10

Gravitation

In the Chapter

- The law of gravitation states that the force of attraction between any two objects is proportional to the product of their masses and inversely proportional to the square of the distance between them. The law applies to objects anywhere in the universe. Such a law is said to be universal.
- Gravitation is a weak force unless large masses are involved.
- Force of gravitation due to the earth is called gravity.
- The force of gravity decreases with altitude. It also varies on the surface of the earth, decreasing from poles to the equator.
- The weight of a body is the force with which the earth attracts it.
- The weight is equal to the product of mass and acceleration due to gravity.
- The weight may vary from place to place but the mass stays constant.
- All objects experience a force of buoyancy when they are immersed in a fluid.
- Objects having density less than that of the liquid in which they are immersed, float on the surface of the liquid. If the density of the object is more than the density of the liquid in which it is immersed then it sinks in the liquid.

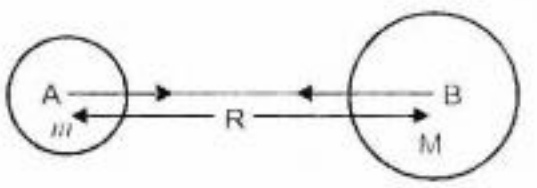
Intext Exercises

Page No. 134

1. State the universal law of gravitation.

Ans. According to this law, the force of attraction between two particles or bodies is (i) directly proportional to the product of their masses and (ii) inversely proportional to the square of the distance between these particles or bodies.

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. Consider two bodies A and B of masses m_1 and m_2 separated by a distance R, then

$$F \alpha m_1 \times m_2$$

or $$F \alpha \frac{m_1 \times m_2}{R^2}$$

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

Page No. 136

1. What do you mean by free fall?

Ans. Whenever object fall towards the earth, we say that the objects are in free fall.

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

Ans. The acceleration acquired by a body falling freely towards the earth is called acceleration due to gravity. It is denoted by 'g'. The acceleration due to gravity is described as
Acceleration due to gravity

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

Where m_e = Mass of earth

R = Radius of earth

Thus 'g' does not depend upon the mass of the falling object, i.e., the acceleration due to gravity is same for all the freely falling bodies.

Page No. 138

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

Ans. Mass

1. Mass is the amount of matter contained in a body.
2. Mass in any object remains constant at all places.
3. It is measured in kilogram (kg) unit.
4. Mass is measured with the help of a physical balance.

Weight

1. Weight is the force with which a body is attracted towards the earth.
2. Weight of an object varies from place to place.
3. It is measured in newton (N) unit.
4. Weight is measured by using a spring balance.

2. Why is the weight of an object on the moon 1/6th its weight on the earth?

Ans. By definition

$W = m \times g$

Where W = Weight of an object
m = Mass of an object
g = Gravitational force

The mass of an object is constant and does not change on the earth or on the moon. Hence, the weight of the object depends on the gravitational force. As the gravitational force of the moon is about one sixth of what it is on the earth, the weight of the object on the moon is also 1/6 th the weight on the earth.

Page No. 141

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

Ans. A school bag has wide strap so that weight of the bag may fall over a large area of the shoulder of the child producing less pressure on the shoulder. As a result, it will be comfortable to carry the bag.

2. What do you mean by buoyancy?

Ans. The property of fluids (gases and liquids) by virtue of which they exert an upward thrust on a body immersed into it is called the buoyancy.

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

Ans. The objects of density lesser than that of water will float on water. The objects of density greater than that of water will sink in water.

Page No. 142

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

Ans. Our mass will be less than 42 kg.

2. 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 is heavier and why?

Ans. In reality, the bag of cotton will be heavier. This is because the buoyancy of a fluid (air in this case) is directly proportional to the volume.

Exercise

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

Ans. By universal law of gravitation, the gravitational force between two objects is inversely proportional to the square of the distance between them.

i.e., $F \alpha \frac{1}{r^2}$

When the distance is reduced to half, then

$$F \alpha \frac{4}{(r/2)^2}$$

or $$F \alpha \frac{4}{r^2}$$

so, $$\frac{F'}{F} \alpha \frac{\frac{4}{r^2}}{\frac{1}{r^2}}$$

$$\frac{F'}{F} = 4$$

Thus, the gravitational force will increase four times when the distance is reduced to half.

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. An object experiences acceleration during free fall denoted by 'g'. It is given by $g = GM/R^2$ where G = Gravitational constant, M = Mass of the earth, R = Radius of the earth. Thus, it is independent of mass. Hence a heavy body does not fall faster than a light body.

3. What is the magnitude of the gravitational force between the earth and 1 kg object on its surface? (Mass of the earth = 6 × 1024 kg and radius of the earth = 6.4 × 106m)

Ans. Gravitational constant

$G = 6.67 \times 10^{-17}\ Nm^2Kg^{-2}$

Mass of the earth, $m_1 = 6 \times 10^{24}$ kg

Mass of the body, $m_2 = 1$ kg

Radius of the earth. $R = 6.4 \times 106$ m

By universal law of gravitation,

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

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

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. This is because by universal law of gravitation, every object in the universe attracts every other object in the universe with a force which is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

5. If the moon attracts the earth, why does the earth not move towards the moon?

Ans. According to Newton's third law of motion, the moon also attracts the earth. But according to Newton's second law of motion, acceleration is inversely proportional to the mass of an object. The mass of the moon is less than that of the earth. So, we don't see the earth moving towards the moon.

6. What happens to be 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 the objects are doubled?

Ans. By universal law of gravitation,

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

Where m_1, m_2 = mass of two objects

R = distance between them.

(i) The force becomes doubled when the mass of one body is doubled.

(ii) The force becomes one-fourth when the distance between the bodies is doubled. The force becomes one-ninth when the distance between the bodies is tripled.

(iii) The force becomes four times if the masses of both the bodies are doubled.

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

Ans. The universal law of gravitation successfully explained several phenomena which were believed to be unconnected.

(a) The force that binds us to the earth.

(b) The motion of the moon around the earth.

(c) The motion of planets around the sun.

(d) The tides due to the moon and the sun.

8. What is the acceleration of free fall?

Ans. Whenever an object falls towards the earth, acceleration is involved. This acceleration is due to earth's gravitational force. Therefore, the acceleration is called as acceleration due to gravitational force of earth. It is denoted by 'g'.

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

Ans. The gravitational force between the earth and our body is known as weight.

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 friends agree with the weight of gold bought? If not, why?

Ans. No, the friend will not agree with the weight of gold because weight of an object depends on the value of 'g'. The value of 'g' is greater at poles than at equator. Therefore, weight of gold will be less at the equator than at the poles.

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

Ans. This is because the air offers resistance to the motion, due to friction to the falling objects. The resistance offered to the sheet of paper is more than the resistance offered by air to the ball form. Also wind may deflect the sheet of paper sideways.

12. Gravitational force on the surface of the moon is only 1/6th as strong as gravitational force on the earth. What is the weight is newton's of a 10kg object on the moon and on the earth?

Ans. Mass of an object remains constant. It does not change on moon or on the earth. Hence mass of the object on moon and on the earth is 10kg.

On earth

$W = m \times g$

$W = 10\,kg \times 9.8\,ms^{-2}$

$W = 98N$

On moon

Gravitational force on moon,

$$g' = \frac{1}{6} \times g$$

$$= \frac{1}{6} \times 9.8 ms^{-1}$$

$= 1.63\,ms^{-2}$

Weight, $W_1 = m \times g$

$W_1 = 10\,kg \times 1.63\,ms^{-2}$

$= 16.3N$

Thus, weight of the object on the earth is 90N and its weight on the moon will be 16.3 N.

13. A ball is thrown vertically upwards with a velocity of $48ms^{-1}$. Calculate
(i) the maximum height to which it rises.
(ii) the total time it takes to return to the surface of the earth.

Ans. Initial velocity, $u = 48\,ms^{-1}$

Final velocity, $V = 0\,ms^{-1}$

Acceleration due to gravity,

$g = -9.8\,ms^{-2}$

Distance = Weight, h = ?

By third law of motion

$V^2 - u^2 = 2gs$

$\Rightarrow \quad (0\,ms^{-1})^2 - (48\,ms^{-1})^2 = 2 \times (-9.8\,ms^{-2}) \times s$

$\Rightarrow \quad -(48\,ms^{-1})^2 = 19.6\,ms^{-2} \times s$

$\Rightarrow \quad -2304\,m^2s^{-2} = 19.6\,ms^{-2} \times s$

$$\Rightarrow \quad \frac{-2304 m^2 s^{-2}}{-19.6 ms^{-2}} = s$$

$\Rightarrow \quad s = 117.55\,m$

By first law of motion,

$V = u + gt$

$\Rightarrow (0\,ms^{-1}) = 48\,ms^{-1} + (-19.8\,ms^{-2} \times t)$

$\Rightarrow -48\,ms^{-1} = -19.8\,ms^{-2} \times t$

$\Rightarrow \frac{-48ms^{-1}}{-9.8\,ms^{-2}} = t$

$\Rightarrow 4.9s = t$

$\therefore$ The maximum height to which the ball rises is 117.55m.

The total time it takes to return to the surface of the Earth is

$4.9s + 4.9\,s = 9.8\,s.$

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

Ans. Initial velocity, $u = 0\,ms^{-1}$

Final velocity, $V = ?$

Height of tower, $s = 19.6\,m$

Acceleration due to gravity,

$g = 9.8\,ms^{-2}$

By third law of motion,

$v^2 - u^2 = 2gs$

$v^2 - (0ms^{-1})^2 = 2 \times 9.8\,ms^{-2} \times 19.6\,m$

$v^2 = 19.6 \times 19.6\,m^2s^{-2}$

$v = \sqrt{19.6 \times 19.6 m^2 s^{-2}}$

$v = 19.6\,ms^{-1}$

15. A stone is thrown vertically upward with an initial velocity of 40 m/s. Taking g = 10 m/s², find the maximum height reached by the stone. What is the net displacement and the total distance covered by the stone?

Ans. (i) Initial velocity, $u = 40ms^{-1}$

Final velocity, $V = 0\,ms^{-1}$

Acceleration due to gravity,

$g = -10\,ms^{-2}$

Height reached by the stone, $h = ?$

By third law of motion,

$v^2 - u^2 = 2gs$

$\Rightarrow v^2 - (0ms^{-1})^2 = (40 \times 2\,ms^{-1})^2 = 2 \times (-10\,ms^{-2}) \times h$

$\Rightarrow -1600\,m^2s^{-2} = -20\,ms^{-2} \times h$

$\Rightarrow h = \frac{-1600m^2s^{-2}}{-20ms^{-2}} = 80m$

(ii) Net displacement = 0 (Since the stone reaches back on the ground)

(iii) Total distance covered by stone

$= 80\,m + 80\,m = 10\,m.$

16. Calculate the force of gravitation between the earth and the Sun, given that the mass of the earth = 6×10^{24} kg and the sun = 2×10^{30} kg. The average distance between the two is 1.5×10^{14} m.

Ans.

$$F_{gravitation} = \frac{G \times M_{earth} \times M_{sun}}{(\text{Distance of the earth from the sun})^2}$$

$$= \frac{6.67\times10^{-11}\,\text{Nm}^2\text{kg}^{-2}\times6\times10^{24}\,\text{kg}\times2\times10^{30}\,\text{kg}}{1.5\times10^{11}\,\text{m}\times1.5\times10^{11}\,\text{m}}$$

$$= \frac{6.67\times6\times2\times10^{-11+24+30-11-11}}{2.25}\,\text{N}$$

$$= 35.57\times10^{21}\,\text{N}$$

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 stones meet. (Take g = 10 ms^{-2}).

Ans. Let x be the distance from the ground where the two stones meet after time t.

For the stone coming down :

Distance $(h) = 100 - x$

Time $(t) = ?$

Acceleration due to gravity

$(g) = 10\ ms^{-1}$

Initial velocity $(u) = 0$

Applying $\quad h = ut + \frac{1}{2}gt^2$

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

$100 - x = 5t^2$

For the stone moving vertically upward:

Initial Velocity $(u) = 25\ ms^{-1}$

Time $(t) = ?$

Acceleration due to gravity

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

[g is negative in upward direction]

Distance $(h) = x$

Applying, $\quad h = ut + \frac{1}{2}gt^2$

$x = 25 \times t + \quad \times 10t^2 \frac{1}{2}$

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

Substituting the value of x from (ii) in (i)

$\Rightarrow \quad 100 - (25t - 5t^2) = 5t^2$

$\Rightarrow \quad 100 - 25t + 5t^2 = 5t^2$

$\Rightarrow \quad 25t = 100$

$t = 4\ s$

$$= \frac{6.67\times10^{-11}\,\text{Nm}^2\text{kg}^{-2}\times6\times10^{24}\,\text{kg}\times2\times10^{30}\,\text{kg}}{1.5\times10^{11}\,\text{m}\times1.5\times10^{11}\,\text{m}}$$

$$= \frac{6.67\times6\times2\times10^{-11+24+30-11-11}}{2.25}\,\text{N}$$

$$= 35.57\times10^{21}\,\text{N}$$

18. A ball thrown up vertically returns to the thrower after 6s. Find
(a) the velocity with which it was thrown up.
(b) the height attained. (take $g = 9.8\ m/s^2$)
(c) the position after 4s.

Ans. Time to reach maximum height,

$$t = \frac{6}{2} = 3s$$

$v = 0$ (at the maximum height)
$a = -9.8\ ms^{-2}$
(a) Using, $v = u + at$, we get
$0 = u - 9.8 \times 3$
or $u = 28.4\ ms^{-1}$
Thus, the velocity with which it was thrown up $= 29.4\ ms^{-1}$
(b) Using, $2as - v^2 - u^2$, we get

$$s = \frac{v^2 - u^2}{2a} = \frac{0 - 29.4 \times 29.4}{-2 \times 9.8}$$

$= 44.1\ m$
Thus, maximum height it reaches $= 44.1\ m$
(c) Here, $t = 4s$. In 3s the ball reaches the maximum height and in 1s it falls from the top.
Distance covered in 1s from maximum height,

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

$$= 0 + \frac{1}{2} \times 9.8 \times 1 = 4.9m$$

$\therefore$ The ball will be 4.9 m below the top of the tower after 4s.

19. In what direction does the buoyant force on an immersed in a liquid act?
Ans. The buoyat force on an object acts in an upward direction.
20. Why does a block of plastic released under water come up to the surface of water?
Ans. The weight of an object is the force due to gravitational attraction of the earth. When the block of plastic piece is immersed, the upward force exerted by the water on the plastic block is greater than its weight. Therefore it comes to the surface of 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. Mass $= 50\ g$
Volume $= 20\ cm^3$
Density $= ?$
Density $=$ Mass / Volume
$= 50\ g / 20\ cm^3$
$= 2.5\ g\ cm^{-3}$
Relative density
= Density of a substance / Density of water

$$= \frac{2.5 g\ cm^{-3}}{1 g\ cm^{-3}}$$

$= 2.5$
Since the relative density is greater than 1, therefore the substance will sink.

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. (i) Mass = 500 g
Volume = 350 cm^3
Density = ?
Density = Mass / Volume
= 500 g / 350 cm^3
= 1.42 g cm^{-3}

(ii) Relative density
= Density of a substance / Density of water
1.42 g cm^{-3} / 1 g cm^{-3} = 1.42 cm

(iii) Since the relative density is greater than 1, therefore the packet will sink.

(iv) The solid will displace water equal to its own volume (i.e., 350 cm^3). The weight of 350 cm^3 of water is 350 gram-weight. Thus, the weight of water displaced is 350 gram-weight.

Additional Questions

1. State the significance of universal law of gravitation.

Ans. The universal law of gravitation is responsible for:
(i) The force that binds us to the earth.
(ii) The tides due to the moon and the sun.

2. Write the mathematical expression for the gravitational force between the earth and the moon using usual symbols of the physical quantities involved.

Ans. $$F = \frac{GM_P Mm}{R^2}$$

3. A cork floats while the nail sinks in water. Give reason.

Ans. In the case of the cork, the upthrust water on the cork is greater than the weight of the cork, so it floats. The upthrust of water on the nail is less than the weight of nail and therefore it sinks in water.

4. Why are sleepers used below the rails ?

Ans. By placing sleepers below the rails, cross-sectional area is increased. This in turn reduces the pressure due to the weight of the train on the rails as pressure is defined as force area.

5. In what direction does the thrust act?

Ans. Normal to a surface.

6. How is pressure related to thrust?

Ans. Pressure = Total thrust/Total surface area.

7. Name the SI unit of pressure.

Ans. A Pascal (1 Pa), where 1 Pa = 1 Nm^{-2}.

8. What is the direction of pressure?

Ans. Pressure always acts normally at a surface.

9. Why does a truck or a bus has much wider tyres ?

Ans. So that pressure acting on the road due eight of truck or bus may be small.

10. An army tank weighing more than hundred tonne move conveniently even on an earthen road. How?

Ans. The army tank rests upon a continuous broad chain. So, the total surface area is large and pressure on road due to weight of tank is not very high.

11. State universal law of gravitation.

Ans. 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 centres.

12. Write SI unit of G.

Ans. Nm2 kg^{-2}.

13. Two bodies of different masses are allowed to fall freely. How do their acceleration vary?

Ans. Acceleration produced in freely falling bodies is the same for all bodies, irrespective of their masses.

14. State two factors on which gravitation of force depends?

Ans. (i) Masses of the two bodies.
(ii) Distance between the bodies.

15. A man at the top of a tower throws an object horizontally where as he simply drops another. Will these two objects reach the earth at the same time?

Ans. Yes, as the vertical distance travelled by both is same and takes place under the same acceleration due to gravity.

16. What is weightlessness ?

Ans. It is a state when objects do not weigh anything. This occurs when bodies are in a state of free fall under the effect of gravity.

17. What is the unit of relative density? Why?

Ans. Relative density is a unitless quantity because it is a pure ratio (i.e., ratio of two terms having same units).

18. When will an object sink in a liquid ?

Ans. When density of the object is more than that of liquid.

19. A steel block sinks in water but floats in mercury. Why?

Ans. Because density of steel is more than the density of water but less than the density of mercury.

20. Name two forces which act on a body immersed in a liquid. Give the directions in which they act.

Ans. Two forces which act on a body immersed in a liquid:
(i) An upthrust (bouyant force) acting upward.
(ii) Weight of the body acting downward.

21. A steel needle sinks in water but a steel ship floats. Explain how?

Ans. A steel needle sinks in water because steel has more density than water.
A steel ship floats because it displaces a large weight of water which provides a greater buoyant force to keep it afloat.

22. Why is it easier to swim in sea water than in river water?

Ans. It is easier to swim in sea water than in river water because sea water exerts a greater buoyant force on the swimmer due to its higher density. When salt is mixed with water it increases the density of water.

23. Define density and write its SI Unit.

Ans. Density : The density of a substance is defined as mass of the substance per unit volume.
The SI unit of density is kilogram per cubic metre.

24. (a) State Archimedes' principle.
(b) Define relative density of a substance, why it has no units?

Ans. (a) When a body is partially or wholly immersed in a fluid, it experiences an upthrust,

which is equal to the weight of the fluid displaced by the immersed part of the body.
(b) The ratio between density of a substance and density of water is called relative density. Relative density is a ratio of similar qualities. It is a pure number and has no unit.

25. 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. This force depends on the product of the masses of the planet and Sun and the square of the distance between them.

26. 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 stones will take the same time to reach the ground because the two stones fall from the same height.

27. Suppose the gravity of earth suddenly becomes zero; then in which direction will the moon begin to move if no other celestial body affects it?

Ans. The moon will begin to move in a straight line in the direction in which it was moving at that time because the circular motion of moon is due to centripetal force provided by the gravitational force of earth.

28. 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 the earth? Justify your answer.

Ans. The value of 'g' at the equator of the earth is less than that at poles. Therefore, the packet falls slowly at equator in comparison to the poles. Thus, the packet will remain in air for a longer time, when it is dropped at the equator.

Multiple Choice Questions

1. The atmosphere is held to the earth by :

(a) gravity (b) wind
(c) cloud (d) earth's magnetic field

Ans. (a)

2. The force of attraction between two units point masses separated by a unit distance is called :

(a) universal gravitational constant
(b) gravitational potential
(c) gravitational field
(d) acceleration due to gravity

Ans. (a)

3. An object weighs 10N in air. When immersed fully in water, it weights only 8 N. The weight of the liquid displaced by the object will be :

(a) 2N (b) 8N
(c) 10N (d) 12N

Ans. (a)

4. 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 box will be :

(a) maximum when length and breadth form the base.
(b) maximum when width and length form the base.

(c) maximum when breadth and width form the base.
(d) the same in all the above three cases.

Ans. (c)

5. 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)

6. The value of acceleration due to gravity :
(a) is same on equator and poles.
(b) is least on equator.
(c) is least on poles.
(d) increases from pole to equator.

Ans. (b).

7. When a boy was whirling a stone tied with a string in an horizontal circular path, the string breaks. The stone :
(a) will continue to move in the circular path.
(b) will move along a straight lines 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 from the boy.

Ans. (c)

8. Gravity is the force of attraction between :
(a) the sun and the moon
(b) the moon and the satellite
(c) the earth and an object
(d) the sun and Jupiter

Ans. (c)

9. 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 same mass
(d) two charged bodies only

Ans. (c)

10. 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) depend on both mass and radius of earth
(d) is independent of mass and radius of the earth

Ans. (d)