Board – CBSE | Class –9th | Topic – Force and Laws of Motion

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.

Ans. Yes. Even when an object experiences a net zero external unbalanced force, the object may be 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. A net non-zero external unbalanced force must be applied to the object to change the state of motion.

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

Ans. The 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 into 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.

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

Ans. 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.

4. A batsman hits a cricket ball which then rolls on 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.

Ans. (c) A batsman hits a cricket ball, which then rolls on 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.

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 metric tonnes (Hint: 1 metric tonne = 1000 kg).

Ans. 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

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

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

$$a = 2\ m/s^2$$

1 metric tonne = 1000 kg (Given)

∴ 7 metric tonnes = 7000 kg

Mass of truck, m = 7000 kg

From Newton's second law of motion:

Force, F = Mass × Acceleration

F = ma = 7000 × 2 = 14000 N

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

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

Ans. The initial velocity of the stone, u = 20 m/s

The 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.

7. A 8000 kg engine pulls a train of 5 wagons, each 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;

(b) The acceleration of the train; and

(c) The force of wagon 1 on wagon 2.

Ans. (a) 35000 N (b) $1.944\ m/s^2$ (c) 15552 N

(a)Force exerted by the engine, F = 40000 N

Frictional force offered by the track, $F_f = 5000$ N

Net accelerating force, $Fa = F - F_f = 40000 - 5000 = 35000$ 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 five wagons.

Net accelerating force on the wagons, $Fa = 35000$ N

Mass of the wagons, m = Mass of a wagon × Number of wagons

Mass of a wagon = 2000 kg

Number of wagons = 5

$\therefore m = 2000 \times 5 = 10000$ kg

Total mass of the train, M = m + mass of engine = 10000 + 8000 = 18000 kg

From Newton's second law of motion:

$Fa = Ma$

$a = \frac{Fa}{m} = \frac{35000}{18000} = 1.944 \text{ m } s^{-2}$

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

(c) Mass of all the wagons except wagon 1 is $4 \times 2000 = 8000$ kg

Acceleration of the wagons = 1.944 m/s^2

Thus, the force exerted on all the wagons or wagon 2 by wagon 1

$= 8000 \times 1.944 = 15552$ N

Hence, the force exerted by wagon 1 on wagon 2 is 15552 N.

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}?

Ans. 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.

9. What is the momentum of an object of mass m, moving with a velocity v?

$(a)\ (mv)^2$ $(b)\ mv^2$ $(c)\ \frac{1}{2}mv^2$ $(d)\ mv$

Ans. (d) mv

Mass of the object = m

Velocity = v

Momentum = Mass × Velocity

Momentum = mv

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

Ans. 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 frictional force exerted on the cabinet. Hence, a frictional force of 200 N is exerted on the cabinet.

11. Two objects, each mass 1.5 kg, are moving in the same straight line but 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?

Ans. Mass of one of the objects, $m_1 = 1.5$ kg

Mass of the other object, $m_2 = 1.5$ kg

The velocity of m_1 before the collision, $v_1 = 2.5$ m/s

The velocity of m_2, moving in the opposite direction before the collision, $v_2 = -2.5$ m/s

(Negative sign arises because mass m_2 is moving in an opposite direction)

After the collision, the two objects stick together.

The total mass of the combined object = $m_1 + m_2$

The velocity of the combined object = v

According to the law of conservation of momentum:

Total momentum before collision = Total momentum after the collision

$$m_1v_1 + m_2v_2 = (m_1 + m_2)\,v$$

$1.5(2.5) + 1.5\,(-2.5) = (1.5 + 1.5)\,v$

$3.75 - 3.75 = 3\,v$

$v = 0$

Hence, the velocity of the combined object after the collision is 0 m/s.

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.

Ans. 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 static friction. Therefore, when someone pushes the truck, and the truck does not move. It can be said that the applied force in one direction is cancelled out by the frictional force of an equal amount acting in the opposite direction.

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

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

Ans. 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 = $mv_1 - mv_2 = 0.2\,[10 - (-5)] = 0.2\,(15) = 3$ kg m s^{-1}

Hence, the change in momentum of the hockey ball is 3 kg m s^{-1}.

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.

Ans. 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)

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

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

According to the third equation of motion:

$v^2 = u^2 + 2as$

$0 = (150)^2 + 2\,(-5000)\,s$

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

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 the force exerted by the wooden block on the bullet is 50 N.

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.

Ans. Mass of the object, $m_1 = 1$ kg

The velocity of the object before the 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 the collision, the object and the wooden block stick together.

The total mass of the combined system = $m_1 + m_2$

The velocity of the combined object = v

According to the law of conservation of momentum:

Total momentum before collision = Total momentum after the collision

$m_1 v_1 + m_2 v_2 = (m_1 + m_2)\ v$

1 (10) + 5 (0) = (1 + 5) v

$v = \frac{10}{6} = \frac{5}{3}$

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 = $(m_1 + m_2)\ v = 6\times\frac{5}{3} = 10 kg\ ms^{-1}$

Hence, the velocity of the combined object after collision = $\frac{5}{3} m/s$

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.

Ans. The initial velocity of the object, u = 5 m/s

The final velocity of the object, v = 8 m/s

Mass of the object, m = 100 kg

Time taken 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, $F = \frac{mv - mu}{t}$

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

The initial momentum of the object is 500 kg m s^{-1}.

The final momentum of the object is 800 kg m s^{-1}.

Force exerted on the object is 50 N.

17. Akhtar, Kiran and Rahul were riding in a motorcar 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 than 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. While putting an entirely new explanation, Rahul said that both the motorcar and the insect experienced the same force and a change in their momentum. Comment on these suggestions.

Ans. According to the law of conservation of momentum:

The momentum of the car and insect system before collision = Momentum of the car and insect system after the 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 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 than the car is correct. The momentum of the insect after collision becomes very high because the car is moving at 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 compared to the insect's mass.

Rahul correctly explained that both the car and the insect experienced equal forces caused by 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.

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}.

Ans. 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

The initial velocity of the dumbbell, u = 0

The 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

$= mv = 10 \times 4 = 40$ kg m s^{-1}.