# NCERT Solutions for Class 9 Science

# Chapter 8 – Force and Laws of Motion

## INTEXT EXERCISE 1

**1. Which of the following has more inertia:**

**(a) a rubber ball and a stone of the same size?**

**Ans:** The inertia of an object is measured by its mass. Heavier or more massive objects offer larger inertia.

Stone is heavier than the rubber ball of the same size. e. Hence, the inertia of the stone is greater than that of a rubber ball.

**(b) a bicycle and a train?**

**Ans:** Train is heavier than bicycle. Hence, inertia of the train is greater than that of the

bicycle

**(c) a five-rupees coin and a one-rupee coin?**

**Ans:** A five rupee coin is heavier than a one rupee coin. Hence, inertia of the five-rupee coin is greater than that of the one-rupee coin.

**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.**
**Ans:** The ball's velocity changes four times.

First change: The ball's speed changes from 0 to a specific amount as the football player kicks it. value. As a result, the ball's velocity is altered.

Second change: Another player is kicking the ball to the goal post in the second change. As a result of this, the direction of the ball is changed. As a result, its speed varies. In this case, the player used force. to change the velocity of the ball.

Third change: The ball is being collected by the goalie in the third change. The ball finally comes to a halt. As a result, its speed is lowered to zero from a specific value. The pace of the ball has changed. In this situation, the goalie utilised a counterforce to slow down or modify the pace of the ball.

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

**Ans**: Because of the inertia of rest, when the branch is quickly moved, the leaves attached to it tend to stay in their resting position. The leaves and branch junctions are put under a lot of stress as a result of this. This strain causes some leaves to detach off the branch**.**

Fourth change-The goalkeeper kicks the ball to his teammates. As a result, the ball's velocity increases from zero to a certain number. As a result, its velocity shifts once more. In this case, the goalkeeper used force to change the ball's velocity.

**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:** We move in the forward direction when a moving bus is braking because our upper portion of the body and the bus are both in motion when the bus is moving, and when the bus is breaking our body is trying to be in motion due to inertia of motion and thereby we experience a forward push. Similarly, when the bus accelerates from the rest, the passenger tends to fall backwards. This is because the passenger's inertia tends to oppose the bus's forward motion when the bus accelerates. Therefore, when the bus accelerates, the passenger tends to fall backwards.

**INTEXT EXERCISE 2**

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

**Ans:** With his foot, a horse pushes the earth in a rearward way. According to Newton's third law of motion, the Earth exerts a reaction force on the horse in the forward direction. As a result, the cart advances.

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

**Ans:** When a significant volume of water is discharged from a hose at a high velocity, Newton's Third Law of Motion states that the water pushes the hose backwards with the same force. As a result, gripping a hose that ejects a significant volume of water at a rapid rate is difficult for a firefighter.

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

**Given:**

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 $= v_1$

Initial velocity of bullet, $v_2 = 35 \text{ m/s}$

**Ans:** As, the riffle is at rest, 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:

$= m_1 v_1 + m_2 v_2$

$= 4(v_1) + 0.05 \times 35$

$= 4v_1 + 1.75$

According to the law of conservation of momentum,

Total momentum after the firing = Total momentum before the firing

$4v_1 + 1.75 = 0$

$4v_1 = -1.75$

$v_1 = \frac{-1.75}{4}$

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

The negative sign indicates that the rifle recoils backwards with a velocity $v_1 = -0.4375 \text{ m/s}$

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

**Given:**

Mass of one of the objects, $m_1 = 100 \text{ g} = 0.1 \text{ kg}$

Mass of the other object, $m_2 = 200 \text{ g} = 0.2 \text{ kg}$

Velocity of $m_1$ before collision, $v_1 = 2 \text{ m/s}$

Velocity of $m_2$ before collision, $v_2 = 1 \text{ m/s}$

Velocity of $m_1$ after collision, $v_3 = 1.67 \text{ m/s}$

**Ans:**

Velocity of $m_2$ after collision $= v_4$

According to the law of conservation of momentum:

Total momentum before collision $=$ Total momentum after collision

$m_1v_1 + m_2v_2 = m_3v_3 + m_4v_4$

$(0.1)2+(0.2)1=(0.1)1.67+(0.2)v_4$

$0.2+0.2=0.167+0.2v_4$

$0.4=0.167+0.2v_4$

$0.4-0.167=0.2v_4$

$0.233=0.2v_4$

$v_4=\frac{0.233}{0.2}$

$v_4=1.165\ \text{m/s}$

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

**NCERT EXERCISE**

**1. An object experiences a net zero external unbalanced force. Is it possible for the object to be travelling at a non-zero velocity? If yes, state the conditions that must be placed on the magnitude and direction of the velocity. If not, provide a reason.**

**Ans:** Yes. An object can travel at a non-zero velocity even if it has a net zero external unbalanced force. This is only possible if the item moves at a consistent speed in a specified direction. As a result, the body is not subjected to any net imbalanced forces. The item will continue to travel at a velocity greater than zero. A net non-zero external unbalanced force must be supplied to the item to change its state of motion.

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

**Ans:** Using a stick to beat a carpet; causing the carpet to move quickly, while dust particles trapped in the carpet's pores prefer to stay still, since inertia of an item resists any change in its state of rest or motion. The dust particles, according to Newton's first rule of motion, remain at rest as the carpet moves. As a result, dust particles emerge from the carpet.

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

**Ans:** According to Newton's First Law of Motion, luggage on a bus' roof tends to maintain its condition of rest when the bus is at rest and retain its state of motion when the bus is in motion. When the bus starts moving again after a period of rest, luggage on the roof may fall down to maintain the resting spot. Similarly, owing to inertia of motion, luggage on the roof top of a moving bus will tumble forward when it arrives in the rest state. To avoid this, any luggage kept on a bus's roof should be tied with a rope.

**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:** Option(c). When the ball moves on the ground, the force of friction opposes its movement and after some time ball comes to a state of rest.

**5. A truck starts from rest and rolls down a hill with 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).**

**Given:**

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

Distance travelled, s $=400$ m

Time taken, t $=20$ s

**Ans:**

According to the second equation of motion:

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

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

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

$$400 = a(200)$$

$$a = \frac{400}{200}$$

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

$1\,\text{metric tonne} = 1000\ \text{kg}$

$\therefore 7\,\text{metric tonnes} = 7000\,\text{kg}$

Mass of truck, $m = 7000\,\text{kg}$

From Newton's second law of motion:

Force, F = Mass × Acceleration

F = ma

F= $= 7000 \times 2$

F $= 14000\,\text{N}$

Hence, the acceleration of the truck is $2\,\text{m/s}^2$ and the force acting on the truck F $= 14000\ \text{N}$

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

**Given:**

Initial velocity of the stone, u $=20\,\text{m/s}$

Final velocity of the stone, v $=0$ (finally the stone comes to rest)

Distance covered by the stone, s $=50\,\text{m}$

**Ans:**

According to the third equation of motion:

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

$0^2 = (20)^2 + 2 \times a \times 50$

$0 = 400 + 100a$

$100a = -400$

$a = -\frac{400}{100}$ $a = -4$

$\text{a} = -4\ \frac{m}{s^2}$

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 $=1 \times -4$

F $= -4$ N

Hence, the force of friction between the stone and the ice F $= -4$ N.

**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 5000N, then calculate:**

**(a) the net accelerating force.**

**Given:**

Force exerted by the engine, F = 40000 N

Frictional force offered by the track, F = 5000 N

**Ans:**

Net accelerating force,

$$F_{net} = F - F_{friction}$$

$$F_{net} = 40000 - 5000$$

$$F_{net} = 35000 \text{ N}$$

Hence, the net accelerating force $F_{net} = 35000 \text{ N}$

**(b) the acceleration of the train; and**

**Given:**

The engine exerts a force of 40000N on all the five wagons.

Net accelerating force on the wagons, $F_{net} = 35000 \text{ N}$

Mass of a wagon $= 2000$ kg

Number of wagons $= 5$

**Formula:**

Total Mass of the wagons,

m = Mass of a wagon × Number of wagons

**Ans:**

Total Mass of the wagons,

$\mathrm{m} = 2000 \times 5 \mathrm{m} = 10000 \mathrm{kg}$

Mass of the engine, $\mathrm{m}' = 8000 \mathrm{kg}$

Total mass, $\mathrm{M} = \mathrm{m} + \mathrm{m}' = 10000 + 8000 = 18000$ kg

From Newton's second law of motion:

$$Fa = Ma$$

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

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

$$a = 1.944 \mathrm{m/s^2}$$

Hence, the acceleration of the wagons and the train $a = 1.944 \mathrm{m/s^2}$

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

**Ans:** The force of wagon 1 on wagon 2 = mass of four wagons x acceleration

Mass of 4 wagons $= 4 \times 2000 = 8000 \mathrm{kg}$

$F = 8000\,kg \times 1.944\,m/s^2$

$F = 1552\,N$

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

**Given:**

Mass of the automobile vehicle, m $= 1500\,kg$

Final velocity, $v = 0$

Acceleration of the automobile, a $= -1.7\ ms^{-2}$

**Ans**

From Newton's second law of motion,

Force = Mass × Acceleration $= 1500 \times (-1.7) = -2550\,N$

Hence, the force between the automobile and the road $= -2550$ N.

Negative sign shows that the force is acting in the opposite direction 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)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 a constant velocity. What is the friction force that will be exerted on the cabinet?**

**Ans:**

The same amount of force will act in the opposite direction, according to Newton's third law of motion. Friction is the name of this force. As a result, the cabinet is subjected to a **200** N frictional force.

**11. 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 static friction force is quite strong due to the truck's massive bulk. Because the student's effort is insufficient to overcome the static friction, the truck cannot be moved. In this circumstance, the net imbalanced force in either direction is zero, which explains why there is no movement. The force exerted by the learner and the force exerted owing to static friction cancel each other out.

As a result, the student is correct in claiming that the two equal and opposing forces cancel each other out.

**12. 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 the hockey ball, m $= 200\,\text{g} = 0.2\,\text{kg}$

velocity of the ball, $v_1 = 10\,\text{m/s}$

Initial momentum $= mv_1$

velocity of the ball after struck by the stick, $v_2 = -5\,\text{m/s}$

Final momentum $= mv_2$

Change in momentum $= mv_1 - mv_2 = m(v_1 - v_2) = 0.2(10-(-5)) = 0.2\times 15 = 3\,\text{kg}\ ms^{-1}$

Hence, the change in momentum of the hockey ball $= 3\,\text{kg}\ ms^{-1}$

**13. A bullet of mass 10g travelling horizontally with a velocity of 150 $ms^{-1}$ strikes a stationary wooden block and comes to rest in 0.03s. 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.**

**Given:**

Initial velocity of the bullet, u $= 150$ m/s

Final velocity, $v = 0$

Time, $t = 0.03\,\text{s}$

**Ans:**

According to the first equation of motion, $v = u + at$

Acceleration of the bullet, a

$0 = 150 + (a\times 0.03s)$ $a = -\dfrac{150}{0.03}$ $a = -5000$ m/s$^2$

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

According to the third equation of motion:

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

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

$0 = 22,500 - 10000s$

$10000s = 22,500$ $s = \dfrac{22,500}{10000}$ $s = 2.25$ m

Hence, the distance of penetration of the bullet into the block $s = 2.25\,\text{m}$

From Newton's second law of motion:

Force, F = Mass × Acceleration

Mass of the bullet, m $= 10$ g $= 0.01\,\text{kg}$

Acceleration of the bullet, a $= -5000\,\dfrac{m}{s^2}$ F = ma $= 0.01 \times -5000 = -50$

Hence, the magnitude of force exerted by the wooden block on the bullet $= -50\,\text{N}$ but it acts in opposite direction.

**14. 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.**

**Given:**

Mass of the object,

$m_1 = 1$ kg

Velocity of the object before collision, $v_1 = 10\,\text{m/s}$

Mass of the wooden block, $m_2 = 5$ kg

Velocity of the wooden block before collision, $v_2 = 0$ m/s

**Ans:**

$\therefore$ Total momentum before collision $= m_1 v_1 + m_2 v_2$

$= 1(10) + 5(0) = 10$ kg $ms^{-1}$

It is given that after collision, the object and the wooden block stick together.

Total mass of the combined system,

$m = m_1 + m_2 = 1\,\text{kg} + 5\,\text{kg} = 6\,\text{kg}$

Velocity of the combined object $= v$

According to the law of conservation of momentum:

Total momentum before collision $=$ Total momentum after collision

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

$\Rightarrow 1(10) + 5(0) = (1+5) v \Rightarrow 10 = 6v$

$\Rightarrow v = \frac{10}{6} \Rightarrow v = \frac{5}{3}$ m/s

$v = 1.66$ m/s

Total momentum after collision $m_1 v + m_2 v = v(m_1 + m_2) = 10(6 \times 6) = 10\,\text{kg m/s}$

The total momentum after collision is also **10** kg m/s.

Total momentum just before the impact $= 10$ kg m/s.

Total momentum just after the impact $= 10$ kg m/s.

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

**15. An object of mass 100kg 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.**

**Given:**

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 taken by the object to accelerate, t $= 6$ s

**Ans:**

Initial momentum $= \mathrm{mu} = 100 \times 5 = 500$ kg $ms^{-1}$

Final momentum $= \mathrm{mv} = 100 \times 8 = 800$ kg $ms^{-1}$

Force exerted on the object,

F = mv-mu/t

$$F = \left(\frac{800-500}{6}\right) F = \frac{300}{6} F = 50\,\mathrm{N}$$

Initial momentum of the object is 5**00** kg $ms^{-1}$.

Final momentum of the object is **800** kg $ms^{-1}$.Force exerted on the object is **50**N.

**16. Akhtar, Kiran and Rahul were riding in a motor car 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.**

**Ans:**

As a result, the vehicle and insect systems have no change in momentum.

In this case, the insect experiences a bigger change in velocity, which results in a greater shift in momentum. Kiran's assessment is correct from this perspective.

The motorcar travels at a faster speed and has a bigger mass than the insect.

Furthermore, the motorcar continues to travel in the same direction after the collision, indicating that the motorcar has the least amount of momentum change, whilst the insect has the most. As a result, Akhtar's statement is likewise correct.

Because the momentum acquired by the bug is equal to the momentum lost by the motorcar, Rahul's observation is likewise true. This is also in agreement with the conservation of momentum law. However, he committed an error since the system suffers from a flaw. Because the momentum before the collision is identical to the momentum after the impact, there is no change in momentum following the accident.

**17. 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** $ms^{-2}$.

**Given:**

Mass of the dumbbell, m $=10$ kg

Distance covered by the dumbbell, s $= 80$ cm $= 0.8$ m

Acceleration in the downward direction, a $= 10\ \frac{m}{s^2}$

Initial velocity of the dumbbell, u $= 0$

**Ans:**

Final velocity of the dumbbell v =?

According to the third equation of motion:

$v^2 = u_2 + 2as$

$v^2 = 0 + 2(10)0.8$

$v^2 = 20 \times 0.8$

$v^2 = 16$

$v = \sqrt{16}\ v = 4$ m/s

Hence, the momentum with which the dumbbell hits the floor is $= \text{mv} = 10 \times 4 = 40$ kg $ms^{-1}$

**ADDITIONAL EXERCISE:**

**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?**

**Ans:**

From the table, we can see that the distance changes unequally in equal intervals of time. Thus, the object is said to be in non- uniform motion. Since, velocity of the object is increasing with time, the acceleration is also increasing.

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

**Ans:**

According to Newton’s second law of motion, $F = mat$. In the given case, acceleration is increasing, which indicates that the force is also increasing.

**2. Two persons manage to push a motorcar of mass 1200kg 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)**

**Given:**

Mass of the motor car $= 1200$ kg

Acceleration produced by the car, when it is pushed by the third person, a $= 0.2\ \frac{m}{s^2}$

**Ans:**

Let the force applied by the third person be F.

From Newton’s second law of motion:

Force = Mass × Acceleration

$F = 1200 \times 0.2\, F = 240\,N$

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.

**3. A hammer of mass 500g, 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?**

**Given:**

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 $= 0.01\,\text{s}$

Velocity of the hammer, v $= 0$

**Ans:**

From Newton's second law of motion:

Force, F =m(v-u)/t

$$F = \frac{0.5(0-50)}{0.01}$$

F $= -2500$ The hammer strikes the nail with a force F $= -2500$ 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 1200kg is moving along a straight line with a uniform velocity of 90km/h. Its velocity is slowed down to 18 km/h in $4\,\text{s}$ by an unbalanced external force. Calculate the acceleration and change in momentum. Also calculate the magnitude of the force required.**

**Given:**

Mass of the motor car, m $= 1200$ kg

Initial velocity of the motor car, u $= 90\,\text{km/h} = 25\,\text{m/s}$

Final velocity of the motor car, v $= 18\ \text{km/h} = 5\,\text{m/s}$

Time taken, t $= 4$ s

**Ans:**

According to the first equation of motion:

$$v = u + at$$

$5 = 25 + a(4)$

$5 - 25 = a(4)$

$20 = a(4)$

$a = \frac{20}{4}\ a = -5\ \text{m/s}^2$

Change in momentum = mv − mu = m (v−u)

$= 1200(5 - 25) = 1200(-20)$

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

Force = Mass × Acceleration

Force $= 1200 \times -5$

Force $= -6000\,\text{N}$

Acceleration of the motor car $= -5\ \text{m/s}^2$

Change in momentum of the motor car $= -24000\,\text{kg}\ ms^{-1}$

Hence, the force required to decrease the velocity $= -6000\ \text{N}$.