Class – 9 - Ch-9 -Gravitation

Q.1 State the universal law of gravitation.

Ans**.** Every object in the universe attracts every other object with a force which is proportional to the product of their masses and inversely proportional to the square of the distance between them. The force is along the line joining the centres of two objects

$$F \propto \frac{Mn}{d^2} \text{ or } F = \frac{GMm}{d^2}$$

Q.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. The formula to find the magnitude of the gravitational force between the Earth and an object on its surface is:

$F = G \times (M \times m) / R^2$

Where:

*** F** = gravitational force

*** G** = universal gravitational constant (6.674×10^{-11} $N \cdot m^2/kg^2$)

*** M** = mass of the Earth

*** m** = mass of the object

*** R** = radius of the Earth

This formula is derived from **Newton's Law of Universal Gravitation**.

Q.3 What do you mean by free fall?

Ans. Free fall is the motion of an object under the influence of gravitational force only, without any air resistance. In free fall, the object accelerates towards the Earth with a constant acceleration called acceleration due to gravity (g), which is approximately 9.8 m/s^2.

In simple words, when an object falls freely towards the Earth, only gravity is acting on it.

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

Ans. Acceleration due to gravity is the acceleration produced in a body due to the gravitational force of the Earth. It is denoted by **g**.

Its value near the surface of the Earth is approximately **9.8 m/s^2**, which means that the velocity of a freely falling object increases by **9.8 meters per second every second**.

In simple words, it is the rate at which objects speed up when they fall freely towards the Earth.

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

Ans.

Mass	**Weight**
1. Mass of a body is the measure of its inertia.	1. Weight of the body is the force with which it is attracted towards the earth (W = m x g).
2. Its S.I. unit is kg.	2. Its S.I unit is Newton.
3. It remains constant everywhere and it cannot be zero.	3. Its value changes from place to place and it can be zero.
4. It can be measured by beam-balance.	4. It can be measured by spring balance.
5. It has only magnitude i.e. it is a scalar quantity.	5. It has both magnitude and direction i.e.

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

Ans. The weight of an object depends on the gravitational force acting on it. The moon has much weaker gravity than the Earth.

The acceleration due to gravity on the moon is about 1/6th that of the Earth. So, the gravitational force on the moon is also 1/6th.

Since weight = mass × gravity, the weight of an object on the moon is 1/6th of its weight on the Earth.

Therefore, the weight of an object on the moon is 1/6th because the moon's gravity is 6 times weaker than the Earth's more than the weight of a same body on moon.

QUESTIONS FROM NCERT TEXTBOOK

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

Ans: According to Newton's law of gravitation, the gravitational force between two objects is inversely proportional to the square of the distance between them.

The formula is:

$F = G \times (m_1 \times m_2) / r^2$

If the distance r is reduced to half, then the new distance becomes r/2.

Now, the new force:

$F' = G \times (m_1 \times m_2) / (r/2)^2$

$= G \times (m_1 \times m_2) / (r^2/4)$

$= 4 \times [G \times (m_1 \times m_2) / r^2]$

$= 4F$

Therefore, when the distance between two objects is reduced to half, the gravitational force becomes 4 times stronger.

Q.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: Gravitational force is proportional to mass, so a heavy object experiences a greater force than a light object.

However, heavier objects also have more inertia (resistance to acceleration), which means they require more force to accelerate.

These two effects cancel each other out, so all objects fall with the same acceleration due to gravity (g), regardless of their mass.

Therefore, a heavy object does not fall faster than a light object in free fall. Both fall at the same rate when there is no air resistance.

Q3. 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. The magnitude of the gravitational force between earth and an object is given by the formula.

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

$m = 1$ kg, $M = 6 \times 10^{24}$ kg.

$R = 6.4 \times 10^6$ m, $G = 6.67 \times 10^{-11}$ Nm^2/kg^2

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

$\therefore F = 9.8$ 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?

Ans. The value of F is same for earth and the moon. Both bodies will exert the same amount of force on each other.

As per universal law of gravitation, every body attracts the other body with some force and this force is same for both the bodies called gravitational force.

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

Ans. Actually, the Earth does move towards the Moon. Both the Earth and the Moon exert gravitational forces on each other, so they both attract each other.

However, because the Earth is much more massive than the Moon, its acceleration towards the Moon is much smaller (Newton's second law: a=F/m

As a result, the Earth moves very slightly, while the Moon moves more noticeably around the Earth. This mutual attraction causes the Moon to orbit the Earth, and the Earth and Moon both orbit their common center of mass.

Q6. 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) If the mass of one object is doubled, the force between two objects will be doubled (increases)

ii) If the distance been the objects is doubled the force between two objects will be one-fourth and if t he distance will be tripled, the force will be one-ninth (1/9).

iii) If the masses of both objects are doubled the force will be 4 times.

$$\text{As } F \propto \frac{Mm}{d^2}$$

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

Ans. The universal law of gravitation explains several phenomena:

i) it explains about the force that binds the earth,

ii) the motion of the moon around the earth,

iii) the motion of planets around the sun, and

iv) the tides due to the moon and the sun.

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

Ans. The acceleration of free fall is; when the Body falls due to earth's gravitational pull, its velocity changes and is said to be accelerated due to .the earth's gravity and it falls freely called as free fall. This acceleration is calculated to be 9.8 m/s^2.

Q9. What do we call the gravitational force between the earth and an object?

Ans. The gravitational force between the earth and an object is called force due to gravity.

Q10. Amit buys few grams of gold at the poles 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? [Hints: The value of g is greater at the poles than at the equator.]

Ans. Weight of the body is given by the formula

$W = mg$

It depends ors the value of 'g' i.e., acceleration due to gravity.

The weight of gold at poles = $W_p = m \times g$ (poles)

Value of g at poles is more than the value of g at equator.

The weight of gold at equator = $W_e = m \times g$ (equator)

$\therefore W_p > W_e$.

The weight at pole of the same gold is found to be more as compared to the weight at the equator.

Q11. Why will a sheet of paper fall slower than one that is crumpled into a ball?

Ans. A sheet of paper has larger surface area and while falling down it has to overcome the force exerted by air/wind. current, called as air resistance.

The crumpled paper has smaller surface area and it has to overcome very less amount of air current.

Q.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 Newtons of a 10 kg object on the moon and on the earth?

Ans. Mass of the object = 10 kg

Weight of the object on earth = $W = m \times g$

$\therefore W = 10 \times 9.8$

$W = 98$ N

Weight of the object on moon = $\frac{1}{6}$th the weight on the earth.

As the gravitational force on the surface of the moon is only $\frac{1}{6}$th as strong as gravitational force on the surface of the earth.

$\therefore$ Weight of the object on moon $= \frac{98}{6} = 16.3$ N

Weight on earth = 98 N

Weight on moon = 16.3 N

Q13. 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) Initial velocity = 49 m/s
Final velocity = 0 m/s
$a = g = -9.8\ m/s^2$
Height = Distance = s = ?
$\therefore v^2 - u^2 = 2gs$
$0^2 - (49)^2 = 2\ (-9.8) \times s$

$$\therefore s = \frac{(49) \times -(49)}{2(-9.8)} = 122.5\ m$$

ii) Time take t = ?
$v = u + gt$
$\therefore 0 = 49 + (-9.8) \times t$

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

Total time taken to return the surface of the earth by the ball is 5 s + 5 s = 10 s.

Q14. 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. Data u = 0 m/s
v = ?
h = s = 19.6 m
$g = 9.8\ m/s^2$ (falling down)
$v^2 - u^2 = 2gs$
$v^2 - (0)^2 = 2 \times 9.8 \times 19.6$
v = 19.6 m/s
The final velocity just before touching the ground is 19.6 m/s.

Q15. 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?

Ans. u = 40 m/s
$g = -10\ m/s^2$ (going against gravity)
h = s = ?
v = 0
$v^2 - u^2 = 2gs$
$(0)^2 - (40)^2 = 2\ (-10) \times s$

$$\therefore s = \frac{-(40 \times 40)}{2(-10)}$$

$$\therefore s = 80\ m$$

Net displacement of the stone = 0 (As the stone falls, back to the same point.)
Total distance covered by stone = 80 m + 80 m
(up) (down)
= 160 m

Q16. 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. $M_e = 6 \times 10^{24}$ kg $G = 6.67 \times 10^{-11}\ Nm^2/kg^2$
$M_s = 2 \times 10^{30}$ kg
$d = 1.5 \times 10^{11}$ m

$$\therefore \text{Gravitational force } F = G\frac{M_e M_s}{d^2}$$

$$\therefore F = \frac{6.67 \times 10^{-11} Nm^2/kg^2 \times 6 \times 10^{24} kg \times 2 \times 10^{30} kg}{(1.5 \times 10^{11} m)^2}$$

$$= \frac{80.04 \times 10^{-11+24+30}}{2.25 \times 10^{22}} = 3.56 \times 10^{22}\ N$$

Q17. A stone is allowed to fall from the top of a tower 100 m high and at the same time another stone is projected vetically upwards from the ground with a velocity of 25 m/s. Calculate when and where the two stones will meet.

Ans. h = 100 m

time t = ? g = 10 m/s^2

Height covered by the falling stone = s^1

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

$$= (29.4 \times 4) + \frac{1}{2}(-9.8)(4)^2$$

$$= 117.6 + \frac{1}{2}(-156.8)$$

$$= 117.6 - 78.4$$

The distance covered by the stone thrown upward = s_2

g = –10 m/s

u = 25 m/s

$$\therefore s_2 = ut + \frac{1}{2}gt^2$$

$$\therefore s_2 = 25t + \frac{1}{2}(-10)t^2$$

$$\therefore s_2 = 25t - 5t^2$$

Total height given = 100 m

$\therefore s_1 + s_2 = 100$m

$5t^2 + (25t - 5t^2) = 100$ m

$\therefore 25t = 100$ m

$$t = \frac{100}{25} = 4 \text{ seconds} \qquad \text{...(3)}$$

Putting the value of (3) in equation (1), we get

$\therefore s1 = 5t^2$

$= 5 \times (4)^2 = 80$ m

$\therefore$ The two stones will meet after 4 seconds when the falling stone has covered a distance of 80 m.

Q18. 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. u = ?

v = 0

g = –9.8 m/s^2 (thrown upward)

Total time = 6 s (to go up and down)

$$= \frac{6}{2} = 3 \text{ s.}$$

$\therefore$ Time for upward journey

(a) v = u + gt

0 = u = (–9.8) × 3

u = 29.4 m/s

(b) Maximum height h = s = ?

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

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

$$= 88.2 + \frac{1}{2}(-88.2)$$

$$= 88.2 - 44.1$$

$$h = 44.1 \text{ m}$$

(c) Position after 4 s

t = 4s

$$\therefore s_1 = ut + \frac{1}{2}gt^2$$

$$\therefore s_1 = 0 \times t + \frac{1}{2}(10)t^2$$

$$\therefore s_1 = 5t^2$$

$\therefore$ Position after 4 s = 39.2 m from the top.