CHAPTER 9

Gravitation

1. NCERT INTEXT QUESTIONS

1. State the universal law of gravitation.

Ans :

Everybody in this universe is attracted with a force by every other body, which is directly proportional to the product of their masses and inversely proportional to the square of distance between their centres.

2. Write the formula to find the magnitude of the gravitational force between the Earth and an object on the surface of the Earth.

Ans :

$$F_{gravitation} = G\frac{M_e \times M_0}{r^2}$$

where G is gravitational constant.

M_e = The mass of the Earth.

M_0 = The mass of the object.

r = The distance between the centre of gravity of the object and the centre of the Earth.

3. What do you mean by free fall?

Ans :

When an object falls with a constant acceleration, under the influence of force of gravitation of the Earth, object is said to have free fall.

4. What do you mean by acceleration due to gravity?

Ans :

The acceleration produced in a body due to force of gravity is called acceleration due to gravity. It is denoted by g. The value of acceleration due to gravity is taken as 9.8 ms^{-2} at the sea level.

5. What are the differences between the mass of an object and its weight?

Ans :

Difference between Mass and Weight

Mass	Weight
The total quantity of matter contained in an object is called mass of an object.	The gravitational force by which Earth attracts an object is called weight of the object.
Mass of an object can be measured by its inertia.	Weight = mass × acceleration (m × g).
Mass of the object remains constant at all the places.	Weight of the object is different at different places.
Mass can be measured by using a pan or beam balance.	Weight can be measured by using a spring balance.
Mass does not change even if value of g is zero at any place.	Weight of the object becomes zero if g is zero.

6. Why is the weight of an object on the Moon $\frac{1}{6}^{th}$ its weight on the Earth?

Ans :

The mass of the Moon of $\frac{1}{100}$ times and its radius $\frac{1}{4}$ times that of the Earth. As a result, the gravitational attraction on the Moon is about one sixth when compared to that on the Earth. Hence, the weight of an object on the Moon is $\frac{1}{6}^{th}$ of the weight on the Earth.

7. Why is it difficult to hold a school bag having a strap made of a thin and strong string?

Ans :

It is difficult to hold a school bag having a thin strap because the pressure on the shoulders is quite large. This is because the pressure is inversely proportional to the surface area on which the force acts. The smaller is the surface area; the larger will be the pressure on the surface. In the case of a thin strap, the contact surface area is very small. Hence, the pressure exerted on the shoulder is very large.

8. What do you mean by buoyancy?

Ans :

The upward force exerted by a liquid on an object immersed in it is known as buoyancy. When you try to immerse an object in water, then you can feel an upward force exerted on the object, which increases as you push the object deeper into water.

9. Why does an object float or sink when placed on the surface of water?

Ans :

If the density of an object is more than the density of the liquid, then it sinks in the liquid. This is because the buoyant force acting on the object is less than the force of gravity. On the other hand, if the density of the object is less than the density of the liquid, then it floats on the surface of the liquid. This is because

the buoyant force acting on the object is greater than the force of gravity.

10. You find your mass to be 42 kg on a weighing machine. Is your mass more or less than 42 kg?

Ans :

Using a weighing machine, we actually measure our weight and from this, we infer about our mass. While measuring weight, the weight recorded is slightly less than the true weight on account of force of buoyancy due to air acting on us. As a result, the true weight and consequently, the true mass must be greater than 42 kg.

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11. You have a bag of cotton and an iron bar, each indicating a mass of 100 kg when measured on a weighing machine. In reality, one is heavier than other. Can you say which one is heavier and why?

Ans :

We know that density of cotton is lesser than that of an iron bar. Hence, for same mass of 100 kg, the volume of cotton is greater than that of iron bar. Due to this, while weight in air using a weighing machine, the upthrust due to air is more on cotton and less on iron bar. As a result, true weight and consequently, the true mass of cotton must be greater than that of iron bar. Thus, cotton is heavier than the iron bar.

2. NCERT EXERCISE QUESTIONS

1. How does the force of gravitation between two objects change when the distance between them is reduced to half?

Ans :

When all other variables remain constant, the force of gravitation is inversely proportional to the square of distance between the two objects.

$$F \propto \frac{1}{r^2}$$

if distance r becomes $\frac{r}{2}$, then the gravitational force will be proportional to

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

Hence, if the distance is reduced to half then the gravitational force becomes four times larger than the previous value.

2. Gravitational force acts on all objects in proportion to their masses. Why then, a heavy object does not fall faster than a light object?

Ans :

A freely falling object of any mass falls under the action of gravity given by

$$g = G\frac{M}{R^2}$$

g = where 'G' is constant to gravitation

M = Mass of Earth

r = The distance between the object and the centre of Earth.

As, the acceleration due to gravity is independent of the mass of the objects. All object fall at the same speed towards the Earth.

3. 3. What is the magnitude of the gravitational force between the Earth and a 1 kg object on its surface? (Mass of the Earth is 6×10^{24} kg and radius of the Earth is 6.4×10^6 m.)

Ans :

$$F_{gravitation} = G\frac{M_e \times M_0}{r^2}$$

Given : m = 1 kg, $M_e = 6 \times 1024$ kg, r = 6.4 × 106 m, G = 6.67×10^{-11} Nm^2/kg^2

$$= \frac{6.67 \times 10^{-11} \times 6 \times 10^{24} \times 1}{(6.4 \times 10^6)^2}$$

$$= \frac{6.67 \times 6 \times 10^{-11+24-12}}{6.4 \times 6.4}$$

$$= \frac{6.67 \times 6 \times 10^{-23+24}}{6.4 \times 6.4}$$

$$= \frac{6.67 \times 6 \times 10^{1}}{6.4 \times 6.4}$$

$$F_{gravitation} = 9.770 \text{ N} = 9.8 \text{ N}$$

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4. The Earth and the Moon are attracted to each other by gravitational force. Does the Earth attract the Moon with a force that is greater or smaller or the same as the force with which the Moon attracts the Earth? Why?

Ans :

The Earth attracts the Moon with the same force with which the Moon attracts the Earth because, the gravitational force between any two bodies is mutual and equal according to Newton's universal law of gravitation.

5. If the Moon attracts the Earth, why does the Earth not move towards the Moon?

Ans :

The Earth does not move towards the Moon because the force exerted by the Earth or the Moon on each other is insufficient to move the Earth on account of its huge mass.

6. What happens to the force between two objects, if
(i) the mass of one object is doubled?
(ii) the distance between the objects is doubled and tripled?
(iii) the masses of both objects are doubled?

Ans :

The gravitational force between two objects is given as :

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

(a) If the mass of one object is doubled to $2m_1$, then new force is given as :

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

Force is doubled.

(b) If the distance between the objects is doubled, then r' = 2p and hence new force is given as

$$F' = \frac{Gm_1m_2}{(2r)^2} = \frac{F}{4}$$

The force is reduced to $\frac{1}{4}$of its original value
If distance is tripled then r" = 3r

$$F'' = \frac{Gm_1m_2}{(3r)^2} = \frac{F}{9}$$

The force is reduced to $\frac{1}{9}$th of its original value.

(c) If masses of both the objects are doubled, i.e.

$$m'_1 = 2m_1 \text{ and } m'_2 = 2m_2$$

$$F' = \frac{G(2m_1)(2m_2)}{r^2} = 4F$$

The force becomes 4 times its original value.

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7. What is the importance of universal law of gravitation?

Ans :

Importance of universal law of gravitation is as follows :

(i) It is the gravitational force between the Sun and the Earth, which makes the Earth to move around the Sun with a uniform speed.

(ii) The tides formed in sea are because of gravitational pull exerted by the Sun and the Moon on the surface of water.

(iii) It is the gravitational pull of Earth, which keeps us and other bodies firmly on the ground.

(iv) It is the gravitational pull of the Earth, which holds our atmosphere in place.

8. What is the acceleration of free fall?

Ans :

The average acceleration of free fall on the surface of Earth is 9.81 ms^{-2}.

9. What do we call the gravitational force between the Earth and an object?

Ans :

It is called weight of the object.

10. Amit buys few grams of gold at the poles as per the instruction of one of his friends. He hands over the same when he meets him at the equator. Will the friend agree with the weight of gold bought? If not, why?
[Hint : The value of g is greater at the poles than at the equator.]

Ans :

Weight of an object = mg
where 'm' is mass of the object at the equator than at the poles as the magnitude of `g' is less at the equator than at the poles.
So, his friend will not agree with weight of the gold at the poles when measured at equator.

11. Why will a sheet of paper fall slower than one that is crumpled into a ball?

Ans :

When a sheet of paper is crumpled into a ball, then its density increases. Hence, resistance to its motion through the air decreases and it falls faster than the sheet of paper.

12. Gravitational force on the surface of the Moon is only 1/6 as strong as gravitational force on the Earth. What is the weight in newton of a 10 kg object on the Moon and on the Earth?

Ans :

Mass of object (m) = 10 kg
Acceleration due to gravity on Earth (g_e) = 9.81 ms^{-2}
Acceleration due to gravity on Moon (g_m) = ms^{-2}
Weight of the object on the Earth

$$= mg_e = 10 \times 9.81 = 98.1 \text{ N}$$

Weight of the object on the Moon

$$= mg_m = 10 \times 9.81/6 = 16.35 \text{ N}$$

13. A ball is thrown vertically upwards with a velocity of 49 ms-1. Calculate :

(i) The maximum height to which it rises.

(ii) The total time it takes to return to the surface of the Earth.

Ans :

(i) Initial velocity of the ball (u) = 49 ms^{-1}

Final velocity of the ball (v) = 0

Acceleration due to gravity (g) = 9.8 ms^{-2}

[In upward direction g is ve.]

Height attained by the ball (s) = ?

Time for rising up (t) = ?

We know; $v^2 - u^2 = 2gs$

$$(0)^2 - (49)^2 = 2 \times (9.8) \times s$$

$$s = -49 \times \frac{-49}{-2} \times 9.8$$

$$= 122.5 \text{ m}$$

We know $v = u + gt$

$$0 = 49 + 9.8 \times t$$

$$t = \frac{49}{9.8} = 5 \text{ sec} = 5 \text{ s}$$

(ii) Now, time for upward journey of the ball = the time for downward journey of the ball.

Total time taken by the ball to return to the surface of Earth = $2 \times t = 2 \times 5 = 10$ s

14. A stone is released from the top of a tower of height 19.6 m. Calculate its final velocity just before touching the ground.

Ans :

Initial velocity of stone (u) = 0

Final velocity of stone (v) = ?

Height attained (h) = 19.6 m

Acceleration due to gravity

(g) = 9.8 ms^2

We know $v^2 = u^2 + 2gh$

$= (0)^2 + 2 \times 9.8 \times 19.6 = 19.6 \times 19.6$

$v = \sqrt{19.6 \times 19.6} = 19.6 \text{ ms}^{-1}$.

15. A stone is thrown vertically upward with an initial velocity of 40 ms^{-1}. Taking g = 10 ms^{-2}, find the maximum height reached by the stone. What is the net displacement and the total distance covered by the stone?

Ans :

Initial velocity of stone (u) = 40 ms^{-1}

Final velocity of stone (v) = 0

Acceleration due to gravity

(g) = 10 ms^{-2}

[For upward direction g is –ve.]

Height attained by stone (h) = ?

We know, $v^2 - u^2 = 2gh$

$(0)^2 - (40)^2 = 2 \times (10) \times h$

$h = \frac{1600}{20} = 80 \text{ m}$

Maximum height attained by stone = 80 m

Net displacement of stone = 0

(Because the stone returns back to the same point)

Total distance covered by the stone

= 2 × height attained = 2 × 80 = 160 m

16. Calculate the force of gravitation between the Earth and the Sun, given that the mass of the Earth = 6 × 10^{24} kg and of the Sun = 2 × 10^{30} kg. The average distance between the two is 1.5 x 10^{11} m.

Ans :

$$F_{\text{gravitation}} = \frac{G \times M_S \times M_E}{r^2}$$

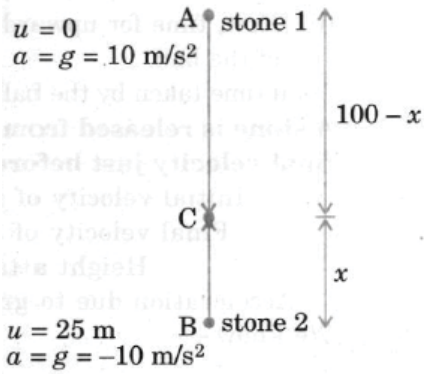
Given : G = 6.7 × 1.0^{-11} NM^2/kg^2, M_s = 2 × 10^{30} kg, M_E = 6 × 10^{24} kg, r = 1.5 × 10^{11} m

$$= \frac{6.7 \times 10^{-11} \times 2 \times 10^{30} \times 6 \times 10^{24}}{(1.5 \times 10^{11})^2}$$

$= 3.57 \times 10^{22}$ N

17. A stone is allowed to fall from the top of a tower 100 m high and at the same time another stone is projected vertically upwards from the ground with a velocity of 25 ms^{-1}. Calculate when and where the two stones will meet.

Ans :



For stone 1

Acceleration due to gravity (g) = 10 ms^{-2}

Initial velocity (u) = 0 ms^{-1}

Distance (s) = 100 – x

Time (t) = ?

$s = ut + \frac{1}{2} gt^2$

$(100 - x) = 0 \times t + \frac{1}{2} \times 10 \times t^2$

$100 - x = 5t^2$

$x = 100 - 5t^2$ ...(1)

For stone 2

Acceleration due to gravity (g) = – 10 ms^{-2}

Initial velocity (u) = 25 ms^{-1}

Distance (s) = x

Time (t) = ?

$s = ut + \frac{1}{2} gt^2$

$x = 25 \times t + \frac{1}{2} \times (-10) \times t^2$

$x = 25t - 5t^2$ ...(2)

Substituting the value of x from (2) in (1), we get

$100 - 5t^2 = 25t - 5t^2$

$100 = 25t$

$t = 4$ sec.

Put the value of t in equation (1)

$x = 100 - 5 \times (4)^2$

$x = 100 - 5 \times 16$

$x = 20$ m

The stones will meet at a height of 20 m from ground after 4 sec.

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18. A ball thrown up vertically returns to the thrower after 6 s. Find :

(a) the velocity with which it was thrown up.

(b) the maximum height it reaches.

(c) its position after 4 s.

Ans :

The ball returns back to the thrower in 6 s, the time for its upward journey

= 6 ÷ 2 = 3 s

(a) For the upward motion of ball

Initial velocity (u) = ?

Final velocity (v) = 0 (Ball comes to rest)

Time (t) = 3 s

Acceleration due to gravity

(g) = 10 ms^{-2}

[In upward direction g is –ve.]

We know $v = u + gt$

$0 = u + (-10) \times 3$

$u = 30$

$u = 30 \text{ ms}^1$

(b) We know $s = ut + \frac{1}{2} gt^2$

$$s = 30 \times 3 + \frac{1}{2}(-10) \times (3)^2$$
$$s = 90 - 45$$
$$s = 45 \text{ m}$$

(c) For the downward motion of ball

Initial velocity (u) = 0

Time for downward fall

$$(t) = 4 - 3 = 1 \text{ s}$$

Acceleration due to gravity

$$(g) = 10 \text{ ms}^{-2}$$

Distance covered in downward direction (s) = ?

We know

$$s = ut + \frac{1}{2}gt^2$$
$$s = 0 \times t + \frac{1}{2} \times 10 \times (1)^2$$
$$s = 5$$
$$s = 5 \text{ m}$$

Position of ball after 4 s from ground = 40 m.

19. In what direction does the buoyant force on an object immersed in a liquid act?

Ans :

An object immersed in a liquid experiences buoyant force in the upward direction.

20. Why does a block of plastic released under water come up to the surface of water?

Ans :

Two forces act on an object immersed in water. One is the gravitational force, which pulls the object downwards, and the other is the buoyant force, which pushes the object upwards. If the upward buoyant force is greater than the downward gravitational force, then the object comes up to the surface of the water as soon as it is released within water. Due to this reason, a block of plastic released under water comes up to the surface of the water.

21. The volume of 50 g of a substance is 20 cm^3. If the density of water is 1 g cm^{-3}, will the substance float or sink?

Ans :

If the density of an object is more than the density of a liquid, then it sinks in the liquid. On the other hand, if the density of an object is less than the density of a liquid, then it floats on the surface of the liquid.

Here, density of the substance

$$= \frac{\text{Mass of the packet}}{\text{Volume of the packet}}$$
$$= \frac{50}{20} = 2.5 \text{ gcm}^{-3}$$

The density of the substance is more than the density of water (1 g cm^{-3}). Hence, the substance will sink in water.

22. The volume of a 500 g sealed packet is 350 cm^3. Will the packet float or sink in water if the density of water is 1 g cm^{-3}? 'What will be the mass of the water displaced by this packet?

Ans :

Density of the 500 g sealed packet

$$= \frac{\text{Mass of the packet}}{\text{Volume of the packet}}$$
$$= \frac{500}{350} = 1.428 \text{ gcm}^{-1}$$

The density of the substance is more than the density of water (1 gcm^{-3}).

Hence, it will sink in water.

The mass of water displaced by the packet is equal to the volume of the packet, i.e., 350 g.

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3. NCERT EXEMPLAR

Objective Type Questions

1. Two objects of different masses falling freely near the surface of Moon would :

(a) Have same velocities at any instant

(b) Have different accelerations

(c) Experience forces of same magnitude

(d) Undergo a change in their inertia

Ans : (a) Have same velocities at any instant

2. The value of acceleration due to gravity :

(a) Is same on equator and poles

(b) Is least on poles

(c) Is least on equator

(d) Increases from pole to equator Ans.

Ans : (c) Is least on equator

3. The gravitational force between two objects is F. If masses of both objects are halved without changing distance between them, then the gravitational force would become :

(a) F/4 (b) F/2

(c) F (d) 2 F

Ans : . (a) F/4

4. A boy is whirling a stone tied with a string in an horizontal circular path. If the string breaks, the stone :

(a) Will continue to move in the circular path

(b) Will move along a straight line towards the centre of the circular path

(c) Will move along a straight line tangential to the circular path

(d) Will move along a straight line perpendicular to the circular path away from the boy

Ans : (c) Will move along a straight line tangential to the circular path

5. In the relation $F = G M m/d^2$, the quantity G :
(a) Depends on the value of g at the place of observation
(b) Is used only when the Earth is one of the two masses
(c) Is greatest at the surface of the Earth
(d) Is universal constant of nature

Ans : (d) Is universal constant of nature

6. Law of gravitation gives the gravitational force between :
(a) The Earth and a point mass only
(b) The Earth and Sun only
(c) Any two bodies having some mass
(d) Two charged bodies only

Ans : (c) Any two bodies having some mass

7. The value of quantity G in the law of gravitation :
(a) Depends on mass of Earth only
(b) Depends on radius of Earth only
(c) Depends on both mass and radius of Earth
(d) Is independent of mass and radius of the Earth

Ans : (d) Is independent of mass and radius of the Earth

8. Two particles are placed at some distance. If the mass of each of the two particles is doubled, keeping the distance between them unchanged, the value of gravitational force between them will be :
(a) 1/4 times (b) 4 times
(c) 1/2 times (d) Unchanged

Ans : (b) 4 times

9. The atmosphere is held to the Earth by :
(a) Gravity
(b) Wind
(c) Clouds
(d) Earth's magnetic field

Ans : (a) Gravity

10. The force of attraction between two unit point masses separated by a unit distance is called :
(a) Gravitational potential
(b) Acceleration due to gravity
(c) Gravitational field
(d) Universal gravitational constant

Ans : (d) Universal gravitational constant

11. The weight of an object at the centre of the Earth of radius R is :
(a) Zero
(b) Infinite
(c) R times the weight at the surface of the Earth
(d) $1/R^2$ times the weight at surface of the Earth

Ans : (a) Zero

12. An object weighs 10 N in air. When immersed fully in water, it weighs only 8 N. The weight of the liquid displaced by the object will be :
(a) 2 N (b) 8 N
(c) 10 N (d) 12 N

Ans : (a) 2 N

13. A girl stands on a box having 60 cm length, 40 cm breadth and 20 cm width in three ways. In which of the following cases, pressure exerted by the brick will be :
(a) Maximum when length and breadth form the base
(b) Maximum when breadth and width form the base
(c) Maximum when width and length form the base
(d) The same in all the above three cases

Ans : (b) Maximum when breadth and width form the base

14. An apple falls from a tree because of gravitational attraction between the Earth and apple. If F_1 is the magnitude of force exerted by the Earth on the apple and F_2 is the magnitude of force exerted by apple on Earth, then :
(a) F_1 is very much greater than F_2
(b) F_2 is very much greater than F_1
(c) F_1 is only a little greater than F_2
(d) F_1 and F_2 are equal

Ans : (d) F_1 and F_2 are equal

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Short Answer Questions

15. What is the source of centripetal force that a planet requires to revolve around the Sun? On what factors does that force depend?

Ans :

Gravitational force is the source of centripetal force that a planet requires to revolve around the Sun.
It depends upon the following factors :
(i) Mass of the planet and the Sun, i.e., depends on the product of the masses of the planet and the Sun.
(ii) Distance between the planet and the Sun, i.e. depends on the square of distance between the planet and the Sun.

16. On the Earth, a stone is thrown from a height in a direction parallel to the Earth's surface while another stone is simultaneously dropped from the same height. Which stone would reach the ground first and why?

Ans :

Both the stones will take the same time to reach the ground because the two stones fall from the same height.
As both the stones will have initial velocity (u) = 0, a = g (acceleration due to gravity), distance (s) = s; t = ?

Using equation of motion,

$$s = ut + \frac{1}{2}at^2$$

Time taken for the first stone to travel,

$$s = ut + \frac{1}{2}at^2$$

$$s = 0 \times t + \frac{1}{2}gt^2$$

$$s = 0 + \frac{1}{2}gt^2$$

$$s = 0 + \frac{1}{2}gt^2$$

$$\frac{2s}{g} = t^2$$

$$\sqrt{\frac{2s}{g}} = t$$

Time taken for the second stone to travel,

$$s = ut + \frac{1}{2}at2$$

$$s = 0 \times t + \frac{1}{2}gt2$$

$$s = 0 + \frac{1}{2}gt^2$$

$$\frac{2s}{g} = t^2$$

$$\sqrt{\frac{2s}{g}} = t$$

Therefore, time taken for both the stones to reach the ground will be the same.

17. Suppose gravity of Earth suddenly becomes zero, then in which direction will the Moon begin to move if no other celestial body affects it?

Ans :

If gravity of Earth suddenly becomes zero then Moon will begin to move a straight line in the direction in which it was moving at that instant. This straight line will be a tangent to the circular path. This change happens because the circular motion of the Moon is due to the centripetal force provided by the gravitational force of the Earth.

18. Identical packets are dropped from two aeroplanes, one above the equator and the other above the north pole, both at height h. Assuming, all conditions are identical, will those packets take same time to reach the surface of Earth. Justify your answer.

Ans :

At a given place, the value of acceleration due to gravity is constant but it varies from one place to another place on the Earth surface. It is due to this fact that Earth is not a perfect sphere. It is flattened at the poles and bulges out at the equator (ellipsoidal shaped). Thus, the value of `g' is minimum at the equator and maximum at the poles. It means `g' increases as we go from equator to pole. Therefore, the packet falls slowly at equator compared to the poles. Thus, the packet will remain in air for a longer time, when it is dropped at the equator.

19. The weight of any person on the Moon is about 1/6 times that on the Earth. He can lift a mass of 15 kg on the Earth. What will be the maximum mass, which can be lifted by the same force applied by the person on the Moon?

Ans :

$$g_m = \frac{g_e}{6} \quad ...(i)$$

Force applied by the person on Earth to lift a mass 'm'

$$F = ma$$

Therefore, by applying the given values, we get

$$F = mg_e = 15g_e \quad ...(ii)$$

When the same force is applied in mass m' on Moon

Then $F = m'g_m$ ...(iii)

$F = mg_e = 15g_e$ from (ii)

Substituting the values in equation (iii), we get

$$F = m'g_m$$

$$F = 15\ g_e$$

[from (ii); $g_m = \frac{g_e}{6}$ from (i)]

$$m' = \frac{F}{g_m}$$

$$m' = \frac{15g_e}{g_e/6} = 15 \times 6 = 90 \text{ kg}$$

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20. Calculate the average density of the Earth in terms of g, G and R. 'g' is related to Earth's mass "M" and radius "R".

Ans :

By the equation;

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

Therefore, $M = \frac{gR^2}{G}$ ...(i)

Average density of Earth,
From (i), we get

$$\text{Density (D)} = \frac{\text{Mass}}{\text{Volume}} = \frac{gR^2}{G \times V_e} \quad ...(ii)$$

Where V_e is the volume of the Earth
The Earth is approximately a sphere (actually it is sphere slightly flattened at the poles).
Use the equation for the volume of a sphere which is

$$V = \frac{4}{3}\pi \times \text{Radius}^3$$

$$V = \frac{4}{3}\pi \times R^3 \quad ...(iii)$$

Therefore, by substituting equation (iii) in equation (ii), we get

$$D = \frac{gR^2}{G} \div \frac{4}{3}\pi \times R^3$$

$$D = \frac{3g}{4\pi GR}$$

21. The Earth is acted upon by gravitation of Sun, even though it does not fall into the Sun. Why?

Ans :

According to Newton's first law of motion, an object in motion tries to move in straight-line at a constant speed unless external pressure is not applied. When the Earth comes close to the Sun that has a large gravitational force, the path of the Earth is altered due to the unbalanced force of gravity on it. The Sun exerts an attractive force on the Earth, accelerating the Earth directly towards the Sun. It moves toward the Sun as described by Newton's second law. To avoid falling into the Sun, the Earth also counteracts the force that is pulling it towards the Sun. Thus, a force, which tends to make a body move in a curved path, is called a centripetal force is applied by the Earth.

Therefore, we can say that the gravitational force is responsible for providing the necessary centripetal force which allows the Earth to move around the Sun in a defined orbit. Gravitational attraction of the Sun deflects the Earth from a straight path.

Long Answer Questions

22. How does the weight of an object vary with respect to mass and radius of the Earth? In a hypothetical case, if the diameter of the Earth becomes half of its present value and its mass becomes four times of its present value, then how would the weight of any object on the surface of the Earth be affected?

Ans :

From Newton's law of gravitation, we get
Weight of an object is directly proportional to the mass of the Earth and inversely proportional to the square of the radius of the Earth.

Weight of a body = mass of the body × gravity of the Earth

$$W = mg \quad ...(1)$$

Mass of the Earth is same everywhere

$$\text{Weight of a body} = \frac{GMm}{R^2} \quad ...(2)$$

Where M = mass of Earth;
m = mass of the body;
R = radius of the Earth
G = universal gravitational constant
g = 9.8 m/s^2 on Earth

Thus,

$$\text{Weight of a body} \propto M$$

$$\text{Weight of a body} \propto \frac{1}{R^2}$$

$$\text{Original weight } W_o = mg = \frac{mGM}{R_2} \quad \left[\because g = \frac{GM}{R^2}\right] ...(3)$$

When diameter of the Earth becomes half of its present value R becomes R/2, its mass (M) becomes 4 M.
Then, weight becomes $(W_n) = m\ G\ 4M/(R/2)^2 = (16\ m\ G)\ M/R^2 = 16 \times W_o$
The weight of the same object will become 16 times its original weight.

23. How does the force of attraction between the two bodies depend upon their masses and distance between them? A student thought that two bricks tied together would fall faster than a single one under the action of gravity. Do you agree with his hypothesis or not? Comment.

Ans :

From Newton's law of gravitation, we get
Force of attraction between two bodies is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centres.

$$F \propto m_1 m_2 \quad ...(1)$$

$$F \propto \frac{1}{d^2} \quad ...(2)$$

The hypothesis of the student is wrong because acceleration due to gravity is independent of the mass of the falling body. The two objects of different masses (mass of two bricks tied together and the other having the mass of a single brick) will hit the ground at the same time because, when an object is in free fall, it is "weightless". This is because there is no force pushing up on it. Since, both of these objects are experiencing the same force, namely, gravitational force, then they both will fall at the same velocity and they will both hit the ground at the exact same time. Therefore, the two bricks tied together will fall with the same speed and will reach the ground at the same time (free fall) equal to the speed and time of a single brick.

If no air resistance is present, the rate of descent depends only on how far the object has fallen, no matter how heavy the object is. This means that two objects will reach the ground at the same time if they are dropped simultaneously from the same height.

24. Two objects of masses m_1 and m_2 having the same sizes are dropped simultaneously from heights h_1 and h_2 respectively. Find out the ratio of time they would take in reaching the ground. Will this ratio remain the same if (i) one of the objects is hollow and the other one is solid and (ii) both of them are hollow, size remaining the same in each case? Give reason.

Ans :

Two objects of masses m_1 and m_2 having the same sizes are dropped, therefore, initial velocity (u) = 0 and a = g (Acceleration due to gravity — falling object) and it is independent of mass.
By using Newton's equation of motion namely.

$$s = ut + \tfrac{1}{2}at^2$$

For object 1,

$$h_1 = \frac{1}{2}gt_1^2 \quad ...(1)$$

where t_1 = time taken by object 1 to reach the ground
For object 2,

$$h_2 = \frac{1}{2}gt_2^2 \quad ...(2)$$

where t_2 = time taken by object 2 to reach the ground
Therefore, the ratio of time they would take in reaching the ground

$$\frac{h_1}{h_2} = \frac{\frac{1}{2}gt_1^2}{\frac{1}{2}gt_2^2}$$

$$\frac{t_1}{t_2} = \sqrt{\frac{h_1}{h_2}}$$

(i) This ratio of time will be the same even if one of the objects is hollow and the other one is solid. This is because acceleration due to gravity is independent of the mass of the falling body.

(ii) This ratio of time will be the same even if both of them are hollow, size remaining the same in each case. This is because acceleration due to gravity is independent of the mass of the falling body.

25. (a) A cube of side 5 cm is immersed in water and then in saturated salt solution. In which case will it experience a greater buoyant force. If each side of cube is reduced to 4 cm and then immersed in water. What will be the effect on buoyant force experienced by the cube as compared to the first case for water? Give reason for each case.

(b) A ball weighing 4 kg of density 4000 kg m^{-3} is completely immersed in water of density 10^3kg m^{-3}. Find the force of buoyancy on it. (Given g = 10 ms^{-2})

Ans :

(a) (i) As the density of salt solution is greater than that of water so the cube will experience a greater buoyant force in the saturated salt solution.

(ii) The smaller cube will experience lesser buoyant force as its volume is lesser than the initial cube.

(b) Buoyant force = weight of the liquid displayed

= density of water

× volume of water displayed

× gravity

$$= 1000 \times \frac{4}{4000} \times 10 = 10 \text{ N}$$

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