CHAPTER 8

Force and Laws of Motion

1. NCERT INTEXT QUESTIONS

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-rupee coin and a one-rupee coin?

Ans :

(a) A stone of the same size
(b) A train
(c) A five-rupee coin
Reason : More the mass of an object more is its inertia.

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.

	Agent suppling the force	**Change in velocity of ball**
1.	First player kicks a football.	Velocity from 'o' changes to 'u'.
2.	Second player kicks the football towards the goal.	Velocity changes again.
3.	The goalkeeper collects the football.	Velocity becomes zero.
4.	Goalkeeper kicks it towards a player of his team.	Change in velocity.

Ans :

The velocity of football changed four times.

3. Q.3. Explain why some of the leaves may get detached from a tree if we vigorously shake its branch.

Ans :

When the tree's branch is shaken vigorously the branch attain motion but the leaves stay at rest. Due to the inertia of rest, the leaves tend to remain in its position and hence detaches from the tree to fall down.

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?

Ans :

When a moving bus brakes-to a stop : Our body is also in motion along with bus, but due to sudden brakes, the lower part of our body comes to rest as soon as the bus stops. But the upper part of our body continues to be in motion and hence we fall in forward direction due to inertia of motion.

When the bus accelerates from rest we fall backwards When the bus is stationary our body is at rest but when the bus accelerates, the lower part of our body being in contact with the floor of the bus comes in motion, but the upper part of our body remains at rest due to inertia of rest. Hence, we fall in backward direction.

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

Ans :

The third law of motion states that action is always equal to the reaction but they act on two different bodies. In this case the horse exerts a force on the ground with its feet while walking, the ground exerts an equal and opposite force on the feet of the horse, which enables the horse to move forward and the cart is pulled by the horse.

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

Ans :

The water that is ejected out from the hose in the forward direction comes out with a large momentum and equal amount of momentum is developed in the hose in the opposite direction and hence the hose is pushed backward. It becomes difficult for a fireman to hold a hose which experiences this large momentum.

7. From a rifle of mass 4 kg, a bullet of mass 50 g is fired with an initial velocity of 35 m/s. Calculate the initial recoil velocity of the rifle.

Ans :

$$\text{Mass of the bullet, } m_1 = 50 \text{ g} = \frac{50}{1000} \text{ kg}$$
$$= 0.05 \text{ kg}$$
$$\text{Mass of the rifle, } m_2 = 4 \text{ kg}$$
$$\text{Initial velocity of bullet } (u_1) = 0 \text{ ms}^{-1}$$
$$\text{Initial velocity of rifle, } u_2 = 0 \text{ ms}^{-1}$$
$$\text{Final velocity of bullet, } v_1 = 35 \text{ ms}^{-1}$$
$$\text{Final velocity of rifle} = v_2$$

According to the law of conservation of momentum,
Total momentum before the fire

$$= \text{Total momentum after the fire}$$

$$= m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

$$0 = 0.05 \text{ kg} \times 0 \text{ ms}^{-1} + 4 \text{ kg} \times 0 \text{ ms}^{-1}$$

$$0 = 0.05 \text{ kg} \times 35 \text{ ms}^{-1} + 4 \text{ kg} \times v_2$$

$$0 = 1.75 \text{ kg ms}^{-1} + 4 \text{ kg} \times v_2$$

$$v_2 = -1.75 \text{ kg ms}^{-1}/4 \text{ kg}$$

$$= -0.4375 \text{ ms}^{-1}$$

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

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

Ans :

$$\text{Mass of first object } (m_1) = 100 \text{ g} = 100/1000 \text{ kg}$$

$$= 0.1 \text{ kg}$$

$$\text{Mass of second object } (m_2) = 200 \text{ g} = 200/1000 \text{ kg}$$

$$= 0.2 \text{ kg}$$

Initial velocity of the first object $(u_1) = 2 \text{ ms}^{-1}$
Initial velocity of the second object $(u_2) = 1 \text{ ms}^{-1}$
Final velocity of the first object $(v_1) = 1.67 \text{ ms}^{-1}$
Final velocity of the second object $(v_2) = ?$
According to the law of conservation of momentum,
Total momentum before collision

$$= \text{Total momentum after collision}$$

$$= m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

$$0.1 \text{ kg} \times 2 \text{ ms}^{-1} + 0.2 \text{ kg} \times 1 \text{ ms}^{-1}$$

$$= 0.1 \text{ kg} \times 1.67 \text{ ms}^{-1} + 0.2 \text{ kg} \times v_2$$

$$0.4 \text{ kg ms}^{-1} = 0.167 \text{ kg ms}^{-1} + 0.2 \text{ kg } v_2$$

$$0.4 - 0 - 0.167 = 0.2 \text{ kg } v_2$$

$$0.233 \text{ kg ms}^{-1} = 0.2 \text{ kg } v_2$$

$$v_2 = 0.233/0.2 = 1.165 \text{ ms}^{-1}$$

2. NCERT EXERCISE QUESTIONS

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 :

When an object experiences a net zero external unbalanced force, in accordance with second law of motion its acceleration is zero. If the object was initially in a state of motion, then in accordance with the first law of motion, the object will continue to move in same direction with same speed. It means that the object may be travelling with a non-zero velocity but the magnitude as well as direction of velocity must remain unchanged or constant throughout.

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

Ans :

The carpet with dust is in state of rest. When it is beaten with a stick the carpet is set in motion, but the dust particles remain at rest. Due to inertia of rest the dust particles retain their position of rest and falls down due to gravity.

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

Ans :

In moving vehicle like bus, the motion is not uniform, the speed of vehicle varies and it may apply brake suddenly or takes sudden turn. The luggage will resist any change in its state of rest or motion, due to inertia and this luggage has the tendency to fall sideways, forward or backward. It is tied with a rope to avoid the fall of the luggage.

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.

Ans : (c) There is a force on the ball opposing the motion.

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 tone = 1000 kg).

Ans :

Initial velocity, $(u) = 0 \text{ ms}^{-1}$
Distance $(s) = 400 \text{ m}$
Time $(t) = 20 \text{ s}$
Mass $(m) = 7 \text{ metric tons} = 7000 \text{ kg}$
By second equation of motion,

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

$$400 = 0 \text{ ms}^{-1} \times 20 \text{ s} + \tfrac{1}{2} \times a \times (20 \text{ s})^2$$

$$400 = \tfrac{1}{2} \times a \times 400 \text{ s}^2$$

$$a = = \frac{800 \text{ m}}{400 \text{ s}^2} = 2 \text{ ms}^{-1}$$

By Newton's second law of motion :

$$F = m \times a$$

$$= 7000 \text{ kg} \times 2 \text{ ms}^{-1} = 14000 \text{ N}$$

6. A stone of 1 kg is thrown with a velocity of 20 ms^{-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?

Ans :

$$\text{Mass (m)} = 1 \text{ kg}$$
$$\text{Initial velocity (u)} = 20 \text{ ms}^{-1}$$
$$\text{Final velocity (v)} = 0 \text{ ms}^{-1}$$
$$\text{Distance (s)} = 50 \text{ m}$$

By third equation of motion

$$v^2 - u^2 = 2as$$
$$(0 \text{ ms}^{-1})^2 - (20 \text{ ms}^{-1})^2 = 2 \times a \times 50 \text{ m}$$
$$-400 \text{ m}^2\text{s}^{-2} = 100 \text{ m} \times a$$
$$-\frac{400 \text{ m}^2\text{s}^{-2}}{100 \text{ m}} = a$$
$$-4 \text{ ms}^{-2} = a$$

By Newton's second law of motion :

$$F = m \times a$$
$$= 1 \text{ kg} \times (-4 \text{ ms}^{-2})$$
$$= -4\text{N}$$

7. 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,
(b) the acceleration of the train, and
(c) the force of wagon 1 on wagon 2.

Ans :

$$\text{Mass of engine } (m_1) = 8000 \text{ kg}$$
$$\text{Mass of each wagon } (m_2) = 2000 \text{ kg}$$
$$\text{Number of wagons (n)} = 5$$
$$\text{Total mass of 5 wagons} = 2000 \text{ kg} \times 5$$
$$= 10000 \text{ kg}$$
$$\text{Force exerted by engine, } F_1 = 40{,}000 \text{ N}$$

Frictional force offered by the track,

$$F_2 = 5000 \text{ N}$$

(a) Net accelerating force,

$$F = F_1 - F_2$$
$$= (40{,}000 - 5{,}000) \text{ N}$$
$$= 35{,}000 \text{ N}$$

(b) Acceleration of the train,

$$a = \frac{F}{m}$$
$$A = \frac{35000 \text{ N}}{10000 \text{ kg}} = 3.5 \text{ ms}^{-2}$$

(c) Force of wagon 1 on wagon 2

$$= (35{,}000 - 35{,}000/5) \text{ N}$$
$$= (35{,}000 - 7000) \text{ N}$$
$$= 28{,}000 \text{ N}$$

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 ms^{-2}?

Ans :

Mass of vehicle (m) = 1500 kg

Acceleration (a) = – 1.7 ms^{-2}

By second law of motion :

$$F = m \times a$$
$$= 1500 \times -1.7$$
$$= -2550 \text{ N}$$

Negative sign shows that the force is in a direction opposite to the direction of motion of the vehicle.

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

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?

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

Ans :

$$\text{Mass of first object } (m_1) = 1.5 \text{ kg}$$
$$\text{Mass of second object } (m_2) = 1.5 \text{ kg}$$
$$\text{Initial velocity of the first object } (u_1) = 2.5 \text{ ms}^{-1}$$
$$\text{Initial velocity of the second object } (u_2) = -2.5 \text{ ms}^{-1}$$

Let the combined velocity = v ms^{-1}

According to the law of conservation of momentum,

Momentum before collision

$$= \text{Momentum after collision}$$
$$= m_1u_1 + m_2u_2 = (m_1 + m_2)\text{ v}$$
$$1.5\ (2.5) + 1.5\ (-2.5) = (1.5 + 1.5)\text{ v}$$
$$3.75 - 3.75 = 3\text{ v}$$
$$0 = 3\text{ v}$$
$$v = 0 \text{ ms}^{-1}$$

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 :

According to the third law of motion, action and reaction forces are equal and opposite but they both

act on different bodies. Hence, they cannot cancel each other. When we push a massive truck, then the force applied on the truck is not sufficient to overcome the force of friction between the tyres of the truck and ground. Hence, the truck does not move. The truck will move only if the force applied on it is greater than the frictional force. Therefore, the justification of the student is not correct.

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

Ans :

Mass of hockey ball (m) = 200 g

$= \frac{200}{1000} = 0.2$ kg

Initial velocity of the ball (u) = 10 ms^{-1}

Final velocity of the ball (v) = – 5 ms^{-1} (Hockey ball travels in opposite direction)

Initial momentum of the ball = m × u

$= 0.2 \text{ kg} \times 10 \text{ ms}^{-1}$

$= 2 \text{ kg ms}^{-1}$

Final momentum of the ball = m × v

$= 0.2 \text{ kg} \times (-5 \text{ ms}^{-1})$

$= -1 \text{ kg ms}^{-1}$

Change of momentum = mv – mu

$= (-1 - 2) \text{ kg ms}^{-1}$

$= -3 \text{ kg ms}^{-1}$

14. A bullet of mass 10 g travelling horizontally with a velocity of 150 ms^{-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 :

Mass (m) = 10 g $= \frac{10}{1000}$kg = 0.01 kg

Initial velocity (u) = 150 ms^{-1}

Final velocity (v) = 0 ms^{-1}

Time (t) = 0.03 s

According to first equation of motion,

$v = u + at$

Acceleration (a) $= \frac{v-u}{t} = \frac{(0-150)\,\text{ms}^{-1}}{0.03\,\text{s}}$

$= -5000 \text{ ms}^{-2}$ (Negative sign indicates that the velocity of the bullet is decreasing.)

By second equation of motion :

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

$= 150 \text{ ms}^{-1} \times 0.03\text{s}$

$+ \frac{1}{2} \times (5000 \text{ ms}^{-2}) \times (0.03 \text{ s})^2$

$= 4.50 \text{ m} - 2.25 \text{ m} = 2.25 \text{ m}$

By second law of motion :

$F = m \times a$

$= 0.01 \text{ kg} \times (5000 \text{ ms}^{-2})$

$= 50 \text{ N}$

Hence, the distance of penetration of the bullet into the block is 2.25 m and the magnitude of 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 ms^{-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 object $(m_1) = 1$ kg

Initial velocity $(u_1) = 10 \text{ ms}^{-1}$

Mass of stationary wooden block $(m_2) = 5$ kg

Velocity of wooden block before collision,

$(u_2) = 0$ m/s

Let velocity of combined object = v

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Total momentum just before impact

$= m_1 \times u_1$

$= 1 \text{ kg} \times 10 \text{ ms}^{-1}$

$= 10 \text{ kg ms}^{-1}$

By law of conservation of momentum,

Total momentum before impact

= Total momentum after impact

$m_1u_1 + m_2u_2 = (m_1 + m_2)\, v$

$1(10) + 5(0) = (1 + 5)\, v$

$v = = \frac{10}{6} = \frac{5}{3} \text{ ms}^{-1} = 1.67 \text{ ms}^{-1}$

16. An object of mass 100 kg is accelerated uniformly from a velocity of 5 ms^{-1} to 8 ms^{-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 :

Mass of object $m = 100$ kg

Initial velocity $u = 5 \text{ ms}^{-1}$

Final velocity $v = 8 \text{ ms}^{-1}$

Time $t = 6$ s

Initial momentum

$m \times u = 100 \text{ kg} \times 5 \text{ ms}^{-1}$

$= 500 \text{ kg ms}^{-1}$

Final momentum

$m \times v = 100 \text{ kg} \times 8 \text{ ms}^{-1}$

$= 800 \text{ kg ms}^{-1}$

$F = \frac{mv - mu}{t}$

$$= \frac{(800 - 500)\,\text{kg ms}^{-1}}{6\,\text{s}}$$

$$= \frac{300\,\text{kg ms}^{-1}}{6\,\text{s}} = 50\ \text{N}$$

17. Akhtar, Kiran and Rahul were riding in a motorcar 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 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.

Ans :

Rahul gave the correct reasoning and explanation that both the motorcar and the insect experienced the same force and a change in their momentum. (As per the law of conservation of momentum)
When 2 bodies collide :
Initial momentum before collision

= Final momentum after collision

$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$
The equal force is exerted on both the bodies but, because the mass of insect is very small it will suffer greater change in velocity.

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

Ans :

$$\text{Mass (m)} = 10\ \text{kg}$$
$$\text{Final velocity (u)} = 0\ \text{ms}^{-1}$$
$$\text{Distance (s)} = 80\ \text{cm} = 0.8\ \text{m}$$
$$\text{Acceleration (a)} = 10\ \text{ms}^{-1}$$

By third equation of motion :

$$v^2 - u^2 = 2as$$
$$v^2 - (0\ \text{ms}^{-1})^2 = 2 \times 10\ \text{ms}^{-2} \times 0.8\ \text{m}$$
$$v = 4\ \text{ms}^{-1}$$

Momentum transferred to the floor :

$$= m \times v$$
$$= 10\ \text{kg} \times 4\ \text{ms}^{-1}$$
$$= 40\ \text{kg ms}^{-1}$$

3. NCERT ADDITIONAL

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?

Ans :

(a) There is an unequal change of distance in an equal interval of time. So, the given objects have a non-uniform motion. Thus, the acceleration is increasing as the velocity of the object increases with time.
(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.

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 ms^{-2}. With what force does each person push the motorcar?
(Assume that all persons push the motorcar with the same muscular effort)

Ans :

Mass of the motorcar = 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,

$$a = 0.2\ \text{m/s}^2$$

Let the force applied by the third person be F.
From Newton's second law of motion :

$$\text{Force} = \text{Mass} \times \text{Acceleration}$$
$$F = 1200 \times 0.2 = 240\ \text{N}$$

Thus, the third person applies a force of magnitude 240 N.
Hence, each person applies a force of 240 N to push the motorcar.

3. A hammer of mass 500 g, moving at 50 ms^{-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?

Ans :

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 :

Force, $f = m\frac{v-u}{t}$

$= 0.5\frac{0-50}{0.01}$

$= -2500$ 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.

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.

Ans :

Mass of the motorcar, $m = 1200$ kg

Initial velocity of the motorcar,

$u = 90$ km/h $= 25$ m/s

Final velocity of the motorcar,

$v = 18$ 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

Negative sign indicates that its a retarding motion, i.e. velocity is decreasing.

Change in momentum $= mv - mu = m(v - u)$

$= 1200\,(5 - 25)$

$= -24000$ kg ms^{-1}

Force = Mass × Acceleration

$=1200 \times -5$

$= -6000$ N

Acceleration of the motorcar $= -5$ m/s^2

Change in momentum of the motorcar

$= -24000$ kg ms^{-1}

Hence, the force required to decrease the velocity is 6000 N.
(Negative sign indicates retardation, decrease in momentum and retarding force)

5. A large truck and a car, both moving with a velocity of magnitude v, have a head-on collision and both of them come to a halt after that. If the collision lasts for 1 s :
(a) Which vehicle experiences the greater force of impact?
(b) Which vehicle experiences the greater change in momentum?
(c) Which vehicle experiences the greater acceleration?
(d) Why is the car likely to suffer more damage than the truck?

Ans :

Let the mass of the truck be M and that of the car be m
Thus, M > m
Initial velocity of both vehicles, v
Final velocity of both vehicles, v' = 0 (since the vehicles come to rest after collission)

Time of impact, $t = 1$ s

(a) From Newton's second law of motion, the net force experienced by each vehicle is given by the relation :

$$F_{car} = m\frac{v'-v}{t} = mv$$

$$F_{truck} = M\frac{v'-v}{t} = Mv$$

Since, the mass of the truck is greater than that of the car, it will experiences a greater force of impact.

(b) Initial momentum of the car = mv

Final momentum of the car = 0

Change in momentum = mu

Initial momentum of the truck = Mv

Final momentum of the truck = 0

Change in momentum = Mv

Since, the mass of the truck is greater than that of the car, it will experience a greater change in momentum.

(c) From the first equation of motion, acceleration produced in a system is independent of the mass of the system, the initial velocity, the final velocity, and the time of impact remain the same in both the cases. Hence, both the car and the truck experience the same amount of acceleration.

(d) According to Newton's third law of motion, for every action there is an equal and opposite reaction that acts on different bodies. Since the truck experiences a greater force of impact (action), this larger impact force is also experienced by the car (reaction). Thus, the car is likely to suffer more damage than the truck.

4. NCERT EXEMPLAR

Objective Type Questions

1. Which of the following statement is not correct for an object moving along a straight path in an accelerated motion?
(a) Its speed keeps changing.
(b) Its velocity always changes.
(c) It always goes away from the Earth.
(d) A force is always acting on it.

Ans : (c) It always goes away from the Earth.

2. According to the third law of motion, action and reaction :
(a) Always act on the same body.
(b) Always act on different bodies in opposite directions.

(c) Have same magnitude and directions.
(d) Act on either body at normal to each other.

Ans : (b) Always act on different bodies in opposite directions.

3. A goalkeeper in a game of football pulls his hands backwards after holding the ball shot at the goal. This enables the goalkeeper to :
(a) Exert larger force on the ball.
(b) Reduce the force exerted by the ball on hands.
(c) Increase the rate of change of momentum.
(d) Decrease the rate of change of momentum.

Ans : (b) Reduce the force exerted by the ball on hands.

4. The inertia of an object tends to cause the object :
(a) To increase its speed
(b) To decrease its speed
(c) To resist any change in its state of motion
(d) To decelerate due to friction

Ans : (c) To resist any change in its state of motion

5. A passenger in a moving train tosses a coin which falls behind him. It means that motion of the train is
(a) Accelerated
(b) Uniform
(c) Retarded
(d) Along circular tracks

Ans : (a) Accelerated

6. An object of mass 2 kg is sliding with a constant velocity of 4 ms-1 on a frictionless horizontal table. The force required to keep the object moving with the same velocity is :
(a) 32 N (b) 0 N
(c) 2 N (d) 8 N

Ans : (b) 0 N

7. Rocket works on the principle of conservation of :
(a) Mass (b) Energy
(c) Momentum (d) Velocity

Ans : (c) Momentum

8. A water tanker filled up to 2/3 of its height is moving with a uniform speed. On sudden application of the brake, the water in the tank would :
(a) Move backward (b) Move forward
(c) Be unaffected (d) Rise upwards

Ans : (b) Move forward

Short Answer Questions

9. There are three solids made up of aluminum, steel and wood, of the same shape and same volume. Which of them would have highest inertia?

Ans :

As the mass is a measure of inertia, the ball of same shape and size, having more mass than other balls will have highest inertia. Since steel has greatest density and greatest mass, therefore, it has highest inertia.

10. Two balls of the same size but of different materials, rubber and iron are kept on the smooth floor of a moving train. The brakes are applied suddenly to stop the train. Will the balls start rolling? If so, in which direction will they move with the same speed? Give reasons for your answer.

Ans :

Yes. Both the balls will start rolling due to inertia of motion and they roll in the direction in which the train was moving. Due to the application of the brakes, the train comes to rest but due to inertia the balls try to remain in motion, therefore, they continue to roll. The two balls will not roll with the same speed. Since the masses of the balls are not the same, therefore, the inertial forces are also not same on both the balls. Thus, the balls will move with different speeds. In fact the iron being heavier will move with a speed comparatively lesser than that of the rubber ball.

11. Two identical bullets are fired one by a light rifle and another by a heavy rifle with the same force. Which rifle will hurt the shoulder more and why?

Ans :

As both the bullets are said to be identical and are fired with the same force, therefore, as per Newton's third law of motion, 'Every action has an equal and opposite reaction'; same force will be applied on both the rifles. As the same amount force is applied on both the rifles, the lighter rifle will move more quickly in the backward direction causing serious injury to the shoulder.

12. A horse continues to apply a force in order to move a cart with a constant speed. Explain, why?

Ans :

A horse continues to apply a force to move a cart with a constant speed so as to overcome the force of friction between the cart and the ground. Once the cart starts moving, the force of friction comes into action. It starts working on the wheels of the cart in a direction opposite to the direction of motion of the cart. So, the horse has to apply a continuous force in the forward direction to maintain constant speed.

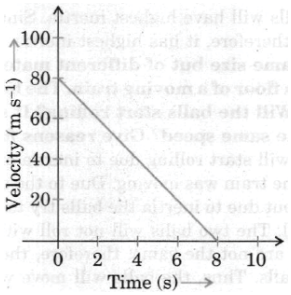
13. Suppose a ball of mass m is thrown vertically upward with an initial speed v, its speed decreases continuously till it becomes zero. Thereafter, the ball begins to fall downward and attains the speed v again before striking the ground. It implies that the magnitude of initial and final momentums of the ball is same. Yet, it is not an example of conservation of momentum. Explain, why?

Ans :

Law of conservation of momentum is applicable to

isolated system. An isolated system is a system that is free from the influence of a net external force that alters the momentum of the system. In the given example, the change in velocity is due to the gravitational force of Earth. This is an external force. Therefore, it is not an example of conservation of momentum.

14. Velocity versus time graph of a ball of mass 50 g rolling on a concrete floor is shown in figure. Calculate the acceleration and frictional force of the floor on the ball.



Ans :

Given, m = 50 g, F = ?
The velocity of the ball zero time is 80 ms^{-1}. It decelerates due to the friction of the floor with itself and comes to rest after 8 s

$$a = \text{change in velocity/time}$$
$$= \frac{0-80}{8}\ ms^{-2} = -10\ ms^{-2}$$

The negative sign indicates that the frictional force exerted opposes the motion of the ball.
Now, using Newton's relation

$$F = ma$$
$$F = \frac{50}{1000}\,kg \times (-10)\,ms^{-2}$$
$$F = -0.5\ N$$

15. A truck of mass M is moved under a force F. If the truck is then loaded with an object equal to the mass of the truck and the driving force is halved, then how does the acceleration change?

Ans :

Given, the initial mass $m_1 = M$, initial force $f_1 = F$
Given that, new mass $m_2 = M + M = 2M$ and new force $f_2 = F/2$ (as force is halved)
From Newton's second law,

$$F = ma$$

Therefore, $$a = \frac{F}{m}$$

Initial acceleration $$(a_1) = \frac{F}{M}$$

New acceleration $$(a_2) = \frac{F/2}{2M}$$

Change in acceleration $$= \frac{a_1}{a_2} = \frac{F/M}{\frac{F/2}{2M}}$$
$$= \frac{F}{M} \times \frac{2M \times 2}{F}$$
$$= 2M \times \frac{2}{M} = \frac{4M}{M} = 4$$

Therefore, $$\frac{a_1}{a_2} = 4$$
$$\frac{a_1}{4} = a_2$$

Thus, the new acceleration (a_2) will be one-fourth of the old acceleration (a_1).

16. Two friends on roller-skates are standing 5 m apart facing each other. One of them throws a ball of 2 kg towards the other, who catches it, how will this activity affect the position of the two? Explain your answer.

Ans :

Separation between them will increase. Initially the momentum of both of them are zero. In order to conserve the momentum the one who throws the ball would move backward. The second will experience a net force after catching the ball and therefore, will move backwards that is in the direction of the force.

17. Water sprinkler used for grass lawns begins to rotate as soon as the water is supplied. Explain the principle on which it works.

Ans :

The working of the rotation of sprinkler is based on third law of motion. As the water comes out of the nozzle of the sprinkler, an equal and opposite reaction force comes into play. So, the sprinkler starts rotating.

18. Using second law of motion, derive the relation between force and acceleration. A bullet of 10 g strikes a sand-bag at a speed of $10^3\ ms^{-1}$ and gets embedded after travelling 5 cm. Calculate :
(i) The resistive force exerted by the sand on the bullet.
(ii) The time taken by the bullet to come to rest.

Ans :

(i) Given,

$$m = 10\ g = \frac{10}{1000}\,kg;\ u = 10^3\ ms^{-1};\ v = 0;$$
$$s = 5\ cm = \frac{5}{100}\,m$$
$$v^2 - u^2 = 2\ as$$
$$0 - (10^3)^2 = 2 \times a \times \frac{5}{100}$$
$$-(10^3) \times (10^3) = \frac{10a}{100}$$
$$a = \frac{-1000 \times 1000}{10} \times 100$$
$$= -10^7\ ms^{-2}$$
$$F = ma = \frac{1}{100} \times -10^7 = -10^5 N$$

(ii)
$$v = u + at$$
$$0 = (10^3) - 10^7 \times t$$
$$t = \frac{10^3}{10^7} = 10^{-4}\ d$$

19. Derive the unit of force using the second law of motion. A force of 5 N produces an acceleration of 8 ms^{-2} on a mass m_1 and an acceleration of 24 ms^{-2} on a mass

m_2. What acceleration would the same force provide if both the masses are tied together?

Ans :

According to Newton's second law of motion,

$$\text{Force} = \text{mass} \times \text{acceleration}$$

$$\text{Unit of mass} = \text{kg}$$

$$\text{Unit of acceleration} = \text{m/s}^2$$

$$\text{F} = \text{kg} \times \text{m/s}^2$$

Therefore, $\text{unit of force} = \text{kg.m/s}^2$

$$1 \text{ kgm/s}^2 = 1 \text{ Newton}$$

Given, F = 5 N, mass = m_1, a = 8 ms^{-2}

$$F = ma$$

$$5 = m_1 \times 8$$

$$m_1 = \frac{5}{8} \text{ kg}$$

Similarly,

Given, F = 5 N, mass = m_2, a = 24 ms^{-2}

$$5 = m_2 \times 24 \text{ ms}^{-2}$$

$$m_2 = = \frac{5}{24} \text{ kg}$$

If both the masses are tied together, then

$$\text{Total mass} = m_1 + m_2$$

$$= \frac{5}{8} + \frac{5}{24} = \frac{15+5}{24}$$

$$= \frac{20}{24} = \frac{5}{6} \text{ kg}$$

Now, acceleration for mass $\frac{5}{6}$ kg,

$$F = 5N$$

$$F = ma$$

$$a = \frac{F}{m} = \frac{5}{5/6}$$

$$= \frac{5 \times 6}{5}$$

$$= 6 \text{ ms}^{-2}$$

20. What is momentum? Write its SI unit. Interpret force in terms of momentum. Represent the following graphically :

(a) Momentum versus velocity when mass is fixed.

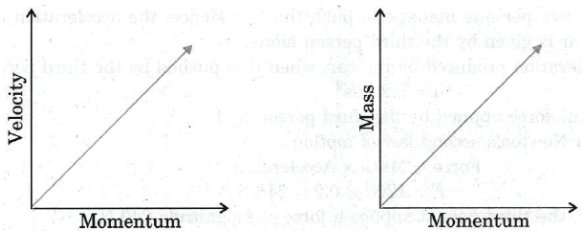
(b) Momentum versus mass when velocity is constant.

Ans :

Momentum = mass × velocity

SI unit of momentum is kg ms^{-1}

Force = Rate of change in momentum



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Science IX

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