Question 1:
State the universal law of gravitation

Solution 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 given by:
$G = 6.67 \times 10^{-11}\ Nm^2\ kg^{-2}$

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.

Solution 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:

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

Intext Exercise 2

Question 1:
What do you mean by free fall?

Solution 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 be free fall.

Question 2:
What do you mean by acceleration due to gravity?

Solution 2:

When an object falls freely towards the surface of earth from a certain height, then its velocity changes. This change in velocity produces acceleration. This acceleration is known as acceleration due to gravity (g). The value of acceleration due to gravity is 9.8 m/s^2.

Intext Exercise 3

Question 1:

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

Solution 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 value 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?

Solution 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:

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

So, ratio of weight of object on moon to weight on earth is

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

Where, $M_E = 5.98 \times 10^{24}$ kg, $M_M = 7.36 \times 10^{22}$ kg

$R_E = 6.4 \times 10^6 m, R_M = 1.74 \times 10^6 m$

$$\therefore \frac{W_M}{W_E} = \frac{7.36 \times 10^{22} \times (6.37\times10^6)^2}{5.98\times10^{24} \times (1.74\times10^6)} = 0.165 \approx \frac{1}{6}$$

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

Intext Exercise 4

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

Solution 1:
It is difficult to hold a school bag having a thin strap because the pressure on the shoulders is quite large. This is because the pressure is inversely proportional to the surface area on which the force acts. The smaller is the surface area; the larger will be the pressure on the surface. In the case of a thin strap, the contact surface area is very small. Hence, the pressure exerted on the shoulder is very large.

Question 2:
What do you mean by buoyancy?

Solution 2:
When an object is placed in a liquid, the liquid exerts an upward force on it. The tendency of liquid to exert such an upward force on the object is called buoyancy and the upward force exerted by the liquid on the object is called the buoyant force.

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

Solution 3:
If the density of an object is more than the density of the liquid, then it sinks in the liquid. This is because the buoyant force acting on the object is less than the force of gravity. On the other hand, if the density of the object is less than the density of the liquid, then it floats on the surface of the liquid. This is because the buoyant force acting on the object is greater than the force of gravity.

Intext Exercise 5

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

Solution 1:

When you weigh your body, an upward force acts on it. This upward force is the buoyant force. As a result, the body gets pushed slightly upwards, causing the weighing machine to show a reading less than the actual value.

Question 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 one is heavier and why?

Solution 2:

The bag of cotton is heavier than iron bar. This is because

Weight measured =Actual weight – buoyant force

Therefore, Actual weight = weight measured + buoyant force

As the surface area of cotton bag is larger than the iron bar, more buoyant force acts on the bag than that on an iron bar. This makes the cotton bag lighter than its actual value. For this reason, the iron bar and the bag of cotton show the same mass on the weighing machine, but actually the mass of cotton bag is more than that of the iron bar.

NCERT Exercise

Question 1:

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

Solution 1:

According to the universal law of gravitation, gravitational force (F) acting between two objects is given by

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

Where m_1 and m_2 are the masses of two bodies and r is the distance between them, G is universal gravitational constant.

When the distance is reduced to half, $r^2 = \frac{r}{2}$ then

$$F = \frac{Gm_1m_2}{\left(\frac{r}{2}\right)^2} = 4F$$

Hence, if the distance is reduced to half, then the gravitational force becomes four times of its 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?

Solution 2:

All objects fall towards 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 6×10^{24} kg and radius of the earth is 6.4×10^{6} m).

Solution 3:

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

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

Where,

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

Mass of object, m = 1 kg

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

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

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

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?

Solution 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?

Solution 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, the acceleration experienced by earth due to gravitational pull of moon is very small in comparison to that experienced by moon due to 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?

Solution 6:

(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:

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

(i) F is directly proportional to the product of masses of the two 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 distance 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?

Solution 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?

Solution 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 denoted by g and its value on the surface of earth is 9.8 m s^{-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?

Solution 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].

Solution 10:

Weight of a body on the Earth is given by:

W = mg

Where,

m = Mass of the body

g = Acceleration due to gravity

Since 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?

Solution 11:

When a sheet of paper is crumbled into a ball, then its surface area becomes much lesser than the surface area of plain flat sheet of paper. 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 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?

Solution 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 = (1/6) X 98 N =16.3N

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.

Solution 13:
(i) 122.5 m (ii) 10 s
(i) According to the equation of motion under gravity:
$v^2 - u^2 = 2\,gh$
Where,
u = Initial velocity of the ball
v = Final velocity of the ball
h = Height achieved by the ball
g = Acceleration due to gravity
At maximum height, 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,

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

$$h = \frac{49 \times 49}{2 \times 9.8} = 122.5\ m$$

(ii) 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

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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.

Solution 14:

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}.

Question 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?

Solution 15:

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,

$$0 - (40)^2 = 2 \times h \times (-10)$$

$$h = \frac{40 \times 40}{20} = 80\ m$$

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

Net displacement of the stone 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 = 6×10^{24} kg and of the Sun = 2×10^{30} kg. The average distance between the two is 1.5×10^{11} m.

Solution 16:

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}

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

Question 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.

Solution 17:

Let the two stones meet after time t from the start.

(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,

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

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

$$\therefore s = 4.9t^2 \qquad (1)$$

(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,

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

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

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

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

$$\therefore s + s' = 100$$

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

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

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

$s = \frac{1}{2} \times 9.8 \times 4^2 = 78.4m$

Therefore, the stones will meet after 4 s at a height (100 – 78.4) = 21.6 m from the ground

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Question 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.

Solution 18:

(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, time taken for upward journey , $t = \frac{6}{2} = 3s$

Final velocity of the ball at the maximum height, v = 0

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

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

0 = u + (−9.8 × 3)

u = 9.8 × 3 = 29.4 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 m s^{-1}

Final velocity, v = 0

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

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

From the equation of motion,

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

(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

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.

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

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

Total height = 44.1 m

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

Question 19:

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

Solution 19:

An object immersed in a liquid experiences buoyant force in the vertically upward direction.

Question 20:

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

Solution 20:

Two forces act on an object immersed in water. One is the gravitational force, which pulls the object downwards, and the other is the buoyant force, which pushes the object upwards. If the upward buoyant force is greater than the downward gravitational force, then the object comes up to the surface of the water as soon as it is released within water. Here the upward buoyant force is more than the downward gravitational force on the plastic block. Due to this reason, a block of plastic released under water comes up to the surface of the water.

Question 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?

Solution 21:

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.

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

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

Question 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?

Solution 22:

Density of the 500 g 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 cm^3