## Page 134

**Question 1:**
State the universal law of gravitation

**Answer 1:**
The universal law of gravitation states that every object in the universe attracts every other object with a force called the gravitational force. The force acting between two objects is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centers.

For two objects of masses $m_1$ and $m_2$ and the distance between them r, the force (F) of attraction acting between them is given by the universal law of gravitation as:

$$F = \frac{Gm_1m_2}{r^2}$$

Where, G is the universal gravitation constant and its value is $6.67 \times 10^{-11} Nm^2kg^{-2}$.

**Question 2:**
Write the formula to find the magnitude of the gravitational force between the earth and an object on the surface of the earth.

**Answer 2:**
Let $M_E$ be the mass of the Earth and *m* be the mass of an object on its surface. If R is the radius of the Earth, then according to the universal law of gravitation, the gravitational force (F) acting between the Earth and the object is given by the relation:

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

## Page 136

**Question 1:**

What do you mean by free fall?

**Answer 1:**

Gravity of the Earth attracts every object towards its centre. When an object is released from a height, it falls towards the surface of the Earth under the influence of gravitational force. The motion of the object is said to have free fall.

**Question 2:**

What do you mean by acceleration due to gravity?

**Answer 2:**

When an object falls towards the ground from a height, then its velocity changes during the fall. This changing velocity produces acceleration in the object. This acceleration is known as acceleration due to gravity (g). Its value is given by 9.8 $m/s^2$.

## Page 138

**Question 1:**
What are the differences between the mass of an object and its weight?

**Answer 1:**

| S.No. | Mass | Weight |
|---|---|---|
| I. | Mass is the quantity of matter contained in the body. | Weight is the force of gravity acting on the body. |
| II. | It is the measure of inertia of the body. | It is the measure of gravity. |
| III. | Mass is a constant quantity. | Weight is not a constant quantity. It is different at different places. |
| IV. | It only has magnitude. | It has magnitude as well as direction. |
| V. | Its SI unit is kilogram (kg). | Its SI unit is the same as the SI unit of force, i.e., Newton (N). |

**Question 2:**
Why is the weight of an object on the moon $\frac{1}{6}^{th}$ its weight on the earth?

**Answer 2:**
Let $M_E$ be the mass of the Earth and m be an object on the surface of the Earth. Let $R_E$ be the radius of the Earth. According to the universal law of gravitation, weight $W_E$ of the object on the surface of the Earth is given by,

$$W_E = \frac{GM_E m}{R_E^2}$$

Let $M_M$ and $R_M$ be the mass and radius of the moon. Then, according to the universal law of gravitation, weight $W_M$ of the object on the surface of the moon is given by:

$$W_M = \frac{GM_M m}{R_M^2}$$

Now,

$$\Rightarrow \frac{W_M}{W_E} = \frac{M_M R_E^2}{M_E R_M^2}$$

Where,

$M_E = 5.98 \times 10^{24}\ kg$
$M_M = 7.36 \times 10^{22}\ kg$
$R_E = 6.4 \times 10^{6}\ m$
$R_M = 1.74 \times 10^{6}\ m$

$$\Rightarrow \frac{W_M}{W_E} = \frac{7.36 \times 10^{22} \times (6.4 \times 10^{6})^2}{5.98 \times 10^{24} \times (1.74 \times 10^{6})^2} = 0.165 \approx \frac{1}{6}$$

Therefore, weight of an object on the moon is $\frac{1}{6}$ of its weight on the Earth.

## Exercises

**Question 1:**

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

**Answer 1:**

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, then the gravitational force becomes four times larger than the previous value.

**Question 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?

**Answer 2:**

All objects fall on ground with constant acceleration, called acceleration due to gravity (in the absence of air resistances). It is constant and does not depend upon the mass of an object. Hence, heavy objects do not fall faster than light objects.

**Question 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 $6 \times 10^{24}$ kg and radius of the earth is $6.4 \times 10^6$ m).

**Answer 3:**

According to the universal law of gravitation, 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
Therefore, the gravitational force

$$F = \frac{GMm}{r^2} = \frac{6.7 \times 10^{-11} \times 6 \times 10^{24} \times 1}{(6.4 \times 10^6)^2} = 9.8\ N$$

**Question 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 4:**
According to the universal law of gravitation, two objects attract each other with equal force, but in opposite directions. The Earth attracts the moon with an equal force with which the moon attracts the earth.

**Question 5:**
If the moon attracts the earth, why does the earth not move towards the moon?
**Answer 5:**
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.

**Question 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 6:**
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.

**Question 7:**
What is the importance of universal law of gravitation?
**Answer 7:**
The universal law of gravitation proves that every object in the universe attracts every other object.

**Question 8:**
What is the acceleration of free fall?
**Answer 8:**
When objects fall towards the Earth under the effect of gravitational force alone, then they are said to be in free fall. Acceleration of free fall is 9.8 $ms^{-2}$, which is constant for all objects (irrespective of their masses).

**Question 9:**

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

**Answer 9:**

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

**Question 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].

**Answer 10:**

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.

**Question 11:**

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

**Answer 11:**

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.

**Question 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 12:**

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 $= \frac{1}{6} \times 98 = 16.3$ N

**Question 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 13:**

**(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 m/s

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

Let h be the maximum height attained by the ball.

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

We have, $0^2 - 49^2 = 2(-9.8)h \Rightarrow h = \frac{49\times49}{2\times9.8} = 122.5\ m$

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,

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

But,
Time of ascent = Time of descent

Therefore, total time taken by the ball to return = 5 + 5 = 10 s

**Question 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 14:**
According to the equation of motion under gravity $v^2 - u^2 = 2gs$
Where,

u = Initial velocity of the stone = 0 m/s
v = Final velocity of the stone
s = Height of the stone = 19.6 m
g = Acceleration due to gravity = $9.8 \text{ ms}^{-2}$

$\therefore v^2 - 0^2 = 2 \times 9.8 \times 19.6$
$\Rightarrow v^2 = 2 \times 9.8 \times 19.6 = (19.6)^2$
$\Rightarrow v = 19.6 \text{ ms}^{-1}$

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

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

**Answer 15:**

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

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.

**Question 16:**

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

**Answer 16:**

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

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

Where,

$M_{Sun}$ = Mass of the Sun = $2 \times 10^{30}$ kg

$M_{Earth}$ = Mass of the Earth = $6 \times 10^{24}$ kg

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

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

$$F = \frac{6.7 \times 10^{-11} \times 2 \times 10^{30} \times 6 \times 10^{24}}{(1.5 \times 10^{11})^2} = 3.57 \times 10^{22}\ N$$

Hence, the force of gravitation between the Earth and the Sun is $3.57 \times 10^{22}\ N$