Board – CBSE | Class –9th | Topic – Gravition

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

Ans. According to the universal law of gravitation, gravitational force (F) acting between two objects is inversely proportional to the square of the distance (r) between them, i.e.,

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

If distance r becomes r/2, then the gravitational force will be proportional to

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

Hence, if the distance is reduced to half, 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. All objects fall on the ground with constant acceleration, called acceleration due to gravity (without air resistance). It is constant and does not depend upon the mass of an object. Hence, heavy objects do not fall faster than light objects.

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. According to the universal law of gravitation, the gravitational force exerted on an object of mass m is given by:

$$F = \frac{GMm}{r^2}$$

Where,

Mass of Earth, $M = 6 \times 10^{24}$ kg

Mass of object, $m = 1$ kg

Universal gravitational constant, $G = 6.7 \times 10^{-11}\ Nm^2\ kg^{-2}$

Since the object is on the surface of the Earth, r = radius of the Earth (R)

$r = R = 6.4 \times 10^{6}$ m

Gravitational force, $F = \frac{GMm}{R^2}$

$$= \frac{6.7\times10^{-11}\times6\times10^{24}\times1}{\left(6.4\times10^{6}\right)^{2}} = 9.8N$$

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

Ans. According to the universal law of gravitation, two objects attract each other with equal force but opposite directions. The Earth attracts the moon with an equal force with which the moon attracts the Earth.

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

Ans. The Earth and the moon experience equal gravitational forces from each other. However, the mass of the Earth is much larger than the mass of the moon. Hence, it accelerates at a rate lesser than the acceleration rate of the moon towards the Earth. For this reason, the Earth does not move towards the moon.

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. (i)Doubled (ii)One-fourth and one-ninth (iii)four times

According to the universal law of gravitation, the force of gravitation between two objects is given by:

$$F = \frac{GMm}{r^2}$$

(i) F is directly proportional to the masses of the objects. If the mass of one object is doubled, then the gravitational force will also get doubled.

(ii) F is inversely proportional to the square of the distances between the objects. If the distance is doubled, then the gravitational force becomes one-fourth of its original value.

Similarly, if the distance is tripled, then the gravitational force becomes one-ninth of its original value.

(iii) F is directly proportional to the product of masses of the objects. If the masses of both the objects are doubled, then the gravitational force becomes four times the original value.

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

Ans. The universal law of gravitation proves that every object in the universe attracts every other object.

8. What is the acceleration of free fall?

Ans. When objects fall towards the Earth under the effect of gravitational force alone, then they are said to be in free fall. Freefall accelerations 9.8 m s^{-} are constant for all objects (irrespective of their masses).

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

Ans. The gravitational force between the Earth and an object is known as the weight of the object.

10. Amit buys a 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. The weight of a body on the Earth is given by:

W = mg

Where,

m = mass of the body

g = acceleration due to gravity

The value of g is greater at poles than at the equator. Therefore, gold at the equator weighs less than at the poles. Hence, Amit's friend will not agree with the weight of the gold bought.

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

Ans. When a sheet of paper is crumbled 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 $\frac{1}{6}$as strong as gravitational force on the Earth. What is the weight in newtons of a 10 kg object on the moon and on the Earth?

Ans. Weight of an object on the moon = $\frac{1}{6}$ × Weight of an object on the Earth

Also,

Weight = Mass × Acceleration

Acceleration due to gravity, g = 9.8 m/s^2

Therefore, the weight of a 10 kg object on the Earth = 10 × 9.8 = 98 N

And, the weight of the same object on the moon = $\frac{1}{6}\times 98 = 16.3\ N$

13. A ball is thrown vertically upwards with a velocity of 49 m/s. 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) 122.5 m (ii) 10 s

According to the equation of motion under gravity:

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

Where,

u = Initial velocity of the ball

v = Final velocity of the ball

s = height achieved by the ball

g = acceleration due to gravity

At maximum height, the final velocity of the ball is zero, i.e., v = 0

u = 49 m/s

During upward motion, $g = -\ 9.8\ m\ s^{-2}$

Let h be the maximum height attained by the ball.

Hence,

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

$$h = \frac{49\times49}{2\times9.8} = 122.5m$$

Let t be the time taken by the ball to reach the height 122.5 m, then according to the equation of motion:

v = u + gt

We get,

$$0 = 49 + t\times(-\ 9.8)$$

$$9.8t = 49$$

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

But,

Time of ascent = Time of descent

Therefore, total time taken by the ball to return = 5 + 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. According to the equation of motion under gravity:

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

Where,

u = Initial velocity of the stone = 0

v = Final velocity of the stone

s = Height of the stone = 19.6 m

g = Acceleration due to gravity = $9.8\ m\ s^{-2}$

$\therefore v^2 - 0^2 = 2 \times 9.8 \times 19.6$

$v^2 = 2 \times 9.8 \times 19.6 = (19.6)^2$

$v = 19.6\ m\ s^{-1}$

Hence, the velocity of the stone just before touching the ground is $19.6\ m\ s^{-1}$.

15. A stone is thrown vertically upward with an initial velocity of 40 m/s. Taking $g = 10\ m/s^2$, find the maximum height reached by the stone. What are the net displacement and the total distance covered by the stone?

Ans. According to the equation of motion under gravity:

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

Where,

u = Initial velocity of the stone = 40 m/s

v = Final velocity of the stone = 0

s = Height of the stone

g = Acceleration due to gravity = $-10\ m\ s^{-2}$

Let h be the maximum height attained by the stone.

Therefore,

$$0 - (40)^2 = 2 \times h \times (-10)\ h = \frac{40 \times 40}{20} = 80m$$

Therefore, total distance covered by the stone during its upward and downward journey = 80 + 80 = 160 m

The net displacement of the stone during its upward and downward journey

= 80 + (−80) = 0

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 1.5×10^{11} m.

Ans. According to the universal law of gravitation, the force of attraction between the Earth and the Sun is given by:

$$F = \frac{GM_{Sun}M_{Earth}}{R^2}$$

Where,

M_{Sun} = mass of the Sun = 2×10^{30} kg

M_{Earth} = Mass of the Earth = 6×10^{24} kg

R = Average distance between the Earth and the Sun = 1.5×10^{11} m

G = Universal gravitational constant = 6.7×10^{-11} Nm^2 kg^{-2}

$$F = \frac{6.7\times10^{11}\times2\times10^{30}\times6\times10^{24}}{\left(1.5\times10^{11}\right)^2} = 3.57\times10^{22}N$$

17. A stone is allowed to fall from the top of a tower 100 m high. At the same time, another stone is projected vertically upwards from the ground with a velocity of 25 m/s. Calculate when and where the two stones will meet.

Ans. Let the two stones meet after a time t.

(i) For the stone dropped from the tower:

Initial velocity, u = 0

Let the displacement of the stone in time t from the top of the tower be s.

Acceleration due to gravity, g = 9.8 m s^{-2}

From the equation of motion,

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

$$= 0\times t + \frac{1}{2}\times9.8\times t^2$$

$$\therefore s = 4.9t^2$$

(ii) For the stone thrown upwards:

Initial velocity, u = 25 m s^{-1}

Let the displacement of the stone from the ground in time t be s'.

Acceleration due to gravity, g = −9.8 m s^{-2}

Equation of motion,

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

$= 25t - \frac{1}{2}\times 9.8\times t^2$

$\therefore s' = 25t - 4.9t^2$

The combined displacement of both the stones at the meeting point is equal to the tower 100 m.

$\therefore s + s' = 100$

$\frac{1}{2}gt^2 + 25t - \frac{1}{2}gt^2 = 100$

$t = \frac{100}{25} = 4s$

In 4 s, the falling stone has covered a distance given by equation (1) as

$s = \frac{1}{2}\times 10\times 4^2 = 80m$

Therefore, the stones will meet after 4 s at a height $(100 - 80) = 20$ m from the ground

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, and

(c) Its position after 4 s.

Ans. (a) 29.4 m/s (b) 44.1 m (C) 39.2 m above the ground

(a) Time of ascent is equal to the time of descent. The ball takes a total of 6 s for its upward and downward journey.

Hence, it has taken 3 s to attain the maximum height.

The final velocity of the ball at the maximum height, $v = 0$

Acceleration due to gravity, $g = -9.8 \text{ m s}^{-2}$

Equation of motion, $v = u + gt$ will give,

$0 = u + (-9.8 \times 3)$

$u = 9.8 \times 3 = 29.4 \text{ ms}^{-1}$

Hence, the ball was thrown upwards with a velocity of 29.4 m s^{-1}.

(b) Let the maximum height attained by the ball be h.

Initial velocity during the upward journey, $u = 29.4 \text{ m s}^{-1}$

Final velocity, $v = 0$

Acceleration due to gravity, g = $-9.8\ m\ s^{-2}$

From the equation of motion, $s = ut + \frac{1}{2}at^2$

$$h = 29.4 \times 3 + \frac{1}{2} \times -9.8 \times (3)^2 = 44.1m$$

(c) Ball attains the maximum height after 3 s. After attaining this height, it will start falling downwards.

In this case,

Initial velocity, u = 0

The ball's position after 4 s of the throw is given by its distance during its downward journey in 4 s − 3 s = 1 s.

Equation of motion, $s = ut + \frac{1}{2}at^2$ will give,

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

Total height = 44.1 m

This means that the ball is 39.2 m (44.1 m − 4.9 m) above the ground after 4 seconds.

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 the water?

Ans. Two forces act on an object immersed in water. One is the gravitational force, which pulls the object downwards. The other is the buoyant force, which pushes the object upwards. Suppose the upward buoyant force is greater than the downward gravitational force. In that case, the object comes up to the water's surface as soon as it is released within the 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, it floats on the surface of the liquid.

Here, the density of the substance = $\frac{Mass\ of\ the\ substance}{Volume\ of\ the\ substance} = \frac{50}{20} = 2.5g\ cm^{-3}$

The density of the substance is more than the density of water ($1\ g\ cm^{-3}$). Hence, the substance will sink into the 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. The density of the 500 g sealed packet $= \frac{Mass\ of\ the\ packet}{Volume\ of\ the\ packet} = \frac{500}{350} = 1.428 gcm^{-3}$

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

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