SCIENCE -9 (CH-09- FORCE & LAW OF MOTION)

Question 1:

Which of the following has more inertia: (a) a rubber ball and a stone of the same size? (b) a bicycle and a train? (c) a five-rupees coin and a one-rupee coin?

Answer 1:

Inertia is the measure of the mass of the body. The greater is the mass of the body; the greater is its inertia and vice-versa.
(a) Mass of a stone is more than the mass of a rubber ball for the same size. Hence, inertia of the stone is greater than that of a rubber ball.
(b) Mass of a train is more than the mass of a bicycle. Hence, inertia of the train is greater than that of the bicycle.
(c) Mass of a five rupee coin is more than that of a one-rupee coin. Hence, inertia of the five rupee coin is greater than that of the one-rupee coin.

Question 2:

In the following example, try to identify the number of times the velocity of the ball changes:
"A football player kicks a football to another player of his team who kicks the football towards the goal. The goalkeeper of the opposite team collects the football and kicks it towards a player of his own team".
Also identify the agent supplying the force in each case.

Answer 2:

The velocity of the ball changes four times.
As a football player kicks the football, its speed changes from zero to a certain value. As a result, the velocity of the ball gets changed. In this case, the player applied a force to change the velocity of the ball. Another player kicks the ball towards the goal post. As a result, the direction of the ball gets changed. Therefore, its velocity also changes. In this case, the player applied a force to change the velocity of the ball. The goalkeeper collects the ball. In other words, the ball comes to rest. Thus, its speed reduces to zero from a certain value. The velocity of the ball has changed. In this case, the goalkeeper applied an opposite force to stop/change the velocity of the ball. The goalkeeper kicks the ball towards his team players. Hence, the speed of the ball increases from zero to a certain value. Hence, its velocity changes once again. In this case, the goalkeeper applied a force to change the velocity of the ball.

Question 3:

Explain why some of the leaves may get detached from a tree if we vigorously shake its branch.

Answer 3:

Some leaves of a tree get detached when we shake its branches vigorously. This is because when the branches of a tree are shaken, it moves to and fro, but its leaves tend to remain at rest. This is because the inertia of the leaves tend to resist the to and fro motion. Due to this reason, the leaves fall down from the tree when shaken vigorously.

Question 4:

Why do you fall in the forward direction when a moving bus brakes to a stop and fall backwards when it accelerates from rest?

Answer 4:

Due to the inertia of the passenger
Every body tries to maintain its state of motion or state of rest. If a body is at rest, then it tries to remain at rest. If a body is moving, then it tries to remain in motion. In a moving bus, a passenger moves with the bus. As the driver applies brakes, the bus comes to rest. But, the passenger tries to maintain his state of motion. As a result, a forward force is exerted on him. Similarly, the passenger tends to fall backwards when the bus accelerates from rest. This is because when the bus accelerates, the inertia of the passenger tends to oppose the forward motion of the bus. Hence, the passenger tends to fall backwards when the bus accelerates forward.

Question 1:

If action is always equal to the reaction, explain how a horse can pull a cart.

Answer 1:

A horse pushes the ground in the backward direction. According to Newton's third law of motion, a reaction force is exerted by the Earth on the horse in the forward direction. As a result, the cart moves forward.

Question 2:

Explain, why is it difficult for a fireman to hold a hose, which ejects large amounts of water at a high velocity.

Answer 2:

Due to the backward reaction of the water being ejected
When a fireman holds a hose, which is ejecting large amounts of water at a high velocity, then a reaction force is exerted on him by the ejecting water in the backward direction. This is because of Newton's third law of motion. As a result of the backward force, the stability of the fireman decreases. Hence, it is difficult for him to remain stable while holding the hose.

Question 3:

From a rifle of mass 4 kg, a bullet of mass 50 g is fired with an initial velocity of 35 m s^{-1}. Calculate the initial recoil velocity of the rifle.

Answer 3:

Mass of the rifle, $m_1 = 4\,\text{kg}$
Mass of the bullet, $m_2 = 50\,\text{g} = 0.05\ \text{kg}$
Recoil velocity of the rifle = v_1
Bullet is fired with an initial velocity, $v_2 = 35\ \text{m/s}$
Initially, the rifle is at rest.
Thus, its initial velocity, $v = 0$
Total initial momentum of the rifle and bullet system $= (m_1 + m_2)v = 0$
Total momentum of the rifle and bullet system after firing:
$= m_1v_1 + m_2v_2 = 4(v_1) + 0.05 \times 35 = 4v_1 + 1.75$
According to the law of conservation of momentum:
Total momentum after the firing = Total momentum before the firing

$$4v_1 + 1.75 = 0$$

$$v_1 = -\frac{1.75}{4} = -0.4375\ \text{m/s}$$

The negative sign indicates that the rifle recoils backwards with a velocity of 0.4375 m/s.

Question 4:

Two objects of masses 100 g and 200 g are moving along the same line and direction with velocities of 2 m s^{-1} and 1 m s^{-1}, respectively. They collide and after the collision, the first object moves at a velocity of 1.67 m s^{-1}. Determine the velocity of the second object.

Answer 4:

Mass of one of the objects, m_1 = 100 g = 0.1 kg
Mass of the other object, m_2 = 200 g = 0.2 kg
Velocity of m_1 before collision, $v_1 = 2$ m/s
Velocity of m_2 before collision, $v_2 = 1$ m/s
Velocity of m_1 after collision, $v_3 = 1.67$ m/s
Velocity of m_2 after collision = v_4
According to the law of conservation of momentum:
Total momentum before collision = Total momentum after collision

$$\therefore m_1v_1 + m_2v_2 = m_1v_3 + m_2v_4$$
$$(0.1)2 + (0.2)1 = (0.1)1.67 + (0.2)v_4$$
$$0.4 = 0.167 + 0.2\,v_4$$
$$\therefore v_4 = 1.165 \text{ m/s}$$

Hence, the velocity of the second object becomes 1.165 m/s after the collision.

Question 1:

An object experiences a net zero external unbalanced force. Is it possible for the object to be travelling with a non-zero velocity? If yes, state the conditions that must be placed on the magnitude and direction of the velocity. If no, provide a reason.

Answer 1:

Yes. Even when an object experiences a net zero external unbalanced force, it is possible that the object is travelling with a non-zero velocity. This is possible only when the object has been moving with a constant velocity in a particular direction. Then, there is no net unbalanced force applied on the body. The object will keep moving with a non-zero velocity. To change the state of motion, a net non-zero external unbalanced force must be applied on the object.

Question 2:

When a carpet is beaten with a stick, dust comes out of it. Explain.

Answer 2:

Inertia of an object tends to resist any change in its state of rest or state of motion. When a carpet is beaten with a stick, then the carpet comes to motion. But, the dust particles try to resist their state of rest. According to Newton's first law of motion, the dust particles stay in a state of rest, while the carpet moves. Hence, the dust particles come out of the carpet.

Question 3:

Why is it advised to tie any luggage kept on the roof of a bus with a rope?

Answer 3:

When the bus accelerates and moves forward, it acquires a state of motion. However, the luggage kept on the roof, owing to its inertia, tends to remain in its state of rest. Hence, with the forward movement of the bus, the luggage tends to remain at its original position and ultimately falls from the roof of the bus. To avoid this, it is advised to tie any luggage kept on the roof of a bus with a rope.

Question 4:

A batsman hits a cricket ball which then rolls on a level ground. After covering a short distance, the ball comes to rest. The ball slows to a stop because

(a) the batsman did not hit the ball hard enough.

(b) velocity is proportional to the force exerted on the ball.

(c) there is a force on the ball opposing the motion.

(d) there is no unbalanced force on the ball, so the ball would want to come to rest.

Answer 4:

(c) A batsman hits a cricket ball, which then rolls on a level ground. After covering a short distance, the ball comes to rest because there is frictional force on the ball opposing its motion. Frictional force always acts in the direction opposite to the direction of motion. Hence, this force is responsible for stopping the cricket ball.

Question 5:

A truck starts from rest and rolls down a hill with a constant acceleration. It travels a distance of 400 m in 20 s. Find its acceleration. Find the force acting on it if its mass is 7 tonnes (*Hint*: 1 tonne = 1000 kg).

Answer 5:

Initial velocity, $u = 0$ (since the truck is initially at rest)

Distance travelled, $s = 400$ m

Time taken, $t = 20$ s

According to the second equation of motion:

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

Where,

Acceleration = a

$$400 = 0 + \frac{1}{2}a(20)^2$$

$$400 = \frac{1}{2}a(400)$$

$$a = 2 \text{ m/s}^2$$

1 tonne = 1000 kg (Given)

∴ 7 tonnes = 7000 kg

Mass of truck, $m = 7000$ kg

From Newton's second law of motion:

Force, F = Mass × Acceleration

$F = ma = 7000 \times 2 = 14000$ N

Hence, the acceleration of the truck is 2 m/s^2 and the force acting on the truck is 14000 N.

Question 6:

A stone of 1 kg is thrown with a velocity of 20 m s^{-1} across the frozen surface of a lake and comes to rest after travelling a distance of 50 m. What is the force of friction between the stone and the ice?

Answer 6:

Initial velocity of the stone, $u = 20$ m/s
Final velocity of the stone, $v = 0$ (finally the stone comes to rest)
Distance covered by the stone, $s = 50$ m
According to the third equation of motion:
$v^2 = u^2 + 2as$
Where,
Acceleration, a
$(0)^2 = (20)^2 + 2 \times a \times 50$
$a = -4$ m/s^2
The negative sign indicates that acceleration is acting against the motion of the stone.
Mass of the stone, $m = 1$ kg
From Newton's second law of motion:
Force, F = Mass × Acceleration
$F = ma$
$F = 1 \times (-4) = -4$ N
Hence, the force of friction between the stone and the ice is −4 N.

Question 7:

A 8000 kg engine pulls a train of 5 wagons, each of 2000 kg, along a horizontal track. If the engine exerts a force of 40000 N and the track offers a friction force of 5000 N, then calculate:
(a) the net accelerating force and
(b) the acceleration of the train.

Answer 7:

(a) 35000 N (b) 1.944 m/s^2
(a)Force exerted by the engine, $F = 40000$ N
Frictional force offered by the track, $F_f = 5000$ N
Net accelerating force, $F_a = F - F_f = 40000 - 5000 = 35000$ N
Hence, the net accelerating force is 35000 N.

(b)Acceleration of the train = a
The engine exerts a force of 40000 N on all the five wagons.
Net accelerating force on the wagons, F_a = 35000 N
Mass of the wagons, m = Mass of a wagon × Number of wagons
Mass of a wagon = 2000 kg
Number of wagons = 5
∴ m = 2000 × 5 = 10000 kg
Total mass of the train, M = m + mass of engine = 10000 + 8000 = 18000 kg
From Newton's second law of motion:
$F_a = Ma$

$$a = \frac{F_a}{m}$$

$$= \frac{35000}{18000}$$

$$= 1.944 \text{ m s}^{-2}$$

Hence, the acceleration of the train is 1.944 m/s^2.

Question 8:

An automobile vehicle has a mass of 1500 kg. What must be the force between the vehicle and road if the vehicle is to be stopped with a negative acceleration of 1.7 $m\ s^{-2}$?

Answer 8:

Mass of the automobile vehicle, m = 1500 kg
Final velocity, v = 0 (finally the automobile stops)
Acceleration of the automobile, a = −1.7 ms^{-2}
From Newton's second law of motion:
Force = Mass × Acceleration = 1500 × (−1.7) = −2550 N
Hence, the force between the automobile and the road is −2550 N, in the direction opposite to the motion of the automobile.

Question 9:

What is the momentum of an object of mass m, moving with a velocity v?
(a) $(mv)^2$ (b) mv^2 (c) ½ mv^2 (d) mv

Answer 9:

(d) mv
Mass of the object = m
Velocity = v
Momentum = Mass × Velocity
Momentum = mv

Question 10:

Using a horizontal force of 200 N, we intend to move a wooden cabinet across a floor at a constant velocity. What is the friction force that will be exerted on the cabinet?

Answer 10:

A force of 200 N is applied in the forward direction. Thus, from Newton's third law of motion, an equal amount of force will act in the opposite direction. This opposite force is the fictional force exerted on the cabinet. Hence, a frictional force of 200 N is exerted on the cabinet.

Question 11:

Two objects, each of mass 1.5 kg are moving in the same straight line but in opposite directions. The velocity of each object is 2.5 m s^{-1} before the collision during which they stick together. What will be the velocity of the combined object after collision?

Answer 11:

Mass of one of the objects, m_1 = 1.5 kg
Mass of the other object, m_2 = 1.5 kg
Velocity of m_1 before collision, v_1 = 2.5 m/s
Velocity of m_2, moving in opposite direction before collision, v_2 = −2.5 m/s
(Negative sign arises because mass m_2 is moving in an opposite direction)
After collision, the two objects stick together.
Total mass of the combined object = $m_1 + m_2$
Velocity of the combined object = v
According to the law of conservation of momentum:
Total momentum before collision = Total momentum after collision
$m_1 v_1 + m_2 v_2 = (m_1 + m_2) v$
$1.5(2.5) + 1.5(-2.5) = (1.5 + 1.5) v$
$3.75 - 3.75 = 3 v$
$v = 0$
Hence, the velocity of the combined object after collision is 0 m/s.

Question 12:

According to the third law of motion when we push on an object, the object pushes back on us with an equal and opposite force. If the object is a massive truck parked along the roadside, it will probably not move. A student justifies this by answering that the two opposite and equal forces cancel each other. Comment on this logic and explain why the truck does not move.

Answer 12:

The truck has a large mass. Therefore, the static friction between the truck and the road is also very high. To move the car, one has to apply a force more than the static friction. Therefore, when someone pushes the truck and the truck does not move, then it can be said that the applied force in one direction is cancelled out by the frictioal force of equal amount acting in the opposite direction.

Therefore, the student is right in justifying that the two opposite and equal cancel each other.

Question 13:

A hockey ball of mass 200 g travelling at 10 m s^{-1} is struck by a hockey stick so as to return it along its original path with a velocity at 5 m s^{-1}. Calculate the magnitude of change of momentum occurred in the motion of the hockey ball by the force applied by the hockey stick.

Answer 13:

Mass of the hockey ball, m = 200 g = 0.2 kg

Hockey ball travels with velocity, v_1 = 10 m/s

Initial momentum = mv_1

Hockey ball travels in the opposite direction with velocity, v_2 = −5 m/s

Final momentum = mv_2

Change in momentum = $mv_1 - mv_2 = 0.2 [10 - (-5)] = 0.2 (15) = 3$ $kgms^{-1}$

Hence, the magnitude of change of momentum of the hockey ball is 3 $kgms^{-1}$.

Question 14:

A bullet of mass 10 g travelling horizontally with a velocity of 150 m s^{-1} strikes a stationary wooden block and comes to rest in 0.03 s. Calculate the distance of penetration of the bullet into the block. Also calculate the magnitude of the force exerted by the wooden block on the bullet.

Answer 14:

Now, it is given that the bullet is travelling with a velocity of 150 m/s.
Thus, when the bullet enters the block, its velocity = Initial velocity, u = 150 m/s
Final velocity, v = 0 (since the bullet finally comes to rest)
Time taken to come to rest, t = 0.03 s
According to the first equation of motion, $v = u + at$
Acceleration of the bullet, a
0 = 150 + (a ×0.03 s)

$$a = \frac{-150}{0.03} = -5000 \text{ m/s}^2$$

(Negative sign indicates that the velocity of the bullet is decreasing.)

According to the third equation of motion:
$v^2 = u^2 + 2as$
$0 = (150)^2 + 2(-5000)s$

$$s = \frac{-(150)^2}{-2(5000)} = \frac{22500}{10000} = 2.25 \text{ m}$$

Hence, the distance of penetration of the bullet into the block is 2.25 m.
From Newton's second law of motion:
Force, F = Mass × Acceleration
Mass of the bullet, m = 10 g = 0.01 kg
Acceleration of the bullet, a = 5000 m/s^2
$F = ma$ = 0.01 × 5000 = 50 N
Hence, the magnitude of force exerted by the wooden block on the bullet is 50 N.

Question 15:

An object of mass 1 kg travelling in a straight line with a velocity of 10 m s^{-1} collides with, and sticks to, a stationary wooden block of mass 5 kg. Then they both move off together in the same straight line. Calculate the total momentum just before the impact and just after the impact. Also, calculate the velocity of the combined object.

Answer 15:

Mass of the object, m_1 = 1 kg
Velocity of the object before collision, v_1 = 10 m/s
Mass of the stationary wooden block, m_2 = 5 kg
Velocity of the wooden block before collision, v_2 = 0 m/s
∴ Total momentum before collision = $m_1 v_1 + m_2 v_2$
= 1 (10) + 5 (0) = 10 kg m s^{-1}
It is given that after collision, the object and the wooden block stick together.
Total mass of the combined system = $m_1 + m_2$
Velocity of the combined object = v

According to the law of conservation of momentum:
Total momentum before collision = Total momentum after collision
$m_1 v_1 + m_2 v_2 = (m_1 + m_2) v$
1 (10) + 5 (0) = (1 + 5) v
$v = \frac{10}{6} = \frac{5}{3}$ m/s
The total momentum after collision is also 10 kg m/s.
Total momentum just before the impact = 10 kg m s^{-1}
Total momentum just after the impact = $(m_1 + m_2)\, v$ = $6 \times \frac{5}{3} = 10$ kg m s^{-1}
Hence, velocity of the combined object after collision = $\frac{5}{3}$ m/s

Question 16:

An object of mass 100 kg is accelerated uniformly from a velocity of 5 m s^{-1} to 8 m s^{-1} in 6 s. Calculate the initial and final momentum of the object. Also, find the magnitude of the force exerted on the object.

Answer 16:

Initial velocity of the object, u = 5 m/s
Final velocity of the object, v = 8 m/s
Mass of the object, m = 100 kg
Time take by the object to accelerate, t = 6 s
Initial momentum = mu = 100 × 5 = 500 kg m s^{-1}
Final momentum = mv = 100 × 8 = 800 kg m s^{-1}
Force exerted on the object, $F = \frac{mv - mu}{t}$

$$= \frac{m(v-u)}{t} = \frac{800-500}{6} = \frac{300}{6} = 50\ \text{N}$$

Initial momentum of the object is 500 kg m s^{-1}.
Final momentum of the object is 800 kg m s^{-1}.
Force exerted on the object is 50 N.

Question 17:

Akhtar, Kiran and Rahul were riding in a motorocar that was moving with a high velocity on an expressway when an insect hit the windshield and got stuck on the windscreen. Akhtar and Kiran started pondering over the situation. Kiran suggested that the insect suffered a greater change in momentum as compared to the change in momentum of the motorcar (because the change in the velocity of the insect was much more than that of the motorcar). Akhtar said that since the motorcar was moving with a larger velocity, it exerted a larger force on the insect. And as a result the insect died. Rahul while putting an entirely new explanation said that both the motorcar and the insect experienced the same force and a change in their momentum. Comment on these suggestions.

Answer 17:

According to the law of conservation of momentum:
Momentum of the car and insect system before collision = Momentum of the car and insect system after collision
Hence, the change in momentum of the car and insect system is zero.
The insect gets stuck on the windscreen. This means that the direction of the insect is reversed. As a result, the velocity of the insect changes to a great amount. On the other hand, the car continues moving with a constant velocity. Hence, Kiran's suggestion that the insect suffers a greater change in momentum as compared to the car is correct. The momentum of the insect after collision becomes very high because the car is moving at a high speed. Therefore, the momentum gained by the insect is equal to the momentum lost by the car.
Akhtar made a correct conclusion because the mass of the car is very large as compared to the mass of the insect.
Rahul gave a correct explanation as both the car and the insect experienced equal forces caused by the Newton's action-reaction law. But, he made an incorrect statement as the system suffers a change in momentum because the momentum before the collision is equal to the momentum after the collision.

Question 18:

How much momentum will a dumbbell of mass 10 kg transfer to the floor if it falls from a height of 80 cm? Take its downward acceleration to be 10 m s^{-2}.

Answer 18:

Mass of the dumbbell, m = 10 kg
Distance covered by the dumbbell, s = 80 cm = 0.8 m
Acceleration in the downward direction, a = 10 m/s^2
Initial velocity of the dumbbell, u = 0
Final velocity of the dumbbell (when it was about to hit the floor) = v
According to the third equation of motion:
$v^2 = u^2 + 2as$
$v^2 = 0 + 2\,(10)\,0.8$
v = 4 m/s
Hence, the momentum with which the dumbbell hits the floor is
= mv = 10 × 4 = 40 kg m s^{-1}

Question 1:

The following is the distance-time table of an object in motion:

Time in seconds	Distance in metres
0	0
1	1
2	8
3	27
4	64
5	125
6	216
7	343

(a) What conclusion can you draw about the acceleration? Is it constant, increasing, decreasing, or zero?

(b)What do you infer about the forces acting on the object?

Answer 1:

(a) There is an unequal change of distance in an equal interval of time.
Thus, the given object is having a non – uniform motion. Since the velocity of the object increases with time, the acceleration is increasing.

(b)According to Newton's second law of motion, the force acting on an object is directly proportional to the acceleration produced in the object. In the given case, the increasing acceleration of the given object indicates that the force acting on the object is also increasing.

Question 2:

Two persons manage to push a motorcar of mass 1200 kg at a uniform velocity along a level road. The same motorcar can be pushed by three persons to produce an acceleration of 0.2 m s^{-2}. With what force does each person push the motorcar? (Assume that all persons push the motorcar with the same muscular effort)

Answer 2:

Mass of the motor car = 1200 kg
Only two persons manage to push the car. Hence, the acceleration acquired by the car is given by the third person alone.
Acceleration produced by the car, when it is pushed by the third person,
$a = 0.2\ m/s^2$
Let the force applied by the third person be F.
From Newton's second law of motion:
Force = Mass × Acceleration
$F = 1200 \times 0.2 = 240$ N
Thus, the third person applies a force of magnitude 240 N.
Hence, each person applies a force of 240 N to push the motor car.

Question 3:

A hammer of mass 500 g, moving at 50 m s^{-1}, strikes a nail. The nail stops the hammer in a very short time of 0.01 s. What is the force of the nail on the hammer?

Answer 3:

Mass of the hammer, m = 500 g = 0.5 kg
Initial velocity of the hammer, u = 50 m/s
Time taken by the nail to the stop the hammer, t = 0.01 s
Velocity of the hammer, v = 0 (since the hammer finally comes to rest)
From Newton's second law of motion:

$$\text{Force, } F = \frac{m(v-u)}{t} = \frac{0.5(0-50)}{0.01} = -2500 \text{ N}$$

The hammer strikes the nail with a force of −2500 N. Hence, from Newton's third law of motion, the force of the nail on the hammer is equal and opposite, i.e., +2500 N.

Question 4:

A motorcar of mass 1200 kg is moving along a straight line with a uniform velocity of 90 km/h. Its velocity is slowed down to 18 km/h in 4 s by an unbalanced external force. Calculate the acceleration and change in momentum. Also calculate the magnitude of the force required.

Answer 4:

Mass of the motor car, m = 1200 kg
Initial velocity of the motor car, u = 90 km/h = 25 m/s
Final velocity of the motor car, v = 18 km/h = 5 m/s
Time taken, t = 4 s
According to the first equation of motion:
$v = u + at$
5 = 25 + a (4)
a = -5 m/s^2
Change in momentum = $mv - mu = m(v-u)$
= 1200 (5 − 25) = -24000 kg m s^{-1}
Force = Mass × Acceleration
= 1200 × (-5) = -6000 N
Acceleration of the motor car = -5 m/s^2
Change in momentum of the motor car = -24000 kg m s^{-1}
Hence, the force required to decrease the velocity is -6000 N.
(Negative sign indicates the retardation , decrease in momentum and retarding force respectively)