frac{GM}{L}}$

The energy of mass 'm' means its kinetic energy (KE) only and not the potential energy of interaction between m and the two bodies (of mass M each)– which is the potential energy of the system.

Example 10 :

A Bullet is fired vertically upwards with velocity v from the surface of a spherical planet. When it reaches its maximum height, its acceleration due to the planet's gravity is 1/4th of its value at the surface of the planet. If the escape velocity from the planet is

(Ignore energy loss due to atmosphere)

Sol. 2. When it reaches its maximum height, its acceleration due to the planet's gravity is $1/4$ th of its value at the surface of the planet.

2 2 GM 1 GM r R ⁴ ; r = 2R By conservation of mechanical energy GMm 1 GMm ² mv 0 R 2 r ^r 1 GMm ² mv 2 2R esc 2GM v v N R ; N = 2

Example 11 :

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UNERT STEVE UNDER THE UNDER THE VALUE OF STEVER UNDER THE SURFACT OF SPACE UP A large spherical mass M is fit

maximum height, its acceleration due to the planet of M (see A large spherical mass M is fixed at one position and two identical point masses m are kept on a line passing through the centre of M (see figure). The point masses are connected by a rigid massless rod of length ℓ and this assembly is free to move along the line connecting them. All three masses interact only through their mutual gravitational interaction. When the point mass nearer to M is at a distance $r = 3\ell$ from M, the tension in the rod is zero for $m = k (M/288)$. The value of k is mental mass in the kept on a line passing
point masses m are kept on a line passing
the centre of M (see figure). The point masses
ceted by a rigid massless rod of length ℓ and
the single term once along the line conne **STUDY MATERIAL: PHYSICS**

ge spherical mass M is fixed at one position and two

icial point masses m are kept on a line passing

glp the centre of M (see figure). The point masses

someocted by a rigid massless rod of **STUDY MATERIAL: PHYSICS**

ge spherical mass M is fixed at one position and two

cical point masses m are kept on a line passing

ght the centre of M (see figure). The point masses

somenceted by a rigid massless rod of l spherical mass M is fixed at one position and two
al point masses m are kept on a line passing
the centre of M (see figure). The point masses
mected by a rigid massless rod of length ℓ and
embly is free to move along t All three masses interact only through their mutual
tational interaction. When the point mass nearer to
at a distance $r = 3\ell$ from M, the tension in the rod is
for $m = k$ (M/288). The value of k is

For point mass at d tational interaction. When the point mass nearer to

at a distance $r = 3\ell$ from M, the tension in the rod is

for m = k (M/288). The value of k is
 $\frac{m}{r}$

For point mass at distance $r = 3\ell$
 $\frac{GMm}{(3\ell)^2} - \frac{Gm^2}{\$ ly is free to move along the line connecting
ree masses interact only through their mutual
dimetraction. When the point mass nearer to
tance $r = 3\ell$ from M, the tension in the rod is
k (M/288). The value of k is
 $\frac{m}{r}$

Sol. 7. For point mass at distance $r = 3\ell$

$$
\frac{GMm}{(3\ell)^2} - \frac{Gm^2}{\ell^2} = ma
$$

For point mass at distance $r = 4\ell$

$$
\frac{GMm}{(4\ell)^2} + \frac{Gm^2}{\ell^2} = ma
$$

CHAPTER 9 : GRAVITATION

EXERCISE - 1 [LEVEL-1]

Choose one correct response for each question. PART - 1 : NEWTON'S LAW OF

GRAVITATION

Q.1 Two stars of masses m_1 and m_2 are parts of a binary star system. The radii of their orbits are r_1 and r_2 respectively, measured from the centre of mass of the system. The magnitude of gravitational force m_1 exerts on m_2 is – **VITATION BANK** CUESTION BANK
 EXERCISE -1 [LEVEL-1]
 EXERCISE -1 [LEVEL-1]
 EXERCISE -1 [LEVEL-1]
 EXERCISE -1 [LEVEL-1]
 EXERCISE -1 [LEVEL-1]

Two stars of masses m₁ and n_2 are parts of a binary star

Tw

(A)
$$
\frac{Gm_1m_2}{(r_1+r_2)^2}
$$
 (B) $\frac{Gm_1}{(r_1+r_2)^2}$

(C)
$$
\frac{Gm_2}{(r_1 + r_2)^2}
$$
 (D) $\frac{G(m_1 + m_2)}{(r_1 + r_2)^2}$

Q.2 The gravitational force between two stones of mass 1 kg each separated by a distance of 1 metre in vacuum is (A) Zero (B) 6.675×10^{-5} N Q.9

(C)
$$
6.675 \times 10^{-11} \text{N}
$$
 (D) $6.675 \times 10^{-8} \text{N}$

- **Q.3** Far from any other masses, two masses, m_1 and m_2 , are interacting gravitationally. The value for the mass of m_1 suddenly doubles. What happens to the value of the gravitational force that mass m_2 exerts on mass m_1 ?
	- (A) It doubles.
	- (B) It decreases by a factor of 2.
	- (C) It quadruples.
	- (D) Nothing, because the mass m_2 did not change.
- **Q.4** Two identical solid copper spheres of radius R placed in contact with each other. The gravitational attraction between them is proportional to

 $(A) R²$ $(B) R^{-2}$ $R - 4$

- **Q.5** The Moon remains in its orbit around the Earth rather than falling to the Earth because –
	- (A) it is outside of the gravitational influence of the Earth.
	- (B) it is in balance with the gravitational forces from the $Q.11$ Sun and other planets.
	- (C) the net force on the Moon is zero.
	- (D) none of these
- **Q.6** 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) 3F (B) F

Q.7 Mass M is divided into two parts x M and $(1 - x)$ M. For a given separation, the value of x for which the gravitational attraction between the two pieces becomes maximum is

PART - 2 : GRAVITATIONAL FIELD INTENSITY

Q.8 Which one of the following groups represents correctly the variation of the gravitational intensity I with the distance r from the centre of a spherical shell of mass M and radius R?

Q.9 A uniform ring of mass m and radius a is placed directly above a uniform sphere of mass M and of equal radius. centre of the sphere. Find the gravitational force exerted

(A)
$$
\frac{\sqrt{3} \text{G} \text{Mm}}{8a^2}
$$
 (B) $\frac{\sqrt{5} \text{G} \text{Mm}}{8a^2}$
(C) $\frac{\sqrt{3} \text{G} \text{Mm}}{5a^2}$ (D) $\frac{\sqrt{2} \text{G} \text{Mm}}{5a}$

Q.10 The gravitational intensity at the centre of a hemispherical shell of uniform mass density has the direction indicated by the arrow (see Fig.) (A) a (B) b $(C)c$ (D) 0

by the sphere on the ring.

For the above problem, the direction of the gravitational intensity at an arbitrary point P is indicated by the arrow $(A) d$ (R)

(C) f (D) g

PART - 3 : GRAVITATIONAL POTENTIAL AND POTENTIAL ENERGY

Q.12 A particle of mass m is placed at the centre of a uniform spherical shell of mass 3m and radius R. The gravitational potential on the surface of the shell is –

$$
(A) -\frac{Gm}{R} \qquad \qquad (B) -\frac{3Gm}{R}
$$

$$
(C) -\frac{4Gm}{R} \qquad (D) -\frac{2Gm}{R}
$$

Q.13 A block of mass m is lying at a distance r from a spherical shell of mass m and radius r as shown in the figure. Then

- (A) only gravitational field inside the shell is zero.
- (B) gravitational field and gravitational potential both are zero inside the shell.
- (C) gravitational potential as well as gravitational field inside the shell are not zero.
- (D) can't be ascertained.
- **Q.14** Two bodies of mass 10^2 kg and 10^3 kg are lying 1m (C) 3 apart. The gravitational potential at the mid-point of the line joining them is (4) 0 (B) –1.47 Joule/kg

(C) 1.47 Joule/kg
 (D)
$$
-1.47 \times 10^{-7}
$$
 Joule/kg

Q.15 If g is the acceleration due to gravity on the earth's surface, the gain in potential energy of an object of mass m raised from the surface of the earth to a height of the radius R of the earth is -

(A) mgR (B) 2mgR

(C)
$$
\frac{1}{2}
$$
 mgR \t\t\t(D) $\frac{1}{4}$ mgR

Q.16 Four particles each of mass m are placed at the vertices of a square of side ℓ . The potential energy of the system (A) \geq K (C) 1.414 R is –

(A) ² 2Gm 1 ² 2 (B) (C) ² 2Gm 1 ² 2 (D)

Q.17 The radius of the earth is R_e and the acceleration due to gravity at its surface is g. The work required in raising a body of mass m to a height h form the surface of the earth

\n trace, the gain in potential energy of an object of mass in a single system of the earth is 100 m/s² radius R of the earth is 60 m/s² (A) magR (B) 2 mgR (C) 1.25 × 10⁻¹ rad/sec (C)
$$
\frac{1}{2}
$$
 mgR (D) $\frac{1}{4}$ mgR (D) $\frac{1}{4}$ mgR (E) 23 A t what distance from the coefficient of the surface (R = radius of earth) of a square of side *l*. The potential energy of the system is -\n

\n\n Q.23 At what distance from the coefficient of the surface (R = radius of earth) of a square of side *l*. The potential energy of the system is -\n

\n\n Q.24 If density of earth increases 4 half of that it is, our weight of the mass and the radii of the starth is R_e and the acceleration due to the electric field (A) for the mass and the radius of the earth is R_e and the acceleration due to the surface of the earth is 1% of the mass and the radius of the earth is R_e and the acceleration due to the surface of the earth is the same than the point of the starth is 1% of the surface of the earth is the same than the point of the starth is 1% of the starth is

PART - 4 : ACCELERATION DUE TO GRAVITY

Q.18 Two planets have the same average density but their radii are R_1 and R_2 . If acceleration due to gravity on these planets be g_1 and g_2 respectively, then –

(A) 1 1 2 2 g R g R (B) 1 2 g R (C) 2 1 1 2 2 2 g R g R (D) 3 3 2 2 g R

TERIAL: PHYSICS
 $\frac{1}{2} = \frac{R_2}{R_1}$
 $\frac{S_1}{S_2} = \frac{R_1^3}{R_2^3}$

in the ratio 4 : 1 and

: 2. The acceleration ATERIAL: PHYSICS
 $\frac{g_1}{g_2} = \frac{R_2}{R_1}$
 $\frac{g_1}{g_2} = \frac{R_1^3}{R_2^3}$

in the ratio 4 : 1 and

1 : 2. The acceleration

be in the ratio – TERIAL: PHYSICS
 $\frac{1}{2} = \frac{R_2}{R_1}$
 $\frac{1}{2} = \frac{R_1^3}{R_2^3}$

in the ratio 4 : 1 and

: 2. The acceleration

e in the ratio – **Solution 1.1**

<u>g₁</u> = $\frac{R_2}{R_1}$
 $\frac{g_1}{g_2} = \frac{R_1^3}{R_2^3}$

in the ratio 4 : 1 and

1 : 2. The acceleration

be in the ratio –
 \therefore 3 **Q.19** The diameters of two planets are in the ratio 4 : 1 and their mean densities are in the ratio 1 : 2. The acceleration due to gravity on the planets will be in the ratio – $(A) 1 : 2 \t\t (B) 2 : 3$

(C) 2 : 1 (D) 4 : 1

Q.20 At what altitude in metre will the acceleration due to gravity be 25% of that at the earth's surface (Radius of $earth = R m)$ (A) R/4

(C) 3R/8 (D) R/2

- the shell is zero.

due to gravity on the planes will be in the ratio-

incidential contains the state of the state of the state of the ratio-

(0) 1:2

(2) 24 A what alitude in metre will the acceleration due to

gravita **Q.19** The diameters of two planets are in the ratio 4 : 1 and
their mean desiriests are in the ratio 1 : 2. The acceleration
lis zero.
(A) 1: 2. The acceleration
(C)2 : 1
(B)2: 3
(B)2: 3
(B)2: 3
(B)2: 1
(D)4: 1
(A) Head **1.9 13** contribute the shell is zero.

their diameters of two planets are in the ratio 1:2. The acceleration

due to gravity on the planets will be in the ratio -

(A) 1: 2

(A) 2: 1

(B) 2: 1

1. (B) 2: 1

1. (B) 2: 1
 Q.21 If the angular speed of the earth is doubled, the value of acceleration due to gravity (g) at the north pole (A) Doubles (B) Becomes half (C) Remains same (D) Becomes zero
	- **Q.22** The angular speed of earth, so that the object on equator may appear weightless, is $(g = 10 \text{ m/s}^2, \text{ radius of earth } 6400 \text{ km})$
		- (A) 1.25×10^{-3} rad/sec (B) 1.56×10^{-3} rad/sec (C) 1.25×10^{-1} rad/sec (D) 1.56 rad/sec
- 1 **Q.23** At what distance from the centre of the earth, the value $\frac{4}{4}$ mgK of acceleration due to gravity g will be half that on the surface $(R =$ radius of earth) (A) 2 R (B) R
	- $(D) 0.414 R$
	- **Q.24** If density of earth increased 4 times and its radius become half of that it is, our weight will – (A) four times (B) Be doubled
	- 2) (C) Remain same (D) Be halved
	- $\frac{1}{2}$ 1%, the value of the acceleration due to gravity will **Q.25** If both the mass and the radius of the earth decrease by (A) Decrease by 1% (B) Increase by 1% (C) Increase by 2% (D) Remain unchanged
- onal poison of the system of (2) 2BM the mid-point of (2) 2BM the mid-point of (2) 2BM (B) Reconstraints (A) D) R/2

(A) R/2 the mi the shell is zero.

(a)1:2

itional potential both (C)2:1

axional potential both (C)2:1

as gravitational field gravity be 25% of that at the earth's surface (Radius of

earth-R m)

(A) R4 and the meth = Rm)

(A) R4 and of an object of mass may appear weightes, is

the to height of the (g = 10 m/s², radius of earth 6400km)

(A) 1.25×10^{-3} rad/sec (B) 1.56×10^{-3} rad/sec

(D) 1.56×10^{-3} rad/sec

1

1
 Q.23 At valuat distanc rth to a height of the (g = 10 m/s²; radius of carth 4400km)

2.3 A via distance from the centre of the carth, the value
 $\frac{1}{4}$ mgR

(2.3 A via distance from the centre of the carth, the value

placed at the vertice $\frac{1}{4}$ mgR
 $\frac{1}{4}$ mgR
 $\frac{1}{4}$ mgR
 $\frac{1}{4}$ mgR
 $\frac{1}{4}$ mgac at the vertices

(A) 2 R

(C) 1.414R

(C) 1.414R

(C) 1.414R

(C) 1.414R

(D) 0.414 R

(D) 0.4 and a the vertices

and the vertices

or the system

(A) 2 R

(C) 1.414 R

(C) 1.414 R

(C) 1.414 R

(C) 2.41 If density of earth increased 4 times and its radius become

and its source into the acceleration due to

(C) R **Q.26** If the change in the value of g at a height h above the surface of the earth is the same as at a depth x below it, then (both $x \& h$ being much smaller than the radius of the earth)

(A)
$$
x = h
$$

\n(B) $x = 2h$
\n(C) $x = h/2$
\n(D) $x = h^2$

- R_e **Q.27** A body of mass m is taken to the bottom of a deep mine. Then **–**
	- (A) Its mass increases (B) Its mass decreases
	- (C) Its weight increases (D) Its weight decreases
- $1 + \frac{R}{R_e}$ **Q.28** A body weight W newton at the surface of the earth. Its weight at a height equal to half the radius of the earth will

Q.29 The depth at which the effective value of acceleration due to gravity is g/4 is

Q.30 If the radius of the earth were to shrink by one percent, Q.38 its mass remaining the same, the acceleration due to gravity on the earth's surface would -

Q.31 Assuming that the moon is a sphere of the same mean density as that of the earth and one quarter of its radius, the length of a seconds pendulum on the moon (its length on the earth's surface is 99.2 cm) is

(A) 24.8 cm (B) 49.6 cm

(C) 99.2 cm (D)
$$
\frac{99.2}{\sqrt{2}}
$$
 cm (C) $V_e = V/2$

PART - 5 : ESCAPE VELOCITY

- **Q.32** Escape velocity will depend on
	- (A) Mass of the planet
	- (B) Mass of the particle escaping
	- (C) Radius of the planet
	- (D) Both (A) and (C)
- **Q.33** v_e and v_p denotes the escape velocity from the earth and another planet having twice the radius and the same mean density as the earth. Then –

(A)
$$
v_e = v_p
$$

\n(C) $v_e = 2v_p$
\n(B) $v_e = v_p/2$
\n(D) $v_e = v_p/4$

Q.34 The escape velocity of a sphere of mass m from earth having mass M and radius R is given by –

(A)
$$
\sqrt{\frac{2GM}{R}}
$$

\n(B) $2\sqrt{\frac{GM}{R}}$
\n(C) $\sqrt{\frac{2GMm}{R}}$
\n(D) $\sqrt{\frac{GM}{R}}$
\n(D) $\sqrt{\frac{GM}{R}}$
\n(D) $\sqrt{\frac{GM}{R}}$
\n(D) $\sqrt{\frac{GM}{R}}$
\n(E) Equal to the
\n(D) Zero.
\n14. (A) $(r_1/r_2)^{1/2}$

- **Q.35** There are two planets. The ratio of radius of the two planets is K but ratio of acceleration due to gravity of **Q.43** both planets is g. What will be the ratio of their escape
	- velocity
(A) $(Kg)^{1/2}$ (B) (Kg)^{-1/2} (C) (Kg)² (D) (Kg)⁻²
- **Q.36** A missile is launched with a velocity less than the escape velocity. The sum of its kinetic and potential energy is (A) Positive
	- (B) Negative
	- (C) Zero

(D) May be positive or negative depending upon its initial velocity.

Q.37 The escape velocity of a body on an imaginary planet which is thrice the radius of the earth and double the mass of the earth is (v_e) is the escape velocity of earth)

(A)
$$
\sqrt{\frac{2}{3}}v_e
$$

\n(B) $\sqrt{\frac{3}{2}}v_e$
\n(C) $\frac{\sqrt{2}}{3}v_e$
\n(D) $\frac{2}{\sqrt{3}}v_e$

Q.38 If the radius of a planet is four times that of earth and the value of g is same for both, the escape velocity on the planet will be **–**

(A) 11.2 km/s (B) 5.6 km/s (C) 22.4 km/s (D) None

Q.39 A spherical uniform planet is rotating about its axis. The velocity of a point on its equator is V. Due to the rotation of planet about its axis the acceleration due to gravity g at equator is 1/2 of g at poles. The escape velocity of a particle on the pole of planet in terms of V. erical uniform planet is rotating about its axis. The

tity of a point on its equator is V. Due to the rotation

net about its axis the acceleration due to gravity g

atator is 1/2 of g at poles. The escape velocity of a
 e atauas or a phanet is four times that of early and

radius of g is same for both, the escape velocity on

lanet will be –

1.2 km/s

(B) 5.6 km/s

(D) None

herical uniform planet is rotating about its axis. The

herica (B) 5.6 km/s

(B) 5.6 km/s

(D) None

otating about its axis. The

or is V. Due to the rotation

celeration due to gravity g

. The escape velocity of a

in terms of V.

(B) V_e = V

(D) V_e = V

(D) V_e = V

(D) Ve = **EXECUTE:**
 EXEC (C) 22.4 km/s

(D) None

A spherical uniform planet is rotating about its axis. The

A spherical uniform planet is rotation

of planet about its axis the acceleration due to gravity g

at equator is 1/2 of g at poles. The be radius of a planet is four times that of earth and
value of g is same for both, the escape velocity on
planet will be –
11.2 km/s
(B) 5.6 km/s
berical uniform planet is rotating about its axis. The
city of a point on i one
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 Z. Due to the rotation

tion due to gravity g

escape velocity of a

ns of V.
 $\frac{1}{2} = V$
 $\frac{1}{2} = \sqrt{3}V$
 AW OF

a given point P, it is
 $\frac{1}{2}$ and has a speed V_1 .

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The state of earth and

the escape velocity on

5.6 km/s

None

ting about its axis. The

V. Due to the rotation

ation due to gravity g

g e scape velocity of a

rms of V.
 $V_e = V$
 $V_e = \sqrt{3}$

(2)
$$
V_e = 2V
$$
 (3) $V_e = V$ (4) $V_e = 2V$ (5) $V_e = \sqrt{3}V$ (6) $V_e = \sqrt{3}V$

PART - 6 : KEPLER'S LAW OF PLANETARY MOTION

Q.40 A planet moves around the sun. At a given 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)
$$
\frac{d_1^2 v_1}{d_2^2}
$$
 (B) $\frac{d_2 v_1}{d_1}$
\n(C) $\frac{d_1 v_1}{d_2}$ (D) $\frac{d_2^2 v_1}{d_1^2}$

Q.41 The orbital speed of Jupiter is **–**

- (A) Greater than the orbital speed of earth.
- (B) Less than the orbital speed of earth.
- (C) Equal to the orbital speed of earth.
- $2\sqrt{\frac{GM}{R}}$ (D) Zero. (D) Zero.
	- R **Q.42** Two planets move around the sun. The periodic times $\frac{GM}{R}$ respectively. The ratio T_1/T_2 is equal to R (A) $(r_1/r_2)^{1/2}$ and the mean radii of the orbits are T_1 , T_2 and r_1 , r_2 $\int_{2}^{1/2}$ (B) r₁/r₂
		- $(C) (r_1/r_2)^2$ **Q.43** A planet is revolving around the sun as shown in elliptical path The correct option is $-$
			- D_b (A) The time taken in travelling DAB is less than that for BCD.

 $(D) (\dot{r}_1 / \dot{r}_2)^{3/2}$

B

 \overline{C}

- (B) The time taken in travelling DAB is greater than that for BCD.
- (C) The time taken in travelling CDA is less than that for ABC.
- (D) The time taken in travelling CDA is greater than that for ABC.
- **Q.44** In the previous question the orbital velocity of the planet will be minimum at –

(B) $\sqrt{\frac{3}{2}}v_e$ **Q.45** The radius of orbit of a planet is two times that of the 2^{-e} earth. The time period of planet is –

Q.46 According to Kepler, the period of revolution of a planet (T) and its mean distance from the sun (r) are related by the equation constant

(C)
$$
Tr^3
$$
 = constant (D) T^2r = constant

- **Q.47** The earth revolves round the sun in one year. If the distance between them becomes double, the new period of revolution will be
	-

(C) 4 years (D) 8 years

Q.48 The mass of a planet that has a moon whose time period **Q.57** and orbital radius are $T \& R$ respectively can be written

Q.49 If a graph is plotted between T^2 and r^3 for a planet then \overrightarrow{O} 58 its slope will be - (A) $4\pi^2/GM$ \sqrt{GM} (B) $GM/4\pi^2$

- **Q.50** A satellite following an elliptical path around a planet has an angular velocity ω_{far} when at its maximum 0.59 distance d units from the planet's center. At its closest point, the distance between the satellite and planet's center is d/3. The satellite's angular velocity at that closest point is:
	- (A) $\omega_{\text{far}}/3$ (B) ω_{far}
(C) $3\omega_{\text{far}}$ (D) $9\omega_{\text{f}}$ (D) 9 ω_{far}
- **Q.51** The planet Neptune travels around the Sun with a period of 165 year. Find the radius of Neptune orbit in $Q.60$ terms of Earth's orbit, both being considered as circular. $(A) 30 R_1$ (B) 25 R₁ (C) 15 R₁ $(D) 10 R_1$

PART - 7 : SATELLITE

- **Q.52** Consider a satellite going round the earth in an orbit. Which of the following statements is wrong
	- (A) It is a freely falling body
	- (B) It suffers no acceleration
	- (C) It is moving with a constant speed
	- (D) Its angular momentum remains constant.
- **Q.53** Two satellites of masses m_1 and m_2 ($m_1 > m_2$) are revolving round the earth in circular orbits of radius r_1 and r_2 ($r_1 > r_2$) respectively. Which of the following statements is true regarding their speeds v_1 and v_2 ? (A) $v_1 = v_2$ (B) $v_1 < v_2$ **EXERUME 12: SATELLITE**

Consider a satellitie going round the eentir of Earth at all times.

(C) points toward the eenter of Earth at all times.

(C) this a freely falling body

(A) It is a freely falling body

(A) It is Consider a satellite going round the earth in an orbit.

(D) points in the direction that the satellite is moving

(A) It is a freely falling body

(B) tustifies no occeleration

(C) It is moving with a constant speed

(C

(C)
$$
v_1 > v_2
$$
 (D) $\frac{v_1}{r_1} = \frac{v_2}{r_2}$

- **Q.54** A geo-stationary satellite is orbiting the earth at a height of 6 R above the surface of earth, R being the radius of earth. The time period of another satellite at a height of 2.5R from the surface of earth is –
	-
	-

Q.55 Two satellites of mass m and 9m are orbiting a planet in orbits of radius R. Their periods of revolution will be in the ratio of –

Q.56 A geostationary satellite is revolving around the earth. To make it escape from gravitational field of earth, is velocity must be increased –

(A) 100% (B) 41.4% (C) 50% (D) 59.6%

**EXERCISE LEASING SET UNITED ANTIFIED STEP SET UNITED MATERIAL: PHYSE

According to Kepler, the period of revolution of a planet Q.55** Two satellites of mass m and 9m are orbiting a planet

(T) and its mean distance from **COLESTION BANK**

According to Kepler, the period of revolution of a planet **O.55** Two satellites of mass m and 9m are orbiting a planet in

(T) and its mean distance from the sun (n) are related by orbits of radius R. Th **COUESTION BANK**

COUESTION BANK STUDY MATERIAL: PHYSICS

According to Kepler, the period of revolution of a planet **Q.55** Two satellites of mass m and 9m are orbiting a planet in

(1) and its mean distance from the sum (**Q.57** The orbital speed of an artificial satellite very close to the surface of the earth is V_0 . Then the orbital speed of another artificial satellite at a height equal to three times the radius of the earth is

(A) 4V⁰ (B) 2V⁰ (C) 0.5 V⁰ (D) 4V⁰

Q.58 The 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) 4T (B) T/4

(C) 8T (D) T/8

- **Q.59** Which of the following statements is incorrect regarding the polar satellites?
	- (A) A polar satellites goes around the earth's pole in north-south direction.
	- (B) Polar satellites are used to study topography of Moon, Venus and Mars.
	- (C) A polar satellite is a high altitude satellite.
	- (D) The time period of polar satellite is about 100minutes.
- **Q.60** A communication satellite is in a circular orbit around Earth. If the speed of the satellite is constant, the force acting on the satellite
	- (A) is zero.
	- (B) is decreasing.
	- (C) points toward the center of Earth at all times.
	- (D) points in the direction that the satellite is moving.

PART - 8 : MISCELLANEOUS

Q.61 Mass of moon is 1/81 times that of earth and its radius is 1/4 the earth's radius. If escape velocity at surface of earth is

- ² **Q.62** Calculate the escape velocity for an atmospheric particle (B) $25 R_1$ (A) is zero.
 ILLITE (B) is decreasing.

(B) is decreasing.

(B) is decreasing.

(D) points to the direction that the satellite

nents is wrong

(D) points in the direction that the satell

mains constant.
 ^{1 00}_{th} vnotatellite is a high differed of Deptute of Neptune orbit in

(C) A polar satellite is a high altitude satellite.

(D) The time period of polar satellite is about 100minutes

on Septeme orbit in

2.60 A commu For the Sun with a pe-

(b) The time period of polar stellite is about 100minutes.

The time period of polar stellite is about 100minutes.

Singlet a science of the seed of the satellite is about 100minutes.

Singlet and 1000 km above the Earth's surface, given that the radius of the Earth = 6.4×10^6 m and acceleration due to gravity on the surface of the Earth = 9.8 m s^{-2} . .
	- (A) 12.42 km/s (B) 10.42 km/s
	- (C) 11.22 km/s (D) 9.42 km/s
	- **Q.63** A particle is suspended from a spring and it stretches the spring by 1 cm on the surface of earth. The same particle will stretch the same spring at a placed 800 Km above earth surface by

- **Q.64** The little prince (the main character of the novel written by antoine de saint-Exupery) lives on the spherical planet named B-612, the density of which is 5200 kg/m³. The $Q.69$ Little Prince noticed that if he quickens his pace, he feels himself lighter. When he reached the speed of 2m/s he became weightless, and began to orbit about the planet as a satellite. What is escape speed on the surface of planet. **VITATION**

The little prince (the main character of the novel written

by antoine de saint-Exupery) lives on the spherical planet

(C) c

named B-612, the density of which is 5200 kg/m³. The

C.69 Let obe the angular v **IVITATION**
 EXERCISE TRIMENT CONSTRAINTS

The little prince (the main character of the novel written

by andone de sain-Extupry) lives on the spherical planet

named B-612, the density of which is 5200 kg/m³. The **Q.**
	-

(C)
$$
4\sqrt{2}
$$
 m/s (D) $8\sqrt{2}$ m/s

Q.65 Suppose earth had no atmosphere and a ball was fired from the top of Mt. Everest in a direction tangent to the ground. If the initial speed is high enough to cause the ball to travel in a circular trajectory around earth, the ball's acceleration would. (g is value of acceleration due to gravity at the surface of earth)

- (A) be much less than g (because the ball doesn't fall to the ground)
- (B) be approximately g
- (C) depend on the ball's speed
- (D) much larger than g
- **Q.66** The acceleration due to gravity on the surface of the moon is 1/6 that on the surface of earth and the diameter of the moon is one-fourth that of earth. The ratio of escape velocities on earth and moon will be –

ball to travel in a circular trajectory around earth, the **Q.70** The kinetic energy of a soll soll saceleration would, (g is value of acceleration due

to gravity at the surface of earth)

to gravity at the surface of ear to gravity at the surface of earth)

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

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

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

(A) be methods than a (because the ball doesn't fall to

(A) be approximately g

(B) approximately g

(D) and **Q.67** The cosmonauts who landed at the pole of a planet found that the force of gravity there is 0.01 of that on the Earth, while the duration of the day on the planet is the same as that on the Earth. It turned out besides that the force of gravity on the equator is zero. Determine the radius R of the planet.

Q.68 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 –

Q.69 Let ω 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 $(d \ll R)$. The value of d is – 2 2 ^R **EXECUTE ARNING**
 EXEC EXERCISED AND RESOLUTION
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2 2 (B) b

2 2 (D) d

2 2 (D) d

2 2 (D) d

2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 3 2 2 2 2 3 2 2 3 2 3 2 3 2 3 2 3 2 3 3 4 4 4 5 2 3 3 3 4 4 5 4 4 5 2 3 3 4 4 5 4 (C) c

(C) c

(Let obe 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

(A)
$$
\frac{\omega^2 R^2}{g}
$$
 \t\t (B) $\frac{\omega^2 R^2}{2g}$
(C) $\frac{2\omega^2 R^2}{g}$ \t\t (D) $\frac{\sqrt{Rg}}{g}$

Q.70 The kinetic energy of a satellite in an orbit close to the surface of the earth is E. What should be its kinetic energy so that it escapes from the gravitational field of the earth ?

$$
(A) \sqrt{2}E \qquad (B) 2E
$$

-
- **Q.71** A geo-stationary satellite orbits around the earth in a circular orbit of radius 36000 km. Then, the time period of a spy satellite orbiting a few hundred kilometers above the earth's surface $(R_{earth}=6400 km)$ will approximately be

Q.72 A simple pendulum has a time period T_1 when on the earth's surface, and T_2 when taken to a height R above the earth's surface, where R is radius of earth. The value of T_2/T_1 is

(A) 1
(B)
$$
\sqrt{2}
$$

(C) 4
(D) 2

Q.73 The figure shows a planet in elliptical orbit around the sun S. Where is the kinetic energy of the planet maximum

Q.74 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 $r + \Delta r$ ($\Delta r \ll r$) with time period $T + \Delta T$ then, s of earth. The value
 $\frac{1}{2}$

cal orbit around the

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 $\rightarrow P_2$
 $\rightarrow P_2$
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earth in an orbit of

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

$$
(A) \frac{\Delta T}{T} = \frac{3}{2} \frac{\Delta r}{r}
$$
 (B) $\frac{\Delta T}{T} = \frac{2}{3} \frac{\Delta r}{r}$

(C)
$$
\frac{\Delta T}{T} = \frac{\Delta r}{r}
$$
 (D) $\frac{\Delta T}{T} = -\frac{\Delta r}{r}$

17

EXERCISE - 2 [LEVEL-2]

ONLY ONE OPTION IS CORRECT

 $(R =$ radius of earth)

Q.1 In an experiment a boy draws graph between v^2 and a^2 (where $v =$ velocity and $a =$ acceleration) for a simple pendulum. The graph is found to be a straight line of negative slope making an angle of 30° when experiment was done on the ground and 60° when experiment was done at height h above the ground. Then h must be

- **Q.2** A magnetic storm from sun can disrupt a satellite as well **Q.7** as move it, either toward or away from Earth radially. Ground-based enginners start it back in a new circular orbit at the new position. Due to the storm –
	- (A) The period of a satellite displaced further away is more than the previous period.
	- (B) The mechanical energy of a satellite displaced towards earth is more than the previous energy.
	- (C) The speed of a satellite displaced further away is more than the previous speed.
	- (D) The angular momentum of a satellite displaced towards earth is more than the previous angular momentum
- **Q.3** A straight rod of length extends L from $x = a$ to $x = L + a$. The gravitational force exerted on a point mass m at

 $x = 0$ if the mass per unit length of the rod is $A + Bx^2$, is

(A) 1 1 GmA BL a L a (C) 1 1 Gm A BL a L a (C) Gm(2)(m m) 1 2

Q.4 Two thin rings each of radius R are coaxially placed at a distance R. The rings have a uniform mass distribution and have mass m_1 and m_2 respectively. Then the work done in moving a mass m from centre of one ring to that of the other is

(A) zero
\n(B)
$$
\frac{Gm(m_1 - m_2)(\sqrt{2} - 1)}{\sqrt{2}R}
$$

\n(C) $\frac{Gm(\sqrt{2})(m_1 - m_2)}{R}$
\n(D) $\frac{Gm m_1(\sqrt{2} + 1)}{m_2 R}$
\n(D) $\frac{Gm m_1(\sqrt{2} + 1)}{m_2 R}$
\n9.8 in parti

Q.5 In older times, people used to think that the earth was flat. Imagine that the earth is indeed not a sphere of radius R, but an infinite plate of thickness H. What value $\overline{0.11}$ of H is needed to allow the same gravitational acceleration to be experienced as on the surface of the actual earth ? (Assume that the earth's density is uniform and equal in the two models)

(A)
$$
2R/3
$$

(B) $4R/3$
(C) $8R/3$
(D) $R/3$

Q.6 Our Sun, with mass 2.0×10^{30} kg, revolves about the center of the Milky Way galaxy, which is 2.2×10^{20} m away, once every 2.5 \times 10⁸ years. Assuming that each of the stars in the galaxy has a mass equal to that of our Sun, that the stars are distributed uniformly in a sphere about the galactic center, and that our Sun is eccentially at the edge of that sphere, estimate roughly the number of stars in the galaxy. stars in the galaxy has a mass equal to that of our
that the stars are distributed uniformly in a sphere
the galactic center, and that our Sun is eccentially
e edge of that sphere, estimate roughly the number
ars in the g of the Milky Way galaxy, which is 2.2 × 10²m
once every 2.5 × 10⁹ years. Assuming that each of
its in the galaxy has a mass equal to that of our
at the stars are distributed uniformly in a sphere
be galactic center, a mass equal to that of our
ted uniformly in a sphere
that our Sun is eccentially
imate roughly the number
(B) 5.1 × 10¹⁶
(D) 5.1 × 10¹⁶
sun is elliptical orbit. The
planet is 4.0 × 10¹⁶ m²/s.
lanet and the sun is
n

(A)
$$
2.1 \times 10^{10}
$$

\n(B) 5.1×10^6
\n(C) 5.1×10^{10}
\n(D) 5.1×10^{16}

Q.7 A planet revolves about the sun is elliptical orbit. The areal velocity (dA/dt) of the planet is 4.0×10^{16} m²/s. The least distance between planet and the sun is

 2×10^{12} m. Then the maximum speed of the planet in km/s is $-$

(A) 10 (B) 20 (C) 30 (D) 40

Q.8 In a certain region of space gravitational field is given by $E = -(K/r)$. Taking the reference point to be at $r = r_0$ with $V = V_0$, the potential is –

(A)
$$
V = V_0 \ln \left(\frac{r}{r_0}\right)
$$

\n(B) $V = V_0 e^{-r/r_0}$
\n(C) $V = V_0 + K \ln \frac{r}{r_0}$
\n(D) $V = V_0 e^{+r/r_0}$

on any gound and of value of the space eight habove the ground. Then h must be

of stars in the galaxy.

(B) 0.24 R

(B) 0.24 R

(C) N and the case consider of this process of earth)

(B) 5.1 × 10⁶

(B) 6.5 × 10¹⁶

(C) S.1 × 10¹⁶

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(C) 5.1×10¹⁰

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The areal velocity (dA/dt) of the planet is 4.0×10¹⁶ m²/s.

The of stars in the galaxy.

(A) 2.1 × 10¹⁰ (D) 5.1 × 10¹⁶

a satellite as well

(C) 5.1 × 10¹⁰ (D) 5.1 × 10¹⁶

m Earth radially, Q.7 A planet revolves about the sun is elliptical orbit. The

in a new circular The lea (A) 2.1 × 10¹⁰ (B) 5.1 × 10⁶

(C) 5.1 × 10¹⁰ (D) 5.1 × 10¹⁶

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the sun are equal to r_1 and r_2 respectively. Find the m experiment was

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(B) 5.1 × 10¹⁶

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of stars in the galaxy.

(A) 2.1 × 10¹⁰ (B) 5.1 × 10¹⁶

(C) 5.1 × 10¹⁶ (D) 5.1 × 10¹⁶

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 (B) 0.24 R

(A) 2.1 × 10¹⁰ (B) 5.1 × 10¹⁶

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R (C) 5.1 × 10¹⁶

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(C) 5.1 × 10¹⁶

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 $1-\pi$

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dege of that sphere, estimate roughly the number

in the galaxy.
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 $\times 10^{10}$ (D) 5.1 × 10¹⁶
 $\times 10^{10}$ (D) 5.1 × 10¹⁶

et revolves **Q.9** A planet of mass m moves along an ellipse around the sun so that its maximum and minimum distances from angular momentum of this planet relative to the centre of the sun. $-r/r_0$
 $-r/r_0$

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 $\frac{Mr_1r_2}{r_1+r_2}$ (D) 40

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\n(B) The mechanical energy of a satellite displaced further away is

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\n(E) The gravitational force exerted on a point mass that

\n(E) The gravitational force exerted on a point mass that

\n(E) The gravitational force exerted on a point mass that

\n(E) The gravitational force exerted on a point mass that

\n(E) The angular momentum of the rod is A + Bx². is

\n(A)
$$
G = V_0 + K \ln \frac{r}{l_0}
$$

\n(B) $V = V_0 \ln \left(\frac{r}{l_0}\right)$

\n(C) $V = V_0 + K \ln \frac{r}{l_0}$

\n(D) $V = V_0 e^{-r/r_0}$

\n29. A planet of mass m moves along an ellipse around the sun are equal to r_1 and r_2 respectively. Find the angular momentum of this planet relative to the centre of the sun.

\n(D) The angular momentum of the sun.

\n(E) The ring have a uniform mass distribution of the sun.

\n(E) $\frac{Gm(n_1 - m_2)(\sqrt{2} - 1)}{\sqrt{2R}}$

\n(E) $\frac{Gm(m_1 - m_2)(\sqrt{2} - 1)}{\sqrt{2R}}$

\n(E) $\frac{Gm(m_1 - m_2)(\sqrt{2} + 1)}{\sqrt{2R}}$

\n(E) $\frac{Gm(m_1 + m_2)(\sqrt{2} + 1)}{\sqrt{2R}}$

\n(E) $\frac{Gm$

2R **Q.10** A particle is fired vertically upward with a speed of 2^R 9.8 m/s². Consider only earth's gravitation. $\frac{1}{2}$ particle. Radius of earth = 6400 km and g at the surface = 9.8 km/s. Find the maximum height attained by the

(A) 17900 km (B) 10900 km (C) 15900 km (D) 20900 km

Q.11 A uniform sphere has a mass M and radius R. Find the pressure P inside the sphere, caused by gravitational compression, as a function of the distance r from the centre. Evaluate P at the centre of the Earth, assuming it to be a uniform sphere.

Q.12 The gravitational potential of two homogeneous spherical shells A and B of same surface density at their respective centres are in the ratio 3 : 4. If the two shells coalesce into single one such that surface charge density remains same, then the ratio of potential at an internal point of the new shell to shell A is equal to – **ION**
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Q.13 A point P lies on the axis of a fixed ring of mass M and radius R, at a distance 2R from its centre O. A small particle starts from P and reaches O under gravitational attraction only. Its speed at O will be –

(A) zero
\n(B)
$$
\sqrt{\frac{2GM}{R}}
$$

\n(C) $\sqrt{\frac{2GM}{R}(\sqrt{5}-1)}$
\n(D) $\sqrt{\frac{2GM}{R}(1-\frac{1}{\sqrt{5}})}$

Q.14 Three identical stars, each of mass M, form an equilateral triangle (stars are positioned at the corners) that rotates around the centre of the triangle. The system is isolated and edge length of the triangle is L. The amount of work done, that is required to dismantle the system is : $\sqrt{\frac{2GM}{R}(\sqrt{5}-1)}$ (D) $\sqrt{\frac{2GM}{R}(1-\frac{1}{\sqrt{5}})}$ (A) $\frac{GMm}{C}|\frac{1}{R}-\frac{1}{r}|$ (B) $\frac{GM}{C}$

eidentical stars, each of mass M, form an equilateral

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 (B) $\frac{3GM^2}{2L}$ (C) $\frac{3GM^2}{4L}$ (D) $\frac{GM^2}{2L}$ the sphere. Find the strength

Q.15 The eccentricity of the earth's orbit is 0.0167. The ratio of its maximum speed in its orbit to its minimum speed is

Q.16 Two bodies of masses M_1 and M_2 are placed at a distance d apart. What is the potential at the position where the gravitational field due to them is zero ?

(C)
$$
\sqrt{\frac{2GM}{R}}(\sqrt{5}-1)
$$
 (D) $\sqrt{\frac{2GM}{R}}(1-\frac{1}{\sqrt{5}})$
\nThree identical stars, each of mass M, form an equilateral
\ntriangle (C) $\frac{1}{2C} [\frac{1}{R} - \frac{1}{L}]$ (D) $\frac{2GMm}{C} [\frac{1}{R}$
\ntriangle (D) $\frac{2GMm}{C} [\frac{1}{R}$
\ntriangle (E) $\frac{1}{R}$
\naround the centre of the triangle: The system is isolated
\ndone, that is required to dismantle the system is :
\n(A) $\frac{3GM^2}{L}$ (B) $\frac{3GM^2}{2L}$ (C) $\frac{3GM^2}{4L}$ (D) $\frac{GM^2}{2L}$
\nThe eccentricity of the earth's orbit is 0.0167. The ratio
\nof its maximum speed in its orbit to its minimum speed is
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\n(b) 0.167 (C) 1 (D) 0.167 (D) 0.167
\n5. (A) 1.67 (B) 1.034
\n(b) 0.167 (E) 1.034
\n(b) 0.167 (E) 0.0167
\n5. (B) 1.034
\n6. (C) 1 (D) 1.034
\n6. (D) 1.04
\n6. (E) 1.05 (E) 1.034
\n6. (A) $\frac{4}{3} G \pi \rho \ell$ (B) $\frac{1}{3} G \pi \rho \ell$ (C) $\frac{2}{3} G \pi \rho \ell$
\n(d) $\frac{2}{3} G \pi \rho \ell$ (e) $\frac{2}{3} G \pi \rho \ell$
\n(f) 1 (g) 1.057 (h) 1.07 (i) 0.0167
\n7. (a) 1.07 (b) 0.0167
\n8. (a) 1.07 (b) 0.0167
\n7. (b) 0.0167 (c) 0.20 The mass M of a planet-centh is uniformly
\ncor a spherical volume of radius R. Calculate
\nd apart. What is the potential at the position where the
\ngravitational field due to them is zero ?

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We homogeneous Q.17 A cavity of radius R/2 is made inside a solid sphere of

face density at their radius R. The center of the cavity is located at a distance

FAC at distance R/2 from the center of **Q.17** A cavity of radius R/2 is made inside a solid sphere of radius R. The centre of the cavity is located at a distance R/2 from the centre of the sphere. The gravitational force on a particle of mass 'm' at a distance R/2 from the centre of the sphere on the line joining both the centres of sphere and cavity is $-$ (opposite to the centre of gravity) SUPER THE CONTROLLER CONTROLLER (SUPER THE CONTROLLER CONTROLLER CONTROLLER TO THE CONTROLLER CONTROLLER THE CONTROLLER CONTROLLER THE CONTROLLER CONTROLLER THE SUPER CONTROLLER CONTROLLER CONTROLLER CONTROLLER CONTROLLER EXERCISE THE CONDUCTER (THE UP)

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[Here $g = GM/R²$, where M is the mass of the sphere]

(A)
$$
\frac{mg}{2}
$$
 (B) $\frac{3mg}{8}$ (C) $\frac{mg}{16}$ (D) None of these

2GM satellite to reach the earth. **Q.18** A satellite of mass m is orbiting the earth in a circular orbit of radius R. It starts losing energy due to small air resistance at the rate of CJ/s. Find the time taken for the

R
\n
$$
\frac{GM}{R} \frac{1}{(1-\frac{1}{\sqrt{5}})}
$$
\n(A)
$$
\frac{GMm}{C} \left[\frac{1}{R} - \frac{1}{r} \right]
$$
\n(B)
$$
\frac{GMm}{2C} \left[\frac{1}{R} + \frac{1}{r} \right]
$$
\n(10)
$$
\frac{2GMm}{C} \left[\frac{1}{R} + \frac{1}{r} \right]
$$
\n(21)
$$
\frac{2GMm}{C} \left[\frac{1}{R} + \frac{1}{r} \right]
$$

Q.19 Inside a uniform sphere of density ρ there is a spherical cavity whose centre is at a distance ℓ from the centre of

 $4L$ ^{2L} 5 of the gravitational field inside the cavity at the point P.

(A)
$$
\frac{4}{3}
$$
 $G\pi\rho\vec{\ell}$ (B) $\frac{1}{3}G\pi\rho\vec{\ell}$ (C) $\frac{2}{3}G\pi\rho\vec{\ell}$ (D) $\frac{1}{2}G\pi\rho\vec{\ell}$

Q.20 The mass M of a planet-earth is uniformly distributed over a spherical volume of radius R. Calculate the energy needed to disassemble the planet against the gravitational pull amongst its constituent particles. the point P.

(a) $\frac{1}{2}$ G $\pi \rho \vec{\ell}$

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 $s - \frac{3\sqrt{3GM}}{8R^3}$

Given : MR = 2.5 × 1031 kg-m and g = 10 m/s² (A) 3.0 × 1032 J (B) 2.5 × 1032 J (C) 0.5 × 1028 J (D) 1.5 × 1032 J

Q.21 A satellite is launched in the equatorial plane in such a way that it can transmit signals upto 60° latitude on the earth. The angular velocity of the satellite is –

(A)
$$
\sqrt{\frac{GM}{8R^3}}
$$
 (B) $\sqrt{\frac{GM}{2R^3}}$ (C) $\sqrt{\frac{GM}{4R^3}}$ (D) $\sqrt{\frac{3\sqrt{3}GM}{8R^3}}$

EXERCISE - 3 (NUMERICAL VALUE BASED QUESTIONS)

NOTE : The answer to each question is a NUMERICAL VALUE.

- **Q.1** If the radius of the earth be increased by a factor of 5, its density should be changed by factor 1/A to keep the value of g same. Find the value of A.
- **Q.2** A man of mass m starts falling towards a planet of mass **Q.7** M and radius R. As he reaches near to the surface, he realizes that he will pass through a small hole in the planet. As he enters the hole, he sees that the planet is really made of two pieces a spherical shell of negligible thickness of mass 2M/3 and a point mass M/3 at the centre. Change in the force of gravity experienced by **EXERCISE - 3 (NUMERICAL VALUE BASED QUESTIONS**
 EXERCISE - 3 (NUMERICAL VALUE BASED QUESTIONS
 Concedit question is a NUMERICAL VALUE. Q.6 Two point masses of mass

of the earth be increased by a factor 1/A to keep t If the radius of the earth be increased by a factor of 5, its spearand by didistance are revolving under mutual force

density should be changed by factor 1/A to keep the

value of A.

A man of mass anstarts failing towar

the man is $\frac{2}{\text{A}} \frac{34 \text{ m}}{\text{R}^2}$. Find the value of A.

- **Q.3** Two planets A and B have the same material density. If the radius of A is twice that of B, then the ratio of the 0.9 escape velocity v_A/v_B is
- **Q.4** The escape velocity of a planet is v_e . A tunnel is dug along a diameter of the planet and a small body is dropped into it at the surface. When the body reaches

the value of A.

Q.5 An artificial satellite moving in a circular orbit around the earth has a total (K.E. + P.E.) = E_0 . Its potential energy is AE_0 . Find the value of A.

- Two point masses of mass 4m and m respectively separated by d distance are revolving under mutual force of attraction. Ratio of their kinetic energies is 1/A. Find the value of A.
- Satellites A and B are orbiting around the earth in orbits of ratio R and 4R respectively. The ratio of their areal velocities is (1/A). Find the value of A.

Q.8 A particle is projected vertically upward from the surface

of the earth with a speed of $\sqrt{\frac{3}{2}} gR$, R being the radius

of the earth and g is the acceleration due to gravity on the surface of the earth. Then the maximum height ascended is aR (neglect cosmic dust resistance). Find the value a. **E BASED QUESTIONS)**
Two point masses of mass 4m and m respectively
separated by d distance are revolving under mutual force
of attraction. Ratio of their kinetic energies is 1/A. Find
the value of A.
Satellites A and B a

Q.9 A missile, which missed its target when into orbit around the earth at a mean radius 3 times as great as the parking

day. Find the value of X.

Q.10 Gravitational acceleration on the surface of a planet is

 $\frac{\sqrt{6}}{11}$ g, where g is the gravitational acceleration on the

surface of the earth. The average mass density of the planet is 2/3 times that of the earth. If the escape speed on the surface of the earth is taken to be 11 km s^{-1} , the escape speed on the surface of the planet in $km s^{-1}$ will be :

EXERCISE - 4 [PREVIOUS YEARS AIEEE / JEE MAIN QUESTIONS]

Q.1 A mass m is raised from a distance 2 Re from surface of earth to 3Re. Work done to do so against gravity will be- **[AIEEE-2002]**

(A)
$$
\frac{mg Re}{10}
$$
 (B) $\frac{mg Re}{11}$ (C) $\frac{mg Re}{12}$ (D) $\frac{mg Re}{14}$

- **EXERCISE 4 [PREVIOUS YEARS AIEEE/JEE MAIN QUI

A mass m is raised from a distance 2 Re from surface of Q.10 If 'g' is the acceleration

earth to 3Re. Work done to do so against gravity will be-

[A)** $\frac{mg Re}{10}$ **(B) \frac Q.2** The escape velocity of a body of mass m from earth depends on - **[AIEEE-2002]** (A) m² $(B) m¹$ $(C) m⁰$ (D) None of above
- **Q.3** If suddenly gravitational force on a satellite becomes zero it will – **[AIEEE-2002]**
	- (A) go in tangential direction of orbit
	- (B) fall on earth
	- (C) follow hellical path towards earth
	- (D) follow hellical path away from earth
- **Q.4** The kinetic energy needed to project a body of mass m from the earth surface (radius R) to infinity is (A) mgR/2 (B) 2 mgR **[AIEEE-2002]**

(C) mgR (D) mgR/4

- **Q.5** The escape velocity for a body projected vertically upwards from the surface of earth is 11 km/s. If the body is projected at an angle of 45º with the vertical, the escape velocity will be– **[AIEEE-2003]** (A) 22 km/s (B) 11 km/s
	-
- **Q.6** 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 – **[AIEEE-2003]** (A) 80 hours (B) 40 hours (C) 20 hours (D) 10 hours
- **Q.7** Two spherical bodies of mass M and 5 M and redii R and 2R respectively 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 just before collision is – **[AIEEE-2003]** $(A) 4.5 R$ (B) 7.5 R $(C) 1.5 R$ (D) 2.5 R
- **Q.8** A satellite of mass m revolves around the earth of radius R at a height x from its surface. If g is the acceleration $Q.16$ due to gravity on the surface of the earth, the orbital speed of the satellite is **[AIEEE-2004]**

(A) gx (B)
$$
\frac{gR}{R-x}
$$
 (C) $\frac{gR^2}{R+x}$ (D) $\left(\frac{gR^2}{R+x}\right)^{1/2}$

- **Q.9** The time period of an earth satellite in circular orbit is independent of – **[AIEEE-2004]**
	- (A) The mass of the satellite.
	- (B) Radius of its orbit.
	- (C) Both the mass and radius of the orbit.
	- (D) Neither the mass of the satellite nor the radius of its orbit.
- **EXERCISE 4 [PREVIOUS YEARS AIEEE/JEE MAIN QUESTIONS]**

sm is raised from a distance 2 Re from surface of Q.10 If 'g' is the acceleration due to gravity

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[AIEEE-2002] **EXECUTE CONSTION BANK**

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[AIEEE-2002] **EVIOUS YEARS AIEEE / JEE MAIN QUESTIONS**

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12 Re from surface of Q.10 If 'g' is the acceleration due to gravity on the earth's

inst gravity will be-

[AIEEE-2002] mass 'm' raised 14 (C) $1/4$ mgR (D) mgR **Q.10** 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– **[AIEEE-2004]** (A) 2 mgR (B) 1/2 mgR **E MAIN QUESTIONS**
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	- **Q.11** Suppose the gravitational force varies inversely as the n th power of distance. Then the time period of a planet in circular orbit of radius 'r' around the sun will be proportional to – **[AIEEE-2004]**

(A)
$$
r^{\frac{n+1}{2}}
$$
 (B) $r^{\frac{n-1}{2}}$ (C) r^n (D) $r^{\frac{n-2}{2}}$

Q.12 Average density of the earth **[AIEEE-2005]** (A) does not depend on g (B) is a complex function of g (C) is directly proportional to g (D) is inversely proportional to g

The escape velocity of a body of mass m from earth

(C) \ln^2

(A) \ln^2

(C) \ln^2

(**Q.13** 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 one of the following is correct ? **[AIEEE-2005]** (A) $d = h/2$ (B) $d = 3h/2$

$$
(C) d = 2h \qquad (D) d = h
$$

Q.14 A particle of mass 10 g is kept on the surface of a uniform sphere of mass 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

 $(Take G = 6.67 \times 10^{-11} Nm^2/kg^2)$) **[AIEEE-2005]** (A) 13.34×10^{-10} J (B) 3.33×10^{-10} J $(C) 6.67 \times 10^{-9}$ J $(D) 6.67 \times 10^{-10}$ J

Q.15 If g_E and g_m are the accelerations due to gravity on the surfaces of the earth and the moon respectively and if Millikan's oil drop experiment could be performed on the two surfaces, one will find the ratio (electronic charge on the moon/ electronic charge on the earth) to be

$$
(A) 1 \t\t (B) 0 \t\t [AIEEE-2007]
$$

- (C) g_F/g_M (D) g_M/g_E
- (C) d=2h

(D) 11 $\sqrt{2}$ km/s

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to take the particle far away from the sphere

to take the particle far awa IEEE-2003]

(A) d = h/2

(C) d = 2h

(C) d = 3h/2

(C) d = 2h

(D) d = h

nours. If the

nours. If the

notarisal of the case (C) d = 2h

(D) d = 1h

(D) d = 1h

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nours. If the worker of mass 10 g is kept on the surface of a uniform

sphere of mass 10 g is kept on the surface of a uniform

sphere of mass 10 g and adis **Statement-1 :** For a mass M kept at the centre of a cube of side 'a', the flux of gravitational field passing through its sides is $4 \pi GM$. and **[AIEEE-2008] Statement-2 :** If the direction of a field due to a point source is radial and its dependence on the distance 'r' from the source is given as $1/r^2$, its flux through a closed surface depends only on the strength of the source enclosed by the surface and not on the size or shape of the surface.

(A) Statement-1 is true, Statement-2 is true; Statement-2 is a correct explanation for Statement-1

(B) Statment-1 is true, Statement-2 is true; Statement-2 is not a correct explanation for Statement-1

- (C) Statement-1 is true, Statement-2 is false
- (D) Statement-1 is false, Statement-2 is true

Q.17 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 is 11 km s^{-1} , the escape velocity from the surface of the planet would be **[AIEEE-2008] EXERCUTE:**

A planet in a distant solar system is 10 times more massive Q.24 A satellite is revolving in

than the earth and its radius is 10 times smaller. Given

than the earth solar system is 10 times smaller. Given

Q.18 The height at which the acceleration due to gravity becomes $g/9$ (where $g =$ the acceleration due to gravity on the surface of the earth) in terms of R, the radius of the earth, is -*[AIEEE-2009]*

(C) $\sqrt{2} R$ (D) 2R

Q.19 Two bodies of masses m and 4m are placed at a distance r. The gravitational potential at a point on the line joining them where the gravitational field is zero is**[AIEEE-2011]**

(A) zero (B)
$$
-\frac{4Gm}{r}
$$
 (C) $-\frac{6Gm}{r}$ (D) $-\frac{9Gm}{r}$ **Q.26**

Q.20 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) are 10m/s^2 and 6400 km (A) respectively. The required energy for this work will be – **[AIEEE-2012]**

Q.21 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 2R?

[JEE MAIN 2013]

(A)
$$
\frac{5\text{GmM}}{6R}
$$
 (B) $\frac{2\text{GmM}}{3R}$ (C) $\frac{\text{GmM}}{2R}$ (D) $\frac{\text{GmM}}{3R}$ **Q.28** Four identical particles of mass M are located at the corners of a square of

Q.22 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)
$$
\sqrt{\frac{GM}{R}(1+2\sqrt{2})}
$$
 (B) $\frac{1}{2}\sqrt{\frac{GM}{R}(1+2\sqrt{2})}$ circumscribing the square?
\n(C) $\sqrt{\frac{GM}{R}}$ (D) $\sqrt{2\sqrt{2}\frac{GM}{R}}$ (A) $1.21\sqrt{\frac{GM}{a}}$ (B) $1.41\sqrt{\frac{GM}{a}}$

Q.23 From a solid sphere of mass M and radius R, a spherical portion of radius $(R/2)$ is removed, as shown in the figure.

Taking gravitational potential $V = 0$ at $r = \infty$, the potential at the centre of the cavity thus formed is

(G = gravitational constant) **[JEE MAIN 2015]**

(A)
$$
\frac{-GM}{R}
$$
 (B) $\frac{-2GM}{3R}$ (C) $\frac{-2GM}{R}$ (D) $\frac{-GM}{2R}$ (A) $E/4$ (C) $E/32$

Q.24 A satellite is revolving in a circular orbit at a height 'h' from the earth's surface (radius or earth R; $h \ll R$). The minimum increase in its orbital velocity required, so that the satellite could escape from the earth's gravitational field, is close to: (Neglect the effect of atmosphere) **STUDYMATERIAL: PHYSICS**

A satellite is revolving in a circular orbit at a height 'h'

from the earth's surface (radius or earth R; h <<R). The

minimum increase in its orbital velocity required, so that

the satellite **STUDY MATERIAL: PHYSICS**

A satellite is revolving in a circular orbit at a height 'h'

from the earth's surface (radius or earth R; h <<R). The

minimum increase in its orbital velocity required, so that

the satellite

[JEE MAIN 2016]

$$
(A) \sqrt{gR} \qquad (B) \sqrt{gR/2}
$$

Q.25 The variation of acceleration due to gravity g with distance d from centre of the earth is best represented by $(R = Earth's radius)$: **[JEE MAIN 2017]**

$$
(A) \bigcup_{O}^{g} (B) \bigcup_{R}^{g} (B) \bigcup_{O}^{g} (C) \bigcap_{R}^{g} (D) \bigcup_{O}^{g} (D) \bigcup_{A}^{g}
$$

 $4Gm \t\t 6Gm \t\t 6Gm$ $9Gm \t\t 9Gm$ 26 A particle is moving with a uniform speed in a circular $-\frac{2GM}{r}$ Q.20 A particle is moving with a difficult of radius R in a central force inversely proportional to the nth power of R. If the period of rotation of the particle is T, then: *[JEE MAIN 2018]* (A) $T \propto R^{(n+1)/2}$ (B) T \propto R^{n/2}

(C)
$$
T \propto R^{3/2}
$$
 for any n
 (D) $T \propto R^{\frac{n}{2}+1}$

Q.27 If the angular momentum of a planet of mass m, moving around the Sun in a circular orbit is L, about the center of the Sun, its areal velocity is : **[JEE MAIN 2019 (JAN)]** (A) 4L/m (B) L/m

$$
(C) L/2m \qquad (D) 2L/m
$$

 $rac{3R}{3R}$ (C) $rac{2R}{3R}$ (D) $rac{3R}{3R}$ are located at the corners of a square of ass of a spaceship is 1000 kg. It is to be launched

ass of a spaceship is 1000 kg. It is to be launched

to the nth power of R. If the per

te earth's surface out into free space. The value of

the nth power of R. If $\frac{1}{\sqrt{2}}$ (B) = Transfer and the m^h power of R. If the period of rotation of the particle is 3, that is the nearbor of R. If the period of rotation of the singular momentum (A) T ∞ Rⁿ⁺¹⁾² (B) T ∞ Rⁿ⁺²
for this lm/s² and 6400 km

fr this work will be-

this work will be-
 4×10^8 Judes

(ATEEE-2012] (C) T \propto R^{3/2} for any n (D) T \propto R³⁺¹
 4×10^{10} Judes

Q.27 If the angular momentum of a planet of mass m, mov side 'a'. What should be their speed if each of them revolves under the influence of other's gravitational field in a circular orbit circumscribing the square? **[JEE MAIN 2019 (APRIL)]**

1

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a and a structure of the structure

square?

Figure (1 + 2√2)	square?	[JEE MAN2019 (APRIL)]
\overline{SM}	(A) 1.21 $\sqrt{\frac{GM}{a}}$	(B) 1.41 $\sqrt{\frac{GM}{a}}$
R, a spherical	(C) 1.16 $\sqrt{\frac{GM}{a}}$	(D) 1.35 $\sqrt{\frac{GM}{a}}$

$$
\frac{\text{3M}}{\text{a}}
$$
 (D) 1.35 $\sqrt{\frac{\text{GM}}{\text{a}}}$

Q.29 A rocket has to be launched from earth in such a way that it never returns. If E is the minimum energy delivered by the rocket launcher, what should be the minimum energy that the launcher should have if the same rocket is to be launched from the surface of the moon ? Assume that the density of the earth and the moon are equal and that the earth's volume is 64 times the volume of the moon : **[JEE MAIN 2019 (APRIL)]**

Q.30 A satellite of mass M is launched vertically upwards with an initial speed u from the surface of the earth. After it reaches height R ($R =$ radius of the earth), it ejects a rocket of mass M/10 so that subsequently the satellite moves in a circular orbit. The kinetic energy of the rocket is (G is the gravitational constant; M_e is the mass of the earth): **[JEE MAIN 2020 (JAN)] EXECUTE AS AND THE SET UP ON A SAMPLE SET UP AND ANTION BANK**

A satellite of mass M is launched vertically upwards **Q.32** Consider two solid spheres of radii R₁ = 1m,

with an initial speed u from the surface of the e **ON COUESTION BANK**

lite of mass M is launched vertically upwards **Q.32** Consider two solid spheres of radii R₁ = 1m,

limitial speed u from the surface of the earth,

reaches height R (R = radius of the earth), it rea **OND**

(OUESTION BANK)

lite of mass M is launched vertically upwards **0.32** Consider two solid spheres of radii $R_1 = 1m$,

initial speed u from the surface of the earth), it

reaches height R (R = radius of the earth), **MITATION**

A satellite of mass M is launched vertically upwards **Q.32** Consider two solid spheres of radii R₁ = 1m,

with an initial speed u from the surface of the earth.

A satellite norse high R (R = radius of the e **EXECUTE SET CONSUMERED ANTENDAMENT (OUTESTION BANK)**

THE SET CONSIDENT BANK (RET rations of the earth, it it reaches height R (RET rations of the earth), it is a rocket of mass M/10 so that subsequently the wind of M₁ **ION COUESTION BANK**

Lite of mass M is launched vertically upwards **Q.32** Consider two solid spheres of radii R₁ = 1m,

initial speed u from the surface of the earth, $R_2 = 2m$ and masses M_1 and M_2 , respectively. (III: of mass M is launched vertically upwards Q.32 Consider two solid spheres of radii R₁ = 1m,

imids need u from the surface of the earth), it

reaches height R (R = radius of the earth), it

reaches height R (R = ra

(A)
$$
5M\left(u^2 - \frac{119 \text{ GM}_e}{200 \text{ R}}\right)
$$

\n(B) $5M\left(u^2 - \frac{113 \text{ GM}_e}{200 \text{ R}}\right)$
\n(C) $\frac{M}{20}\left(u^2 - \frac{119 \text{ GM}_e}{100 \text{ R}}\right)$
\n(D) $\frac{M}{20}\left(u^2 - \frac{113 \text{ GM}_e}{200 \text{ R}}\right)$

Q.31 A box weighs 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):

Q.32 Consider two solid spheres of radii $R_1 = 1m$, $R_2 = 2m$ and masses M_1 and M_2 , respectively. The gravitational field due to sphere 1 and 2 are shown. The value of M_1/M_2 is : is : **[JEE MAIN 2020 (JAN)]**

EXECUTE ANTIVE ANTIVE ANTIVE SET AND SURFACE SURFACE SURFACE SURFACE SURFACE SURFACE OF the earth, it spread to the and masses M_1 **and** M_2 **, respectively. The states also the earth, it spread to the and** M_1M_2 **is th Q.33** An asteroid is moving directly towards the centre of the earth. When at a distance of 10R (R is the radius of the earth) from the earths centre, it has a speed of 12 km/s. Neglecting the effect of earths atmosphere, what will be the speed of the asteroid when it hits the surface of the earth (escape velocity from the earth is 11.2 km/s) ? Give your answer to the nearest integer in kilometer/s

[JEE MAIN 2020 (JAN)]

EXERCISE - 5 (PREVIOUS YEARS AIPMT/NEET EXAM QUESTIONS)

Choose one correct response for each question.

Q.1 Imagine a new planet having the same density as that of earth but it is 3 times bigger than the earth in size. If the acceleration due to gravity on the surface of earth is g and that on the surface of the new planet is g', then –
(A) $g' = g/9$ (B) $g' = 27g$ **[AIPMT 200**

(A)
$$
g' = g/9
$$

\n(B) $g' = 27g$ [AIPMT 2005]
\n(C) $g' = 9g$
\n(D) $g' = 3g$ Q.9

Q.2 For a satellite moving in an orbit around the earth, the ratio of kinetic energy to potential energy is

(A)
$$
1/2
$$
 (B) $1/\sqrt{2}$ [AIPMT 2005]

Q.3 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 equal is fv, where v is its escape velocity from the surface of the earth. The value of f is – **[AIPMT 2006] EXERCISE - 5 (PREVIOUS YEARS AIPMIT/BET EXAM QUESTIONS)**
 EXERCISE - 5 (PREVIOUS YEARS AIPMIT/NEET EXAM QUESTIONS)
 EXERCISE - 5 (PREVIOUS YEARS AIPMIT/NEET EXAM QUESTIONS)

and distance them in sight than the cart i

Q.4 Two satellites of 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 potential energies of earth satellites in the two cases are equal.

- (B) S_1 and S_2 are moving with the same speed
- (C) The kinetic energies of the two satellites are equal.
- (D) The time period of S_1 is four times that of S_2 .
- **Q.5** 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 (A) and t_2 is the time to move from A to B then

 $(C) t_1 = t_2$ $(D) t_1 > t_2$ **Q.6** The radii of circular orbits of two satellites A and B of the earth, are 4R and R, respectively. If the speed of satellite A is 3V, then the speed of satellite B will be –

Q.7 A particle of mass M is situated at the center 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 (PRE) 2010]**

(A)
$$
-\frac{3GM}{a}
$$
 (B) $-\frac{2GM}{a}$ (C) $-\frac{GM}{a}$ (D) $-\frac{4GM}{a}$

EXERCISE - 5 (PREVIOUS VEARS AIPMT/NEET EXAM QUESTIONS)
 EXERCISE - 5 (PREVIOUS VEARS AIPMT/NEET EXAM QUESTIONS)
 EXERCISE - 5 (PREVIOUS VEARS AIPMT/NEET EXAM QUESTIONS)
 EXERCISE - 5 (PREVIOUS VEARS AIPMT/NEET EXA Q.8 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 v_1/v_2 is [AIPMT (PRE) 2011] (A) r_1/r_2 $\rm (\bar{B})$ $\rm (r_1/r_2)^2$ $(C) r_2/r_1$ $(D) (r_2/r_1)^2$

The height at which the weight of a body becomes 1/ $16th$, its weight on the surface of earth (radius R), is :

- (C) 2 (D) 2 **Q.10** 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 **[AIPMT (PRE) 2012]** (A) $4GM_p/D_p^2$ 2 (B) GM_pm/D_p²₂ 2
	- (C) GM_p $/D_p^2$ (D) $4GM_pm/D_p²$ **Q.11** A geostationary satellite is orbiting the earth at a height of 5R above that surface of the earth, R being the radius of the earth. The time period of another satellite in hours at a height of 2R from the surface of the earth is :

- (A) r_1/r_2 (B) $(r_1/r_2)^2$

(C) r_2/r_1 (D) $(r_2/r_1)^2$

The height at which the weight of a body becomes 1/

16th, its weight on the surface of earth (radius R), is:

16th, its weight on the surface of earth (radius **Q.12** Infinite number of bodies, each of mass 2 kg are situated on x-axis at distance 1m, 2m, 4m, 8m,, respectively, from the origin. The resulting gravitational potential due to this system at the origin will be – **[NEET 2013]** $(A) - 4G$ (B) –G (C) (–8/3) G (D) (–4/3) G
- **Q.13** 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 $(D) 100$ m
- **Q.14** Dependence of intensity of gravitational field (E) of earth with distance (r) from centre of earth is correctly represented by – **[AIPMT 2014]**

Q.15 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
 $2mc_8R^2$

relation between G and K is described as:**[AIPMT 2015]** (A) GMK = $4\pi^2$ $(B) K = G$ (C) K = $1/G$ (D) GK = $4\pi^2$

- **Q.16** 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, **[RE-AIPMT 2015]**
	- (A) the acceleration of S is always directed towards the centre of the earth.
	- (B) the angular momentum of S about the centre of the earth changes in direction, but its magnitude remains constant.
	- (C) the total mechanical energy of S varies periodically with time.
	- (D) the linear momentum of S remains constant in $Q.24$ magnitude.
- **Q.17** 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**[RE-AIPMT 2015]** (A) 6.67 km/s (B) 7.76 km/s (C) 8.56 km/s (D) 9.13 km/s
- **Q.18** 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

Q.19 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 PHASE 1]**

(A) 1 : 2 (B) 1 :
$$
2\sqrt{2}
$$
 (C) 1 : 4 (D) 1 : $\sqrt{2}$ (C) Raindrops will fall faster.

Q.20 Starting from the centre of the earth having radius R, the variation of g (acceleration due to gravity) is shown by

Q.21 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 PHASE 2]** DDM ADVANCED LEARNING

arth (of radius R) at

nergy of the satellite

ion due to gravity at

T 2016 PHASE 2]
 $\frac{mg_0R^2}{R + h}$

height 1 km above

elow the surface of

[NEET 2017]

NK	CDMADVAINGED LEARINING
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 $[\text{NEET 2016 PHASE 2}]$	
(A) $\frac{mg_0R^2}{2(R+h)}$	(B) $-\frac{mg_0R^2}{2(R+h)}$
(C) $\frac{2mg_0R^2}{R+h}$	(D) $-\frac{2mg_0R^2}{R+h}$
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 = 1 km	(B) d = 2/3 km
(C) d = 2 km	(D) d = 1/2 km
(C) d = 2 km	(D) d = 1/2 km
Two astronauts are floating in gravitational free space after having lost contact with their spaceship. The two	

EDENTADYANGED LEARNING
 EXECUTE 2016 PHASE 2
 $\frac{mg_0R^2}{2(R+h)}$
 $\frac{2mg_0R^2}{R+h}$
 $t \text{ a height 1 km above}$
 $d = 2/3 \text{ km}$ **SPONDIVANCED LEARNING**

Earth (of radius R) at

nergy of the satellite

ion due to gravity at

ET 2016 PHASE 2]
 $\frac{mg_0R^2}{R+h}$
 $\frac{2mg_0R^2}{R+h}$

height 1 km above

below the surface of

[NEET 2017]

= 2/3 km

itationa **SPARE AND ADVANCED LEARNING**
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 EXECUTE 2016 PHASE 21
 $-\frac{mg_0R^2}{2(R+h)}$
 $-\frac{2mg_0R^2}{R+h}$
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 $-\frac{2mg_0R^2}{R+h}$
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 EXE Q.22 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]** $(A) d = 1 km$ (B) $d = 2/3 km$

(C)
$$
d = 2 \text{ km}
$$
 (D) $d = 1/2 \text{ km}$

- **Q.23** Two astronauts are floating in gravitational free space after having lost contact with their spaceship. The two will – **INEET 2017**
	- (A) Move towards each other.
	- (B) Move away from each other.
	- (C) Will become stationary
	- (D) Keep floating at the same distance between them.
- , **Q.24** 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 **B** [NEET 2018]

(A)
$$
K_B < K_A < K_C
$$

\n(C) $K_A < K_B < K_C$
\n(D) $K_B > K_A > K_C$
\n(E) $K_A > K_C$
\n(E) $K_A > K_C$

Q.25 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.
-
- (D) 'g' on the Earth will not change.
- **Q.26** 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]** $(A) 150 N$ (B) 200 N
	- $(C) 250 N$ (D) 100 N
- **Q.27** 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) mgR (B) 2mgR

(C)
$$
\frac{1}{2}
$$
 mgR \t\t(D) $\frac{3}{2}$ mgR

 \mathbf{I}

ANSWER KEY

EXERCISE - 2

$$
\Gamma \sin \theta = \frac{Gm^2}{(a - x)^2} \quad ; \quad \Gamma \cos \theta = mg
$$

Dividing we get,
$$
\tan \theta = \frac{mG}{(a - x)^2 g}
$$

$$
T = 2\pi \sqrt{\frac{\ell}{a - x}}
$$

$$
\lim_{\text{mg}} \leftarrow a-x
$$
\n
$$
\lim_{\text{mg}} \left(\frac{1}{a-x}\right)^2
$$
\n<

Get $E = constant$

- (3) (A). As E is constant, so the Potential (V = $-\int$ E dr) will be proportional to r.
- **(4)** Conservation of energy says

$$
-\frac{GMm}{R} + \frac{1}{2}m (v_0)^2 = -\frac{GMm}{R_E} + \frac{1}{2}mv^2
$$

where M is the mass of the earth and R_E is its radius, the initial separation is $R = 80,000 \times 10^3$ m, and initial velocity is $v_0 = 2000$ m/s from which we get v = 1.09×10^4 m/s.

(5) The gravitational field at any point on the ring due to the sphere is equal to the field due to single particle of mass M placed at the centre of the sphere.

Thus, the force on the ring due to the sphere is also equal to (9) the force on it by particle of mass M placed at this point. By Newton's third law it is equal to the force on the particle by the ring. Now the gravitational field due to the ring at a

$$
g = \frac{Gmd}{(a^2 + d^2)^{3/2}} = \frac{\sqrt{3}Gm}{8a^2}
$$

The force on sphere of mass M placed here is

$$
= Mg = \frac{\sqrt{3GMm}}{8a^2}
$$

LIITIONS

\n
$$
g = \frac{Gmd}{(a^{2} + d^{2})^{3/2}} = \frac{\sqrt{3}Gm}{8a^{2}}
$$
\nThe force on sphere of mass M placed here is

\n
$$
F = Mg = \frac{\sqrt{3}GMm}{8a^{2}}
$$
\n(6) (A). $g = \frac{GM}{R^{2}} = \frac{G(\rho)(\frac{4}{3}\pi R^{3})}{R^{2}} = \frac{4}{3}G\pi\rho R$

\n
$$
g \propto R
$$
\nAs Radius of the moon is one forth so g on moon is also one fourth.

\nTime period of a second pendulum on the earth.

\n
$$
T = 2\pi \sqrt{\frac{\ell}{\rho}}
$$
\n1.44 m\rho = 1.2 m\sqrt{\frac{\ell}{\rho}}

As Radius of the moon is one forth so g on moon is also one fourth.

Time period of a second pendulum on the earth.

(a x) g r 0 E.ds 4 G dv r 0 ^k E 4 r 4 G 4 r dr **(3) (A).** As E is constant, so the Potential (V = E dr 2 2 GMm 1 GMm 1 m (v) mv R 2 R 2 earth T 2 g ; at moon moon T 2 g Dividing, moon earth g 1 g 4 9.2 24.8cm 4 g R h ² 1 R 2 R h R 1 R h ² R h ² 2 1 0.414 h 0.414 R 0.414 6400 km or h = 2649.6 km

(7) We know that
$$
\frac{g_h}{g} = \left(\frac{R}{R+h}\right)^2
$$
; But $g_h = \frac{g}{2}$

$$
\therefore \quad \frac{1}{2} = \left(\frac{R}{R+h}\right)^2 \quad \text{or} \quad \frac{R}{R+h} = \frac{1}{\sqrt{2}}
$$

or
$$
\frac{R+h}{R} = \sqrt{2}
$$
 or $\frac{h}{R} = \sqrt{2} - 1 = 0.414$

At a height of 2649.6 km from the Earth's surface, the acceleration due to gravity will be half its value on the surface. **(8)** Consider small element dx of the rod whose mass

fourth.
\nTime period of a second pendulum on the earth.
\n
$$
T = 2\pi \sqrt{\frac{\ell}{g_{\text{earth}}}}
$$
; at moon $T = 2\pi \sqrt{\frac{\ell}{g_{\text{moon}}}}$
\nDividing, $\ell' = \ell \frac{g_{\text{moon}}}{g_{\text{earth}}} = \ell(\frac{1}{4})$
\n
$$
\ell' = \frac{99.2}{4} = 24.8 \text{cm}
$$
\nWe know that $\frac{g_h}{g} = (\frac{R}{R+h})^2$; But $g_h = \frac{g}{2}$
\n $\therefore \frac{1}{2} = (\frac{R}{R+h})^2$ or $\frac{R}{R+h} = \frac{1}{\sqrt{2}}$
\nor $\frac{R+h}{R} = \sqrt{2}$ or $\frac{h}{R} = \sqrt{2} - 1 = 0.414$
\n $h = 0.414 \times R = 0.414 \times 6400 \text{ km}$ or $h = 2649.6 \text{ km}$
\nAt a height of 2649.6 km from the Earth's surface, the acceleration due to gravity will be half its value on the surface.
\nConsider small element dx of the rod whose mass
\n
$$
dm = \frac{M}{\ell} dx
$$

\n
$$
dm = \frac{M}{\ell} dx
$$

\n
$$
= \frac{M}{\ell} dx
$$

\n
$$
= \frac{1}{\ell} dU = -\frac{GmM}{\ell} \int_{\frac{1}{\ell}}^{\frac{1}{\ell}} \frac{dx}{x} = -\frac{GmM}{\ell} [\ln x]_a^{\frac{1}{\ell} + \ell}
$$

\n
$$
\Rightarrow U = -\frac{GmM}{\ell} \log_e (\frac{a+\ell}{a})
$$

\nFig. shows three particles located at vertices A, B and C of
\nparticles move in a circle with O as the centre and radius
\n $r = OA = OB = OC$
\n
$$
= \frac{BD}{\cos 30^\circ} = \frac{a}{\sqrt{3}/2} = \frac{a}{\sqrt{3}}
$$

(9) Fig. shows three particles located at vertices A, B and C of an equilateral triangle of sides $AB = BC = CA = a$. These particles move in a circle with O as the centre and radius $r = OA = OB = OC$

$$
r = \frac{BD}{\cos 30^{\circ}} = \frac{a/2}{\sqrt{3}/2} = \frac{a}{\sqrt{3}}
$$

Let us find the net gravitational force acting on one particle, say at A, due to particles at B and C.

Particle at A is attracted

towards B with a force, $F_1 = \frac{Gmm}{a^2}$ and towards C with a $I_{far} \omega_{far} = I_{near} \omega_{near}$

force,
$$
F_2 = \frac{Gmm}{a^2}
$$
 Setting

Notice that $F_1 = F_2 = F$ (say) = $\frac{2}{\sqrt{2}}$. 2 a^2

The angle between these equal forces is $\theta = \angle BAC = 60^{\circ}$. The resultant force on the particle at A is

 $F_r = (F^2 + F^2 + 2F^2 \cos 60^\circ)^{1/2}$

$$
\Rightarrow
$$
 F_r = $\sqrt{3}$ F ; F_r = $\sqrt{3} \frac{Gm^2}{a^2}$ directed along AO.

Thus the net force on particle at A is radial. Similarly, the net force on particle at B and at C is F_r , each directed towards centre O. This force provides the necessary centripetal force. If v is the required initial velocity of each particle,

towards B with a force,
$$
F_1 = \frac{Gmn}{a^2}
$$
 and towards C with a
\nforce, $F_2 = \frac{Gmn}{a^2}$
\nforce, $F_2 = \frac{Gmn}{a^2}$
\nNotice that $F_1 = F_2 = F (say) = \frac{Gm^2}{a^2}$.
\nNotice that $F_1 = F_2 = F (say) = \frac{Gm^2}{a^2}$.
\nTo
\nThe angle between these equal forces is $0 = \angle BAC = 60^\circ$.
\nThe result for one on particle at A is
\n $F_1 = (F^2 + F^2 + F^2 + 2F^2 \cos 60^\circ)^{1/2}$
\n $\Rightarrow F_1 = \sqrt{3}F$; $F_1 = \sqrt{3} \frac{Gm^2}{a^2}$ directed along AO.
\nThe result for one on particle at A is
\n $F_1 = (F^2 + F^2 + 2F^2 \cos 60^\circ)^{1/2}$
\n $\Rightarrow F_1 = \sqrt{3}F$; $F_1 = \sqrt{3} \frac{Gm^2}{a^2}$ directed along AO.
\nThe result of force on particle at A is
\ncentre on particle at A is radiated towards
\ncentre O. This force provides the necessary centripetal force.
\nIf v is the required initial velocity of each particle.
\n $\Rightarrow F_1 = \sqrt{3} \frac{Gm^2}{a^2}$
\n $\Rightarrow \frac{Gm^2}{f}$
\n $\Rightarrow \frac{Gm^2}{f}$
\n $\Rightarrow \frac{Gm^2}{f}$
\n $\Rightarrow \frac{Gm^2}{f}$
\n $\frac{Gm^2}{a}$
\n $\Rightarrow \frac{Gm^2}{f}$
\n $\frac{Gm^2}{a}$
\n $\Rightarrow \frac{Gm^2}{f}$
\n $\frac{Gm^2}{a}$
\n $\Rightarrow \frac{Gm^2}{f}$
\n $\Rightarrow \frac{Gm^2}{f^2} = \frac{Gm^2}{a}$
\n $\Rightarrow \frac{Gm^2}{f}$
\n $\Rightarrow \frac{Gm^2}{f^2} = \frac{Gm}{a}$
\n $\Rightarrow \frac{Gm}{f}$
\n $\Rightarrow \frac{Gm}{f}$
\n

rom eq. (1) and (2),
$$
V_e = \sqrt{2 \times 2V^2} \Rightarrow V_e = 2V
$$

STUDY MATERIAL: PHYSICS
\n**(2)** (A). L = mvr
$$
\Rightarrow
$$
 L = m $\sqrt{\frac{GM}{r}}$ r
\n \Rightarrow L = m \sqrt{GMr} (1)
\nL = 2m $\frac{dA}{dt}$ (2)
\nFrom eq. (1) and (2),
\n $\frac{dA}{dt} \propto \sqrt{r} \Rightarrow \frac{(dA/dt)_1}{(dA/dt)_2} = \sqrt{\frac{4}{1}} = \frac{2}{1}$
\n**(3)** (D).
\n**(4)** (D). As there are no external torques acting on the system, angular momentum is conserved.
\n $I_{far} \omega_{far} = I_{near} \omega_{near}$

$$
\frac{dA}{dt} \propto \sqrt{r} \Rightarrow \frac{(dA/dt)_1}{(dA/dt)_2} = \sqrt{\frac{4}{1}} = \frac{2}{1}
$$

(3) (D).

(4) (D). As there are no external torques acting on the system, angular momentum is conserved.

$$
I_{far} \omega_{far} = I_{near} \omega_{near},
$$

or $(mR_{far}^2) \omega_{far} = (mR_{near}^2) \omega_{near}.$
Setting $R_{near} = d/3$ and $R_{far} = d$,
we get $\omega_{near} = 9\omega_{far}.$

 $\frac{Gm^2}{2}$. An alternative is to look at the same of the same o An alternative is to look at the body's translational motion. We can write the conservation of angular momentum as R_{far} $x p_{\text{far}} = R_{\text{near}} x p_{\text{near}}$

 $\frac{1}{3}$ Gm² directed along AO. so the cross products become (p)(R)sin 90^o terms and we At the near and far points, the angle between R and p is 90° , , can write $(mv_{far}) d = (mv_{near}) (d/3)$, or $v_{near} = 3v_{far}$.

Noting that
$$
v_{far} = d\omega_{far}
$$
 and $v_{near} = (d/3) \omega_{near}$,
we can rewrite $v_{near} = 3v_{far}$ as $(d/3) \omega_{near} = 3(d) \omega_{far}$,

or $\omega_{\text{near}} = 9\omega_{\text{far}}$.

(5) (AC).

a Gm conclusion, though there are several steps analyzing kinetic $\frac{3}{3}$ or $v = \sqrt{\frac{3m}{a}}$ and gravitational potential energy to get there. $v = \sqrt{\frac{3m}{m}}$ (A) Ultimately conservation of energy can lead you to this

 $\int_{1/2}^{1/2}$ Velocity. This is silly. (B) There is no such law as Conservation of Angular

 $R\omega^2 = \frac{g}{2}$ a clear and direct path to $v_A = v_B$. and variables the cross products become (p)(R)sin 90° terms and w

can write $(mv_{far}) d = (mv_{near}) (d/3)$, or $v_{near} = 3v_{far}$.

Similarly, the net

of directed towards

of directed towards

or $w_{ear} = 9\omega_{far}$

(5) (AC).

(A) Ultimate (C) An analysis using conservation of Angular Momentum leads directly to $m_A v_A R_A \sin \theta_A = m_B v_B R_B \sin \theta_B$, and given that R , θ , and m are the same at positions A and B, you have we can rewrite $v_{near} = 3v_{far}$ as (d/3) $\omega_{near} = 3(d) \omega_{far}$
or $\omega_{near} = 9\omega_{far}$.
(5) (AC).
(A) Ultimately conservation of energy can lead you to this
conclusion, though there are several steps analyzing kinetic
and gravitation

2 (D) Conservation of electrical charge, though true, does not help you with this problem.

 $T = 6 \times 10^{15}$ s = 200 Million years.

28

GRAVITATION TRY SOLUTIONS

(7) The law of conservation of energy says that at any two points on the orbit labelled 1 and 2, **TRY SOLUTIONS**

ation of energy says that at any two The semi major axis of such ellipse is

belled 1 and 2,
 $\frac{2}{1^2} = -\frac{GMm}{r_2} + \frac{1}{2}mv_2^2$
 $\frac{1}{2^2} = \left[\frac{R}{2}\right]^3 \left[\frac{1}{R^3}\right]$

Where T is the time period of nor **ON**

of conservation of energy says that at any two

the orbit labelled 1 and 2,
 $\frac{\pi m}{1} + \frac{1}{2} m v_1^2 = -\frac{GMm}{r_2} + \frac{1}{2} m v_2^2$
 $\frac{Mm}{1} = R_E + 890 \text{km} = 6.37 \times 10^6 \text{m} + 8.9 \times 10^5 \text{m}$
 $\frac{1}{1} = 7.23 \times 10^3 \text{m/s$ **TRY SOLUTIONS**

w of conservation of energy says that at any two

on the orbit labelled 1 and 2,

GMm $+\frac{1}{2}mv_1^2 = -\frac{GMm}{r_2} + \frac{1}{2}mv_2^2$
 $\frac{GMm}{r_1} + \frac{1}{2}mv_1^2 = -\frac{GMm}{r_2} + \frac{1}{2}mv_2^2$

Where T is the time perio **EXECUTIONS**

Experimental of energy says that at any two

The semi-major axis of such ellipse is R/2.

It labelled 1 and 2,
 $mv_1^2 = -\frac{GMm}{r_2} + \frac{1}{2}mv_2^2$
 $v_1 = \frac{GMm}{r_2} + \frac{1}{2}mv_2^2$
 $v_2 = \left[\frac{R}{2}\right]^3 \left[\frac{1}{R^3}\right]$ **ON**

of conservation of energy says that at any two

of conservation of energy says that at any two

The semi major axis of such ellipse is R/2.

the orbit labelled 1 and 2,
 $\frac{Mm}{I_1} + \frac{1}{2}mv_1^2 = -\frac{GMm}{I_2} + \frac{1}{2}mv$ **EXECUTION**

Law of conservation of energy says that at any two

the semi-major axis of such ellipse is R/2.

Is on the orbit labelled 1 and 2,
 $-\frac{GMm}{r_1} + \frac{1}{2}mv_1^2 = -\frac{GMm}{r_2} + \frac{1}{2}mv_2^2$
 \therefore Now $\frac{T'^2}{T^2} = \left$

$$
-\frac{GMm}{r_1} + \frac{1}{2}mv_1^2 = -\frac{GMm}{r_2} + \frac{1}{2}mv_2^2
$$

Cancelling m and plugging in

$$
r_1 = R_E + 890 \text{km} = 6.37 \times 10^6 \text{m} + 8.9 \times 10^5 \text{m}
$$

and $v_1 = 7.23 \times 10^3$ m/s

and similarly for r_2 , we find $v_2 = 7.95$ km/s.

(8) **30 R**₁.

$$
T_1 = T_{Earth} = 1
$$
 year, $T_2 = T_{Neptune} = 165$ year

Let R_1 and R_2 be the radii of the circular orbits of Earth and

ANTIATION
\nThe law of conservation of energy says that at any two
\npoints on the orbit labelled 1 and 2,
\n
$$
-\frac{GMm}{r_1} + \frac{1}{2}mv_1^2 = -\frac{GMm}{r_2} + \frac{1}{2}mv_2^2
$$
\n
$$
-\frac{GMm}{r_1} + \frac{1}{2}mv_1^2 = -\frac{GMm}{r_2} + \frac{1}{2}mv_2^2
$$
\n
$$
r_1 = R_E + 890 \text{km} = 6.37 \times 10^6 \text{m} + 8.9 \times 10^5 \text{m}
$$
\nand $v_1 = 7.23 \times 10^3 m/s$
\nand similarly for r_2 , we find $v_2 = 7.95$ km/s.
\n30 R_1 .
\n
$$
T_1 = T_{Earth} = 1 \text{ year, } T_2 = T_{Neptune} = 165 \text{ year}
$$
\n
$$
T_1 = \frac{T}{R_{eff}} = \frac{365}{4\sqrt{2}} \approx 65 \text{ day}
$$
\n
$$
T_2 = \frac{R_1^3}{R_2^3} \therefore R_2^3 = \frac{R_1^3 T_2^2}{T_1^2} \text{ or } R_2 \approx 30 R_1.
$$
\n
$$
R_3 = \frac{R_1^3}{R_3} \therefore R_3^3 = 165^2 R_1^3 \text{ or } R_2 \approx 30 R_1.
$$
\n
$$
R_4 = \frac{R_1^2}{R_3} \therefore R_4^3 = \frac{R_1^3 T_2^2}{R_4^3} \text{ or } R_5 \approx 30 R_1.
$$
\n
$$
R_5 = \frac{R_1^2}{R_5} \text{ and } R_6 = \frac{4\pi^2 R_3}{4\sqrt{2}}
$$
\n
$$
R_6 = \frac{4\pi^2 R_3^3}{4\sqrt{2}}
$$
\n
$$
R_7 = \frac{R_1^3}{R_2^3} \therefore R_2^3 = 165^2 R_1^3 \text{ or } R_2 \approx 30 R_1.
$$
\n
$$
R_8 = \frac{R_1^2 R_2^3}{R_
$$

(7) The law of conservation of energy says that at any two The semi major axis of such ellipse is R/2.

points on the orbit habelled 1 and 2,
 $-\frac{GMm}{t_1} + \frac{1}{2}mv_1^2 = -\frac{GMm}{2} + \frac{1}{2}mv_2^2$

(Ancelling mand plugging in
 into the Sun and (suppose) it comes back. If the effect of temperature of Sun is ignored, we can say that the Earth would continue to move along a strongly extended flat ellipse whose extreme points are located at the Earth's orbit and at the centre of the Sun.

The semi major axis of such ellipse is R/2.

Now
$$
\frac{T'^2}{T^2} = \left[\frac{R}{2}\right]^3 \left[\frac{1}{R^3}\right]
$$

Where T is the time period of normal orbit of earth.

TRY SOLUTIONS
\n
$$
\begin{array}{rcl}\n\text{TRY SOLUTIONS} & \text{DeMADVANCED LEARNING} \\
\hline\n\text{DeMADVANCED LEARNING} \\
\text{DeMADVANCED LEARNING} \\
\text{Delled 1 and 2,} \\
\text{1: } & \frac{1}{1} = -\frac{GMm}{r_2} + \frac{1}{2}mv_2^2 \\
\text{1: } & \frac{1}{1} = -\frac{GMm}{r_2} + \frac{1}{2}mv_2^2\n\end{array}
$$
\n
$$
\begin{array}{rcl}\n\text{Now} & \frac{T'^2}{T^2} = \left[\frac{R}{2}\right]^3 \left[\frac{1}{R^3}\right] \\
\text{Where T is the time period of normal orbit of earth.} \\
\text{Using in} & \text{or} & \frac{T'^2}{2} = \frac{T^2}{8} \text{ or } & \frac{T'}{2\sqrt{2}}\n\end{array}
$$

Now, time required to fall into the Sun,

$$
t = \frac{T'}{2} = \frac{T}{4\sqrt{2}} = \frac{365}{4\sqrt{2}} \approx 65 \text{ day}
$$

mi major axis of such ellipse is R/2.

T¹² = $\left[\frac{R}{2}\right]^3 \left[\frac{1}{R^3}\right]$

T is the time period of normal orbit of earth.
 $r^2 = \frac{T^2}{8}$ or $T' = \frac{T}{2\sqrt{2}}$
 $\frac{1}{2} = \frac{T}{4\sqrt{2}} = \frac{365}{4\sqrt{2}} \approx 65$ day

E Earth would tak So, the Earth would take slightly more than 2 months to fall into the Sun.

Now $\frac{T'^2}{T^2} = \left[\frac{R}{2}\right]^3 \left[\frac{1}{R^3}\right]$

Where T is the time period of normal orbit of earth.
 5^5m or $T'^2 = \frac{T^2}{8}$ or $T' = \frac{T}{2\sqrt{2}}$

Now, time required to fall into the Sun,
 $t = \frac{T'}{2} = \frac{T}{4\sqrt{2}} = \frac{365}{4\sqrt{2}} \$ TRV SOLUTIONS

Solutions The semi-major axis of such ellipse is R/2.
 $\frac{1}{2}$
 $\frac{1}{2}$

Now $\frac{T'^2}{T^2} = \left[\frac{R}{2}\right]^3 \left[\frac{1}{R^3}\right]$

Where T is the time period of normal orbit of earth.

8.9 × 10⁵m or $T'^2 = \frac{T^2}{8}$ Sigmin major axis of such ellipse is R/2.

T² = $\left[\frac{R}{2}\right]^3 \left[\frac{1}{R^3}\right]$

Te T is the time period of normal orbit of earth.

T² = $\frac{T^2}{8}$ or T' = $\frac{T}{2\sqrt{2}}$

t, time required to fall into the Sun,

t = $\frac{T'}{2$ **EXERCISE A FAILURE 12**
 EXERCISE A FAILURE 2
 EXERCISE A FAILURE 2
 EXERCISE 2
 EXECUTE:
 E (10) If R is the radius of the lunar orbit. T is the time period of the

Mass of the Earth
$$
M_e = \frac{4 \pi^2 R^3}{GT^2}
$$

f normal orbit of earth.

T
 $\sqrt{2}$

o the Sun,

65 day

htly more than 2 months to fall

orbit. T is the time period of the
 $\frac{2 R^3}{T^2}$
 $4 \times 60 \times 60$ second; R = 3.9 × 10⁵
 $10^{-11} N m^2 kg^{-2}$ s of such ellipse is R/2.
 $\int_0^3 \left[\frac{1}{R^3} \right]$

e period of normal orbit of earth.
 $T' = \frac{T}{2\sqrt{2}}$

to fall into the Sun,
 $= \frac{365}{4\sqrt{2}} \approx 65$ day

d take slightly more than 2 months to fall

the lunar orbit. T is Here, T = 27.3 days = 27.3 \times 24 \times 60 \times 60 second; R = 3.9 \times 10⁵ $\text{km} = 3.9 \times 10^8 \text{ m}, \text{G} = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$

Substituting the values, we get

or
$$
T'^2 = \frac{T^2}{8}
$$
 or $T' = \frac{T}{2\sqrt{2}}$
\nNow, time required to fall into the Sun,
\n $t = \frac{T'}{2} = \frac{T}{4\sqrt{2}} = \frac{365}{4\sqrt{2}} \approx 65$ day
\nSo, the Earth would take slightly more than 2 months to fall
\ninto the Sun.
\nIf R is the radius of the lunar orbit. T is the time period of the
\nMoon around the Earth.
\nMass of the Earth $M_e = \frac{4\pi^2 R^3}{GT^2}$
\nHere, T = 27.3 days = 27.3 × 24 × 60 × 60 second; R = 3.9 × 10⁵
\n $cm = 3.9 \times 10^8$ m, G = 6.67 × 10⁻¹¹ N m² kg⁻²
\nSubstituting the values, we get
\n $M_e = \frac{4 \times (3.142)^2 \times (3.9 \times 10^8)^3}{6.67 \times 10^{-11} \times (27.3 \times 24 \times 60 \times 60)^2}$ kg = 6.3×10²⁴ kg

CHAPTER-9 : GRAVITATION EXERCISE-1

(1) (A). The situation is as shown in the figure. According to \int \int CM Newton's law of gravitation, gravitational force **(1) (A) The situation**
 (1) (A) INSERCISE-1

shown in the figure.

According to

shown is as

shown is a solved by the strain of the particular

gravitation,

gravitation,

gravitation,

gravitation,

gravitati

between two bodies of masses m_1 and m_2 is

 $\begin{pmatrix} m_1 \\ n_2 \end{pmatrix}$ $\begin{pmatrix} 1 \\ n_1 \end{pmatrix}$ $\begin{pmatrix} 1 \\ n_2 \end{pmatrix}$ r_1 r_2

$$
F = \frac{Gm_1m_2}{r^2}
$$
, where r is the distance between the two

masses. Hence,
$$
r = r_1 + r_2
$$
 \therefore $F = \frac{Gm_1m_2}{(r_1 + r_2)^2}$

(2) (C).
$$
F = G \frac{m_1 m_2}{r^2} = 6.675 \times \frac{1 \times 1}{1^2} \times 10^{-11} = 6.675 \times 10^{-11} N
$$
 (1)

(3) (A).
$$
F_G = \frac{Gm_1m_2}{r^2}
$$

shown in the figure.

According to

Newton's law of

gravitation,

gravitational force

between two bodies of masses m_1 and m_2 is
 $F = \frac{Gm_1m_2}{r^2}$, where r is the distance between the two

masses. Hence, $r = r_1 +$ Doubling the value of either one of the masses, while (15) not changing anything else, will double the value of the force.

Newton's law of
gravitational force
gravitational force
between two bodies of masses
$$
m_1
$$
 and m_2 is
 $F = \frac{Gm_1m_2}{r^2}$, where r is the distance between the two
masses. Hence, $r = r_1 + r_2$ \therefore $F = \frac{Gm_1m_2}{(r_1 + r_2)^2}$
(11) (B). Travitational potential
 $V = Gravitational potential
 $V = Gravitational potential
 $(V_1) + Gravitational field
 $(V_1) + Gritational field
 $(V_1) + Grit$$$

- **(5) (B).** The Moon remains in its orbit around the Earth because it is in balance with the gravitational forces from the Sun and other planets.
- **(6) (B).** It will remain the same as the gravitational force is independent of the medium separating the masses.

(7) **(A).**
$$
F \propto xm \times (1-x)m = xm^2(1-x)
$$

\nFor maximum force $\frac{dF}{dx} = 0$
\n $\Rightarrow \frac{dF}{dx} = m^2 - 2xm^2 = 0 \Rightarrow x = 1/2$

- **(8) (D).** We know that, for $r \le R$, $I = 0$ and $r \ge R$; $I \propto 1/r^2$. So the curve (D) gives the correct relationship.
- **(9) (A).** The gravitational field at any point on the ring due to the sphere is equal to the field due to single particle of mass M placed at the centre of the sphere.

The force on sphere of mass M placed here is

$$
F = Mg = \frac{\sqrt{3}GMm}{8a^2}
$$

CHAPTER 9: GRANTATION	Q.B.-SOLUTION	STUDY MATERIAL: PHYSICS		
CHAPTER 9: GRANTATION	(10) (C). Gravitational intensity is zero at all points inside a hol low spherical shell the net gravitational force acting on the particle at the centre and at any other point equation, gravitational force	the particle at the centre and at any other point gravitational force	the particle at the centre and at any other point gravitational force	the particle at the centre and at any other point gravitational potential on the surface of the shell is reavitational potential on the surface of the shell is reavitational potential on the surface of the field masses. Hence, $r = r_1 + r_2$ \therefore $F = \frac{Gm_1m_2}{(r_1 + r_2)^2}$ \n $F = G \frac{m_1m_2}{r^2} = 6.675 \times \frac{1 \times 1}{1^2} \times 10^{-11} = 6.675 \times 10^{-11} \text{ N}$ \n $F_G = \frac{Gm_1m_2}{r^2}$ \n $G = \left(\frac{\pi}{T^2}R^3\rho\right)^2$ \n $G = \left(\frac{\pi}{T^2}R$

(11) (B). The gravitational intensity at P will be along 'e'.

(12) (C). Gravitational potential on the surface of the shell is
$$
V = G
$$
ravitational potential due to particle

 (V_1) + Gravitational potential due to shell itself (V_2)

$$
-\frac{Gm}{R} + \left(-\frac{G3m}{R}\right) = -\frac{4Gm}{R}
$$

 $(+r_2)^2$ due to the block. **(13) (C).** Inside the shell gravitational field due to the shell will be zero but there will be some gravitational field

⁴ G R ⁴ 2 2 4 ^R ⁹ **(14) (D).** V^g = Vg1 + Vg2 1 2 = – 6.67 × 10–11 (R R) GM g on surface of earth

(C). The P.E. of the object on the surface of earth is

$$
U_1 = -\frac{GMm}{R}
$$

The P.E. of object at a height R, $U_2 = -\frac{GMm}{(R+R)}$

The gain in P E is
$$
U_2 - U_1 = \frac{GMm}{2R} = \frac{1}{2}
$$
 mgR
\n
$$
\begin{bmatrix} \dots & \text{g} - \frac{GM}{2} \text{ on surface of earth} \end{bmatrix}
$$

 R^2 constructed cannot

(16) (B). From figure,

$$
F = \frac{Gm_1m_2}{r^2}
$$
, where r is the distance between the two
masses. Hence, $r = r_1 + r_2$ \therefore $F = \frac{Gm_1m_2}{(r_1 + r_2)^2}$
\n
$$
F = \frac{Gm_1m_2}{r} = \frac{F}{(r_1 + r_2)^2}
$$

\n
$$
F = \frac{Gm_1m_2}{(r_1 + r_2)^2}
$$

\n
$$
F = \frac{Gm_1m_2}{r^2} = 6.675 \times \frac{1 \times 1}{1^2} \times 10^{-11} = 6.675 \times 10^{-11} N
$$

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

\n
$$
F = \frac{Gm_1m_2}{R}
$$

\n
$$
F = \frac{Gm_1m_1}{R}
$$

\n
$$
F = \frac{Gm_1m_1}{R}
$$

\n
$$
F = \frac{Gm_1}{R}
$$

\n
$$
F = \frac{G
$$

$$
= G \frac{m_1 m_2}{r^2} = 6.675 \times \frac{1 \times 1}{1^2} \times 10^{-11} = 6.675 \times 10^{-11} N
$$
 (14) (D) $V_g = V_{g_1} + V_{g_2} = -\frac{Gm_1}{r_1} - \frac{Gm_2}{r_2}$
\n
$$
= -6.67 \times 10^{-11} \left[\frac{10^2}{0.5} + \frac{10^3}{0.5} \right] = -1.47 \times 10^{-7} \text{ Joule/kg}
$$
\n
$$
= \frac{G \times m \times m}{r^2} = \frac{G \times \left(\frac{4}{3} \pi R^3 p\right)^2}{4R^2} = \frac{4}{9} \pi^2 p^2 R^4
$$
\n
$$
= \frac{G \times m \times m}{(2R)^2} = \frac{G \times \left(\frac{4}{3} \pi R^3 p\right)^2}{4R^2} = \frac{4}{9} \pi^2 p^2 R^4
$$
\nThe E.E. of object at a height R, $U_2 = -\frac{GMm}{R}$
\n
$$
= \frac{G \times m \times m}{\sqrt{2R}}
$$
\n
$$
= \frac{G \times m \times m}{\sqrt{2R}}
$$
\n
$$
= \frac{G \times m \times m}{\sqrt{2R}}
$$
\n
$$
= \frac{G \times m}{\sqrt{2R}}
$$
\n
$$
= \frac{G \times m \times m}{\sqrt{2R}}
$$
\n
$$
= \frac{G \times m \times m}{\sqrt{2R}}
$$

$$
+\left(-\frac{Gm^2}{\ell}\right)+\left(-\frac{Gm^2}{\ell\sqrt{2}}\right)+\left(-\frac{Gm^2}{\ell}\right)
$$

$$
=-\frac{4Gm^2}{\ell} - \frac{2Gm^2}{\ell \sqrt{2}} = -\frac{2Gm^2}{\ell} \left(2 + \frac{1}{\sqrt{2}}\right)
$$

(17) (C). Let M_e be the mass of the earth.

The work required W = GM_e m
$$
\left[\frac{1}{R_e} - \frac{1}{R_e + h} \right]
$$

IDENTIFY
\n
$$
= -\frac{4Gm^2}{\ell} - \frac{2Gm^2}{\ell\sqrt{2}} = -\frac{2Gm^2}{\ell} \left(2 + \frac{1}{\sqrt{2}}\right)
$$
\n(29) (B) $g' = g\left(1 - \frac{d}{R}\right) \Rightarrow \frac{g}{4} = g\left(1 - \frac{d}{R}\right) \Rightarrow d = \frac{3}{4}R$
\nLet M_e be the mass of the earth.
\nThe work required $W = GM$, $m = \frac{R}{R_e}$ and $m = \frac{R}{R_e}$.
\nThe work required $W = GM$, $m = \frac{R}{R_e}$ and $m = \frac{R}{R_e}$.
\nThe work required $W = GM$, $m = \frac{R}{R_e}$ and $m = \frac{R}{R_e}$.
\n
$$
= \frac{GM}{R_e(R_e + h)} = \frac{8R_e^2m h}{R_e(R_e + h)} = \frac{mah}{\left(1 + \frac{h}{R_e}\right)}
$$
\n(31) (A) $g = \frac{GM}{R^2} = \frac{G(p)\left(\frac{4}{3}\pi R^3\right)}{R^2} = \frac{4}{3}G\pi pR$; $g \propto R$
\nAlso one fourth.
\n[$\therefore GM_e = gR_e^2$]
\n $g = \frac{4}{3}\pi\rho GR$. If $\rho = \text{constant then } \frac{g_1}{g_2} = \frac{R}{R_2}$
\n $g' = \frac{4}{3}G\pi R\rho \Rightarrow \frac{g_1}{g_2} = \frac{\rho_1R_1}{\rho_2R_1} = \frac{1}{2} \times \frac{4}{1} = \frac{2}{1}$
\n $g' = g\left(\frac{R}{R + h}\right)^2 \Rightarrow \frac{g}{g} = g\left(\frac{R}{R + h}\right)^2 \Rightarrow \frac{1}{2} = \frac{R}{R + h}$
\n $g' = g\left(\frac{R}{R + h}\right)^2 \Rightarrow \frac{g}{\sqrt{2}} = \frac{g}{R + h}$
\n $\Rightarrow R + h = 2R \therefore h = R$
\n $g' = g\left(\frac{R}{$

(18) (A).
$$
g = \frac{4}{3}\pi \rho GR
$$
. If $\rho = \text{constant}$ then $\frac{g_1}{g_2} = \frac{R_1}{R_2}$

(19) (C). $g = \frac{4}{3} G \pi R \rho \Rightarrow \frac{g_1}{g_1} = \frac{\rho_1 R_1}{\rho_2 R_1} = \frac{1}{2} \times \frac{4}{1} = \frac{2}{1}$ $\rho_2 R_2 \quad 2 \quad 1 \quad 1$ Dividing

(20) **(B).**
$$
g' = g\left(\frac{R}{R+h}\right)^2 \Rightarrow \frac{g}{4} = g\left(\frac{R}{R+h}\right)^2 \Rightarrow \frac{1}{2} = \frac{R}{R+h}
$$
 (32) **(D).** $v_e = \sqrt{\frac{1}{2}g}$

 \Rightarrow R + h = 2R : h = R

(21) (C). Acceleration due to gravity at poles is independent of the angular speed of earth.

(22) (A). For condition of weightlessness of equator

$$
\omega = \sqrt{\frac{g}{R}} = \frac{1}{800} = 1.25 \times 10^{-3} \frac{\text{rad}}{\text{s}}
$$

R_o(R_c + h) R_c(R_c + h)
\nR_c(R_c + h) R_c(R_c + h)
\n[
$$
\cdot
$$
 GM_c = gR_c²]
\n(19) (A) $g = \frac{4}{3}\pi\rho GR$. If p = constant then $\frac{g_1}{g_2} = \frac{R_1}{R_2}$
\n(19) (C) $g = \frac{4}{3}\text{G}rR\rho \Rightarrow \frac{g_1}{g_2} = \frac{\rho_1R_1}{\rho_2R_2} = \frac{1}{2} \times \frac{4}{1} = \frac{2}{1}$
\n(19) (D) $g' = g(\frac{R}{R+h})^2 \Rightarrow \frac{g_1}{g_2} = \frac{\rho_1R_1}{R_2} = \frac{1}{2} \times \frac{4}{1} = \frac{2}{1}$
\n(20) (B) $g' = g(\frac{R}{R+h})^2 \Rightarrow \frac{g_1}{g_2} = g(\frac{R}{R+h})^2 \Rightarrow \frac{1}{2} = \frac{R}{R+h}$
\n(21) (C) According to the gravity at poles is independent
\n $\sigma = \sqrt{\frac{g}{R}} = \frac{1}{800} = 1.25 \times 10^{-3} \frac{1}{10}$
\n(22) (A). For condition of weightlessness of equator
\n $\sigma = \sqrt{\frac{g}{R}} = \frac{1}{800} = 1.25 \times 10^{-3} \frac{1}{10}$
\n(23) (B) $v_e = \sqrt{\frac{2GM}{R}} = R\sqrt{\frac{g}{3}\pi G\rho}$
\n(25) (B) . $g' \approx \rho R$
\n(26) (B) . $g \approx \rho R$
\n(27) (C) $g = g(\frac{R}{R+h})^2 \Rightarrow \frac{1}{\sqrt{2}} = \frac{R}{R+h}$
\n(28) (D) $g' = g(\frac{R}{R+h})^2 \Rightarrow \frac{1}{\sqrt{2}} = \frac{R}{R+h}$
\n(39) $(\frac{g}{\sqrt{2}}\sqrt{$

(25) (B). As $g = \frac{GM}{R^2}$ therefore 1% decrease in mass will **(35) (A).** $v = \sqrt{2gR}$: $\frac{V}{V}$ $=\frac{GM}{R^2}$ therefore 1% decrease in mass will (35)

decreases the value of g by 1%.

But 1% decrease in radius will increase the value of g by 2%. As a whole value of g increase by 1%.

(26) (B). The value of g at the height h from the surface of

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

The value of g at depth x below the surface of earth, (37)

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

These two are given equal, hence

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

On solving, we get $x = 2h$

(27) (D). Because acceleration due to gravity decreases.

(28) (C).
$$
g' = g \left(\frac{R}{R+h}\right)^2 = \frac{4}{9}g
$$
 : $W' = \frac{4}{9}W$

Q.B.-SOLUTIONS
\n
$$
\left(2+\frac{1}{\sqrt{2}}\right)
$$
\n(29) (B). $g' = g\left(1-\frac{d}{R}\right) \Rightarrow \frac{g}{4} = g\left(1-\frac{d}{R}\right) \Rightarrow d = \frac{3}{4}R$
\nh.
\n(A) $g = \frac{GM}{R^2} = \frac{G}{R} \left(\frac{1}{3} - \frac{d}{R}\right) \Rightarrow \frac{1}{3} = \frac{3}{4}R$

$$
(30) \quad (C). \; g \propto \frac{1}{R^2} \; ; \; R \downarrow g \uparrow
$$

2 2 2 4Gm 2Gm 2Gm 1 ² 2 2 ^m e e 1 1 R R h 2 2 g R g R g R 1 4 2 g R 2 1 1 ² g R 4 R h 1 R 2 R h **(29) (B).** d g d g ' g 1 g 1 R 4 R g ; R g **(31) (A).** 3 2 2 ⁴ G () R GM 4 ³ g G R R R ³ ; g ^R **(33) (B).** ^e 2GM 8 v R G

 $\left(1 + \frac{h}{R}\right)$ As radius of the moon is one forth so g on moon is R_e also one fourth.

Time period of a second pendulum on the earth.

(Q.B.-SOLUTIONS)
\n(29) (B).
$$
g' = g\left(1 - \frac{d}{R}\right) \Rightarrow \frac{g}{4} = g\left(1 - \frac{d}{R}\right) \Rightarrow d = \frac{3}{4}R
$$

\n(30) (C). $g \propto \frac{1}{R^2}$; $R \downarrow g \uparrow$
\n $\frac{1}{g h}$
\n(31) (A). $g = \frac{GM}{R^2} = \frac{G(\rho)\left(\frac{4}{3}\pi R^3\right)}{R^2} = \frac{4}{3}G\pi \rho R$; $g \propto R$
\nAs radius of the moon is one forth so g on moon is
\nalso one fourth.
\n $M_e = gR_e^2$ $\frac{R_1}{R_2}$ $T = 2\pi \sqrt{\frac{\ell}{g_{earth}}}$; at moon T = $2\pi \sqrt{\frac{\ell'}{g_{moon}}}$
\nDividing, $\ell' = \ell \frac{g_{moon}}{g_{earth}} = \ell \left(\frac{1}{4}\right)$; $\ell' = \frac{99.2}{4} = 24.8 \text{cm}$
\n $\frac{R}{R + h}$ (32) (D). $v_e = \sqrt{\frac{2GM}{g_{earth}}}$ i.e. escape velocity depends upon the

Dividing,
$$
\ell' = \ell \frac{\text{g}_{\text{moon}}}{\text{g}_{\text{earth}}} = \ell \left(\frac{1}{4} \right)
$$
; $\ell' = \frac{99.2}{4} = 24.8 \text{cm}$

Q.B.-SOLUTIONS
\n**Q.B.-SOLUTIONS**
\n**Q. B.**
$$
g' = g\left(1 - \frac{d}{R}\right) \Rightarrow \frac{g}{4} = g\left(1 - \frac{d}{R}\right) \Rightarrow d = \frac{3}{4}R
$$
\n**Q. B.**
$$
g' = \frac{1}{R^2}; \quad R \downarrow g \uparrow
$$
\n**Q. B.**
$$
g' = \frac{GM}{R^2} = \frac{G(\rho)\left(\frac{4}{3}\pi R^3\right)}{R^2} = \frac{4}{3}G\pi \rho R; \quad g \propto R
$$
\nAs radius of the moon is one fourth so g on moon is also one fourth of a second pendulum on the earth.
\n**R.**
\n**R.**

33) (**B**).
$$
v_e = \sqrt{\frac{2GM}{R}} = R \sqrt{\frac{8}{3} \pi G \rho}
$$

$$
\frac{v_e}{v_p} = \frac{R_e}{R_p} = \frac{1}{2} \implies v_e = \frac{v_p}{2}
$$

(34) (A). Escape velocity does not depend on the mass of the

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

35) (A).
$$
v = \sqrt{2gR}
$$
 : $\frac{v_1}{v_2} = \sqrt{\frac{g_1}{g_2} \times \frac{R_1}{R_2}} = \sqrt{g \times K} = (Kg)^{1/2}$

ER :. h=R

R. :. h=R

and radius of the planet.

Ingular speed of earth,
 $\left(\frac{33}{200}\right)$ (b) $v_e = \sqrt{R}$. Le. exapte velocity

mass and radius of the planet.

In mean density is constant then
 $\left(\frac{33}{200}\right)$ (B) $v_e = \sqrt$ **(32) (D).** $v_e = \ell \frac{g_{\text{moon}}}{g_{\text{earth}}} = \ell \left(\frac{1}{4}\right)$; $\ell' = \frac{99.2}{4} = 24.8 \text{cm}$
 (32) (D). $v_e = \sqrt{\frac{2GM}{R}}$ i.e. escape velocity depends upon the mass and radius of the planet.
 (33) (B). $v_e = \sqrt{\frac{2GM}{R}} = R \sqrt{\frac{8}{$ e. escape velocity depends upon the

of the planet.
 $\sqrt{\frac{8}{3}\pi G\rho}$

is constant then $V_e \propto R$
 $V_e = \frac{V_p}{2}$

does not depend on the mass of the
 $v_e = \sqrt{\frac{2GM}{R}}$
 $\frac{1}{2} = \sqrt{\frac{g_1}{g_2} \times \frac{R_1}{R_2}} = \sqrt{g \times K} = (Kg)^{1/2}$ Example velocity depends upon the

2. escape velocity depends upon the

2. of the planet.
 $\sqrt{\frac{8}{3}\pi Gp}$

is constant then $V_e \propto R$
 $V_e = \frac{V_p}{2}$

does not depend on the mass of the
 $v_e = \sqrt{\frac{2GM}{R}}$
 $\frac{1}{2} = \sqrt{\frac{g_1}{$ V g_{moon}

<u>g_{moon}</u> = $\ell\left(\frac{1}{4}\right)$; $\ell' = \frac{99.2}{4} = 24.8 \text{cm}$

.e. escape velocity depends upon the

so of the planet.
 $R\sqrt{\frac{8}{3}\pi G\rho}$

y is constant then $V_e \propto R$
 $\Rightarrow V_e = \frac{V_p}{2}$

y does not depend on the mass $\frac{99.2}{4} = 24.8 \text{cm}$
depends upon the
 $v_e \propto R$
n the mass of the
 $\frac{g \times K}{g \times K} = (Kg)^{1/2}$
locity then it will
and at infinity its
less than escape
be negative. This $\frac{g_{\text{moon}}}{g_{\text{earth}}} = \ell \left(\frac{1}{4} \right)$; $\ell' = \frac{99.2}{4} = 24.8 \text{cm}$
i.e. escape velocity depends upon the
ss of the planet.
 $R \sqrt{\frac{8}{3} \pi G \rho}$
y is constant then $V_e \propto R$
 $\Rightarrow V_e = \frac{V_p}{2}$
y does not depend on the mass of the $\frac{1}{\pi}$ at moon T = 2π $\sqrt{\frac{2}{g_{\text{moon}}}}$
 $\frac{1}{\pi}$ = $\ell\left(\frac{1}{4}\right)$; $\ell' = \frac{99.2}{4} = 24.8$ cm

escape velocity depends upon the

f the planet.

f the planet.
 $\frac{8}{3}\pi Gp$

constant then v_e α R

e = $\frac{v_p}{2}$
 (36) (B). If missile launched with escape velocity then it will escape from the gravitational field and at infinity its total energy becomes zero. But if the velocity of projection is less than escape **(34) (A).** Escape velocity does not depend on the mass of the

projectile. $v_e = \sqrt{\frac{2GM}{R}}$
 (35) (A). $v = \sqrt{2gR}$ $\therefore \frac{v_1}{v_2} = \sqrt{\frac{g_1}{g_2} \times \frac{R_1}{R_2}} = \sqrt{g \times K} = (Kg)^{1/2}$
 (36) (B). If missile launched wi scape velocity does not depend on the mass of the

ojectile. $v_e = \sqrt{\frac{2GM}{R}}$
 $= \sqrt{2gR}$ $\therefore \frac{v_1}{v_2} = \sqrt{\frac{g_1}{g_2} \times \frac{R_1}{R_2}} = \sqrt{g \times K} = (Kg)^{1/2}$
 \therefore missile launched with escape velocity then it will

cape from $v_e = \sqrt{\frac{v_e}{R}} = R\sqrt{\frac{1}{3}}\pi G\rho$

f mean density is constant then $v_e \propto R$
 $\frac{v_e}{v_p} = \frac{R_e}{R_p} = \frac{1}{2} \Rightarrow v_e = \frac{v_p}{2}$

Siscape velocity does not depend on the mass of the

projectile. $v_e = \sqrt{\frac{2GM}{R}}$
 $v = \sqrt{2gR}$ $\therefore \frac{v$ $v_e = \sqrt{\frac{2GM}{R}} = R\sqrt{\frac{8}{3}\pi G\rho}$

f mean density is constant then $v_e \propto R$
 $\frac{v_e}{v_p} = \frac{R_e}{R_p} = \frac{1}{2} \Rightarrow v_e = \frac{v_p}{2}$

Secape velocity does not depend on the mass of the

rojectile. $v_e = \sqrt{\frac{2GM}{R}}$
 $v = \sqrt{2gR}$ $\therefore \frac{v_1$ e \propto R

i the mass of the
 $\frac{1}{3 \times K}$ = (Kg)^{1/2}

ocity then it will

and at infinity its

less than escape

be negative. This

g on the satellite.
 $v_p = \sqrt{\frac{2}{3}} v_e$
 $\sqrt{1 \times 4} = 2$ **(34) (A).** Escape velocity does not depend on the mass of the

projectile. $v_e = \sqrt{\frac{2GM}{R}}$
 (35) (A). $v = \sqrt{2gR}$ $\therefore \frac{v_1}{v_2} = \sqrt{\frac{g_1}{g_2} \times \frac{R_1}{R_2}} = \sqrt{g \times K} = (Kg)^{1/2}$
 (36) (B). If missile launched wi $e = \frac{p}{2}$

oes not depend on the mass of the
 $= \sqrt{\frac{2GM}{R}}$
 $= \sqrt{\frac{g_1}{g_2} \times \frac{R_1}{R_2}} = \sqrt{g \times K} = (Kg)^{1/2}$

dd with escape velocity then it will

ravitational field and at infinity its

mes zero.

y of projection is $\sqrt{\frac{8}{3}} \pi G_P$

is constant then $v_e \propto R$
 $v_e = \frac{v_p}{2}$

does not depend on the mass of the
 $v_e = \sqrt{\frac{2GM}{R}}$
 $\frac{1}{2} = \sqrt{\frac{g_1}{g_2} \times \frac{R_1}{R_2}} = \sqrt{g \times K} = (Kg)^{1/2}$

ered with escape velocity then it will

gravitationa ∞ R

he mass of the
 $\overline{K} = (Kg)^{1/2}$

ity then it will

d at infinity its

ss than escape

negative. This

on the satellite.
 $= \sqrt{\frac{2}{3}}v_e$
 $\sqrt{1 \times 4} = 2$
 $\frac{gR}{2}$ (1) v_e = $\frac{v_p}{2}$

is constant then v_e \propto R

v_e = $\frac{v_p}{2}$

does not depend on the mass of the
 $v_e = \sqrt{\frac{2GM}{R}}$
 $= \sqrt{\frac{g_1}{g_2} \times \frac{R_1}{R_2}} = \sqrt{g \times K} = (Kg)^{1/2}$

end with escape velocity then it will

gravitatio The planet.

Solution

onstant then $v_e \propto R$
 $= \frac{v_p}{2}$

s not depend on the mass of the
 $\sqrt{\frac{2GM}{R}}$
 $\sqrt{\frac{g_1}{g_2} \times \frac{R_1}{R_2}} = \sqrt{g \times K} = (Kg)^{1/2}$

with escape velocity then it will

vitational field and at infinit (A). Escape velocity does not depend on the mass of the
projectile. $v_e = \sqrt{\frac{2GM}{R}}$
(A). $v = \sqrt{2gR}$ $\therefore \frac{v_1}{v_2} = \sqrt{\frac{g_1}{g_2} \times \frac{R_1}{R_2}} = \sqrt{g \times K} = (Kg)^{1/2}$
(B). If missile launched with escape velocity then it wil = $\sqrt{\frac{g_1}{g_2} \times \frac{R_1}{R_2}}$ = $\sqrt{g \times K}$ = $(Kg)^{1/2}$
d with escape velocity then it will
ravitational field and at infinity its
mes zero.
of projection is less than escape
of energies will be negative. This
we force i $\sqrt{\frac{2GM}{R}}$
 $\sqrt{\frac{g_1}{g_2} \times \frac{R_1}{R_2}} = \sqrt{g \times K} = (Kg)^{1/2}$

with escape velocity then it will

vitational field and at infinity its

s zero.

f projection is less than escape

f energies will be negative. This

force i = $\sqrt{2gR}$ $\therefore \frac{v_1}{v_2} = \sqrt{\frac{g_1}{g_2} \times \frac{R_1}{R_2}} = \sqrt{g \times K} = (Kg)^{1/2}$

missile launched with escape velocity then it will

cape from the gravitational field and at infinity its

tal energy becomes zero.

locity then s scape velocity then it will
nal field and at infinity its
ection is less than escape
gies will be negative. This
is working on the satellite.
 $=\sqrt{\frac{2}{3}}$ \therefore $v_p = \sqrt{\frac{2}{3}}v_e$
 $\frac{p}{R_e} = \sqrt{1 \times 4} = 2$
4 km/s
 $R\omega^2$
 $\frac{r$ $\sqrt{\frac{g_1}{g_2} \times \frac{R_1}{R_2}} = \sqrt{g \times K} = (Kg)^{1/2}$
with escape velocity then it will
witational field and at infinity its
es zero.
of projection is less than escape
f energies will be negative. This
force is working on the s

velocity then sum of energies will be negative. This shows that attractive force is working on the satellite.

(A).
$$
\frac{v_p}{v_e} = \sqrt{\frac{M_p}{M_e} \times \frac{R_e}{R_p}} = \sqrt{2 \times \frac{1}{3}} = \sqrt{\frac{2}{3}}
$$
 $\therefore v_p = \sqrt{\frac{2}{3}} v_e$

$$
k + n
$$

\n⇒ R + h = √2R ⇒ h = (√2 – 1)R = 0.414R
\ng ∝ pR
\nAs g = $\frac{GM}{R^2}$ therefore 1% decrease in mass will
\ndecreases the value of g by 1%.
\n(d) (35) (A) $v = \sqrt{2gR}$ ∴ $\frac{v_1}{v_2} = \sqrt{\frac{g_1}{g_2} \times \frac{R_1}{R_2}} = \sqrt{g \times K} = (K_1 + K_2)$
\ndecreases the value of g by 1%.
\n(b) If $\frac{1}{2} \times 2 = \sqrt{g \times K} = \sqrt{g \times K} = (K_1 + K_2)$
\ndecreases the value of g by 1%.
\n(b) If $\frac{1}{2} \times 2 = \sqrt{g \times K} = \sqrt{g \times K} = (K_1 + K_2)$
\n $\frac{1}{2} \times 2 = \sqrt{g \times K} = (K_1 + K_2)$
\n $\frac{1}{2} \times 2 = \sqrt{g \times K} = (K_1 + K_2)$
\n $\frac{1}{2} \times 2 = \sqrt{g \times K} = (K_2 + K_1)$
\n $\frac{1}{2} \times 2 = \sqrt{g \times K} = (K_1 + K_2)$
\n $\frac{1}{2} \times 2 = \sqrt{g \times K} = (K_1 + K_2)$
\n $\frac{1}{2} \times 2 = \sqrt{g \times K} = 2$
\n $\frac{1}{2} \times 2 = \sqrt{g \times K} = 2$
\n $\frac{1}{2} \times 2 = \sqrt{g \times K} = 2$
\n $\frac{1}{2} \times 2 = \sqrt{g \times K} = 2$
\n $\frac{1}{2} \times 2 = \sqrt{g \times K} = 2$
\n $\frac{1}{2} \times 2 = \sqrt{g \times K} = 2$
\n $\frac{1}{2} \times 2 = \sqrt{g \times K} = 2$
\n $\frac{1}{2} \times 2 = \sqrt{g \times K} = 2$
\n $\frac{1}{2} \times 2 = \sqrt{g \$

(39) (A).
$$
g_e = g_p - R\omega^2 \Rightarrow \frac{g}{2} = g - R\omega^2
$$

$$
\Rightarrow \quad R\omega^2 = \frac{g}{2} \Rightarrow \quad R^2\omega^2 = \frac{gR}{2} \Rightarrow V^2 = \frac{gR}{2} \quad \dots \dots \dots (1)
$$

From eq. (1) and (2), $V_e = \sqrt{2 \times 2V^2} \Rightarrow V_e = 2V$

(40) (C). Angular momentum remains constant

$$
iv_1d_1 = mv_2d_2 \Rightarrow v_2 = \frac{v_1d_1}{d_2}
$$
 (55)

(41) (B). Orbital radius of Jupiter > Orbital radius of Earth

Q.B.-SOLUTIONS	STUDY		
$V_e = \sqrt{2gR}$	(54)	(D). Distances of the satellite fro	
From eq. (1) and (2), $V_e = \sqrt{2 \times 2V^2} \Rightarrow V_e = 2V$	$\frac{T_2}{T_1} = \left(\frac{R_2}{R_1}\right)^{3/2} \Rightarrow T_2 = 24\left(\frac{mv_1d_1}{mv_1d_1} = mv_2d_2 \Rightarrow v_2 = \frac{v_1d_1}{d_2}$	(55)	(B). Time period is independent
Orbital radius of Jupiter > Orbital radius of Earth	(56)	(B). $v_e = \sqrt{2}v_0 = 1.414 v_0$	
$v = \sqrt{\frac{GM}{r}}$. As $r_J > r_e$ therefore $v_J < v_e$	$\left(\frac{\Delta v}{m_f}\right) = \frac{v_e - v_0}{v_e} = 0.414$		

(42) (D). $T^2 \propto r^3 \Rightarrow \frac{T_1}{T_2} = \left(\frac{r_1}{r_2}\right)^{3/2}$ 3/2

- **1. (34) (D.B.- SOLUTIONS**
 2. $\mathbf{e} = \sqrt{2gR}$ **(54) (D).** Distances of the

comeq. (1) and (2), $\mathbf{v}_e = \sqrt{2 \times 2V^2} \Rightarrow \mathbf{V}_e = 2\mathbf{V}$

mgular momentum remains constant
 $\mathbf{v}_1\mathbf{d}_1 = \mathbf{m}\mathbf{v}_2\mathbf{d}_2 \Rightarrow \math$ **(0.B.-SOLUTIONS**

(54) **(D).** Distances of the

and (2), $V_e = \sqrt{2 \times 2V^2} \Rightarrow V_e = 2V$

mentum remains constant
 $2d_2 \Rightarrow v_2 = \frac{v_1 d_1}{d_2}$

as of Jupiter > Orbital radius of Earth

As $r_1 > r_e$ therefore $v_1 < v_e$
 $\frac{1}{2} = \$ **(O.B.-SOLUTIONS**
 (S4) (D). Distances of the satellite from th

3.5R respectively.

STUDY MA:
 $y_2d_2 \Rightarrow v_2 = \frac{v_1d_1}{d_2}$
 $v_2d_2 \Rightarrow v_2 = \frac{v_1d_1}{d_2}$
 $v_2d_3 \Rightarrow T_2 = 24\left(\frac{3.51}{7R}\right)^{3/2}$
 $y_3d_2 \Rightarrow v_2 = \frac{v_1d_1}{d$ **1997 (ADDEDITIONS**

V_e = $\sqrt{2gR}$

(54) (D). Distances of the sate

Trom eq. (1) and (2), $V_e = \sqrt{2 \times 2V^2} \Rightarrow V_e = 2V$

Angular momentum remains constant
 $\frac{T_2}{T_1} = \left(\frac{R_2}{R_1}\right)^{3/2} \Rightarrow T_1$
 $mv_1d_1 = mv_2d_2 \Rightarrow v_2 = \frac{v_$ **(a.B. SOLUTIONS STUDYMA**
 (54) (b) Distances of the satellite from th

) and (2), $V_e = \sqrt{2 \times 2V^2} \Rightarrow V_e = 2V$

S.SR respectively.
 $V_2d_2 \Rightarrow V_2 = \frac{V_1d_1}{d_2}$
 $V_2d_2 \Rightarrow V_2 = \frac{V_1d_1}{d_2}$
 (55) (B). Time period **(0.B.- SOLUTIONS STUDYMATE**
 (54) (D). Distances of the satellite from the

(2), $V_e = \sqrt{2 \times 2V^2} \Rightarrow V_e = 2V$

tum remains constant
 $\Rightarrow v_2 = \frac{v_1 d_1}{d_2}$ **(55) (B).** Time period is independent of mass

T₁ = $(\frac{R_2}{$ **(O.B.- SOLUTIONS**
 (S4) (D). Distances of the satellite from the

signal π of $\sqrt{2gR}$

(S4) **(D)**. Distances of the satellite from the

signal momentum remains constant
 $\frac{T_2}{T_1} = \left(\frac{R_2}{R_1}\right)^{3/2} \Rightarrow T_2 = 24$ **(43) (A).** During path DAB planet is nearer to sun as comparison with path BCD. So time taken in travelling DAB is less than that for BCD because velocity of planet will be more in region DAB. rbital radius of Jupiter > Orbital radius of Earth (56) (B). $v_e =$
 $=\sqrt{\frac{GM}{r}}$. As $r_J > r_e$ therefore $v_J < v_e$ ($\frac{\Delta v}{\sqrt{v}}$
 $\frac{2}{r_2} \propto r^3 \Rightarrow \frac{T_1}{T_2} = \left(\frac{r_1}{r_2}\right)^{3/2}$ \therefore Perce using path DAB planet is nearer = $\sqrt{2gR}$ (54) (54) Distances of the satisfied from the centre and (1) and (2), $v_e = \sqrt{2 \times 2V^2}$ ⇒ $V_e = 2V$

gular momentum remains constant
 $v_1d_1 = mv_2d_2$ ⇒ $v_2 = \frac{v_1d_1}{d_2}$ (55) (B). Time period is independen the sum of $V = \sqrt{\frac{GM}{r}}$. As $r_1 > r_c$ therefore $v_1 < v_2$ and $V = \sqrt{\frac{2V}{r}}$. As $r_1 > r_c$ therefore $v_1 < v_c$ is the sum of (56) (B). Time period is independent of mass.
 $r = \sqrt$ 2^2 ari $\Rightarrow \frac{1}{T_2} = \left(\frac{1}{T_2}\right)$

uring path DAB planet is nearer to sun as compari-

In with path BCD. So time taken in travelling DAB

less than that for BCD because velocity of planet

ill be more in region DAB.
 uring path DAB planet is nearer to sun as compari-

In with path DAB planet is nearer to sun as compari-

less than that for BCD because velocity of planet

ill be more in region DAB.

III be more in region DAB.

III be m
- **(44) (C).** Because distance of point C is maximum from the sun.

(45) (B).
$$
T_2 = T_1 \left(\frac{R_2}{R_1}\right)^{3/2} = 1 \times (2)^{3/2} = 2.8 \text{ year}
$$
 (59)

(46) (B).
$$
\frac{T^2}{r^3} = \text{constant} \implies T^2 r^{-3} = \text{constant}
$$

(47) **(B).**
$$
\frac{T_2}{T_1} = \left(\frac{r_2}{r_1}\right)^{3/2} = (2)^{3/2} = 2\sqrt{2} \implies T_2 = 2\sqrt{2}
$$
 years.

(48) (A).
$$
\text{m}\omega^2 \text{R} = \frac{\text{GMm}}{\text{R}^2} \Rightarrow \left(\frac{2\pi}{\text{T}}\right)^2 \text{R} = \frac{\text{GM}}{\text{R}^2} \Rightarrow \text{M} = \frac{4\pi^2 \text{R}^3}{\text{GT}^2}
$$

(49) (A).
$$
T^2 = \frac{4\pi^2 r^3}{GM}
$$
 (62)

(50) (D). As there are no external torques acting on the system, angular momentum is conserved.

$$
I_{far} \omega_{far} = I_{near}
$$

or $(mR_{far}^2) \omega_{far} = (mR_{near}^2) \omega_{near}$
Setting $R_{near} = d/3$ and $R_{far} = d$, we get $\omega_{near} = 9\omega_{far}$.
(51) (A). $T_1 = T_{Earth} = 1$ year, $T_2 = T_{Neptune} = 165$ year

Let R_1 and R_2 be the radii of the circular orbits of Earth and Neptune respectively. $\frac{1}{2} = \left(\frac{r_2}{r_1}\right)^{3/2} = (2)^{3/2} = 2\sqrt{2} \Rightarrow T_2 = 2\sqrt{2}$ years.
 $\omega^2 R = \frac{GMm}{R^2} \Rightarrow \left(\frac{2\pi}{T}\right)^2 R = \frac{GM}{R^2} \Rightarrow M = \frac{4\pi^2 R^3}{GT^2}$
 $2 = \frac{4\pi^2 r^3}{GM}$
 $\frac{m$ $\frac{1}{11}$ $rac{2}{\pi} = \left(\frac{r_2}{r_1}\right)^{3/2}$ = (2)^{3/2} = 2√2 ⇒ T₂ = 2√2 years.

(61) (C). V_e = 11.2 = $\sqrt{\frac{2GM}{R}}$

(α)²R = $\frac{GMm}{R^2}$ ⇒ $\left(\frac{2\pi}{T}\right)^2$ R = $\frac{GM}{R^2}$ ⇒ M = $\frac{4\pi^2 R^3}{GT^2}$
 $= \frac{4\pi^2 r^3}{GM}$ (62) (B). $\frac{2}{1} = \left(\frac{r_2}{r_1}\right)^{3/2} = (2)^{3/2} = 2\sqrt{2} \Rightarrow T_2 = 2\sqrt{2}$ years.
 $\omega^2 R = \frac{GM}{R^2} \Rightarrow \left(\frac{2\pi}{T}\right)^2 R = \frac{GM}{R^2} \Rightarrow M = \frac{4\pi^2 R^3}{GT^2}$
 $\omega^2 R = \frac{4\pi^2 r^3}{GM}$
 $\omega^2 R = \frac{GM}{R^2} \Rightarrow \left(\frac{2\pi}{T}\right)^2 R = \frac{GM}{R^2} \Rightarrow M = \frac{4\pi^2 R^3}{GT^2$

$$
\frac{T_1^2}{T_2^2} = \frac{R_1^3}{R_2^3} \quad \therefore \quad R_2^3 = \frac{R_1^3 T_2^2}{T_1^2} = \frac{R_1^3 \times 165^2}{1^2}
$$

:
$$
R_2^3 = 165^2 R_1^3
$$
 or $R_2 \approx 30R_1$.

(52) (B). Centripetal acceleration works on it.

(53) (B).
$$
v = \sqrt{\frac{GM}{r}}
$$
 if $r_1 > r_2$ then $v_1 < v_2$ (63) (B). The extensive

Orbital speed of satellite does not depends upon the mass of the satellite

114ARNING
 $V_e = \sqrt{2gR}$ **(34) (D).** Distances of the satel
 $V_e = \sqrt{2gR}$ **(54) (D).** Distances of the satel

3.5R respectively.

Angular momentum remains constant
 $mv_1d_1 = mv_2d_2 \Rightarrow v_2 = \frac{v_1d_1}{d_2}$ **(55) (B).** Time pe **(54) (D).** Distances of the satellite from the centre are 7R and 3.5R respectively.

Q.B.-SOLUTIONS
\n
$$
V_e = \sqrt{2gR}
$$

\nFrom eq. (1) and (2), $V_e = \sqrt{2 \times 2V^2} \Rightarrow V_e = 2V$
\n $2gR$
\n $2gR$ <

- d_2 (55) (b) **(55) (B).** Time period is independent of mass.
- **(O.B.- SOLUTIONS** STUD

(54) **(D).** Distances of the satellite 1
 $\sqrt{2 \times 2V^2} \Rightarrow V_e = 2V$

tims constant
 $\frac{T_2}{T_1} = \left(\frac{R_2}{R_1}\right)^{3/2} \Rightarrow T_2 = 2\frac{R_2}{R_1}$

(55) **(B).** Time period is independe

Orbital radius of Earth Fractional increase in orbital velocity

$$
\left(\frac{\Delta v}{v}\right) = \frac{v_e - v_0}{v_0} = 0.414
$$

 \therefore Percentage increase = 41.4%

(57) (C).
$$
v \propto \frac{1}{\sqrt{r}}
$$
, If $r = R$ then $v = V_0$

If
$$
r = R + h = R + 3R = 4R
$$
 then $v = \frac{V_0}{2} = 0.5V_0$

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

- Summer of the satellite from the centre are 7K and
 $\frac{2}{1} = \left(\frac{R_2}{R_1}\right)^{3/2} \Rightarrow T_2 = 24\left(\frac{3.5R}{7R}\right)^{3/2} = 6\sqrt{2}$ hr

me period is independent of mass.
 $\frac{1}{2} = \sqrt{2}v_0 = 1.414 v_0$

actional increase in orbital vel **STUDY MATERIAL: PHYSICS**

ances of the satellite from the centre are 7R and

trespectively.
 $= \left(\frac{R_2}{R_1}\right)^{3/2} \Rightarrow T_2 = 24 \left(\frac{3.5R}{7R}\right)^{3/2} = 6\sqrt{2}$ hr

e period is independent of mass.
 $= \sqrt{2}v_0 = 1.414 v_0$

tiona **(59) (C).** A polar satellite is a low altitude satellite. Hence, option (C) is an incorrect statement. While all the other statement are correct.
- From eq. (1) and (2), $V_c = \sqrt{2} \times 2V^2 \Rightarrow V_c = 2V$

Angular momentum remains constant

mv₁d₁ = mv₂d₂ = v₂^d₂

mv₁d₁ = mv₂d₂ = v₂^d₂ = v₄^d₂

(55) (B). Time period is independent of mass.

7- (ital radius of Jupiter > Orbital radius of Earth
 $x^2 - \frac{1}{2}x + \frac{1}{2}x = \left(\frac{t_1}{t_2}\right)^{3/2}$
 \therefore Percentage increase in orbital velocity
 $x^2 - \frac{1}{2}x = \frac{1}{2}x = \left(\frac{t_1}{t_2}\right)^{3/2}$
 \therefore Percentage increase = 41.4 ∴ Percentage increase = 41.4%

n as compari-

(57) (C), $v \propto \frac{1}{\sqrt{t}}$, If r = R then $v = V_0$

welling DAB

city of planet

If r = R + h = R + 3R = 4R then $v = \frac{V_0}{2} = 0.5V_0$

num from the

(58) (C), $\frac{T_1}{T_2} = \left(\$.. Percentage increase = 41.4%

sun as compari-

(57) (C). $v \propto \frac{1}{\sqrt{r}}$, If r = R then $v = V_0$

travelling DAB

flocity of planet

If r = R + h = R + 3R = 4R then $v = \frac{V_0}{2} = 0.5V_0$

summ from the

(58) (C), $\frac{T_$ =1×(2)³⁷² = 2.8 year

(39) (C). A communication is a low altitude satellite is not according to

Hence, option (C) is an incorrect statement.

While all the observation are correct statement.

(60) (C). A communication Frace option (C). A communication attention the state is constant

(60) (C). A communication attention the search is a constant, the

force acting on the satellite is constant, the

force acting on the satellite is consta 1×(2)³¹⁷ = 2.8 year

(59) (C), A polar satellite is a low of distance interest calculate statellite

Hence, option (C) is an incorrect statement.

The specific is constant the correct of the set of the set of the set of $\frac{2}{1} = \left(\frac{R_2}{R_1}\right)^{3/2} \Rightarrow T_2 = 24\left(\frac{3.5R}{7R}\right)^{3/2} = 6\sqrt{2}$ hr

me period is independent of mass.
 $\frac{1}{2} = \sqrt{2}v_0 = 1.414 v_0$

acctional increase in orbital velocity
 $\frac{\Delta v}{v} = \frac{v_e - v_0}{v_0} = 0.414$
 $\frac{dv}{v} = \$ **STUDY MATERIAL: PHYSICS**

Distances of the satellite from the centre are 7R and
 $\frac{\Gamma_2}{\Gamma_1} = \left(\frac{R_2}{R_1}\right)^{3/2} \Rightarrow \Gamma_2 = 24\left(\frac{3.5R}{7R}\right)^{3/2} = 6\sqrt{2}$ hr

Time period is independent of mass.
 $v_e = \sqrt{2}v_0 = 1.414 v_0$
 ATERIAL: PHYSICS
the centre are 7R and
 $\frac{5R}{R}$)^{3/2} = 6 $\sqrt{2}$ hr
mass.
elocity
 $v = \frac{V_0}{2} = 0.5V_0$
 $T_2 = 8T_1$
de satellite.
ect statement.
a circular orbit around
ellite is constant, the
ints toward the center. **STUDY MATERIAL: PHYSICS**

Distances of the staellite from the centre are 7R and
 $\frac{T_2}{T_1} = \left(\frac{R_2}{R_1}\right)^{3/2} \Rightarrow T_2 = 24\left(\frac{3.5R}{7R}\right)^{3/2} = 6\sqrt{2} \text{ hr}$

Time period is independent of mass.
 $v_e = \sqrt{2}v_0 = 1.414 v_0$
 (60) (C). A communication satellite is in a circular orbit around Earth. If the speed of the satellite is constant, the force acting on the satellite points toward the center of Earth at all times. $e = R + h = R + 3R = 4R$ then $v = \frac{V_0}{2} = 0.5V_0$
 $= \left(\frac{R_1}{R_2}\right)^{3/2} = \left(\frac{R}{4R}\right)^{3/2} \Rightarrow T_2 = 8T_1$

colar satellite is a low altitude satellite.

nec, option (C) is an incorrect statement.

hile all the other statement ar $\frac{dw}{dx}$ = $\frac{V_e - V_0}{V_0}$ = 0.414

ercentage increase = 41.4%
 $v \propto \frac{1}{\sqrt{r}}$, If r = R then $v = V_0$

f r = R + h = R + 3R = 4R then $v = \frac{V_0}{2} = 0.5V_0$
 $\frac{T_1}{T_2} = \left(\frac{R_1}{R_2}\right)^{3/2} = \left(\frac{R}{4R}\right)^{3/2} \Rightarrow T_2 = 8T_$ se = 41.4%

then v = V₀

3R = 4R then v = $\frac{V_0}{2}$ = 0.5V₀
 $\left(\frac{R}{4R}\right)^{3/2}$ \Rightarrow T₂ = 8T₁

s a low altitude satellite.

i is an incorrect statement.

r statement are correct.

satellite is in a circular orb Fractional interess in orbital velocity
 $\left(\frac{\Delta v}{v}\right) = \frac{v_e - v_0}{v_0} = 0.414$
 \therefore Percentage increase = 41.4%

(C). $v \propto \frac{1}{\sqrt{r}}$, If $r = R$ then $v = V_0$

If $r = R + h = R + 3R = 4R$ then $v = \frac{V_0}{2} = 0.5V_0$

(C). $\frac{T_1}{$ ¹0
 $\frac{1}{\sqrt{r}}$, If $r = R$ then $v = V_0$
 $2 + h = R + 3R = 4R$ then $v = \frac{V_0}{2} = 0.5V_0$
 $\left(\frac{R_1}{R_2}\right)^{3/2} = \left(\frac{R}{4R}\right)^{3/2} \Rightarrow T_2 = 8T_1$

ar satellite is a low altitude satellite.

2, option (C) is an incorrect statemen Percentage increase = 41.4%
 $v \propto \frac{1}{\sqrt{r}}$, If $r = R$ then $v = V_0$

If $r = R + h = R + 3R = 4R$ then $v = \frac{V_0}{2} = 0.5V_0$
 $\frac{T_1}{T_2} = \left(\frac{R_1}{R_2}\right)^{3/2} = \left(\frac{R}{4R}\right)^{3/2} \Rightarrow T_2 = 8T_1$

A polar satellite is a low altitude sa **(58) (C).** $\frac{T_1}{T_2} = \left(\frac{R_1}{R_2}\right)^{3/2} = \left(\frac{R}{4R}\right)^{3/2} \Rightarrow T_2 = 8T_1$
 (59) (C). A polar satellite is a low altitude satellite.

Hence, option (C) is an incorrect statement.
 (60) (C). A communication satel A communication satellite is in a circular orbit around
Earth. If the speed of the satellite is constant, the
force acting on the satellite points toward the center
of Earth at all times.
 $V_e = 11.2 = \sqrt{\frac{2GM}{R}}$, $V_m = \sqrt{\frac{2$). $\frac{T_1}{T_2} = \left(\frac{R_1}{R_2}\right)^{\frac{1}{2}} = \left(\frac{R}{4R}\right)^{2/2} \Rightarrow T_2 = 8T_1$

A polar satellite is a low altitude satellite.

Hence, option (C) is an incorrect statement.

While all the other statement are correct.

A communicatio $\Rightarrow 1_2 = 81_1$
altitude satellite.
neorrect statement.
nent are correct.
is in a circular orbit around
ne satellite is constant, the
ite points toward the center
 $V_m = \sqrt{\frac{2GM_m}{R_m}}$
 $\frac{2}{2gR}$
 $\frac{2gR^2}{(R + h)^2}$
 $\sqrt{\frac{2gR^$ $\frac{T_1}{T_2} = \left(\frac{R_1}{R_2}\right)^{3/2} = \left(\frac{R}{4R}\right)^{3/2} \Rightarrow T_2 = 8T_1$

a polar satellite is a low altitude satellite.

lence, option (C) is an incorrect statement.

While all the other statement are correct.

communication satel Explaination is a low and

Denote a bow antitude same that the statement.

While all the other statement are correct.

Denote the simulation stellite is in a circular orbit around

Earth. If the speed of the satellite is s, experimentally and the other statement are correct.

and the other statement are correct.

mmunication satellite is in a circular orbit around

a. If the speed of the satellite is constant, the

acting on the satellite a polar satellite is a low altitude satellite.

Elence, option (C) is an incorrect statement.

While all the other statement are correct.

communication satellite is in a circular orbit around

anth. If the speed of the s

$$
v = \sqrt{\frac{GM}{r}}
$$
. As $r_3 > r_e$ therefore $v_j < v_e$
\n
$$
(D) F_1^2 \propto r^2 \Rightarrow \frac{T_1}{T_2} = (\frac{r_1}{2})^{3/2}
$$

\n
$$
(D) L = \sqrt{\frac{2 \times r_0}{r}} = 1
$$
\n
$$
F = \sqrt{\frac{R_2}{r}} = 1
$$
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$$
(E) F_1 = \sqrt{\frac{R_1}{r}} = 1
$$
\n
$$
(E) F_2 = \sqrt{\frac{R_1}{r}} = 1
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(E) F_1 = \sqrt{\frac{R_2}{r}} = 1
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(E) F_1 = \sqrt{\frac{R_1}{r}} = 1
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$$
(E) F_2 = \sqrt{\frac{R_1}{r}} = 1
$$
\n
$$
(E) F_1 =
$$

$$
\frac{\pi^2 r^3}{GM}
$$
 (62) (B). Escale velocity, $v_e = \sqrt{2gR}$

At a height h above the Earth's surface,

force acting on the satellite points toward the center
\nof Earth at all times.
\n
$$
V_e = 11.2 = \sqrt{\frac{2GM}{R}}, \quad V_m = \sqrt{\frac{2GM_m}{R_m}}
$$
\n
$$
= \sqrt{\frac{G \times M \times 4}{81 \times R}} = \frac{11.2 \times 2}{9} = 2.5 \text{ km/sec}.
$$
\n
$$
V_e = \sqrt{2gR}
$$
\n
$$
V_e = \sqrt{2g_0 (R + h)}, \quad g_h = \frac{gR^2}{(R + h)^2}
$$
\n
$$
V_e = \sqrt{\frac{2 \times gR^2}{(R + h)^2}} (R + h) = \sqrt{\frac{2gR^2}{R + h}}
$$
\n
$$
g = 9.8 \text{ m s}^{-2}, R = 6.4 \times 10^6 \text{ m}, h = 1,000 \text{ km} = 10^6 \text{ m}
$$
\n
$$
V_e = \sqrt{\frac{2 \times 9.8 \times (6.4 \times 10^6)^2}{(6.4 + 1)10^6}} \text{ ms}^{-1}
$$
\n
$$
= 10.42 \times 10^3 \text{ m s}^{-1} = 10.42 \text{ km s}^{-1}.
$$
\nThe escape velocity at a height 1,000 km from Earth's
\n
$$
\text{rface} = 10.42 \text{ km s}^{-1}.
$$
\n
$$
V_h = \frac{mg}{R^2}
$$
\n
$$
V_e = \frac{mg}{R^2}
$$
\n
$$
V_e = \frac{1}{R^2}
$$
\n
$$
V_e = \frac{1}{R^2}
$$
\n
$$
V_e = \frac{1}{R^2}
$$

$$
g=9.8 \text{ m s}^{-2}, R=6.4 \times 10^6 \text{ m}, h=1,000 \text{ km}=10^6 \text{ m}
$$

$$
v'_{e} = \sqrt{\frac{2 \times 9.8 \times (6.4 \times 10^{6})^{2}}{(6.4 + 1)10^{6}}}
$$
 ms⁻¹
= 10.42 × 10³ m s⁻¹ = 10.42 km s⁻¹.

. \therefore The escape velocity at a height 1,000 km from Earth's surface = 10.42 km s⁻¹. .

(63) (B). The extension in the length of spring is

$$
x_1 = \frac{mg}{k} = \frac{GMm}{R^2k} \qquad \therefore x \propto \frac{1}{R^2}
$$

$$
\therefore \frac{x_2}{x_1} = \frac{R^2}{(R+h)^2} \text{ or } x_2 = 1 \times \left(\frac{6400}{7200}\right)^2 = \frac{64}{81} = 0.79 \text{ cm}
$$
 (73) (D).

(64) (A). Orbital speed
$$
v_0 = \sqrt{\frac{Gm}{R}}
$$
 ; $2 = \sqrt{\frac{Gm}{R}}$

Hence, escape speed
$$
v_e = \sqrt{\frac{2Gm}{R}} = 2\sqrt{2} \text{ m/s}
$$
 $\Rightarrow 2\frac{\Delta T}{T} = 3\frac{\Delta r}{r}$

(65) (B). Acceleration will be due to gravitational pull only.

(66) **(B).**
$$
v_e = \sqrt{2g_e R_e}
$$
; $v_m = \sqrt{2g_m R_m}$

$$
\frac{v_e}{v_m} = \sqrt{\frac{g_e}{g_m} \frac{R_e}{R_m}} = \sqrt{24}
$$
 (1)

EXECUTIONS
 $\therefore \frac{x_2}{x_1} = \frac{R^2}{(R+h)^2}$ or $x_2 = 1 \times \left(\frac{6400}{7200}\right)^2 = \frac{64}{81} = 0.79$ cm conserved.
 \therefore $\frac{x_2}{x_1} = \frac{R^2}{(R+h)^2}$ or $x_2 = 1 \times \left(\frac{6400}{7200}\right)^2 = \frac{64}{81} = 0.79$ cm conserved wis maximum visit.
 THATION
 $\therefore \frac{x_2}{x_1} = \frac{R^2}{(R + h)^2}$ or $x_2 = 1 \times \left(\frac{6400}{7200}\right)^2 = \frac{64}{81} = 0.79$ cm conserved. So, mvr = conn
 x_1 is maximum when r is m

A). Orbital speed $v_0 = \sqrt{\frac{Gm}{R}}$: $2 = \sqrt{\frac{Gm}{R}}$ (74) (A). Since, T **(67) (A).** For a body of mass m resting on the equator of a planet of radius R, which rotates at an angular velocity ω , the equation of motion has the form $m\omega^2 R = mg' - N$. Where N is the normal reaction of the planet surface, and $g' = 0.01g$ is the free-fall acceleration on the planet. By hypothesis, the bodies on the equator are weightless, (2) i.e. N = 0. Considering that $\omega = 2 \pi / T$, where T is the period of rotation of the planet about its axis (equal to the VEm R_m V_{Rm} R_m

VEm R_m Correct a body of mass m resting on the equator of a

correct a body of mass m resting on the equator voles.

Correct at the form moo²R = mg'-N.

(a) is the normal reactor of the planet sta $\frac{g_e}{g_m R_m} = \sqrt{24}$

(b) (C). $\omega - \sqrt{\tan \theta}$
 $g_m R_m = \sqrt{24}$

(c) $\frac{g_m}{g_m R_m} = \frac{\tan \theta}{\tan \theta}$

(

solar day), we obtain
$$
R = \frac{T^2}{4\pi^2} g'
$$
 (C) $v = A$
Substituting the values $T = 8.6 \times 10^4$ s and $g' \approx 0.1$ m/s², (3) (B). Mass
we get $R \approx 1.8 \times 10^7$ m = 18000km.

(68) (B).
$$
g \propto \frac{1}{R^2}
$$
. R decreasing g increase curve b represent variation.

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

(70) (B). Orbital velocity close to surface of earth is \sqrt{gR} . **(4)**

So,
$$
E = \frac{1}{2} m (\sqrt{gR})^2 \Rightarrow E = \frac{1}{2} mgR
$$

If the body is to escape, the velocity at surface of earth is $\sqrt{2gR}$. If E' is the kinetic energy corresponding to this velocity then $E' = \frac{1}{2}m(\sqrt{2gR})^2 \Rightarrow E' = 2E$

(71) (C).
$$
T^2 \propto R^3
$$
 or $(T_2/T_1) = (R_2/R_1)^{3/2}$

or
$$
\frac{T_2}{T_1} = \left(\frac{6400}{36000}\right)^{3/2}
$$
 or $T_2 = \left(\frac{6400}{36000}\right)^{3/2} \times 24 \approx 2$ hr.

(72) (D). The acceleration due to gravity at earth's surface is g and at a distance R from earth's surface it is g/4.

Hence,
$$
\frac{T_2}{T_1} = 2
$$
 [: $T = 2\pi\sqrt{\ell/g}$]

(Q.B.-SOLUTIONS

(R+h)² or $x_2 = 1 \times \left(\frac{6400}{7200}\right)^2 = \frac{64}{81} = 0.79$ cm

(73) (D). Angular momentum of

conserved. So, mvr = constant

v is maximum when r is minim

point P₄.

(14) (A). Since, $T^2 = kr^3$

Differen $(6400)^2$ 64 **(73) (D).** Angular momentum of the planet about S is 7200 81 $\frac{81}{x}$ v is maximum when r is minimum. So, v is maximum at **(0.B.-SOLUTIONS**
 (6400) $=\frac{64}{81} = 0.79 \text{ cm}$

(73) **(D).** Angular momentum of the planet about Solutions of the planet about Solutions of the planet about Solutions of the planet about S is maximum when r is minimum. **Q.B.-SOLUTIONS**
 OREXENTIONS
 $2=1 \times \left(\frac{6400}{7200}\right)^2 = \frac{64}{81} = 0.79 \text{ cm}$ (73) (D). Angular momentum of the planet about S is

conserved. So, mvr = constant.

v is maximum when r is minimum. So, v is maximum at
 \sqrt conserved. So, mvr = constant. point P_4 . **SPARE ASSET AND SUBARY ANCEDEARNING**
 EXECUTE ARRIVED LEARNING
 EXECUTE AND SUBARY AND SET AND SUBARY AND SET AND SUBARY SET AND SUBARY SET AND SET AND SET AND SET A SET AND SUBARY SET AND SUBARY SET AND SUBARY SET AN Magnetary momentum of the planet about S is

Magnetary momentum of the planet about S is

ved. So, mvr = constant.
 $\frac{2}{1}$
 $\frac{2}{1}$

and $\frac{2}{1}$

antitating the above equation
 $\frac{2}{1}$
 $\frac{2}{1}$
 EXERCISE-2
 Angular momentum of the planet about S is

rved. So, mvr = constant.

aximum when r is minimum. So, v is maximum at
 P_4 .

ince, $T^2 = kr^3$

entiating the above equation
 $\frac{\Delta T}{T} = 3 \frac{\Delta r}{r} \Rightarrow \frac{\Delta T}{T} = \frac{3}{2} \frac{\Delta r}{r}$
 SPARADVANCED LEARNING
tum of the planet about S is
onstant.
s minimum. So, v is maximum at
ve equation
 $\frac{T}{\Gamma} = \frac{3}{2} \frac{\Delta r}{r}$
CISE-2
 $2\pi \sqrt{\tan \theta} = 2\pi \sqrt{\frac{\ell}{\sigma}}$ **SPONDOVANCED LEARNING**
 COMMOVANCED LEARNING

Intum of the planet about S is

constant.

is minimum. So, v is maximum at

we equation
 $\frac{\Delta T}{T} = \frac{3}{2} \frac{\Delta r}{r}$
 RCISE-2
 $= 2\pi \sqrt{\tan \theta} = 2\pi \sqrt{\frac{\ell}{g}}$ **SPON ADVANCED LEARNING**
 EDEMADVANCED LEARNING

Intum of the planet about S is

constant.

is minimum. So, v is maximum at

ove equation
 $\frac{\Delta T}{T} = \frac{3}{2} \frac{\Delta r}{r}$
 RCISE-2

$$
= \sqrt{\frac{Gm}{R}} \quad ; \quad 2 = \sqrt{\frac{Gm}{R}}
$$
 (74) (A). Since, $T^2 = kr^3$
Differentiating the above equation

$$
= 2\sqrt{2} \text{ m/s} \qquad \Rightarrow 2\frac{\Delta T}{T} = 3\frac{\Delta r}{r} \Rightarrow \frac{\Delta T}{T} = \frac{3}{2}\frac{\Delta r}{r}
$$

EXERCISE-2

GEANTATION
\n
$$
\frac{x_2}{x_1} = \frac{R^2}{(R+h)^2} \text{ or } x_2 = 1 \times \left(\frac{6400}{7200}\right)^2 = \frac{64}{81} = 0.79 \text{ cm}
$$
\n(73) (D). Angular momentum of the planet about S is
\n
$$
\therefore \frac{x_2}{x_1} = \frac{R^2}{(R+h)^2} \text{ or } x_2 = 1 \times \left(\frac{6400}{7200}\right)^2 = \frac{64}{81} = 0.79 \text{ cm}
$$
\n(74) point, $\frac{1}{4} \times \frac{1}{4} \$

(2) (A).

 (3)

(A)
$$
T^2 \propto r^3
$$
 (B) $E = \frac{-GMm}{2r}$
(C) $v = \sqrt{\frac{GM}{r}}$ (D) $L = mvr = m \sqrt{GMr}$

(3) (B). Mass per unit length $= A + Bx^2$. So the mass of length dx is $dM = dx (A + Bx^2)$

$$
v_e = \sqrt{2g_e R_e}
$$
; $v_m = \sqrt{2g_m R_m}$
\nFor a body of mass m resting on the equator of a
\nFor a body of mass m resting on the equator of a
\nfor a body of mass m resting on the equator of a
\nof radius R, which rotates at an angular velocity ω ,
\n $\therefore g = \frac{\ell}{\tan \theta} \therefore \frac{g_{ground}}{g_h} = \frac{\tan \theta_h}{\tan \theta \text{ ground}} = \frac{(R + h)^2}{R^2}$
\nFor a body of mass m resting on the equator of a
\nof rotation of the planet surface, and
\n $0.01g$ is the free-fall acceleration on the planet.
\n $\tan 50^\circ = \left(\frac{R + h}{R}\right)^2 \Rightarrow h = 0.73 \text{ R}$
\n $\Rightarrow 0. \text{ Considering that } \omega = 2 \pi / T$, where T is the
\ndor fraction of the planet about its axis (equal to the
\ndor rotation of the planet about its axis (equal to the
\n $\tan 30^\circ = \left(\frac{R + h}{R}\right)^2 \Rightarrow h = 0.73 \text{ R}$
\n $\Rightarrow \tan 50^\circ = \frac{GMm}{\tan 50^\circ} = \frac{GMm}{\tan 50^\circ} = \frac{GMm}{2r}$
\n $\Rightarrow \tan 50^\circ = \frac{GMm}{2r}$
\n $\Rightarrow R^2 = 0. \text{ Considering that } \omega = 2 \pi / T$, where T is the
\n $\tan 50^\circ = \frac{GMm}{\tan 50^\circ} = \frac{GMm}{\tan 50^\circ} = \frac{GMm}{\tan 50^\circ} = \frac{GMm}{2r}$
\n $\Rightarrow \tan 50^\circ = \frac{GMm}{\tan 50^\circ} = \frac{Mm}{\tan 50^\circ} = \frac{GMm}{2r}$
\n $\Rightarrow \tan 50^\circ = \frac{GMm}{\tan 50^\circ} = \frac{Mm}{\tan 50^\circ} = \frac{GMm}{\tan 50^\circ} = \frac{Mm}{\tan 50$

Forbolicity of the behavior of the plant about its axis (equal to the
\nsolar day), we obtain R =
$$
\frac{T^2}{4\pi^2}
$$
 g'
\nSubstituting the values T = 8.6 x 10⁴ s and g' ≥ 0.1 m/s²,
\nSubstituting the values T = 8.6 x 10⁴ s and g' ≥ 0.1 m/s²,
\nwe get R = 1.8 x 10⁷ m = 18000km.
\n**(68)** (B). g × $\frac{1}{R^2}$. R decreasing g increase curve b represent
\n
$$
F = \int_{a}^{12} Gm(\frac{1}{x^2}) dx (A + Bx^2)
$$
\nvariation.
\n**(69)** (A). g $\left(1-\frac{d}{R}\right) = g - \omega^2 R$; d = $\frac{\omega^2 R^2}{g}$
\n
$$
= \int_{a}^{14} Gm(\frac{A}{x^2}) dx (A + Bx^2)
$$
\nvariation.
\n**(70)** (B). Orthial velocity close to surface of earth is \sqrt{gR} .
\nSo, E = $\frac{1}{2}m(\sqrt{gR})^2 \Rightarrow E = \frac{1}{2}mgR$
\nIf the body is to escape, the velocity at surface of earth is
\n
$$
\sqrt{2gR}
$$
. IF E' is the kinetic energy corresponding to this
\nvelocity then E' = $\frac{1}{2}m(\sqrt{2gR})^2 \Rightarrow E' = 2E$
\n**(71)** (C). T² ∝ R³ or (T₂/T₁) = (R₂/R₁)^{3/2}
\nor $\frac{T_2}{T_1} = \left(\frac{6400}{36000}\right)^{3/2}$ or T₂ = $\left(\frac{6400}{28000}\right)^{3/2}$ × 24 ≈ 2 hr.
\nHence, $\frac{T_2}{T_1} = 2$ [∴ T = 2π $\sqrt{\ell/g}$]

$$
\overline{33} \quad \boxed{\qquad}
$$

Gauss law for gravitation

$$
\int \vec{g} \cdot d\vec{s} = -m_{in} \cdot 4\pi G \quad ; \quad g = \frac{GM}{R^2} \qquad \text{or} \quad GM \left(\frac{r_1 - r_2}{r_1 r_2} \right);
$$

$$
2 \times \frac{GM}{R^2} \times A = \frac{M}{\frac{4}{3}\pi R^3} (h \times A) \times 4\pi G \implies h = \frac{2R}{3} \qquad \text{or} \quad GM \left(\frac{r_1 - r_2}{r_1 r_2} \right)
$$

(6) (C). Let N be the number of stars in the galaxy, M be the mass of the Sun, and R be the radius of the galaxy. The total mass in the galaxy is NM and the magnitude of the , a v i o n a l f o r c e a c t i n g o n t e s e s $\frac{2}{\sqrt{2}}$

The force points toward the galactic center. The magnitude of the Sun's acceleration is $a = v^2/R$ where v is its speed. If T is the period of the Sun's motion around force points toward the galactic center. The

ditude of the Sun's acceleration is a = v²/R where v is

exed. If T is the period of the Sun's motion around

alactic center then $v = \frac{2\pi R}{T}$ and $a = \frac{4\pi^2 R}{T^2}$.

Now

the galactic center then
$$
v = \frac{2\pi R}{T}
$$
 and $a = \frac{4\pi^2 R}{T^2}$. Now Angular

Newton's second law yields
$$
\frac{GNM^2}{R^2} = \frac{4\pi^2 MR}{T^2}
$$
 (10) (D). At the surface

The solution for N is $N = \frac{N}{\sqrt{2N}}$ $=\frac{4\pi^2R^3}{r^2}$ and the

The period is 2.5×10^8 y, which is 7.88×10^{15} s, so

magnitude of the Sun's acceleration is a = v²/R where v is
\nits speed. If T is the period of the Sun's motion around
\nthe galactic center then
$$
v = \frac{2\pi R}{T}
$$
 and $a = \frac{4\pi^2 R}{T^2}$.
\nNewton's second law yields $\frac{GNM^2}{R^2} = \frac{4\pi^2 MR}{T^2}$.
\nNewton's second law yields $\frac{GNM^2}{R^2} = \frac{4\pi^2 MR}{T^2}$.
\n(10) (D). At the surface of
\nthe earth-particle syst
\nand the kinetic energy is
\nand the kinetic energy is
\nand the kinetic energy is
\n $\frac{4\pi^2 (2.2 \times 10^{20} \text{ m})^3}{(6.67 \times 10^{-11} \text{ m}^3/\text{s}^2 \text{ kg}) (7.88 \times 10^{15} \text{s})^2 (2.0 \times 10^{30} \text{ kg})}$
\n $= 5.1 \times 10^{10}$
\n(D). Let $\frac{4\pi^2 (2.2 \times 10^{20} \text{ m})^3}{(6.67 \times 10^{-11} \text{ m}^3/\text{s}^2 \text{ kg}) (7.88 \times 10^{15} \text{s})^2 (2.0 \times 10^{30} \text{ kg})}$
\n $= 5.1 \times 10^{10}$
\n $= 5.1 \times 10^{10}$
\n $= 5.1 \times 10^{10}$
\nUsing conservation of
\n $= \frac{GMm}{R} + \frac{1}{2} \text{ m} v_0^2 = \frac{GMm}{R} + \frac{1}{2} \text{ m} v_0^2 = \frac{m v_{\text{max}} r_{\text{min}}}{2m} = \frac{dA}{dt}$; $v_{\text{max}} = \frac{2 dA/dt}{r_{\text{min}}} = 40$
\n $= \frac{gR}{R} + \frac{v_0^2}{2} = \frac{-gR^2}{R + H}$
\n $= \frac{R^2}{V_0}$
\n $= \frac{R^2}{R} = \frac{v_0^2}{R}$

(7) **(D).**
$$
\frac{L}{2m} = \frac{dA}{dt}
$$
 $(L = angular momentum)$

$$
\frac{mv_{\text{max}}r_{\text{min}}}{2m} = \frac{dA}{dt} \; ; \; v_{\text{max}} = \frac{2 \, dA/dt}{r_{\text{min}}} = 40
$$

(8) (C).
$$
E = -\frac{K}{r}, \int_{V_0}^{V} dV = -\int_{r_0}^{r} \vec{E} \cdot d\vec{r} = -\int_{r_0}^{r} \frac{K}{r} dr
$$

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

Potential at distance r, $V = V_0 + K \ln \frac{r}{r_0}$ r_0

The period is 2.5 × 10^o y, which is 7.88 × 10^o s, so
\n
$$
N = \frac{4\pi^2 (22 \times 10^{20} \text{ m})^3}{(6.67 \times 10^{-11} \text{ m}^3/\text{s}^2 \text{ kg}) (7.88 \times 10^{15} \text{s})^2 (2.0 \times 10^{30} \text{ kg})}
$$
\n(f) the earth-particle system at this instant is $-\frac{GMm}{R+H}$.
\nUsing conservation of energy,
\n(7) **(D)**. $\frac{L}{2m} = \frac{dA}{dt}$ (*L* = angular momentum)
\n
$$
\frac{mv_{max}r_{min}}{2m} = \frac{dA}{dt}
$$
; $v_{max} = \frac{2 dA/dt}{r_{min}} = 40$
\n**(8) (C)**. $E = -\frac{K}{r}$, $\int_0^V dV = -\int_0^r \vec{E} \cdot d\vec{r} = -\int_0^r \frac{K}{r} dr$
\n $V - V_0 = K \ln \frac{r}{r_0}$
\n $V - V_0 = K \ln \frac{r}{r_0}$
\n $V - V_0 = K \ln \frac{r}{r_0}$
\n $V = V_0 + K \ln \frac{r}{r_0}$
\n $V = V_0 + K \ln \frac{r}{r_0}$
\n $V = V_0 + K \ln \frac{r}{r_0}$
\n $R + H = \frac{(6400 \text{km})^2}{(6400 \text{km})^2} = \frac{(6400 \text{km})^2}{1500 \text{km}}$
\n $V = \frac{(6400 \text{km})^2}{r_0}$
\n $V = \frac$

S
\nS
\nSTUDY MATERIAL: PHYSICS
\nhence
$$
-\frac{GMm}{r_1} + \frac{1}{2}mv_1^2 = -\frac{GMm}{r_2} + \frac{1}{2}mv_2^2
$$
\nwhere M is the mass of the sun.
\n
$$
\begin{bmatrix} 1 & 1 \end{bmatrix} + \frac{v_1^2}{2} + \frac{v_1^2}{2} + \cdots + \frac{v_{\text{max}}}{2} = \frac{v_{\text{max}}}{2}
$$

where M is the mass of the sun.

EXECUTE: Answer 3.1.2.1913
\nAnswer of the *St* in the image.
$$
-\frac{GMm}{t_1} + \frac{1}{2}mv_1^3 = -\frac{GMm}{t_1} + \frac{1}{2}mv_2^2
$$

\n $-\frac{GMm}{t_1} + \frac{1}{2}mv_1^2 = -\frac{GMm}{t_1} + \frac{1}{2}mv_2^2$
\n $-\frac{GM}{t_1} + \frac{1}{2}mv_1^2 = -\frac{GMm}{t_1} + \frac{1}{2}mv_2^2$
\n $-\frac{GM}{R^2} \times A = \frac{M}{2}$
\n $-\frac{GM}{R^2} \times A = \frac{M}{2}$
\n $-\frac{GM}{R^2} \times A = \frac{M}{2}$
\n $-\frac{GM}{R} \times A = \frac{M}{R}$
\n $-\frac{M}{R} \times A = \frac{M}{R}$
\n $-\frac$

$$
\text{Var}(r_1 + r_2) \perp
$$

 π^2 MR (10) (D). At the surface of the earth, the potential energy of

ints toward the galactic center. The

is the Sun's acceleration is a = v^2/R where v is

is the period of the Sun's motion around

ther then $v = \frac{2\pi R}{T}$ and $a = \frac{4\pi^2 R}{T^2}$.

Mow Angular momentum = $mv_1r_1 = m\sqrt{\frac{2}{$ sulation center then $v = \frac{2\pi R}{T}$ and $a = \frac{4\pi^2 R}{T^2}$.

Let πR be second law yields $\frac{GNM^2}{R^2} = \frac{4\pi^2 MR}{T^2}$.

Let πR be surface of the carri-particle system is πR .

Solution for N is $N = \frac{4\pi^2 R^3}{GT^2$ "s acceleration is a = v^2/R where v is
 $v = \sqrt{\frac{2GM_1r_2}{r_1(r_1 + r_2)}}$
 $v = \sqrt{\frac{2GM_1r_2}{r_1(r_1 + r_2)}}$
 d the galactic center. The

blaction is a \Rightarrow $v_1 = \sqrt{\frac{2GMr_2}{r_1(r_1 + r_2)}}$

of the Sun's moion around
 $= \frac{2\pi R}{T}$ and $a = \frac{4\pi^2 R}{T^2}$.
 $\frac{GMr^2}{R^2} = \frac{4\pi^2 MR}{T^2}$.

(10) (D). At the surface of the earth, the pot N is $N = \frac{4\pi^2 R^3}{GT^2 M}$
 $\frac{1}{2} \times 10^8$ y, which is 7.88 × 10¹⁵ s, so
 $\frac{4\pi^2 (2.2 \times 10^{20} \text{ m})^3}{\ln^3/s^2 \text{ kg}} = 10^7 \text{ m/s}^2$
 $= 10^7 \text{ m/s$ r N is $N = \frac{4\pi^2 R^3}{GT^2 M}$
 5×10^8 y, which is 7.88 × 10¹⁵ s, so
 $4\pi^2 (22 \times 10^{20} \text{ m})^3$
 $\frac{1}{10^3/s^2 kg}$ (7.88 × 10¹⁵ s)² (2.0 × 10³⁰ kg)

(L = angular momentum)
 $(1.2 \text{ rad})^2$
 $\frac{4\pi^2 (22 \times 10^{20} \text$ alactic center then $v = \frac{2\pi x}{T}$ and $a = \frac{2\pi x}{T^2}$.

Now Angular momentum = mv_r f_r = m_V₁ = mv₁ = mv₁ = mv₁ = mv The earth-particle system is

in for N is $N = \frac{4\pi^2 R^3}{GT^2 M}$

in Eq. 5 × 10⁸ y, which is 7.88 × 10¹⁵ s, so
 $\frac{4\pi^2 (2.2 \times 10^{20} \text{m})^3}{10^{-11} m^3/s^2 \text{ kg}} (7.88 \times 10^{15} \text{s})^2 (2.0 \times 10^{30} \text{kg})$
 $\frac{dA}{dt}$
 $(L = angular momentum)$ the earth-particle system is $-\frac{G N H}{R}$ GMm and the state of the st and the kinetic energy is $\frac{1}{2}$ m v_0^2 . At the maximum height $1 \tfrac{1}{2}$ and $1 \tfrac{1}{2}$ $\frac{1}{2}$ m v_0^2 . At the maximum height the kinetic energy is zero. If the maximum height reached is H, the potential energy alar momentum = $mv_1r_1 = m\sqrt{\left[\frac{2GMr_1r_2}{(r_1 + r_2)}\right]}$.

e surface of the earth, the potential energy of

particle system is $-\frac{GMm}{R}$

hetic energy is $\frac{1}{2}mv_0^2$. At the maximum height

energy is zero.

imum height $v_1 = \sqrt{\frac{r_1(r_1 + r_2)}{r_1(r_1 + r_2)}}$

Somew Angular momentum = mv₁r₁ = m $\sqrt{\frac{2GMr_1r_2}{(r_1 + r_2)}}$.

Somewheven the example of the earth, the potential energy of

e earth-particle system is $-\frac{GMm}{R}$

d the kinetic ene um = mv₁r₁ = m $\sqrt{\frac{2GMr_1r_2}{(r_1 + r_2)}}$.

the earth, the potential energy of

em is $-\frac{GMm}{R}$

is $\frac{1}{2}$ m v₀². At the maximum height

roo.

reached is H, the potential energy

stem at this instant is $-\frac{GMm}{R$ = mv₁r₁ = m_V $\left[\frac{2GMr_1r_2}{(r_1 + r_2)} \right]$.
earth, the potential energy of
 $-\frac{GMm}{R}$
m v₀². At the maximum height
thed is H, the potential energy
n at this instant is $-\frac{GMm}{R+H}$.
rgy,
 $\frac{Mm}{R+H}$
iding by m, **(D).** At the surface of the earth, the potential energy of

the earth-particle system is $-\frac{GMm}{R}$

and the kinetic energy is $\frac{1}{2}mv_0^2$. At the maximum height

the kinetic energy is zero.

(If the maximum height re Igular momentum = $mv_1r_1 = m\sqrt{\left[\frac{2GM_1r_2}{(r_1 + r_2)}\right]}$.

the surface of the earth, the potential energy of

h-particle system is $-\frac{GMm}{R}$.

kinetic energy is $\frac{1}{2}mv_0^2$. At the maximum height

tic energy is zero.

of the earth-particle system at this instant is $-\frac{Q[WIII]}{R}$. $R + H$ GMm $+H$

Using conservation of energy,

$$
-\frac{GMm}{R} + \frac{1}{2} m v_0^2 = -\frac{GMm}{R+H}
$$

Writing GM = gR² and dividing by m,

$$
-gR + \frac{v_0^2}{2} = \frac{-gR^2}{R+H} \text{ or } \frac{R^2}{R+H} = R - \frac{v_0^2}{2g}
$$

or
$$
R + H = \frac{R^2}{R - \frac{v_0^2}{2g}}
$$

Putting the values of R, v_0 and g on the right side,

N =
$$
\frac{4\pi^2 R^3}{GT^2 M}
$$

\n*x*, which is 7.88 × 10¹⁵ s, so
\n*x* = $\frac{2 (2.2 \times 10^{20} \text{ m})^3}{(2.2 \times 10^{20} \text{ m})^3}$
\n*x* = $\frac{2 (2.2 \times 10^{20} \text{ m})^3}{R + H}$
\n*x* = $\frac{2 dA/dt}{r_{min}}$
\n $\frac{dx}{dx} = 40$
\n $\frac{dA}{dt} = 40$
\n $\$

$$
= 27300 \text{ km}
$$

$$
H = (27300 - 6400)km = 20900 km.
$$

GRAVITATION Q.B. - SOLUTIONS

(11) (A). Consider a strip of thickness dr and area ds at a distance r from the centre of the sphere as shown in figure. Its mass dm = (ds) (dr) ρ

Inward gravitational pull dF on the element dr is due to the part of earth contained within radius r

$$
=\frac{G(ds\;dr)\rho\times\left(\frac{4}{3}\pi r^3\rho\right)}{r^2}\qquad\qquad\dots(i)
$$

where ρ = density of sphere

For equilibrium of the element
\n
$$
dP \cdot ds = -dF
$$
\n
$$
dP \cdot ds = -(G ds dr) \left(\frac{4}{3} \pi r\right) \rho^2 \left(\frac{ds}{d\theta}\right)
$$
\nor
$$
dP = -\frac{4}{3} \pi G \rho^2 r dr
$$
...(ii)

In order to find P, we integrate this expression within

proper limits. Thus
$$
\int_{0}^{P} dP = -\frac{4}{3} \pi G \rho^{2} \int_{R}^{r} r dr
$$

[Here at the outer end, the pressure $P = 0$]

where
$$
p =
$$
 density of the element
\n $dP \cdot ds = -dF$
\n $dP ds = -(G ds dr) \left(\frac{4}{3} \pi r\right) p^3$
\nor $dP = -\frac{4}{3} \pi Gp^2 r dr$
\nIn order to find P, we integrate this expression within
\nproper limits. Thus $\int dP = -\frac{4}{3} \pi Gp^2 \int r dr$
\nHence at the outer end, the pressure $P = 0$]
\n $\therefore P = -\frac{4}{3} \pi Gp^2 \left[\frac{r^2}{2}\right]_R^2$
\n $= -\frac{4}{6} \pi Gp^2 (r^2 - R^2) = +\frac{4}{6} \pi Gp^2 R^2 \left[1 - \frac{r^2}{R^2}\right]$
\n $= -\frac{4}{6} \pi Gp^2 (r^2 - R^2) = +\frac{4}{6} \pi Gp^2 R^2 \left[1 - \frac{r^2}{R^2}\right]$
\n $= -\frac{3}{6} \left[1 - \frac{r^2}{R^2}\right] \frac{GM}{mR} (1 + \frac{GM}{M}) = -\frac{3}{2} \left[1 - \frac{r^2}{R^2}\right]$
\n $= \frac{3}{8} \left[1 - \frac{r^2}{R^2}\right] \frac{GM}{mR} (1 + \frac{GM}{R})$
\n $= 0, R = 6400 \text{ km}, M = 6 \times 10^{24} \text{ kg}$
\nand $G = 6.6 \times 10^{-11} \text{ N} - \text{m}^2/\text{kg}^2$
\nSubstituting these value in eq. (iii), we get
\n $P = 1.69 \times 10^{11} N/m^2 \approx 1.65 \times 10^6$ atmosphere.
\n $V_A = \frac{-GM_A}{R_A}$
\n $V_A = \frac{-GM_A}{R_A}$
\n $V_B = \frac{-GM_B}{R_B} = \frac{d}{q} \pi \frac{R_A}{B}$
\n $V_B = \frac{-GM_B}{R_B} = \frac{R_A}{q} \pi R$
\n $V_B = \frac{GM_A}{R_B} = \frac{\sigma}{\sigma} \pi R_A^2$
\n V_B

Pressure at the centre of the earth:

Substituting these value in eq. (iii), we get

(12) (C).
$$
M_A = \sigma 4\pi R_A^2
$$
, $M_B = \sigma 4\pi R_B^2$,
where σ is surface density

$$
= -\frac{4}{6}\pi G \rho^2 (r^2 - R^2) = +\frac{4}{6}\pi G \rho^2 R^2 \left(1 - \frac{r^2}{R^2}\right)
$$

\n
$$
= \frac{3}{8}\left(1 - \frac{r^2}{R^2}\right) \frac{GM^2}{\pi R^4}
$$

\n
$$
= \frac{3}{8}\left(1 - \frac{r^2}{R^2}\right) \frac{GM^2}{\pi R^4}
$$

\n
$$
= 0, R = 6400 \text{ km}, M = 6 \times 10^{24} \text{ kg}
$$

\n
$$
= 0, R = 6400 \text{ km}, M = 6 \times 10^{24} \text{ kg}
$$

\nand G = 6.6×10⁻¹¹ N – m²/kg²
\nSubstituting these value in eq. (iii), we get
\nP = 1.69×10¹¹ N/m² = 1.65×10⁶ atmosphere.
\n(C) $M_A = \sigma 4\pi R_A^2, M_B = \sigma 4\pi R_B^2$,
\nwhere σ is surface density
\n
$$
V_A = \frac{-GM_A}{R_A}, V_B = \frac{-GM_B}{R_B}
$$

\n
$$
V_A = \frac{-GM_A}{R_A}, V_B = \frac{-GM_B}{\sigma 4\pi R_B^2}R_A = \frac{R_A}{R_B}
$$

\nGiven $\frac{V_A}{V_B} = \frac{M_A}{R_B} \frac{R_B}{\sigma 4\pi R_B^2} = \frac{\sigma 4\pi R_A^2}{R_B} \frac{R_B}{R_A} = \frac{R_A}{R_B}$
\nGiven $\frac{V_A}{V_B} = \frac{R_A}{R_B} = \frac{3}{4}$ then $R_B = \frac{4}{3}R_A$
\nfor new shell of mass M and radius R:
\n
$$
M = M_A + M_B = \sigma 4\pi R_A^2 + \sigma 4\pi R_B^2
$$

\n
$$
\sigma 4\pi R^2 = \sigma 4\pi (R_A^2 + R_B^2)
$$
 then
\n
$$
M = \frac{35}{\pi}
$$

17.110N
\n7.0.0.5:
$$
\text{der } a \text{ strip of thickness } dr \text{ and area as a a}
$$

\nHence $\text{r from the center of the sphere as shown in figure.}$
\n $\frac{V}{V_A} = \frac{M}{R} \frac{R_A}{M_A} = \frac{\sigma 4\pi (R_A^2 + R_B^2)}{(R_A^2 + R_B^2)^{1/2}} \frac{R_A}{\sigma 4\pi R_A^2}$
\n ρ and ρ are in a card or card is the element of π is due to
\npart of each contained pull of π on the element $d\tau$ is the set
\n P . $\text{d}s = -d\Gamma$
\n $\text{d}P \cdot ds = -d\Gamma$
\n $\text{d}P \$

 $4\pi G \times 2 \int_{0}^{R} dx$ Work KE theorem $W = \Delta K \Rightarrow m[v_P - v_Q] = \frac{1}{2}mv^2$ 2 consolar potential at O, $v_O = \frac{-GM}{R}$

E theorem $W = \Delta K \Rightarrow m[v_P - v_O] = \frac{1}{2}mv^2$
 $\frac{M}{k} - \frac{GM}{\sqrt{5}R} = \frac{1}{2}mv^2$ or $\sqrt{\frac{2GM}{R}(1 - \frac{1}{\sqrt{5}})}$

s move around COM. Distance of each star from
 $\frac{2}{3} \times L \cos 30^\circ = \frac{L}{\sqrt{3}}$

$$
m\left[\frac{GM}{R} - \frac{GM}{\sqrt{5}R}\right] = \frac{1}{2}mv^2 \text{ or } \sqrt{\frac{2GM}{R}(1 - \frac{1}{\sqrt{5}})}
$$

(14) (B). Stars move around COM. Distance of each star from

COM is
$$
\frac{2}{3} \times L \cos 30^\circ = \frac{L}{\sqrt{3}}
$$

² Force on each star M due to the other two

$$
\Rightarrow 2 \frac{GMM}{L^2} \cos 30^\circ = \sqrt{3} \frac{GM^2}{L^2}
$$

This acts as centripetal force.

Gravitational potential at P,
$$
v_p = \frac{-GM}{\sqrt{5R}}
$$

Gravitational potential at O, $v_o = \frac{-GM}{R}$
Work KE theorem $W = \Delta K \Rightarrow m[v_p - v_o] = \frac{1}{2}mv^2$
 $m\left[\frac{GM}{R} - \frac{GM}{\sqrt{5R}}\right] = \frac{1}{2}mv^2$ or $\sqrt{\frac{2GM}{R}(1 - \frac{1}{\sqrt{5}})}$
(B). Stars move around COM. Distance of each star from COM is $\frac{2}{3} \times L \cos 30^\circ = \frac{L}{\sqrt{3}}$
Force on each star M due to the other two
 $\Rightarrow 2\frac{GMM}{L^2} \cos 30^\circ = \sqrt{3} \frac{GM^2}{L^2}$
This acts as centripetal force.
 $\sqrt{3} \frac{GM^2}{L^2} = \frac{mv^2}{(L/\sqrt{3})}$
 $\Rightarrow v = \sqrt{\frac{GM}{L}}$
To dismantle the system, energy equal to total energy of the system must be provided.
i.e. $3 \times \frac{1}{2}MV^2 + \left(3 \times \frac{GM^2}{L}\right) = -\frac{3}{2} \frac{GM^2}{L}$
(B). According to the law of conservation of angular momentum, $mv_1r_1 = mv_2r_2$

To dismantle the system, energy equal to total energy of the system must be provided.

i.e.
$$
3 \times \frac{1}{2} MV^2 + \left(3 \times \frac{GM^2}{L}\right) = -\frac{3}{2} \frac{GM^2}{L}
$$

(15) (B). According to the law of conservation of angular momentum, $mv_1r_1 = mv_2r_2$

Q.B.-SOLUTIONS
\n
$$
\frac{v_1}{v_2} = \frac{r_2}{r_1} = \frac{a(1+e)}{a(1-e)},
$$
 where e is eccentricity
\nof the earth's orbit=
$$
\frac{(1+0.0167)}{(1-0.0167)} = 1.034
$$
\n
$$
\vec{I}_1 = \frac{G(\frac{4}{3}\pi R_1^3)\rho(-1)}{R_1^3}
$$
\n(A). Let the gravitational field be zero at a point distant x

of the earth's orbit=
$$
\frac{(1+0.0167)}{(1-0.0167)} = 1.034
$$

$$
\vec{i} - \vec{j} - \vec{k}
$$

(16) (A). Let the gravitational field be zero at a point distant x

of the earth's orbit= (1 0.0167) 1.034 (1 0.0167) from M¹ . 1 2 2 2 GM GM x (d x) ; 1 2 1 1 x M M d x M ; 1 2 1 x M M M d 1 1 2 d M x M M , ² d x GM GM 1 2

Potential at this point due to both the masses will be

x (d x) 1 1 2 2 1 2 1 2 M M M M M M G d M d M = 2 1 2 1 2 1 2 G G M M M M 2 M M d d 4 R I G 3 2 (toward centre) ² 4 R ^G 3 2 (toward centre) 2r ; ² 2C ^r ;

(17) (B). Gravitational field at mass m due to full solid sphere

 $I_1 = G\rho \frac{4}{3}\pi \frac{R}{2}$ (toward centre)

Gravitational field at mass m due to cavity

$$
I_2 = \frac{G\rho \frac{4}{3}\pi \left(\frac{R}{2}\right)^3}{R^2}
$$
 (toward centre)

Net gravitational field = $G\rho \frac{4}{3}\pi \frac{3}{8}R$

Here,
$$
\rho = \frac{M}{(4/3)\pi R^3}
$$
 then $F = \frac{3mg}{8}$

$$
I_2 = \frac{G\rho \frac{4}{3}\pi \left(\frac{R}{2}\right)^3}{R^2}
$$
 (toward centre)
\n
$$
I_2 = \frac{G\rho \frac{4}{3}\pi \left(\frac{R}{2}\right)^3}{R^2}
$$

\nNet gravitational field = $G\rho \frac{4}{3}\pi \frac{3}{8}R$
\nHere, $\rho = \frac{M}{(4/3)\pi R^3}$ then $F = \frac{3mg}{8}$
\n
$$
I_2 = \frac{16}{3}\pi^2 \rho^2 \frac{GM}{R}
$$

\nBut $GM = g$
\n
$$
\therefore W = \frac{3}{5} \frac{1}{5}
$$

\n
$$
V_2 = \frac{3}{5} \frac{1}{5}
$$

\n
$$
V_3 = \frac{3}{5} \frac{1}{5}
$$

\n
$$
V_4 = \frac{GMm}{2}
$$

\n
$$
\int_0^t dt = -\frac{GMm}{2C} \int_r^R \frac{dr}{r^2}; t = \frac{GMm}{2C} \left[\frac{1}{R} - \frac{1}{r}\right]
$$

\n(21) (A). In ΔA
\nHere gravity.
\n(19) (A). For calculation of gravitational field intensity inside the cavity.

$$
\int_{0}^{L} dt = -\frac{GMm}{2C} \int_{r}^{R} \frac{dr}{r^{2}} \quad ; \quad t = \frac{GMm}{2C} \left[\frac{1}{R} - \frac{1}{r} \right]
$$

(19) (A). For calculation of gravitational field intensity inside the cavity.

Noted differential	Q.B.-SOLUTIONS	STUDY MATERIAL: PHYSICS
$\frac{v_1}{v_2} = \frac{r_2}{r_1} = \frac{a(1+e)}{a(1-e)},$ where e is eccentricity\n $\vec{l}_1 = \frac{G\left(\frac{4}{3}\pi R_1^3\right)\rho(-\vec{r}_1)}{R_1^3},$ $\vec{l}_2 = \frac{G\left(\frac{4}{3}\pi R_2^3\right)\rho(-\vec{r}_2)}{R_2^3}$ \n		
<i>if</i> the earth's orbit = $\frac{(1+0.0167)}{(1-0.0167)} = 1.034$		
$\vec{l}_1 = \vec{l}_1 - \vec{l}_2$ (\vec{l}_1 -intensity inside the cavity)		
<i>i</i> from M ₁ .	$\frac{GM_1}{x^2} = \frac{GM_2}{(d-x)^2}$; $\frac{x}{d-x} = \sqrt{\frac{M_1}{M_2}}$	$\vec{l}_2 = \frac{4}{3}\pi R_1^3$
<i>i</i> = $\vec{l}_1 - \vec{l}_2$ (\vec{l}_1 -intensity inside the cavity)		
<i>i</i> = $\frac{1}{3}\pi R_1\vec{l}$	$\vec{l}_2 = \frac{4}{3}\pi R_1\vec{l}$	
<i>i</i> = $\frac{1}{3}\pi R_1\vec{l}$	$\vec{l}_2 = \frac{1}{3}\pi R_1\vec{l}$	
$x = \sqrt{M_1}d - x\sqrt{M_1}$; $x\left[\sqrt{M_1} + \sqrt{M_2}\right] = \sqrt{M_1}d$	$x = \frac{d\sqrt{M_1}}{\sqrt{M_1} + \sqrt{M_2}}$	$x = \frac{d\sqrt{M$

 (\vec{I}) - intensity inside the cavity)

$$
\frac{x}{3} = \frac{M_1}{3} G \pi \rho \left[-\vec{r}_1 + \vec{r}_2 \right] = \frac{4}{3} G \pi \rho \vec{\ell}
$$

 $- x \quad \sqrt{\mathbf{M}_2}$ (20) (D). If M is the mass and R is the radius of earth, then the

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

SIUDYMATE

ccentricity
 $\vec{l}_1 = \frac{G(\frac{4}{3}\pi R_1^3)\rho(-\vec{r}_1)}{R_1^3}$, $\vec{l}_2 = \frac{G(\frac{4}{3}\pi$ **(O.B.-SOLUTIONS** STUDY MATERIAL: PH

eccentricity
 $\vec{l}_1 = \frac{G(\frac{4}{3}\pi R_1^3)\rho(-\vec{\eta})}{R_1^3}$, $\vec{l}_2 = \frac{G(\frac{4}{3}\pi R_2^3)\rho(-\vec{\eta})}{R_2^3}$
 $= 1.034$
 $\vec{l} = \vec{l}_1 - \vec{l}_2$ (\vec{l} - intensity inside the cavity)
 $\frac{x}{d-x} = \sqrt{\frac{M_$ **(O.B.- SOLUTIONS** STUDY MATERIAL: PHYS

secentricity
 $\vec{l}_1 = \frac{G(\frac{4}{3}\pi R_1^3)\rho(-\vec{r}_1)}{R_1^3}$, $\vec{l}_2 = \frac{G(\frac{4}{3}\pi R_2^3)\rho(-\vec{r}_2)}{R_2^3}$

be zero at a point distant x
 $\vec{l} = \vec{l}_1 - \vec{l}_2$ (\vec{l} - intensity inside the $+\sqrt{M_2}$ The spherical volume may be supposed to be formed by a large number of their concentric spherical shells. Let the sphere be disassembled by removing such shells. When there is a spherical core of radius x the energy needed to disassemble a spherical shell of thickness dx is $\vec{I}_1 = \frac{G(\frac{4}{3}\pi R_1^3)\rho(-\vec{n}_1)}{R_1^3}$, $\vec{I}_2 = \frac{G(\frac{4}{3}\pi R_2^3)\rho(-\vec{n}_2)}{R_2^3}$
 $= \vec{I}_1 - \vec{I}_2$ (\vec{I} - intensity inside the cavity)
 $= \frac{4}{3}G\pi\rho[-\vec{n}_1 + \vec{r}_2] = \frac{4}{3}G\pi\rho\vec{\ell}$

(i). If M is the mass and $\left(-\vec{r}_1\right)$, $\vec{l}_2 = \frac{G\left(\frac{4}{3}\pi R_2^3\right)\rho(-\vec{r}_2)}{R_2^3}$
sisty inside the cavity)
 $= \frac{4}{3}G\pi\rho\vec{l}$
and R is the radius of earth, then the
emay be supposed to be formed by
ir concentric spherical shells.
sesembled (a) \vec{l} is \vec{l} s and R is the radius of earth, then the

...

The may be supposed to be formed by

their concentric spherical shells.

Sisassembled by removing such shells.

Sherical core of radius x the energy

ble a spherical shell of b be formed by
al shells.
ng such shells.
s x the energy
thickness dx is
nd thickness
 $\frac{2}{\rho^2}Gx^4dx$ ($\vec{1}$ - intensity inside the cavity)
 \vec{r} = $\frac{4}{13} G \pi \rho \vec{\ell}$

the mass and R is the radius of earth, then the
 $= \frac{M}{\frac{4}{3} \pi R^3}$.

cal volume may be supposed to be formed by

there of their concentric spher = $\frac{4}{3}$ Gπρ ℓ

md R is the radius of earth, then the

may be supposed to be formed by

r concentric spherical shells.

ssembled by removing such shells.

rical core of radius x the energy

a spherical shell of thic R₁

T - intensity inside the cavity)

T₁ + \vec{r}_2] = $\frac{4}{3}$ G $\pi \rho \vec{\ell}$

ne mass and R is the radius of earth, then the
 $\frac{M}{\pi R^3}$.

I volume may be supposed to be formed by

er of their concentric spherical e cavity)

dius of earth, then the

osed to be formed by

spherical shells.

removing such shells.

radius x the energy

hell of thickness dx is

ius x and thickness
 $= \frac{16}{3} \pi^2 \rho^2 Gx^4 dx$
 $\left[\frac{x^5}{5} \right]^R$ based to be formed by
pherical shells.
emoving such shells.
radius x the energy
ell of thickness dx is
us x and thickness
 $= \frac{16}{3} \pi^2 \rho^2 Gx^4 dx$
 $= \frac{16}{3} \pi^2 \rho^2 Gx^4 dx$

$$
dW = \frac{Gm_1m_2}{x} \ ; \ m_1 = \frac{4}{3}\pi x^3 \rho
$$

 m_2 = mass of spherical shell of radius x and thickness $\pi x^2 dx \rho$.

$$
\therefore \quad dW = \frac{G\left(\frac{4}{3}\pi x^3 \rho\right) (4\pi x^2 dx \rho)}{x} = \frac{16}{3} \pi^2 \rho^2 G x^4 dx
$$

: Total energy required

$$
\frac{\sqrt{M_2}}{1-\sqrt{M_1}} = \sqrt{M_1} d - x\sqrt{M_1} \div \sqrt{M_2} = \sqrt{M_1} d
$$
\n
$$
= \frac{d\sqrt{M_1}}{\sqrt{M_1} + \sqrt{M_2}} , d - x = \frac{d\sqrt{M_1}}{\sqrt{M_1} + \sqrt{M_2}} = \sqrt{M_1} d
$$
\n
$$
= \frac{d\sqrt{M_1}}{\sqrt{M_1} + \sqrt{M_2}} , d - x = \frac{d\sqrt{M_1}}{\sqrt{M_1} + \sqrt{M_2}} = \frac{M}{\sqrt{M_1} + \sqrt{M_2}} = \frac{M}{\sqrt{M_1}
$$

But GM = gR^2

$$
\frac{3}{5} \frac{\text{gR}^2}{\text{m}^2} \text{m} = \frac{3}{5} \frac{\text{gR}^2}{\text{m}^2} = \frac{3}{5} \text{gMR} = \frac{3}{5} \times 10 \times 2.5 \times 10^{31}
$$

= 1.5 × 10³² J
= 1.5 × 10³² J

(21) (A). In $\triangle AOB$: $\cos 60^\circ = \frac{R}{OP} \Rightarrow OB = 2R$ OB₂

Here gravitational force will provide the required

centripetal force. Hence,
$$
\frac{GMm}{(OB)^2} = m(OB)\omega^2
$$

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UTIATION
\n
$$
\Rightarrow \omega = \sqrt{\frac{GM}{(OB)^3}} = \sqrt{\frac{GM}{(2R)^3}} \Rightarrow \omega = \sqrt{\frac{GM}{8R^3}}
$$
\n(7) 2. Remember Keplers law
\nArea! velocity = $\frac{dA}{dt} = \frac{J}{2m}$
\n5. $g = \frac{GM}{R^2} = \frac{Gd \frac{4}{3} \pi R^3}{R^2}$ [d = density] ; $g = Gd \frac{4}{3} \pi R$
\nSince g is constant and R increased by factor 5,
\nd decreases by factor 1/5.
\n(8) 3. $\frac{1}{2} mv_0^2 - \frac{GMm}{R} = -\frac{GM}{R}$

(1) 5.
$$
g = \frac{GM}{R^2} = \frac{Gd \frac{4}{3} \pi R^3}{R^2}
$$
 [d = density] ; $g = Gd \frac{4}{3} \pi R$ $\left(\frac{mv}{r} = \frac{G N m}{r^2}\right)$

Since g is constant and R increased by factor 5, d decreases by factor 1/5.

$$
rce of gravity = \frac{GMm}{R^2} - \frac{G\frac{M}{3}r}{R^2}
$$

(only due to mass M/3 due to shell gravitational field is zero (inside the shell)).

(3) 2.
$$
V_e = \sqrt{2gR} = \sqrt{\frac{2GM}{R^2}}R = \sqrt{\frac{2Gd\frac{4}{3}\pi R^3}{R^2}}R
$$

\n $= R\sqrt{2Gd\frac{4}{3}\pi}$ as $V_e \propto R$ for same density, $\frac{V_A}{V_B} = 2$
\n(4) 2. $\frac{1}{2}mv_e^2 = \frac{GMm}{R}$; $v_e = \sqrt{\frac{GMm}{R}} = \sqrt{2gR}$
\n(10) 3. $g = \frac{G}{R}$

In tunnel body will perform SHM at centre $V_{\text{max}} = A\omega$ (see chapter on SHM)

$$
= \frac{R2\pi}{2\pi\sqrt{R/g}} = \sqrt{gR} = \frac{v_e}{\sqrt{2}}
$$

(5) 2. Total energy = kinetic energy + Potential energy

$$
E_0 = \frac{1}{2}mv^2 - \frac{GMm}{r}
$$
...(i)

Further,
$$
\frac{mv^2}{r} = \frac{GMm}{r^2}
$$
 or $\frac{1}{2}mv^2 = \frac{GMm}{2r}$...(ii)

Substituting the value of
$$
\frac{1}{2}mv^2
$$
 in equation (i) from (1) (C).

equation (ii), we get
$$
E_0 = \frac{GMm}{2r} - \frac{GMm}{r} = -\frac{GMm}{2r}
$$

Therefore, P.E. = $-\frac{GMm}{r} = 2E_0$

(6) 4. Due to mutual force of attraction they will revolve about centre of mass with same ω .

$$
\frac{\text{KE}_{4\text{m}}}{\text{KE}_{\text{m}}} = \frac{\frac{1}{2}4\text{m}\omega^2 \left(\frac{d}{5}\right)^2}{\frac{1}{2}\text{m}\omega^2 \left(\frac{4d}{5}\right)^2} = \frac{4 \times \frac{1}{25}}{\frac{16}{25}} = \frac{1}{4}
$$

$$
4m \t\t CM
$$

(7) 2. Remember Keplers law are applicable for satellite also.

VITATION
\n
$$
\Rightarrow \omega = \sqrt{\frac{GM}{(OB)^3}} = \sqrt{\frac{GM}{(2R)^3}} \Rightarrow \omega = \sqrt{\frac{GM}{8R^3}}
$$
\n(7) 2. Remember Keplers law are applicable for satellite also.
\nArea 1 velocity = $\frac{dA}{dt} = \frac{J}{2m} = \frac{1}{2} \text{vr} = \frac{1}{2} \sqrt{\frac{GM}{r}}$
\n5. $g = \frac{GM}{R^2} = \frac{Gd \frac{4}{3} \pi R^3}{R^2}$ [d = density] ; $g = Gd \frac{4}{3} \pi R$
\nSince g is constant and R increased by factor 5,
\nd decreases by factor 1/5.
\n**3.** $\frac{1}{2} m v_0^2 - \frac{GMm}{R} = -\frac{GMm}{R + h}$ and $g = \frac{GM}{R^2}$
\n
\n**4.** The second velocity = 1 : 2
\n $\frac{GMm}{R}$ = $\frac{GMm}{R + h}$ and $g = \frac{GM}{R^2}$

Areal velocity $\alpha \sqrt{\mathbf{r}}$. Hence ratio of areal velocity = 1 : 2

IDENTATION
\n
$$
\frac{1}{2} \omega = \sqrt{\frac{GM}{(OB)^3}} = \sqrt{\frac{GM}{(OR)^3}} \Rightarrow \omega = \sqrt{\frac{GM}{NR^3}}
$$
\n
$$
\frac{1}{2} \sqrt{\frac{GM}{(OB)^3}} = \sqrt{\frac{GM}{RR^3}}
$$
\n**EXERCISE-3**
\n**EXECUTEE-3**
\n**EXECUTEE-4**
\n**EXECUTEE-5**
\n**EXECUTEE-6**
\n**EXECUTEE-7**
\n**EXECUTEE-8**
\n**EXECUTEE-8**
\n**EXECUTEE-9**
\n**EXECUTEE-1**
\n**EXECUTEE-1**
\n**EXECUTEE-1**
\n**EXECUTEE-2**
\n**EXECUTEE-3**
\n**EXECUTEE-4**
\n**EXECUTEE-5**
\n**EXECUTEE-6**
\n**EXECUTEE-6**
\n**EXECUTEE-7**
\n**EXECUTEE-8**
\n**EXECUTEE-9**
\n**EXECUTEE-1**
\n**EXECUTEE-1**
\n**EXECUTEE-1**
\n**EXECUTEE-1**
\n**EXECUTEE-2**
\n**EXECUTEE-3**
\n**EXECUTEE-4**
\n**EXECUTEE-5**
\n**EXECUTEE-6**
\n**EXECUTEE-6**
\n**EXECUTEE-7**
\n**EXECUTEE-8**
\n**EXECUTEE-9**
\n**EXECUTEE-1**
\n**EXECUTEE-1**

2.
$$
\frac{1}{2} \text{ m/s} = -\frac{1}{R}
$$
, $v_e = \sqrt{\frac{R}{R}} = \sqrt{\frac{2kR}{r}}$
\nH number body will perform SHM at centre
\n
$$
= \frac{1}{2\pi \sqrt{R/g}} = \sqrt{gR} = \frac{V_e}{\sqrt{2}}
$$
\n2. Total energy = kinetic energy + Potential energy
\n
$$
E_0 = \frac{1}{2} \text{ m}v^2 = \frac{GMm}{r}
$$
\n3. $g = \frac{g'}{R^2} = \frac{g'}{R} = \frac{g'}{R} = \frac{g'}{R} = \frac{g'}{$

(3) (A). Satellite go in tangential direction.

(4) **(C).** Kinetic energy needed to project body so that it can
$$
\frac{1}{2}
$$

escape out
$$
K = \frac{1}{2}mv_e^2 = \frac{1}{2}m(\sqrt{2gR})^2 = mgR
$$

(5) (B). Escape velocity does not depend on angle.

(B).
$$
\frac{T_1^2}{T_2^2} = \frac{r_1^3}{r_2^3}
$$

37

(6) (B).

Q.B.-SOLUTIONS

\n**ODM ADVANNED ULFARNNING**

\n(7)

\n(B).

\n**Q.B.-SOLUTIONS**

\n
$$
\frac{1}{x} = \frac{2}{r-x}
$$

\n(7)

\n(B).

\nBoth the particles will strike at centre of mass.

\nSo, distance of c.m. from smaller body

\n
$$
r_1 = \frac{m_2 r}{m_1 + m_2} = \frac{5m(9R)}{6m} = 7.5R
$$

\n(8)

\n(D).
$$
v = \sqrt{\frac{GM}{r}} = \sqrt{\frac{gR^2}{(R+x)}}
$$

\n(9)

\n(A). Time period does not depend on mass of satellite.

\n(21)

\n(A).
$$
E_f = \frac{G}{\sqrt{4.5}} = \frac{G}{\sqrt{4.5}} = \frac{G}{\sqrt{4.5}} = \frac{G}{\sqrt{4.5}} = 64 \times 10^9
$$

Both the particles will strike at centre of mass. So, distance of c.m. from smaller body

$$
r_1 = \frac{m_2 r}{m_1 + m_2} = \frac{5m(9R)}{m + 5m} = \frac{5m(9R)}{6m} = 7.5R
$$

(8) **(D).**
$$
v = \sqrt{\frac{GM}{r}} = \sqrt{\frac{gR^2}{(R+x)}}
$$

(9) (A). Time period does not depend on mass of satellite.

(10) (B). Gain in P.E. =
$$
\frac{mgRh}{R+h}
$$

(11) **(A).**
$$
F \propto \frac{1}{r^n} \Rightarrow F = \frac{k}{r^n}
$$

$$
F = \frac{k}{r^n} = \frac{mv^2}{r} \; ; \; v = \sqrt{\frac{k}{m} \left(\frac{1}{r^{n-1}}\right)}
$$

$$
F = \frac{k}{r^n} = \frac{mv^2}{r} \; ; \; v = \sqrt{\frac{k}{m} \left(\frac{1}{r^{n-1}}\right)}
$$

Time period $T = \frac{2\pi r}{v} \Rightarrow T = 2\pi r \sqrt{\frac{m}{k} (r^{n-1})}$; $T \propto r^{\frac{n+1}{2}}$
(A), σ denote \sim 1

(12) (A). g depends on density of earth, but the reverse is not true.

(13) (C).
$$
g_h = \left(1 - \frac{2h}{R}\right)
$$
; $g_d = \left(1 - \frac{d}{R}\right)$
\n $g_h = g_d$; $2h = d$
\n(14) (D). $W = \frac{GMm}{R} = \frac{6.67 \times 10^{-11} \times 100 \times 10 \times 10^{-3}}{10 \times 10^{-2}} = \frac{GMm}{R^2}$

 $W = 6.67 \times 10^{-10}$ J

- **(15) (A).** Electron charge is same everywhere.
- **(16) (A).** Gauss Theorem

(17) **(B).** Escale velocity
$$
v_e = \sqrt{\frac{GM}{r}}
$$

$$
u = \sqrt{\frac{GM}{4R} [1 + 2\sqrt{2}]} = \frac{1}{2} \sqrt{\frac{GM}{R}}
$$

Hence M = 10 M_e.
$$
r = \frac{I_e}{10}
$$

$$
v_e = \sqrt{\frac{G \times 10M_e}{r_e / 10}} = 110 \text{ km/s}
$$

(18) **(D).**
$$
g' = \frac{g}{\left(1 + \frac{h}{R}\right)^2}
$$
; $\frac{g}{9} = \frac{g}{\left(1 + \frac{h}{R}\right)^2}$; $1 + \frac{h}{R} = 3$; $h = 2R$ $V_2 = -\frac{3G}{2}\frac{N}{(R)}$

(19) **(D).**
$$
\frac{Gm}{x^2} = \frac{G (4m)}{(r - x)^2}
$$

\n $m \frac{r}{3}$ $\frac{2r}{3}$ 4m

Q.B.-SOLUTIONS	STUDY MATERIAL: PHYSICS	
\n\n $\frac{M}{N} = \frac{c_m}{r}$ \n	\n $\frac{2R}{N}$ \n	\n $\frac{1}{x} = \frac{2}{r-x}$; $r - x = 2x$; $3x = \frac{r}{3} \Rightarrow x = \frac{r}{3}$ \n
\n\n $V = -\frac{GM}{r/3} - \frac{G(4m)}{2r/3} = -\frac{3GM}{r} - \frac{6Gm}{r} = -\frac{9GM}{r}$ \n		
\n\n $\frac{m_2r}{m_1 + m_2} = \frac{5m(9R)}{m + 5m} = \frac{5m(9R)}{6m} = 7.5R$ \n	\n $\frac{1}{2} = \frac{8m}{r} \Rightarrow \frac{m_2r}{r} = \frac{3m}{r} \Rightarrow x = \frac{3}{3}$ \n	
\n\n $V = -\frac{GMm}{r^2} = \frac{GMm}{R} = \frac{GMm}{R}$ \n		
\n\n $V = \sqrt{\frac{GM}{r}} = \sqrt{\frac{gR^2}{(R + x)}}$ \n	\n $\frac{gR^2}{R} \times \frac{m}{R} = mgR = 1000 \times 10 \times 6400 \times 10^3$ \n	
\n\n $V = \sqrt{\frac{GM}{r}} = \sqrt{\frac{gR^2}{(R + x)}}$ \n	\n $\frac{gR^2}{R} \times \frac{m}{R} = mgR = 1000 \times 10 \times 6400 \times 10^3$ \n	
\n\n $V = \sqrt{\frac{GM}{r}} = \frac{mgR}{(R + x)} = \frac{1}{r} \times \frac{GM}{R} = \frac{GM}{R}$ \n		
\n\n $V = \frac{1}{r} \times \frac{GM}{R} = \frac{GM}{R} = \frac{GM}{R}$ \n		

(20) **(D).** W =
$$
0 - \left(-\frac{GMm}{R}\right) = \frac{GMm}{R}
$$

$$
= gR2 \times \frac{m}{R} = mgR = 1000 \times 10 \times 6400 \times 103
$$

= 64 × 10⁹ J = 6.4 × 10¹⁰

Solution
\n**EXAMPLE 1.21. PHYSICS**
\n**EXAMPLE 1.33. a**
$$
\frac{1}{x} = \frac{2}{r-x}
$$
; $r-x = 2x$; $3x = \frac{r}{3} \Rightarrow x = \frac{r}{3}$
\n**Example 1.34. c Example 1.60 Example 1.61. c Example 1.61. d Example 1.62. d Example 1.63. d Example 1.64. c Example 1.65. d Example 1.66. d Example 1.67. c Example 1.68. d Example 1.69. c Example 1.60. c Example 1.61. d Example 1.61. c Example 1.62. d Example 1.63. d Example 1.64. c Example 1.65. c Example 1.66. c Example 1.67. c Example 1.69. c Example 1.60. c Example 1.61. c Example 1.62. d Example 1.63. d Example 1.64. c Example 1.65. c Example 1.66. c Example 1.67. c Example 1.69. c Example 1.60. c Example 1.61. d Example 1.62. d Example 1.63. d Example 1.64. c Example 1.65. c Example 1.67. d Example 1.69. c Example 1.60. c Example 1.61. d Example 1.62. d Example 1.63. d Example 1.64. c Example 1.65. c Example 1.67. c Example 1.69. c Example 1.61**

M Net force on any one particle

u≧

$$
\frac{435}{45\%}\text{M}
$$

\nNet force on any one particle
\n
$$
= \frac{GM^2}{(2R)^2} + \frac{GM^2}{(R\sqrt{2})^2} \cos 45^\circ + \frac{GM^2}{(R\sqrt{2})^2} \cos 45^\circ
$$
\n
$$
= \frac{GM^2}{R^2} \left[\frac{1}{4} + \frac{1}{\sqrt{2}} \right]
$$

\nThis force will be equal to centripetal force so
\n
$$
\frac{Mu^2}{R} = \frac{GM^2}{R^2} \left[\frac{1+2\sqrt{2}}{4} \right]
$$

\n
$$
u = \sqrt{\frac{GM}{4R} [1 + 2\sqrt{2}]} = \frac{1}{2} \sqrt{\frac{GM}{R} (2\sqrt{2} + 1)}
$$

This force will be equal to centripetal force so

$$
F = \frac{k}{r^{n}} = \frac{mv^{2}}{r}; v = \sqrt{\frac{k}{m} \left(\frac{1}{r^{n-1}}\right)}
$$
\n
$$
Time period T = \frac{2\pi r}{r} \Rightarrow T = 2\pi r \sqrt{\frac{n}{k} (r^{n-1})}; T \propto r^{-\frac{n+1}{2}}
$$
\n(12) (A). g depends on density of earth, but the reverse is not true.
\n(13) (C). $g_{n} = \left(1 - \frac{2h}{R}\right); g_{d} = \left(1 - \frac{d}{R}\right)$
\n $g_{h} = g_{d} : 2h = d$
\n(14) (D). $W = \frac{GMm}{R} = \frac{6.67 \times 10^{-11} \times 100 \times 10 \times 10^{-3}}{10 \times 10^{-2}}$
\n $W = 6.67 \times 10^{-19} \text{ J}$
\n $W = 6.67 \times 10^{-19} \text{ J}$
\n $W = 6.67 \times 10^{-19} \text{ J}$
\n $W = 6.67 \times 10^{-11} \times 100 \times 10 \times 10^{-3}$
\n $W = 6.67 \times 10^{-11} \times 100 \times 10^{-2}$
\n $W = 6.67 \times 10^{-11} \times 100 \times 10^{-2}$
\n $W = 6.67 \times 10^{-11} \times 100 \times 10^{-3}$
\n $W = 6.67 \times 10^{-10} \text{ J}$
\n $W = 6.67 \times 10^{-10} \text{ J}$
\n $W = 6.67 \times 10^{-11} \times 100 \times 10^{-3}$
\n $W = 6.67 \times 10^{-10} \text{ J}$
\n $W = 6.67 \times 10^{-11} \times 100 \times 10^{-3}$
\n $W = 6.67 \times 10^{-10} \text{ J}$
\n $W = 6.67 \times 10^{-11} \times 100 \times 10^{-3}$

GRAVITATION Q.B. - SOLUTIONS

(25) (C).
$$
g = \frac{GM}{R^3}r
$$
, $0 \le r \le R$; $g = \frac{GM}{r^2}$, $r \ge R$

(26) (A). 2 2 n 1 mR Now, 2 2 V R dA L dt 2m 2 2 2 ^C 2 2 2

(27) (C).
$$
\frac{dA}{dt} = \frac{L}{2m}
$$

Net force on particle towards centre of circle is

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

This force will act as centripetal force.

Distance of particle from centre of circle is
$$
\frac{a}{\sqrt{2}}
$$

$$
-\frac{GM_{\rm e}m}{10R} + \frac{1}{2}mv_0^2 = -\frac{C}{r}
$$

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

$$
v^2 = \frac{GM}{a} \left(\frac{1}{2\sqrt{2}} + 1\right) = \frac{GM}{a} (1.35) ; \ v = 1.16 \sqrt{\frac{GM}{a}}
$$

$$
v^2 = \frac{9}{10}
$$

(29) (B). Minimum energy required (E) = – (Potential energy of object at surface of earth)

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

Now, $\frac{E_{\text{moon}}}{E_{\text{earth}}} = \frac{M_{\text{moon}}}{M_{\text{earth}}} \cdot \frac{R_{\text{earth}}}{R_{\text{moon}}} = \frac{1}{64} \times \frac{4}{1}$
 $\Rightarrow E_{\text{moon}} = \frac{E}{16}$ (1) (D). g =

$$
\sqrt{2} \t\t r \t\t \frac{a}{\sqrt{2}} \t\t a^{2} \t\t v^{2} = \frac{GM}{a} \left(\frac{1}{2\sqrt{2}} + 1 \right) = \frac{GM}{a} (1.35) ; \t v = 1.16 \sqrt{\frac{GM}{a}} \t\t v^{2} = \frac{9}{10} v^{2} + v^{2} = \frac{9}{10} \times (11.2)^{2} + (12)
$$
\n(29) **(B)** Minimum energy required (E)
\n= - (Potential energy of object at surface of earth)
\nNow M_{earth} = 64 M_{moon}
\n $\rho \cdot \frac{4}{3} \pi R_{e}^{3} = 64 \cdot \frac{4}{3} \pi R_{m}^{3} \Rightarrow R_{e} = 4R_{m}$
\nNow $\frac{E_{\text{moon}}}{E_{\text{earth}}} = \frac{M_{\text{moon}}}{M_{\text{earth}}} = \frac{1}{64} \times \frac{4}{1}$
\n $\Rightarrow E_{\text{moon}} = \frac{E}{16}$
\n(30) **(A)** $\frac{-GM_{e}M}{R} + \frac{1}{2} M u^{2} = \frac{-GM_{e}M}{2R} + \frac{1}{2} M v^{2}$
\n \therefore $\left(\sum_{k} \right)^{2k} = \sum_{k} \left(\sum_{k} \right)^{2k} \exp\left(-\frac{GM_{e}M}{M} + \frac{1}{2} M u^{2}\right) = \frac{-GM_{e}M}{2R} + \frac{1}{2} M v^{2}$
\n \therefore $\left(\sum_{k} \right)^{2k} = \sum_{k} \left(\sum_{k} \right)^{2k} \exp\left(-\frac{GM_{e}M}{M} + \frac{1}{2} M u^{2}\right) = \frac{-GM_{e}M}{2R} + \frac{1}{2} M v^{2}$
\n \therefore $\left(\sum_{k} \right)^{2k} = \sum_{k} \left(\sum_{k} \right)^{2k} \exp\left(-\frac{GM_{e}M}{M} + \frac{1}{2} M u^{2}\right) = \frac{GM_{e}M}{M} \exp\left(-\frac{GM_{e}M}{M} + \frac{1}{2} M u^{2}\right) = \frac$

 \bigvee 2R

(7).
$$
E = \frac{GM}{R^3}
$$
, $0 \le r \le R$; $g = \frac{GM}{r^2}$, $r \ge R$
\n(A). $F \propto \frac{1}{R^n}$; $F = \frac{k}{R^n} = \frac{mV^2}{R}$
\n(A). $F \propto \frac{1}{R^n}$; $F = \frac{k}{R^n} = \frac{mV^2}{R}$
\n $\Rightarrow V^2 = \frac{k}{mR^{n-1}} \Rightarrow V \propto R^{\frac{(1-n)}{2}}$
\nNow, $T = \frac{2\pi R}{V} \propto \frac{R}{\frac{(1-n)}{R^2}}$
\nNow, $T = \frac{2\pi R}{V} \propto \frac{R}{\frac{(1-n)}{R^2}}$
\n $\Rightarrow V^2 = \frac{k}{mR^{n-1}} \Rightarrow V \propto R^{\frac{n+1}{2}}$
\n $\Rightarrow V^2 = \frac{k}{mR^{n-1}} \Rightarrow V \propto R^{\frac{n+1}{2}}$
\n $\Rightarrow V^2 = \frac{2\pi R}{mR^{n-1}} \propto \frac{R^{\frac{n+1}{2}}}{R^2}$
\n $\Rightarrow \frac{M}{R^2} \propto \frac{R^{\frac{n+1}{2}}}{\frac{(1-n)}{R^2}}$
\n $\Rightarrow \frac{M}{R^2} \propto \frac{R^{\frac{(1-n)}{2}}}{\frac{(1-n)^2}{R^2}}$
\n $\Rightarrow \frac{M}{R^2} \propto \frac{R^{\frac{(1-n)}{2$

$$
= \frac{M}{20} \left(100u^2 - \frac{119GM_e}{2R} \right) = 5M \left(u^2 - \frac{119GM_e}{200R} \right)
$$

(31) (C). At pole, weight = mg = 196 $m = 19.6$ kg At equator, weight = $mg - m\omega^2 R$

$$
=196 - (19.6) \left[\frac{2\pi}{24 \times 3600} \right]^2 \times 6400 \times 10^3 = 195.33 \text{ N}
$$

(32) (D). Gravitational field on the surface of a solid sphere

$$
I_g = \frac{GM}{R^2}
$$
. By the graph, $\frac{GM_1}{(1)^2} = 2$ and $\frac{GM_2}{(2)^2} = 3$

On solving,
$$
\frac{M_1}{M_2} = \frac{1}{6}
$$

(25) (C), E =
$$
\frac{6M}{R^3}
$$
, D = 5K R : E = $\frac{6M}{L^3}$, P = R
\n(26) (A), F = $\frac{R}{R^3}$, F = $\frac{R}{R^3}$, F = $\frac{mv^2}{R}$
\n $\Rightarrow V^2 = \frac{R}{mR^{\text{net}}}$ $\Rightarrow V = \frac{R}{R^3}$
\nNow, T = $\frac{2\pi R}{2\pi R} \times \frac{R}{R}$ \Rightarrow $\frac{R}{R^3}$
\nNow, T = $\frac{2\pi R}{\sqrt{R^3}} \times \frac{R}{R^3}$
\n(27) (C) $\frac{d\Lambda}{d\Lambda} = \frac{L}{2m}$
\n(28) (C) $\times \frac{8}{\sqrt{3\pi}} \times \frac{R}{d\Lambda} = \frac{1}{2m}$
\n(29) (D) $\frac{d\Lambda}{d\Lambda} = 1$ $\frac{1}{\sqrt{2\pi}} \times 1$ $\frac{1}{\sqrt{2\pi}} \times 1$
\n $\frac{1}{\sqrt{2\pi}} \times \frac{R}{d\Lambda} = \frac{1}{\sqrt{2\pi}} \times 1$
\n $\frac{1}{\sqrt{2\pi}} \times \frac{1}{\sqrt{2\pi}} \times 1$
\n $\frac{1}{\sqrt{2\pi}} \times \frac{1}{\sqrt{2\pi}} \times 1$
\n(29) (D) $\frac{d\Lambda}{d\Lambda} = 1$ $\frac{d\Lambda}{d\Lambda$

EXERCISE-5

(1) **(D)**
$$
g = \frac{GM}{R^2} = \frac{G(\frac{4}{3}\pi R^3)\rho}{R^2} = \frac{4}{3}\pi GR\rho
$$

 $\frac{g'}{g} = \frac{R'}{R} = \frac{3R}{R} = 3$ $\therefore g' = 3g$

(2) (A). K.E. of satellite moving in an orbit around the earth is

$$
K = \frac{1}{2}mv^2 = \frac{1}{2}m\left(\sqrt{\frac{GM}{r}}\right)^2 = \frac{GMm}{2r}
$$

P.E. of satellite and earth system is GMm $\left(\begin{array}{cc} \rightarrow \\ \rightarrow \end{array} \right)$

r

$$
= \frac{90 \text{N}}{r} \Rightarrow \frac{R}{U} = \frac{2r}{\frac{GMm}{r}} = \frac{1}{2}
$$

(3) (A). Potential energy at height R = $-\frac{GMm}{2R}$ **Gravitational potential at point P**

If m be the mass of a body which is thrown with velocity v_e so that it goes out of gravitational field from distance R, then

EXAMPLEARINING		
(A). Potential energy at height R = $-\frac{GMm}{2R}$	Gravitational potential at point P due to pa velocity v_e so that it goes out of gravitational field from distance R, then	is $V_1 = -\frac{GM}{(a/2)}$.
or $v_e = \sqrt{gR}$. Now, $v = \sqrt{2gR}$,	Here, total gravitational potential at the $V = V_1 + V_2$	
so, $v = \sqrt{2}v_e$ or $v_e = \frac{v}{\sqrt{2}}$	So $V = \sqrt{2}v_e$ or $v_e = \frac{v}{\sqrt{2}}$	
(A). Potential energy at height R = $-\frac{GMm}{2R}$ is $V_1 = -\frac{GM}{(a/2)}$.		
Gravitational potential at point P due to the $\frac{V}{2}$ and the $V = \frac{GM}{a}$		
or $v_e = \sqrt{gR}$. Now, $v = \sqrt{2gR}$,	Hence, total gravitational potential at the $V = V_1 + V_2$	
comparing it with given equation, $f = 1/\sqrt{2}$	(8) $(C) \cdot v_1r_1 = v_2r_2$ (\because Angular momentum is co	
(D). Since orbital velocity of satellite is	(9) $(C) \cdot g' = \frac{g}{(1 + \frac{h}{R})^2}$ $\frac{g}{16} = \frac{g}{(1 + \frac{h}{R})^2}$	

(4) (B). Since orbital velocity of satellite is

$$
v = \sqrt{\frac{GM}{r}}
$$
, if does not depend upon the mass of the $\left(1 + \frac{h}{R}\right)^2$

satellite. Therefore, both satellites will move with same speed.

(5) (B). SCD : $A_1 - t_1$ (areal velocity constant)

SAB : A₂ - t₂ ;
$$
\frac{A_1}{t_1} = \frac{A_2}{t_2}
$$
, t₁ = t₂. $\frac{A}{A}$
A₁ = 2A₂ \therefore t₁ = 2t₂

(6) (B). Orbit speed of the satellite around the

earth is
$$
v = \sqrt{\frac{GM}{r}}
$$
 $a = \frac{F_g}{m} = \frac{4GM_p}{D^2}$

where, $G =$ Universal gravitational constant $M =$ Mass of earth, $r =$ Radius of the orbit of the satellite. For satellite A

$$
r_A = 4R
$$
, $v_A = 3V$; $v_A = \sqrt{\frac{GM}{r_A}}$ (i) (12) (A).

For satellite B,

$$
r_B = R
$$
, $v_B = ?$, $v_B = \sqrt{\frac{GM}{r_B}}$ (ii)

Dividing equation (ii) by equation (i),

$$
\therefore \quad \frac{v_B}{v_A} = \sqrt{\frac{r_A}{r_B}} \; ; \; v_B = v_A \sqrt{\frac{r_A}{r_B}}
$$

Substituting the given values, we get

$$
v_B = 3V \sqrt{\frac{4R}{R}}
$$
; $v_B = 6V$ = $\frac{2 \times 6.67}{2 \times 6.67}$

(7) (A). Here, Mass of the particle = M Mass of the spherical shell $= M$ Radius of the spherical shell $= a$ Point P is at a distance a/2 from the centre of the shell as shown in figure.

Gravitational potential at point P due to particle at O

2R
ch is thrown with
gravitational field
$$
is V_1 = -\frac{GM}{(a/2)}.
$$

shell is
$$
V_2 = -\frac{GM}{a}
$$

STUDY MATERIAL: PHYSICS

Gravitational potential at point P due to particle at O

is $V_1 = -\frac{GM}{(a/2)}$.

Gravitational potential at point P due to spherical

shell is $V_2 = -\frac{GM}{a}$

Hence, total gravitational potential **STUDY MATERIAL: PHYSICS**
al potential at point P due to particle at O
 $\frac{SN}{1/2}$.
al potential at point P due to spherical
 $= -\frac{GM}{a}$
I gravitational potential at the point P is
 $+\left(-\frac{GM}{a}\right) = -\frac{2GM}{a} - \frac{GM}{a} = -\frac{3GM}{a$ Hence, total gravitational potential at the point P is $V = V_1 + V_2$

 R , R , R , R , R , R

$$
=-\frac{GM}{(a/2)}+\left(-\frac{GM}{a}\right)=-\frac{2GM}{a}-\frac{GM}{a}=-\frac{3GM}{a}
$$

(8) (C). $v_1 r_1 = v_2 r_2$ (: Angular momentum is constant)

Answeratabular	Q.B.-SOLUTIONS	STUDY MATERIAL: PHYSICS
(A). Potential energy at height R = $-\frac{GMm}{2R}$ the mass of a body which is thrown with velocity v_s so that it goes out of gravitational field from distance R, then	is $V_1 = -\frac{GM}{(a/2)}$.	
1. The total energy of the total energy of the magnetic field is	1. The total energy of the magnetic field is	
2. The total energy of the magnetic field is	1. The total energy of the magnetic field is	
3. The total energy of the magnetic field is	1. The total energy of the magnetic field is	
4. The total energy of the magnetic field is	1. The total energy of the electric field is	
5. The initial velocity of the electric field is	1. The initial velocity of the electric field is	
6. The initial velocity of the electric field is	1. The initial velocity of the electric field is	
7. The initial velocity of the electric field is	1. The initial velocity of the electric field is	
8. The initial velocity of the electric field is	1. The initial velocity of the magnetic field is	
9. The initial velocity constant is	1. The initial velocity constant is	
10. The initial velocity constant is	1. The initial velocity constant is	
11. The initial velocity constant is	1. The initial velocity constant is	
12. The initial velocity constant is	1. The initial velocity constant is	
13. The initial velocity constant is	1. The initial velocity constant is	
14. The initial velocity constant is	1. The initial velocity constant is	
15. The initial velocity constant is	1. The initial velocity constant is	
16. The initial velocity constant is	1. The initial velocity constant is	
17. The initial velocity constant is	1. The initial velocity constant is	

(10) (A). Gravitational attraction force on particle B

$$
F_g = \frac{GM_p m}{(D_p / 2)^2}
$$

Acceleration of particle due to gravity

$$
a = \frac{F_g}{m} = \frac{4GM_p}{D_p^2}
$$

In the line of, the
\n*in* the number of, then
\nof a similar region, *x* is given by
\n
$$
v_x = \sqrt{\frac{GM}{R}}
$$
 (10) (4). $G = \frac{GM}{R}$
\n $v_y = \sqrt{\frac{GM}{R}}$
\n $v_x = \sqrt{\frac{GM}{R}}$ (20) $v_y = \frac{N}{\sqrt{2}}$
\n $v_y = \sqrt{\frac{GM}{R}}$ (21) $v_x = \sqrt{\frac{GM}{R}}$
\n $v_y = \sqrt{\frac{GM}{R}}$ (22) $v_y = \frac{GM}{2R}$
\n $v_x = \sqrt{\frac{GM}{R}}$ (23) $v_y = \frac{GM}{\sqrt{2}}$
\n $v_y = \sqrt{\frac{GM}{R}}$ (24) $v_y = \sqrt{\frac{GM}{R}}$
\n $v_y = \sqrt{\frac{GM}{R}}$ (25) $v_x = \sqrt{\frac{GM}{R}}$ (26) $v_x = \sqrt{\frac{GM}{R}}$
\n $v_y = \sqrt{\frac{GM}{R}}$ (27) $v_y = \sqrt{\frac{GM}{R}}$ (28) $v_x = \sqrt{\frac{GM}{R}}$ (29) $v_x = \sqrt{\frac{GM}{R}}$ (20) $v_x = \frac{GM}{R}$ (21) $v_x = \sqrt{\frac{GM}{R}}$ (21) $v_x = \sqrt{\frac{GM}{R}}$ (21) $v_x = \sqrt{\frac{GM}{R}}$
\n $v_y = \sqrt{\frac{GM}{R}}$ (29) $v_x = \sqrt{\frac{M}{R}}$ (20) $v_y = \sqrt{\frac{M}{R}}$ (21) $v_x = \sqrt{\frac{M}{R}}$
\n $v_y = \sqrt{\frac{M}{R}}$ (20) $v_x = \sqrt{\frac{M}{R}}$ (21) $v_x = \sqrt{\frac{M}{R}}$ (21) $v_x = \sqrt{\frac{M}{R}}$
\n $v_y = \sqrt{\frac{M}{R}}$ (21) $v_x = \sqrt{\frac{M}{R}}$ (23) $v_y = \sqrt{\frac{M}{R}}$
\n $v_x = \sqrt{\frac{M}{R}}$ (25) $v_x = \sqrt{\frac{GM}{R}}$

$$
R = \frac{2GM}{C^2} = \frac{2 \times 6.67 \times 10^{-11} \times 5.98 \times 10^{-4}}{(3 \times 10^8)^2}
$$

$$
= \frac{2 \times 6.67 \times 5.98 \times 10^{-3} \text{m}}{9} = 8.86 \times 10^{-3} \text{ m} \approx 10^{-2} \text{ m}
$$

(14) (A).
$$
E_{in} = -\frac{GMr}{R^3}
$$
 $\frac{E}{R}$
\n $E_{out} = -\frac{GM}{r^2}$ $\frac{R}{r}$
\n(15) (A). $T^2 = \frac{4\pi^2}{GM}r^3$. So, $K = \frac{4\pi^2}{GM}$

- **(16) (A).** The gravitation force on the satellite will be aiming toward the centre of earth so acceleration of the satellite will also be aiming toward the centre of earth.
-

$$
v_0 = \sqrt{\frac{GM_e}{(R_e + h)}} = \sqrt{\frac{GM_e}{R_e \left(1 + \frac{h}{R_e}\right)}} = \sqrt{\frac{gR_e}{1 + \frac{h}{R_e}}}
$$

Substituting the values $v_0 = \sqrt{60 \times 10^6}$ m/s times, then $v_0 = 7.76 \times 10^3 \text{ m/s} = 7.76 \text{ km/s}$

GRAPHATION
\n**(16)** (A). The gravitation force on the satellite will be aiming (23) (A). Astronauts move towards each other under mutual
\ntoward the centre of earth so acceleration of the
\nsufficiently also be aiming toward the center of earth.
\n**(17)** (B). For the satellite revolving toward the center of earth.
\n
$$
v_0 = \sqrt{\frac{GM_e}{(R_e + h)}} = \sqrt{\frac{GM_e}{R_e(1 + \frac{h}{R_e})}} = \sqrt{\frac{gR_e}{1 + \frac{h}{R_e}}}
$$
\n
$$
v_0 = \sqrt{\frac{GM_e}{(R_e + h)}} = \sqrt{\frac{gR_e}{R_e(1 + \frac{h}{R_e})}} = \sqrt{\frac{gR_e}{1 + \frac{h}{R_e}}}
$$
\n
$$
v_0 = 7.76 \times 10^3 \text{ m/s} = 7.76 \text{ km/s}
$$
\n**(18)** (A). $v = \frac{GM}{(R + h)} \text{ is } \frac{c}{(R + h)^2} \Rightarrow \frac{V}{g'} = R + h$
\n
$$
= h = (0 - 6.4) \times 10^6 - 2.6 \times 10^6 - 2800 \text{ km}
$$
\n**(19)** (B). $v_e = \sqrt{2gR} = R\sqrt{\frac{g}{3}}\pi Gp$
\n
$$
= \frac{v_e}{v_p} = \frac{R_e \sqrt{b_e}}{R_p \sqrt{b_p}} = \frac{1}{2\sqrt{2}} \qquad \left[\because \frac{W_h}{P_h} = 2R_e\right]
$$
\n
$$
= \frac{G M}{v_p} = \frac{GM}{R_p \sqrt{b_p}} = \frac{1}{2\sqrt{2}} \qquad \left[\because \frac{W_h}{P_h} = 2R_e\right]
$$
\n
$$
= \frac{G M}{v_p} = \frac{GM}{R_p \sqrt{b_p}} = \frac{1}{2\sqrt{2}} \qquad \left[\because \frac{W_h}{P_h} = 2R_e\right]
$$
\n
$$
= \frac{G M}{v_p} = \frac{GMm}{R}
$$
\n**(20)** (B). $g_{m} = \frac{GMm}{R} = \frac{GMm}{R}$ \n
$$
= \frac{GMm}{v^2}
$$
\n
$$
= \frac{GMm}{v^2}
$$
\n
$$
=
$$

$$
\Rightarrow \frac{\mathbf{v}_e}{\mathbf{v}_p} = \frac{\mathbf{R}_e \sqrt{\rho_e}}{\mathbf{R}_p \sqrt{\rho_p}} = \frac{1}{2\sqrt{2}} \quad \left[\begin{array}{c} \because \mathbf{R}_p = 2\mathbf{R}_e \\ \rho_p = 2\rho_e \end{array} \right]
$$
 of ea
Whe

(20) **(B).**
$$
g_{in} = \frac{GMr}{R^3} \Rightarrow g_{in} \propto r
$$

\n
$$
g_{out} = \frac{GM}{r^2}
$$
\n
$$
\Rightarrow g_{out} \propto 1/r^2
$$
\n
$$
\Rightarrow g_{out} \propto 1/r^2
$$
\n
$$
g_{out} = \frac{GM}{r^2}
$$
\n
$$
h = 200 \left(1 - \frac{R}{2R}\right) = \frac{200}{2} = 100 \text{ N}
$$

(21) (B). Total energy = $-\frac{GMm}{2r}$ $-\frac{3m}{2r}$ ea

Here, $r = R + h$ and $GM = g_0 R^2$. $\Rightarrow E = -\frac{mg_0R^2}{2(R+h)}$

(22 (R+h)
(22) (C)
$$
g_h = g_d
$$
; $g\left(1 - \frac{2h}{R}\right) = g\left(1 - \frac{d}{R}\right)$; $d = 2h = 2$ km

(23) (A). Astronauts move towards each other under mutual gravitational force.

16. (a) (A). The gravitation force on the satellite will be aiming. \n\n(a) (b) For the satellite velocity,
$$
v_0 = \sqrt{\frac{GM_e}{(R + h)}} = \sqrt{\frac{GM_e}{R_e(1 + \frac{h}{R_e})}} = \sqrt{\frac{GM_e}{1 + \frac{h}{R_e}}} = \sqrt{\frac{GM_e}{1 + \frac{h}{R_e}}} = \sqrt{\frac{GM_e}{(R + h)^2} = \sqrt{\frac{GM_e}{R_e(1 + \frac{h}{R_e})}} = \sqrt{\frac{GM_e}{1 + \frac{h}{R_e}}} = \sqrt{\frac{GM_e}{1 + \frac{h}{R_e}}}
$$

(25) (D). If Universal Gravitational constant becomes ten times, then $G' = 10 G$ So, acceleration due to gravity increases. i.e. (D) is wrong option. $\int_{C}^{V_C}$
 $\int_{\text{aphelion}}^{V_C}$
 $\int_{\text{aphelion}}^{V_C}$
 \int_{A}^{S} $K_B > K_C$

and constant becomes ten

ravity increases.
 \ldots (1)

due to gravity at earth's

on both sides of (1)
 $\left(d = \frac{R}{2}\right)$
 \ldots

NM C is aphelion

C is aphelion

(A > K_B > K_C

hal constant becomes ten

ravity increases.

(1)

ty at a depth d from surface

(1)

due to gravity at earth's

on both sides of (1)

(d = $\frac{R}{2}$)

(N \Refugnarity at ear

$$
(26) \quad (D). \quad \overbrace{\left(\begin{array}{c} \overline{R} \\ \overline{R} \\ \overline{C} \end{array}\right)}^{\underline{p}}\right)
$$

Acceleration due to gravity at a depth d from surface

$$
\therefore R_p = 2R_e
$$
 of earth $g' = g \left(1 - \frac{d}{R}\right)$...(1)

 $2\rho_e$ surface.

Multiplying by mass 'm' on both sides of (1)

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

$$
= 200\left(1 - \frac{R}{2R}\right) = \frac{200}{2} = 100 \text{ N}
$$

GMm **(27) (C).** Initial potential energy at

$$
U_f = -\frac{GMm}{2R}
$$

As work done = Change in PE

$$
\therefore \quad W = U_f - U_i = \frac{GMm}{2R} = \frac{gR^2m}{2R} = \frac{mgR}{2} \quad (\because GM = gR^2)
$$