CHAPTER 9

GRAVITATION

CLASS 9TH

NCERT EXERCISE AND SOLUTIONS - SCIENCE

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

ANSWER:-

According to the universal law of gravitation, the gravitational force between two objects is inversely proportional to the square of the distance between them. This is expressed as:

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

Now, if the distance (r) is reduced to half, i.e., $r \to \frac{r}{2}$, we can substitute this into the formula:

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

So, if the distance between the objects is reduced to half, the gravitational force will increase by a factor of 4. In other words, the gravitational force becomes four times larger than before.

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

ANSWER:-

All objects fall to the ground with the same constant acceleration, known as acceleration due to gravity, as long as there is no air resistance. This acceleration is the same for all objects, regardless of their weight. So, heavy objects don't fall faster than lighter ones.

Q. 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.)

ANSWER:-

The gravitational force acting on an object on the surface of the Earth is given by the formula:

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

Where:

- $G=6.7\times10^{(-11)}\ Nm^2/kg^2$ (Universal gravitational constant)
- $M=6\times10^{24}kg$ (Mass of Earth)
- m=1kg (Mass of the object)
- $r=R=6.4\times10^6\ m$ (Radius of Earth)

Substituting the values into the formula:

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

Simplifying:

F = 9.8 N

So, the gravitational force acting on the object is 9.8 N .

Q. 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?

ANSWER:-

According to the universal law of gravitation, every object in the universe attracts every other object with a force that is proportional to the product of their masses and inversely proportional to the square of the distance between their centers. This means that the force of attraction between two objects, such as the Earth and the Moon, is equal in magnitude but opposite in direction.

So, the Earth attracts the Moon with a certain gravitational force, and at the same time, the Moon attracts the Earth with the same amount of force, but in the opposite direction. This is a result of Newton's third law of motion, which states that for every action, there is an equal and opposite reaction.

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

ANSWER:-

The Earth and the Moon indeed experience equal gravitational forces according to Newton's third law of motion, but their masses are very different. The Earth has a much larger mass than the Moon, and because of this, the acceleration it experiences due to the force is much smaller than that of the Moon. Acceleration is inversely proportional to mass (according to Newton's second law: F = ma), so with a much larger mass, the Earth's acceleration is much smaller. The Moon, being smaller and lighter, experiences a greater acceleration towards the Earth.

Even though the Earth does accelerate towards the Moon, its movement is so small that it's practically undetectable. The Moon, on the other hand, moves more noticeably because of its smaller mass. This is why, from our perspective, it looks like the Earth remains mostly stationary while the Moon orbits around it.

Q. 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?**

ANSWER:-

According to the universal law of gravitation, the force of gravitation between two objects is given by $F = GMm/r^2$

(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.

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

ANSWER:-

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

Q. 8. What is the acceleration of free fall?

ANSWER:-

When objects fall towards the Earth due to gravity alone, without any other forces acting on them (like air resistance), they are said to be in free fall. During free fall, all objects experience the same constant acceleration of $9.8\ m/s^2$, which is known as the acceleration due to gravity. This acceleration is the same for all objects, no matter their size or mass, meaning a feather and a rock, for example, will fall at the same rate (assuming no air resistance).

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

ANSWER:-

Gravitational force between the earth and an object is known as the weight of the object.

Q. 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 is greater at the poles than at the equator.]

ANSWER:-

Given- 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 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.

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

ANSWER:-

When a sheet of paper is crumpled into a ball, its density increases because the air inside the paper is compressed. This reduces the surface area that the air has to push against, which decreases air resistance. As a result, the crumpled paper ball falls faster than the flat sheet of paper because there is less air resistance slowing it down.

Q. 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?

ANSWER:-

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

Also,

Weight = Mass × Acceleration

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

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

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

Q. 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.

ANSWER:-

(i) According to the equation of motion under gravity $v^2 - u^2 = 2gs$

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, final velocity of the ball is zero, i.e., v = 0 m/s and u = 49

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

Let be the maximum height attained by the ball.

Hence, using $v^2 - u^2 = 2gs$

We have, $0^2 - 49^2 = 2(-9.8)h \Rightarrow h = \frac{49\times 49}{2\times 9.8} = 122.5m$

Let td 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,

$$0 = 49 + (-9.8)t \Rightarrow 9.8t = 49 \Rightarrow t = \frac{49}{9.8} = 5\text{s}$$

But,
Time of ascent = Time of descent
Therefore, total time taken by the ball to return = 5 + 5 = 10s

Q. 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.

ANSWER:-

According to the equation of motion under gravity $v^2 – u^2 = 2gs$ Where,
u = Initial velocity of the stone
v = Final velocity of the stone
s = Height of the stone
g = Acceleration due to gravity = $9.8 ms^{-2}$

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

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

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

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

Q. 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 is the net displacement and the total distance covered by the stone?

ANSWER:-

According to the equation of motion under gravity $v^2 – u^2 = 2gs$
Where,
u = Initial velocity of the stone = 40 m/s
v = Final velocity of the stone = 0 m/s
s = Height of the stone
g = Acceleration due to gravity = $–10 ms^{-2}$
Let h be the maximum height attained by the stone.

Therefore, $0^2 - 40^2 = 2(-10)h \Rightarrow h = \frac{40 \times 40}{0} = 80 \text{ m}$

Therefore, total distance covered by the stone during its upward and downward journey
= 80 + 80 = 160 m
Net displacement during its upward and downward journey = 80 + (–80) = 0.

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

ANSWER:-

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

Where:

- M_Sun = 2×10^{30} kg (mass of the Sun)
- M_Earth = 6×10^{24} kg (mass of the Earth)
- R = 1.5×10^{11} m (average distance between Earth and Sun)
- G = $6.7\times10^{(-11)}$ Nm^2/kg^2 (universal gravitational constant)

Now, plug the values into the formula:

$$F = \frac{(6.7\times10^{-11})\times(2\times10^{30})\times(6\times10^{24})}{(1.5\times10^{11})^2}$$

$$F = \frac{(6.7\times10^{-11})\times(12\times10^{54})}{(2.25\times10^{22})}$$

$$F = \frac{80.4\times10^{43}}{2.25\times10^{22}} = 3.57\times10^{22}\,N$$

Thus, the force of gravitation between the Earth and the Sun is 3.57×10^{22} N.

Q. 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 m/s. Calculate when and where the two stones will meet.

ANSWER:-

Let the two stones meet after a time t.
When the stone dropped from the tower
Initial velocity, u = 0 m/s
Let the displacement of the stone in time from the top of the tower be s.
Acceleration due to gravity, g = 9.8 ms^{-2}
From the equation of motion,
When the stone thrown upwards
Initial velocity, u = 25ms^{-1}
Let the displacement of the stone from the ground in time t be s'.
Acceleration due to gravity, g = –9.8 m^{-2}
Equation of motion,

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

$$s' = 2b \times t - \frac{1}{2} \times 9.8 \times t^2$$

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

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

$$s' + s = 100$$

$$\Rightarrow 25t - 4.9t^2 + 4.9t^2 = 100$$

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

In 4 s,

The falling stone has covered a distance given by (1) as $s = 4.9 \times 4^2 = 78.4$ m Therefore, the stones will meet after 4 s at a height (100-78.4) = 21.6 m from the ground.

Q. 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.

ANSWER:-

(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.

Final velocity of the ball at the maximum height, v = 0” m/s

Acceleration due to gravity, $g = -9.8 ms^{-2}$

Using equation of motion, v = u + at, we have

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

$\Rightarrow u = 9.8 \times 3 = 29.4$ m/s

Hence, the ball was thrown upwards with a velocity of 29.4 m/s.

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

Initial velocity during the upward journey, u = 29.4 m/s

Final velocity, v = 0 m/s

Acceleration due to gravity, $g = -9.8 ms^{-2}$

Using the equation of motion,

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

$$h = y.4 \times 3 - \frac{1}{2} \times 9.8 \times 3^2 \Rightarrow h = 44.1m$$

Hence, the maximum height is 44.1 m.

(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 m/s

Position of the ball after 4 s of the throw is given by the distance travelled by it during its downward journey in 4 s-3 s = 1 s.

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

$$s = u \times 1 + \frac{1}{2} \times 9.8 \times 1^2 \Rightarrow s = 4.9m$$

Now, total height = 44.1 m

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

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

ANSWER:-

When an object is placed in a liquid, it feels a force pushing it upwards, called the buoyant force.

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

ANSWER:-

There are two forces acting on an object in water. One is gravity, which pulls the object down, and the other is the buoyant force, which pushes the object up. If the buoyant force is stronger than the force of gravity, the object will float and rise to the surface when it is released in the water. This is why a plastic block rises to the surface of the water when placed underwater.

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

ANSWER:-

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.

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

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

Q. 22. The volume of a 500 g sealed packet is 350 cm³. 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?

ANSWER:-

$$\text{Density of the 500g sealed packet} = \frac{\text{Mass of the packet}}{\text{Volume of the packet}} = \frac{500}{350} = 1.428\text{g / cm}^3$$

The density of the substance is more than the density of water 1 g/cm^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.