Chapter = 05

GRAVITATION

GRAVITATION:- It is the branch of physics in which we study the force of attraction between two or more material objects in the universe.

GRVITATIONAL FORCE

Definition:- The mutual force of attraction between any two objects in the universe is known as gravitational force.

Symbol:- It is denoted by " $\vec{F_g}$ ".

Unit:- Its SI unit is newton(**N).**

Quantity:- It is **vector** quantity.

Nature:- It is a **derived** quantity.

Explanation:-

(i). It is a **non-contact force**.

(ii). It is a **long range** force.

(iii). It is **attractive** in nature.

(iv). It is the **weakest** force in the universe among other fundamental forces.

(v) Its strength is 10^{-40} compare to strong nuclear force.

Factors:- It has two factors which are given below.

(i) Product of masses ($F_g \propto m_1 m_2$).

(ii) The distance between the objects ($F_g \propto \frac{1}{r^2}$).

Note:- Our whole universe is based on gravitational force . In the absence of gravitational force the whole system will collapse.

Examples:-

(i) The moon revolves around the earth due to gravitational force.

(ii) The earth revolves around the sun due to gravitational force etc.

Gravity:-

Definition:- The property of the earth to pull objects towards itself is known as gravity.

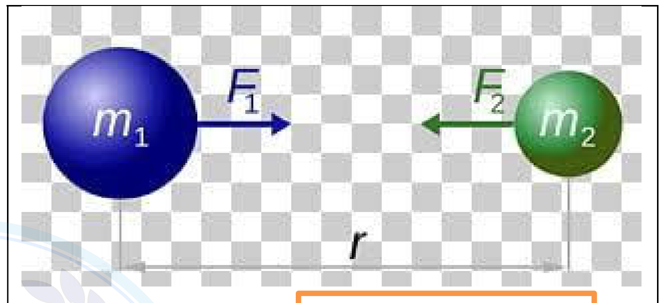
LAW OF UNIVERSAL GRAVITATION

History:- This law was presented by an English Physicist Sir Isaac Newton in 1686.

Purpose:- To find the magnitude of gravitational between two objects.

Statement:- "Every-body in the universe attracts every other body with a force which is directly proportional to the product of their masses and inversely proportional to the square of the distance between their Centers ".

Mathematical Form:- Consider two spherical bodies of masses "m_1" and "m_2" separated by distance "r" as shown in figure.



Constant = G

Then from the above statement .

$$F_g \propto m_1 m_2 \quad \text{.......... (i)}$$

$$F_g \propto \frac{1}{r^2} \quad \text{.......... (ii)}$$

Combining equation (i) and (ii) we get

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

$$F_g = Constant \frac{m_1 m_2}{r^2}$$

$$F_g = G \frac{m_1 m_2}{r^2} \quad \text{.......... (iii)}$$

Equation represents the mathematical form of law of universal gravitational.

In equation (iii) " **G** ":-

(a) **" G "** is constant of proportionality and is known as gravitational constant.

(ii) Its value is 6**.67 x 10^{-11} Nm^2 / kg^2**.

(iii) Its values does not depends upon the medium between two objects.

Applications:-

(i) This law is used to find the magnitude of gravitational force between any two bodies.

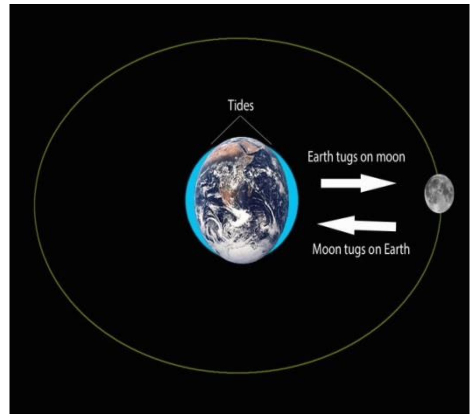
(ii) This law is used to find the mass Earth and other plants.

(iii) This law is used to find the distance any objects in the universe.

(iv) This law is used to find the value of **" G ".**

NEWTON'S THIRD LAW OF MOTION AND UNIVERSAL GRAVITATION

It is to be noted that mass $\boldsymbol{m_1}$ attracts $\boldsymbol{m_2}$ towards it with a force F while mass $\boldsymbol{m_2}$ attracts $\boldsymbol{m_1}$ towards it with a force of the same magnitude F but in opposite direction. If the force acting on m_1 is considered as action then the force acting on m_2 will be reaction. The action and reaction due to force of gravitation are equal in magnitude but opposite in direction.



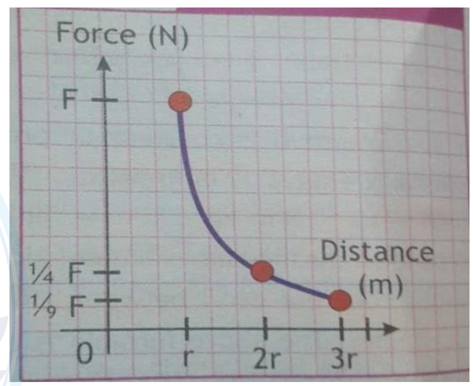
This is in consistence with newton's third law of motion which states **"To every action there is always an equal but opposite reaction".**

Mathematically:- $F_{action} = - F_{reaction}$

Example:- The Earth pulls on the Moon and the Moon pulls on the Earth with a force of equal magnitude as shown in figure.

GRAPHICAL ANALYSIS OF GRAVITATIONAL FORCE

As we known that the gravitational force is an inversely square force , it decreases by a factor of 4 when the distance is increases by a factor of 2, It decreases by a factor of 9 When the distance increases by a factor of 3 and so on. The given graph is a plot of the magnitude of the gravitational force as a function of the distance.

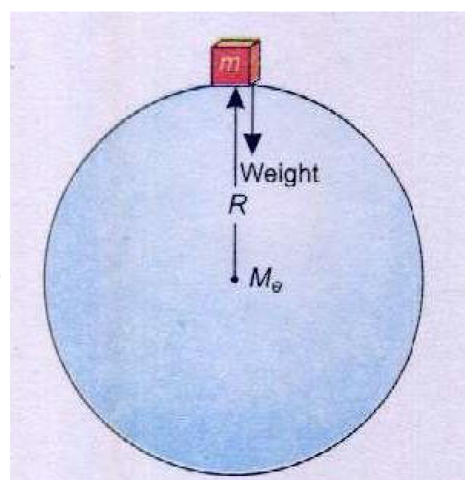


MASS OF EARTH

The mass of earth can be determined by with the help of law of universal gravitation. Consider a body of mass **"m"** is placed on the surface of earth.

(i) Mass of earth is **"M_e".**

(ii) Radius of earth is **"R_e",** as shown in figure.



- **From law of universal gravitational** :-

$$F_g = G\frac{M_e m}{R_e^2} \quad \text{.........................(i)}$$

- We also know that the force of gravity is equal to the weight of the body.

$$F_g = W = mg \quad \text{...................(ii)}$$

- By comparing eq (i) and (ii) we get.

$$mg = G\frac{M_e m}{R_e^2}$$

$$mg = G\frac{M_e m}{R_e^2}$$

$$g = G\frac{M_e}{R_e^2} \quad \text{.......................(iii)}$$

- On re-arranging the equation (iii) becomes.

$$g \times \frac{R_e^2}{G} = M_e \quad \text{OR} \quad M_e = \frac{gR_e^2}{G}$$

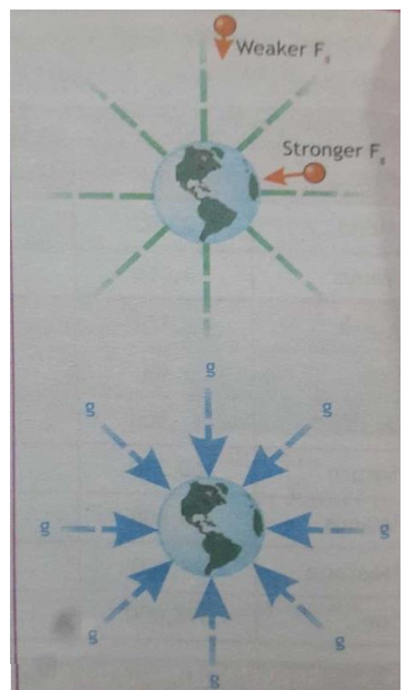
$$M_e = \frac{gR_e^2}{G} \quad \text{.........................} \quad \textbf{(iv)}$$

Calculation:- As we know that
(i) Gravitational Constant = G = 6.67 x 10^{-11}Nm^2/kg^2.
(ii) Gravitational Acceleration Constant = g = 9.8 m/s^2.
Radius of Earth = R_e = 6.4 x 10^6 m.
By putting values in equation (iv) we get

$$M_e = \frac{gR_e^2}{G} = \frac{9.8 \times (6.4 \times 10^6)^2}{6.67 \times 10^{-11}} = \frac{9.8 \times 40.96 \times 10^{12}}{6.67 \times 10^{-11}} = \frac{401.4 \times 10^{12}}{6.67 \times 10^{-11}}$$

M_e = 60.1 x 10^{12+11} = 60.1 x 10^{23} kg OR $M_e = 6.01 \times 10^{24}$ kg

GRAVITATIONAL FIELD



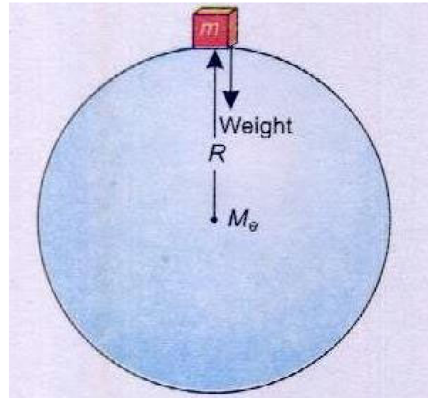
Definition:- It is the region or space where the force of gravitation can be felt is called gravitational field. OR
The space around the earth with in which it exert a force of attraction on other bodies is known as gravitational field.
Explanation:- We know that a body is placed in space surrounding the earth experiences a force which is equal to its weight and is directed towards the center of the earth as shown in figure.

Gravitational Field Strength:-
Definition:- The gravitational force per unit mass on a body is known as gravitational field strength.
Symbol:- It is denoted by " $\vec{g_s}$ ".
Mathematical Form:- $$\vec{g_s} = \frac{\vec{F_g}}{m}$$
Quantity:- It is a **vector** quantity with the magnitude of "g" that points in the direction of the gravitational force.

Unit: - Its SI unit is **N/kg**.
Explanation:- According to Field theory " Masses create a gravitational field in space like charged objects generates an electric fields and magnets develop a magnetic field. A gravitational force is an interaction between a mass and the gravitational field created by the other masses. At any point, Earth's gravitational field can be described by the gravitational field strength.

VARIATION IN WEIGHTS WITH LOCATION

As we know that



- **The value of "g" on the earth surface:-**

  g = $G\frac{M_e}{R_e^2}$ .... (i)

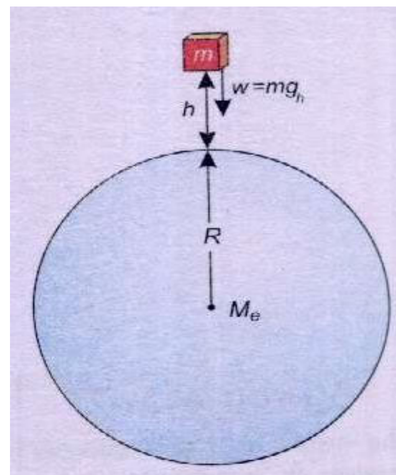
- **Wight of body on the earth surface**:-

  W = mg .... (ii)

- By putting eq(i) in eq (ii) we get

$$W = m \times G\frac{M_e}{R_e^2} = G\frac{M_e m}{R_e^2}$$

$$W = G\frac{M_e m}{R_e^2} \quad .... (iii)$$



- Let the body of mass "m" is brought to altitude "h" from the surface of the earth as shown in figure.
- Then equation (iii) Becomes.

$$W_h = \frac{GM_e}{(R_e + h)^2} \quad .... (iv)$$

As GM_e = Constant then

$$W_h = \frac{Constant}{(R_e + h)^2} \quad \text{OR} \quad W_h \propto \frac{1}{(R_e + h)^2} \quad .... (v)$$

Results:-From relation (v) :-

(i) $W_h \propto \frac{1}{h\ (location\ of\ body)}$

(ii) If "**R_e + h**" increases then the weight of the body will decreases and vice versa.

Gravitational Acceleration

Definition:-The acceleration of bodies falling freely towards the earth is known as Gravitational Acceleration. OR

The acceleration of a body due earth's gravity is known as Gravitational Acceleration.

Symbol:- It is denoted by **"g".**

Value:- Its value is **9.8 ms** $^{-2}$. But for simplicity we take its value is **10 ms** $^{-2}$.

Explanation:-

(i) Its value is independent of the **mass** of the falling object.

(ii) Its value decrease with **altitude**.

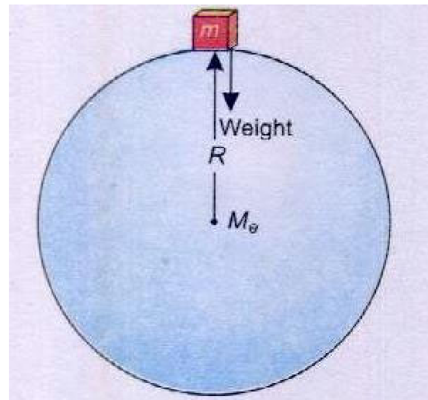
(iii) Its value is zero at the **center** of the earth.

Note: - When bodies of different masses are dropped simultaneously from the same height they will reach the ground (earth) at the same time i-e

- In vacuum or Space
- If the air resistance = 0 (zero).

VARIATION OF "g" WITH ALTIDUDE

Consider a body of mass **"m"** is placed on the surface of as shown in figure.



- **From Newton law of gravitation**:-

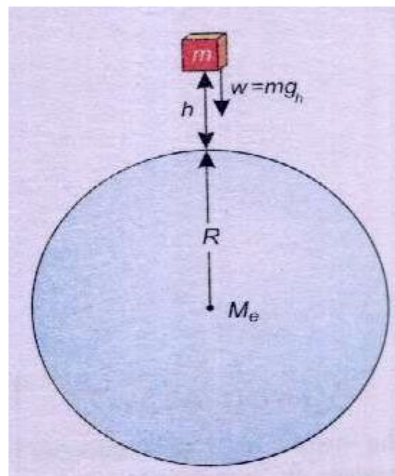
$$F_g = G\frac{M_e m}{R_e^2} \text{ .... (i)}$$

- We also know that :-

$$F_g = W = mg \text{ .... (ii)}$$

By comparing eq(i) and (ii) we get

$$mg = G\frac{M_e m}{R_e^2}$$



$$mg = G\frac{M_e m}{R_e^2}$$

$$g = G\frac{M_e}{R_e^2} \text{ .... (iii)}$$

- In equation (iii) :-
  - "G" and "M_e" are constant.
  - The value of "g" depends on "R_e".
  - $g \propto \frac{1}{R_e^2}$.
  - The value of "g" decreases with altitude.
- Let a body of mass "m" be placed at altitude "h" from the surface of the earth as shown in figure.

  Thus equation (iii) becomes.

$$g_h = \frac{GM_e}{(r_{e+h})^2} \text{ .... (iv)}$$

With the help of Equation (iv) we can determine the value of "g" at any altitude.

Results:- From equation (iv) we can conclude that :-

(a) If we move away from the center of the earth the value of **"g"** decreases. Therefore the value of **"g"** is less on the mountains.

(b) The change in the value of **"g"** is significant only at very large distances.

(c) The value of **"g"** at the pole is greater than at the equator.

Why the value of "g" at the pole is greater than at the equator?

Answer:- **Statement**:- The value of **"g"** at the pole is greater than at the equator.

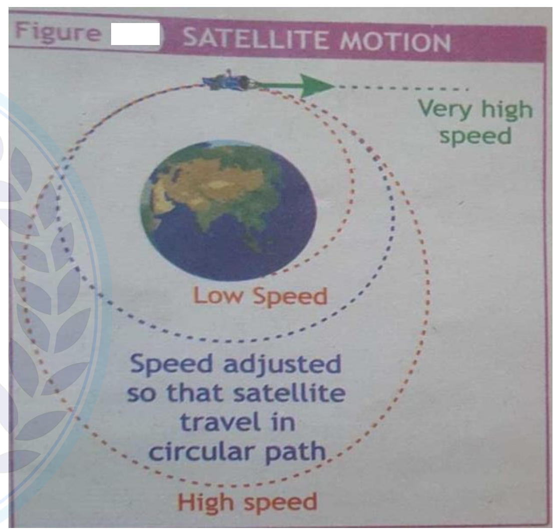
Reason:- Because $g \propto \frac{1}{R_e^2}$

Explanation:- As we know that

$$g = G\frac{M_e}{R_e^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

From equation (1) is cleared that the value of **"g"** varies inversely proportional to the square of the distance. The value of **"g"** at the pole is greater than at the equator because the earth is not a perfect sphere, its equatorial radius is greater than the radius at the poles.

Conclusion:- So as a result we can conclude that the value of **"g"** at the pole is greater than at the equator



SATELLITES

Definition:- It is an object which revolves around a star or planet in a stable orbit. OR
An object that revolves around a planet is known as satellite.

Causes of motion:- It revolves around the planet due to force of gravity.

Types of satellites:- There are two types of satellites which are given below.
(1) Natural Satellites.
(2) Artificial Satellites.

(1) Natural Satellites:-

Definition:- Those satellites which are naturally exist in the universe are known as natural satellites.

Example: - Moon is the natural satellite of the earth.

(2) Artificial Satellites:-

Definition:- Any object purposely placed into orbit of earth or other planets ,stars or sun are known as artificial satellite. OR
It is a space craft which stay in the orbit around the earth. OR
A man made satellite is known as artificial satellite.

Examples:-
(i) Global positioning system (GPS).
(ii) Hubble space Telescope.

(iii) Investigate space etc.

Importance of artificial satellites:- They are used for

(i) Worldwide communication.

(ii) Weather observation.

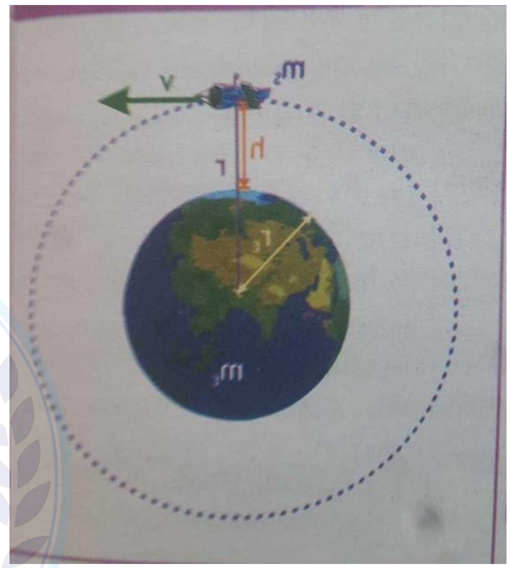
(iii) Military purpose.

(iv) Navigation purpose.

(iv) Scientific study.

(v) Mobile network etc.

ORBITAL SPEED



Definition:- It is the speed of a body of a satellite which moves around the Earth at a specific height.

Symbol:- It denoted by **"V".**

Mathematical Form:- $V = \sqrt{\frac{GR_e}{r_E+h}}$

Derivation of $V = \sqrt{\frac{GR_e}{r_E+h}}$:-

Consider a satellite of mass "m" is revolving with uniform speed "V" is a circular orbit of radius "r". The necessary centripetal force is given by

$$F_c = \frac{m\,V^2}{r} \quad \text{......................} (1)$$

- The gravitational force acting on the satellite is

$$F_g = \frac{G\,m\,M_e}{r^2} \quad \text{..................} (2)$$

- Thus centripetal force provided by gravitational force therefore

$$F_g = F_c \quad \text{......................} (3)$$

- By putting eq (1) and eq (2) we get

$$\frac{G\,m\,M_e}{r^2} = \frac{m\,V^2}{r} \qquad \text{OR} \qquad \frac{G\,M_e}{r} = V^2$$

OR $\sqrt{V^2} = \sqrt{\frac{GM_e}{r}}$ Take square root on both sides.

$$V = \sqrt{\frac{GM_e}{r}} \quad \text{............ (4)}$$

$r = R_e + h$

Then eq (4) becomes $$V = \sqrt{\frac{GM_e}{R_{e} + h}} \quad \text{.............. (5)}$$

The eq (5) represents the formula for orbital speed of an artifical satellite.

Result:- From (5) it is cleared that the value orbital speed of satellite depends upon the following factors:-

(i) **Mass of earth** (M_e):- $V \propto \sqrt{M_e}$.

(ii) **Radius of the orbit** (r):- $V \propto \sqrt{\frac{1}{r}}$.

Note: - The value of orbital speed does not depends upon the mass of the satellite.

Calculation of orbital Speed For Geostationary Communication Satellite :-

Height of geostationary satellite = r = $3.59 \times 10^7 = 35.9 \times 10^6$m

By putting values in eq (4) we get

$$V = \sqrt{\frac{GM_e}{r}} = \sqrt{\frac{6.67 \times 10^{-11} \times 6 \times 6 \times 10^{24}}{22 \times 10^{6}}} = 3.753 \times 10^3 \text{m} = 3.753 \text{ km/s.}$$

$V = 3.753 \times 10^3$m= 3.753 km/s.

Note:- Eq (4) is used to measure the velocity of any Planet or celestial object moving in a circular path.

CONCEPTUAL QUESTIONS

(1)If there is an attractive force between all objects why do not we feel ourselves gravitating toward nearby massive building?

_Ans:- **Statement**:- We do not feel ourselves gravitating towards nearby massive building.

Reason:- It is because of

(i) The value of "G" is very small.

(ii) The product of masses of objects are very small.

Explanation:- As we know that

$$F_g = G\frac{m_1 m_2}{r^2} \text{ .... (1)}$$

From equation (1) it is cleared that the magnitude of gravitational force between the two the objects depends upon:-

(i) The value of gravitational constant ($F_g \propto G$).

(ii) The product of masses of the object ($F_g \propto m_1 m_1$).

As the value of gravitational constant and masses of objects around us are very small.

Conclusion:- As a result We do not feel ourselves gravitating towards nearby massive building.

(2) Does the Sun exert a larger force on the Earth than exerted on the Sun by the Earth? Explain.

Ans:- **Statement**:- No, the Sun and Earth exert same force on each other.

Reason:- It is because the gravitation force between two objects is the action and reaction forces.

Explanation:- It is to be noted that mass m_1 attracts m_2 towards it with a force F_1 while mass m_2 attracts m_1 towards it with a force of the same magnitude F but in opposite direction.

Action and Reaction:-

If the force acting on m_1 is considered as action then the force acting on m_2 will be reaction. The action and reaction due to force of gravitation are equal in magnitude but opposite in direction.

Conclusion:- As a result we can say that the earth and the sun exert same force on each other.

(3) What is the importance of gravitation constant "G"? Why is it difficult to calculate?

Ans:-(a) **Importance of gravitational constant (G):**- The gravitational force and gravitational constant plays an important role in the universe some of them are given below:-

(i) It is used to explain the motion of earth around the sun.

(ii) It is used to explain the motion of moon around the earth.

(iii) It is used to explain the motion of other planets.

(iv) It is used to find the mass of earth and other planets.

(v) It is used to find the radius of earth and other planets.

(vi) It is used to find the density of earth and other plants etc.

(b) It is very difficult to find the value of "G" due to the following reasons:-

(i) It is a weaker force than other basic forces.

(ii) It required very sensitive device to calculate it.

(iii) It has no inter-relation with other basic forces.

(4) If Earth somehow expanded to a larger radius, with no change in mass, how would your weight be affected? How would it be affected if Earth instead shrunk?

Ans:- **Statement**:- When the earth expands to a larger radius with no change in mass then our mass will be decrease.

Reason:- It is because of $W \propto \frac{1}{R_e^2}$

Explanation:- As we know that

$$W = G\frac{M_e\, m}{R_e^2} \quad \text{......................} \; (i)$$

From eq (i) it is cleared that the weight of a body is inversely proportional to the square the radius of the earth. Greater the radius of the earth smaller will be weight of the body and vice versa.

Conclusion:- As a result we can conclude that When the earth expands to a larger radius with no change in mass then our mass will be decrease.

(5) What would happen to your weight on the earth if the mass of the earth doubled but its radius stayed the same?

Ans:- **Statement**:- The weight of the body will become double if the mass of earth is doubles and its radius stay(remains) the same.

Reason: - It is because of $W \propto M_e$

Explanation:- As we know that

$$W = G\frac{M_e\, m}{R_e^2} \quad \text{.......................} \; (i)$$

Condition:- If M_e = 2 M_e then eq(i) becomes

$$W^{/} = G\frac{2M_e\, m}{R_e^2} = 2\,(G\frac{M_e\, m}{R_e^2}) \quad \text{............} \; (ii)$$

As $W = G\frac{M_e\, m}{R_e^2}$ Then eq(ii) becomes

$$W^{/} = 2\,W$$

Conclusion:- As a result we can conclude the weight of the body will become double if the mass of earth is doubles and its radius stay (remains) the same.

(6) Why lighter and heavier objects fall at the same rate towards the Earth?

Ans :- **Statement**:- Lighter and heavier objects fall at the same rate towards the Earth .

Reason:- It is because the value of "g" does not depends upon the mass of an object.

Explanation:- As we know that

$$g = G\frac{M_e}{R_e^2} \quad \text{...........................} \; (1)$$

From Equation (1) it is cleared that the value of "g" depends upon the the

(i) Mass of Earth (M_e).

(ii) Radius of Earth (R_e).

Conclusion:- As a result the Lighter and heavier objects fall at the same rate towards the Earth if the air resistance is ignored.

(7) The value of "g " changes with location on Earth , however we take same value of "g" as 9.8 ms $^{-2}$ for ordinary calculations. Why?

Statement:- The value of "g " changes with location on Earth , however we take same value of "g " as 9.8 ms $^{-2}$ for ordinary calculations.

Reason:- It is because that near the earth surface the variation in the value of "g" is very small.

Explanation:- As we know that

$$g = G\frac{M_e}{R_e^2} \quad \text{..................} \; (i)$$

From (i) It is cleared that the value of "g" varies inversely as the square of the distance. But the change in the value of "g" is significant only at very large distances. Near the earth surface the variation in the value of "g" is very small from one place to another place. Due to small variation in the value of "g" we ignore it.

Result:- As a result we take the same value of "g" as 9.8 m/s^2 for ordinary calculations.

(8) Moon is attracted by the earth does not fall on earth?

Ans:- **Statement**:- The moon is attracted the earth and it does not fall on earth.

Reason: - It is because of gravitational force.

Explanation: - As we that the moon is the natural satellite of the earth. It revolves around the earth. The gravitational interaction between the moon and the earth provides the required centripetal force. The centripetal force compels the moon to revolve around the earth.

Conclusion: - As a result the revolves around the earth and does not fall on earth.

(9) Why for same height larger and smaller satellites must have same orbital speeds?

Ans:- **Statement**:- For same height larger and smaller satellites must have same orbital speeds.

Reason:- It is because the speed of satellite does not depends upon its mass.

Explanation:- As we know that

$$V = \sqrt{\frac{GM_e}{r_E+h}} \quad \text{.....................} \quad (i)$$

From equation (i) it is cleared that the value of orbital speeds upon the following the factors:-

(i) Mass of earth (M_e).

(ii) Radius of earth (R_e).

(iii) Height of satellite from the surface earth (h) only.

Thus the value of orbital speed does not depends upon the mass of satellite.

Conclusion:- As a result we can conclude that For same height larger and smaller satellites must have same orbital speeds.

NUMERICAL QUESTIONS

(1)Pluto's moon Charon is un-usually large considering Pluto's size giving them the character of a double planet. Their masses are 1.25×10^{22}kg and 1.9×10^{21}kg and their average distance from one another is 1.96×10^{4} km .What is the gravitational force between them?

Ans:-Solution:-

Given Data:-

Mass of Pluto = $M_p = 1.25\times10^{22}$kg

Mass of Moon = $M_m = 1.9\times10^{21}$kg

Distance = r = 1.96×10^{4} km

r = $1.96\times10^{4} \times 10^{3}$ m

r = $1.96\times10^{4+3}$ m = 1.96×10^{7}m

Gravitational Constant = G = 6.67×10^{-11} $Nm^2 kg^{-2}$

Required Data:-

Gravitational force = F_g = ?

Formula:- From Newton law of universal gravitation $F_g = \frac{GM_PM_m}{r^2}$ ……………. (i)

Calculation:- By putting values in equation (i) we get.

$$F_g = \frac{6.67\times10^{-11}\times1.25\times10^{22}\times1.9\times10^{21}}{(1.96\times10^{7})^2} = \frac{6.67\times1.25\times1.9\times10^{-11+22+21}}{3.84\times10^{14}}$$

Result:- $F_g = \frac{15.84\times10^{32}}{3.84\times10^{14}} = 4.125\times10^{18}$ N.

(2) The mass of Mars is 6.4×10^{23} kg and having radius of 3.4×10^{6} m. Calculate the gravitational field strength (g) on Mars surface.

Ans:- **Solution**:-

Given Data:-

Mass of Mars = $M_m = 6.4\times10^{23}$ kg.

Radius = $R_m = 3.4\times10^{6}$ m.

Gravitational Constant = G = 6.67×10^{-11} Nm^2 / kg^2.

Required Data:-

Gravitational field strength = g = ?

Formula:- As we know that $g = \frac{F_g}{m}$ OR $g = \frac{GmM_m}{mr^2}$ which can be written as

$$g = \frac{GM_m}{r^2} \quad ....(1)$$

Calculation:- Putting values in equation (1) we get

$$g = \frac{6.67\times10^{-11}\times6.4\times10^{23}}{(3.4\times10^6)^2}$$

Result:- $g = 3.69\ m/sec^2$.

(3)Titan is the largest moon of the Saturn and the only moon in the solar system known to have a substantial atmosphere. Find the acceleration due to gravity on Titan's surface given that its mass is $1.35x10^{18}$ kg and its radius is 2570 km.

Ans:- Solution:-

Given Data:-

Mass of Titan's = M_T = $1.35x10^{23}$ kg.

Radius of Titan's = R_T = 2570 km = 2570000 m = $2.57\ X\ 10^6 m$

Gravitational Constant = G = $6.67x\ 10^{-11}$ Nm^2 / kg^2.

Required Data:- Gravity on the Titan's surface = g_T = ?

Formula:- $g_T = \frac{GM_T}{R_T^2}$ .... (1)

Calculation:- By putting values in equation (1) we get

$$g_T = \frac{GM_T}{R_T^2} = \frac{6.67\times10^{-11}\times1.35\times10^{18}}{(2.57\times10^6)^2}$$

Result:- g_T = 0.0000136 = 1.36×10^{-5} m/sec^2

(4)At which altitude above Earth's surface would the gravitational acceleration be $4.9m/s^{-2}$.

Ans: Solution:-**Given Data**:-

Mass of earth = M_e= $6x10^{24}$ kg.

Radius of earth $= R_e =$ 6.4 x 10^6m

Gravitational Constant = G = 6.67x 10^{-11} Nm^2 / kg^2.

Required Data:- Altitude = h = ?

Formula:- As we know that

$$g_h = \frac{GM_e}{(R_e + h)^2} \quad \text{OR} \quad (R_e + h)^2 = \frac{GM_e}{g_h} \quad \text{OR} \quad h = \sqrt{\frac{GM_e}{g_h}} - R_e \; \ldots\ldots\ldots (1)$$

Calculation:- By putting values in equation (1) we get

$$h = \sqrt{\frac{GM_e}{g_h}} - R_e = \sqrt{\frac{6.67 \times 10^{-11} \times 6 \times 10^{24}}{4.9}} - 6.4 \times 10^6 = \sqrt{\frac{6.67 \times 6 \times 10^{-11+24}}{4.9}} - 6.4 \times 10^6$$

$$h = \sqrt{\frac{40.02 \times 10^{13}}{4.9}} - 6.4 \times 10^6 = \sqrt{8.1 \times 10^{13}} - 6.4 \times 10^6 = \sqrt{81 \times 10^{12}} - 6.4 \times 10^6$$

h = 9.03 x 10^6 - 6.4 x 10^6 = 2.6 x 10^6 m/s.

Result:- h = 2.6 x 10^6 m

(5)Assume that a satellite orbits Earth 225 km above its surface. Given that the mass of the Earths is 6x10^{24} kg and the radius of the Earth is 6.4x10^6m, what is the satellite's orbital speed?

Ans:- Solution:-

Given Data:-

Mass of the Earths = M_e =6x10^{24} kg.

The radius of the Earth = R_e = 6.4x10^6m.

Gravitational Constant = G = 6.67x 10^{-11} Nm^2 / kg^2.

Required Data:-

Orbital speed of satellite = V = ?

Formula:- As we know that $V = \sqrt{\frac{GM_e}{R_e+h}}$ .... (1)

Calculation:- By putting values in equation 910 we get

$$V = \sqrt{\frac{GM_e}{R_e+h}} = \sqrt{\frac{6.67 \times 10^{-11} \times 6 \times 10^{24}}{6.4 \times 10^6 + 0.225 \times 10^6}} = \sqrt{\frac{6.67 \times 6 \; 10^{-11} \times 10^{24}}{6.4+0.225 \times 10^6}}$$

$$V = \sqrt{\frac{40.038 \times 10^{-11+24}}{6.625 \times 10^6}} = \sqrt{\frac{40.038 \times 10^{13}}{6.625 \times 10^6}} = \sqrt{6.04 \times 10^{13-6}} = \sqrt{6.04 \times 10^7}$$

$V = \sqrt{60.4 \times 10^6} = 7.77 \times 10^3$ m/s.

Result: - So as a result the satellite's orbital speed is $V = 7.77 \times 10^3$ m/s

(6)The distance from center of earth to center of moon is 3.8×10^8 m, Mass of earth is 6×10^{24} kg. What is the orbital speed of motion?

Answer:- Solution:-

Given Data:-

Mass of earth = $M_e = 6 \times 10^{24}$ kg.

Distance from center of earth to center of moon = $r = R_e + h = 3.8 \times 10^8$ m.

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

Required Data:-

Orbital Speed of moon = V= ?

Formula:- As we know that

$$V = \sqrt{\frac{GM_e}{R_e+h}} \quad \text{.................................} \quad (1)$$

Calculation: - By putting values in equation we get

$$V = \sqrt{\frac{GM_e}{R_e+h}} = \sqrt{\frac{6.67 \times 10^{-11} \times 6 \times 10^{24}}{3.8 \times 10^8}} = \sqrt{\frac{6.67 \times 6 \ 10^{-11} \times 10^{24}}{3.8 \times 10^8}}$$

$$V = \sqrt{\frac{40.2 \times 10^{-11+24}}{3.8 \times 10^8}} = \sqrt{\frac{40.2 \times 10^{13}}{3.8 \times 10^8}} = \sqrt{10.57 \times 10^{13-8}} = \sqrt{10.57 \times 10^5}$$

$$V = \sqrt{10.57 \times 10 \times 10^4} = \sqrt{105.7 \times 10^4} = 10.28 \times 10^2 \text{ m/s} = 1.028 \times 10^3 \text{ m/s}$$

Result: - So as a result the orbital speed of moon is $V = 10.28 \times 10^2$ m/s $=1.028 \times 10^3$ m/s.

(7)The Hubble space telescope orbits Earth ($M_E = 6 \times 10^{24}$ kg) With an orbital speed of 7.6×10^3 m/s . Calculate its altitude above Earth's surface.

Ans:-Solution:-

Given Data:-

Mass of earth = $M_e = 6 \times 10^{24}$ kg.

Orbital speed = $V = 7.6 \times 10^3$ m/s.

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

Required Data:-

Altitude of Hubble space Telescope above the earth surface = h = ?

Formula:- As we know that

$$V = \sqrt{\frac{GM_e}{R_e+h}} \quad \textbf{OR} \quad (V)^2 = \left(\sqrt{\frac{GM_e}{R_e+h}}\right)^2 \quad \text{OR} \quad V^2 = \frac{GM_e}{R_e+h}$$

$$\text{OR} \quad R_e + h = \frac{GM_e}{V^2} \quad \text{OR} \quad h = \frac{GM_e}{V^2} - R_e \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Calculation:- By putting values in equation (1) we get

$$h = \frac{GM_e}{V^2} - R_e = \frac{6.67 \times 10^{-11} \times 6 \times 10^{24}}{(7.6 \times 10^3)^2} - 6.4 \times 10^6 = \frac{6.67 \times 6 \times 10^{-11+24}}{57.79 \times 10^6} - 6.4 \times 10^6$$

$$h = 0.69 \times 10^{13-6} - 6.4 \times 10^6 = 0.692 \times 10^7 - - 6.4 \times 10^6$$

$$h = 6.92 \times 10^6 - 6.4 \times 10^6 = 0.525 \times 10^6 = 525 \times 10^3 = 525 \text{ km}$$ **10^3 = km**

Result:-

Altitude of Hubble space Telescope above the earth surface = h = 525×10^3 = 525 km