FORCE AND LAWS OF MOTION

NCERT Textbook Questions

Q.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. Mass is a measure of the inertia of an object. If an object has more mass, it has more inertia.

(*a*) A stone has more inertia (than a rubber ball of the same size) because it has more mass than a rubber ball of the same size.

(*b*) A train has more inertia (than a bicycle) because it has more mass than a bicycle.

(*c*) A five-rupee coin has more inertia (than a one-rupee coin) because it has more mass than a one rupee coin.

Q.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. (*i*) The velocity of football changes for the 1st time when a football player kicks the football to another player of his team. The agent supplying the force in this case is the kick applied by the player.

(*ii*) The velocity of football changes for the 2nd time when another player of the same team kicks the football towards the goal. Here the force is supplied by the kick of another player.

(*iii*) The velocity of football changes for the 3rd time when the goalkeeper of opposite team collects the football (or stops the football). In this case the force is applied by the hands of the goalkeeper.

(*iv*) The velocity of football changes for the 4th time when the goalkeeper kicks the stationary football towards a player of his own team. Here the force is supplied by the kick of goalkeeper.

Thus, the velocity of football changes four times.

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

Ans. If we shake the branch of a tree vigorously, then the branch of tree comes in motion but the leaves tend to remain at rest (or stationary) due to their inertia and hence detach from the branch and fall down.

Q.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. (*a*) When a moving bus brakes suddenly to a stop, we fall in the forward direction because though the lower part of our body comes to a stop when the bus stops but the upper part of our body continues to move forward due to its inertia (making us fall in the forward direction).

(*b*) When a bus accelerates from rest, we tend to fall backwards because though the lower part of our body starts moving with the moving bus but the upper part of our body tries to remain at rest due to its inertia (making us fall backwards).

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

Ans. According to the Newton's third law of motion, the horse exerts some force on the cart, and the cart exerts an equal and opposite force on the horse. So, at first glance it seems that the action and reaction forces being equal and opposite cancel out and hence the cart would not move. But it should be noted that it is only the force on the cart which determines whether the cart will move or not, and that the force exerted by the cart on the horse affects the horse alone. Thus, if the horse is able to apply enough force to overcome the frictional forces present, the cart will move. So, to make the cart move, the horse bends forward and pushes the ground with its feet. When the forward reaction to the backward push of the horse is greater than the opposing frictional forces of the wheels, the cart moves.

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

Ans. When a fire hose pipe ejects large amounts of water in the forward direction at a high velocity, then the forward going stream of water exerts a backward reaction force due to which the hose pipe tends to go backward and slips from the hands of fireman. This backward movement of hose pipe makes it difficult for a fireman to hold the hose pipe. And the fireman has to hold the hose pipe strongly.

Q.7. 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.

Ans. We will first calculate the momentum of bullet and of the rifle separately and then apply the law of conservation of momentum.

(i) Momentum of bullet = Mass of bullet × Velocity of bullet

$$= \frac{50}{1000}\,\text{kg} \times 35\ \text{m s}^{-1}$$

$= 0.05 \text{ kg} \times 35 \text{ m s}^{-1}$

$= 1.75 \text{ kg m s}^{-1}$ ... (1)

(*ii*) Suppose the recoil velocity of the rifle is v m s^{-1}. So,

Momentum of rifle = Mass of rifle × Velocity of rifle

$= 4 \text{ kg} \times v \text{ m s}^{-1}$

$= 4v \text{ kg m s}^{-1}$ ...(2)

Now, according to the law of conservation of momentum:

Momentum of bullet = Momentum of rifle

So, $1.75 = 4v$

And $v = \dfrac{1.75}{4}$

$v = 0.4375 \text{ m s}^{-1}$

Thus, the recoil velocity of the rifle is 0.4375 metres per second.

Q.8. 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.

Ans. In order to solve this problem, we will first calculate total momentum of both the objects before and after the collision.

(*a*) Momentum of first object (before collision) = Mass of first object × Velocity of first object

$$= \frac{100}{1000} \text{ kg} \times 2 \text{ m s}^{-1}$$

$= 0.1 \text{ kg} \times 2 \text{ m s}^{-1}$

$= 0.2 \text{ kg m s}^{-1}$

Momentum of second object (before collision) = Mass of second object × Velocity of second object

$$= \frac{200}{1000} \text{ kg} \times 1 \text{ m s}^{-1}$$

$= 0.2 \text{ kg} \times 1 \text{ m s}^{-1}$

$= 0.2 \text{ kg m s}^{-1}$

Total momentum (before collision) $= 0.2 + 0.2$

$= 0.4 \text{ kg m s}^{-1}$ ...(1)

(*b*) After collision, the velocity of first object of mass 100 g becomes 1.67 m s^{-1}. So,

Momentum of first object (after collision) $= \dfrac{100}{1000}\ \text{kg} \times 1.67\ \text{m s}^{-1}$

$= 0.1\ \text{kg} \times 1.67\ \text{m s}^{-1}$

$= 0.167\ \text{kg m s}^{-1}$

After collision, suppose the velocity of second object of mass 200 g becomes v m s^{-1}. So,

Momentum of second object (after collision) $= \dfrac{200}{1000}\ \text{kg} \times v\ \text{m s}^{-1}$

$= 0.2\ \text{kg} \times v\ \text{m s}^{-1}$

$= 0.2v\ \text{kg}\ m\ \text{s}^{-1}$

Total momentum (after collision) $= 0.167 + 0.2v$ ...(2)

Now, according to the law of conservation of momentum:

Total momentum before collision = Total momentum after collision

That is,

$$0.4 = 0.167 + 0.2v$$

$$0.2v = 0.4 - 0.167$$

$$0.2v = 0.233$$

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

$$v = 1.165\ \text{m s}^{-1}$$

Thus, the velocity of second object is 1.165 metres per second.

NCERT Exercises

Q.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, when an object experiences a net zero external unbalanced force, it is possible for the object to be travelling with a non-zero velocity. This can happen under the following conditions:

(*a*) The object should already be travelling with a uniform speed in a straight line path.

(*b*) There should be no change in the magnitude of speed.

(*c*) There should be no change in the direction of motion.

(*d*) The friction between the object and the ground must be zero.

(*e*) The air resistance on the moving object must also be zero.

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

Ans. When a hanging carpet is beaten with a stick then the force of stick makes the carpet move to and fro slightly but the dust particles in it tend to remain at rest (or stationary) due to their inertia and hence come out of it.

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

Ans. It is advised to tie any luggage kept on the roof of a bus with a rope because:

(*a*) If the bus starts moving suddenly, then due to its inertia of rest, the luggage kept on the roof of the bus tends to remain at rest and hence may fall down from the roof of the bus.

(*b*) If the moving bus stops suddenly, then due to its inertia of motion, the luggage kept on the roof of the bus tends to remain in motion and hence may fall down from the roof of the bus.

If, however, the luggage items kept on the roof of a bus are tied with a rope, they cannot fall down when the bus starts suddenly or stops suddenly.

Q.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.

Q.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. (*a*) *Calculation of acceleration*

Here, Initial velocity, $u = 0$

Distance travelled, $s = 400$ m

Time, $t = 20$ s

And, Acceleration, $a = ?$ (To be calculated)

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

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

$$400 = 0 + \frac{1}{2} \times a \times 400$$

$$400 = a \times 200$$

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

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

Thus, the acceleration of the truck is 2 m/s^2.

(*b*) *Calculation of force*

Force, $F = m \times a$

So, $F = 7 \times 1000 \times 2$

$F = 14000$ N

Thus, the force acting on the truck is of 14000 newtons.

Q.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?

Ans. Here, Initial velocity, $u = 20 \text{ m s}^{-1}$

Final velocity, $v = 0$ (The stone stops)

Acceleration, $a = ?$ (To be calculated)

And, Distance travelled, $s = 50$ m

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

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

$$0 = 400 + 100\,a$$

$$100\,a = -400$$

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

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

Now, Force, $F = \text{m} \times \text{a}$

$$F = 1 \times (-4) \text{ N}$$

$$F = -4 \text{ N}$$

Thus, the force of friction between the stone and the ice is 4 newtons. The negative sign shows that this force opposes the motion of stone.

Q.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,

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

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

Ans. (*a*) *Calculation of the net accelerating force*

Here, the force exerted by the engine is 40000 N and the opposing force of friction offered by the track is 5000 N. So,

Net accelerating force, F = Force of engine – Force of friction

$$= 40000 - 5000$$

$$= 35000 \text{ N}$$

Thus, the net accelerating force (F) exerted by the engine is 35000 newtons. This force will be used in further calculations.

(*b*) *Calculation of the acceleration of train*

We have just calculated that the net force exerted by the engine on the train is 35000 N. Now, the mass of 1 wagon of train is 2000 kg, so the mass of 5 wagons of train will be 2000 × 5 = 10000 kg. In other words, the mass of whole train is 10000 kg.

Now, Net force = mass of train × acceleration

$$\text{F} = \text{m} \times \text{a}$$

So, $35000 = 10000 \times \text{a}$

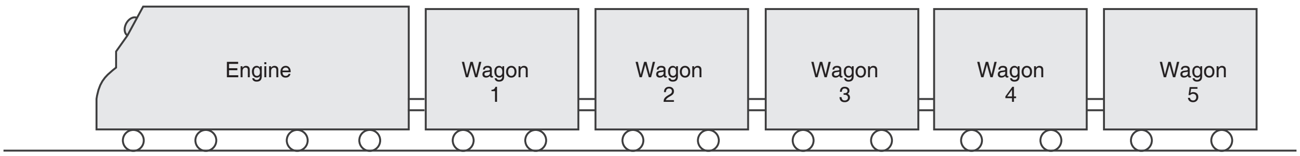
And, $$a = \frac{35000}{10000} \text{ m s}^{-2}$$

$$a = 3.5 \text{ m s}^{-2}$$

Thus, the acceleration of the train is 3.5 m s^{-2}.

(*c*) *Calculation of force of wagon 1 on wagon 2*

There are 5 wagons behind the engine (which have been marked 1, 2, 3, 4 and 5 in the Figure given



above) but there are only 4 wagons behind wagon 1. Now,

Force of wagon 1 on wagon 2 = mass of 4 wagons (behind wagon 1) × acceleration of train

$= 2000 \times 4 \times 3.5$

$= 28000$ N

Thus, the force of wagon 1 on wagon 2 is of 28000 newtons.

Q.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. Here, Mass of vehicle, $m = 1500$ kg

And, Acceleration, $a = -1.7$ m s^{-2}

Now, Force, $F = m \times a$

$F = 1500 \times (-1.7)$ N

$F = -2550$ N

Thus, the force between the vehicle and the road is 2550 newtons. The negative sign of force shows that the force acts in a direction opposite to the direction of motion of the vehicle.

Q.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

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

Ans. Since the wooden cabinet is to be moved at constant velocity, this means that the whole force of 200 N will be used to overcome the force of friction (because no force is spent on producing acceleration in the cabinet). Thus, the force of friction exerted on the cabinet will be equal to the force applied, which is 200 N.

Q.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 objects after collision?

Ans. Mass of first object, m_1 = 1.5 kg

Velocity of first object, v_1 = 2.5 m s^{-1}

So, Momentum of first object $= m_1 \times v_1$

$= 1.5 \times 2.5$

$= 3.75$ kg m s^{-1}

Total momentum before collision $= 3.75 + (-3.75)$

$= 3.75 - 3.75$

$= 0$ kg m s^{-1} ... (1)

The mass of combined objects will be $m_1 + m_2$ = 1.5 kg + 1.5 kg = 3.0 kg. Now, suppose the velocity of combined objects after collision is v m s^{-1}. So,

Total momentum after collision $= (m_1 + m_2) \times v$

$= 3.0 \times v$

...(2)

Now, according to the principle of conservation of momentum:

Total momentum before collision = Total momentum after collision

So, $0 = 3.0 \times v$

And, $$v = \frac{0}{3.0}$$

or, $v = 0$ m s^{-1}

Thus, the velocity of the combined objects after the collision will be zero metres per second which means that the combined objects will come to a stop after the collision.

Q.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 justification given by the student that the two opposite and equal forces cancel each other (and hence the truck does not move) is wrong. This is because the forces of action and reaction do not act on the same body (they act on two different bodies). So, there is no question of their cancellation. Actually, the massive truck does not move in this case because push (or force) applied to it is much smaller than the force of friction between the wheels of the truck and the road. Since the force of push is not able to overcome the force of friction, therefore, the truck does not move.

Q.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 of 5 m s^{-1}. Calculate the change of momentum occurred in the motion of the hockey ball by the force applied by the hockey stick.

Ans. (*a*) *Calculation of initial momentum*

Mass of hockey ball, $m_1 = 200$ g

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

$= 0.2$ kg

And, Initial velocity, $v_1 = 10$ m s^{-1}

So, Initial momentum $= m_1 \times v_1$

$= 0.2 \times 10$

$= 2$ kg m s^{-1} ...(1)

(*b*) *Calculation of final momentum*

Mass of hockey ball, $m^2 = 200$ g (Same as above)

$= 0.2$ kg

And, Final velocity, $v^2 = -5$ m s^{-1} (Reverse direction)

So, Final momentum $= m_2 \times v_2$

$= 0.2 \times (-5)$

$= -1$ kg m s^{-1} ...(2)

Now Change in momentum = Final momentum – Initial momentum

$= -1 - 2$

$= -3$ kg m s^{-1}

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

Q.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. We will first calculate the acceleration (or rather retardation) of the bullet.

Now, Initial velocity, $u = 150$ m s^{-1}

Final velocity, $v = 0$

And, Time, $t = 0.03$ s

Now, $v = u + at$

So, $0 = 150 + a \times 0.03$

$0.03\ a = -150$

$a = -\frac{150}{0.03}$

$a = -5000$ m s^{-2}

Let us calculate the distance of penetration of bullet now.

We know that: $v^2 = u^2 + 2as$

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

$0 = 22500 - 10000 \times s$

$10000\ \text{s} = 22500$

So, $s = \dfrac{22500}{10000}$

$s = 2.25$ m

Thus, the distance of penetration of the bullet into the block of wood will be 2.25 metres.

We will now calculate the magnitude of force. Now:

Force, $F = m \times a$

$$F = \frac{10}{1000}\ \text{kg} \times (-5000)\ \text{m s}^{-2}$$

$F = 50$ N

Thus, the magnitude of force exerted by the wooden block on the bullet is 50 newtons.

Q.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 objects.

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

And, Velocity of object, $v_1 = 10$ m s^{-1}

So, Momentum of object $= m^1 \times v_1$

$= 1 \times 10$ kg m s^{-1}

$= 10$ kg m s^{-1} ...(1)

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

And, Velocity of wooden block, $v_2 = 0$ (It is stationary)

So, Momentum of wooden block $= m_2 \times v_2$

$= 5 \times 0$

$= 0$ kg m s^{-1} ...(2)

Total momentum before impact $= 10 + 0$

$= 10$ kg m s^{-1} ....(3)

Now, according to the law of conservation of momentum, the total momentum just after the impact will be the same as the total momentum just before the impact. This means that the total momentum just after the impact will also be 10 kg m s^{-1}.

Now, Total momentum $= 10 \text{ kg m s}^{-1}$

Total mass of object $= 1 \text{ kg} + 5 \text{ kg}$

and wooden block $= 6 \text{ kg}$

And Velocity of object $= v \text{ m s}^{-1}$ (Supposed)

and wooden block

So, $10 = 6 \times v$

And, $v = \dfrac{10}{6}$

$v = 1.67 \text{ m s}^{-1}$

Thus, the velocity of the object and wooden block together is 1.67 metres per second.

Q.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. (*i*) Initial momentum = mass × initial velocity

$= 100 \times 5$

$= 500 \text{ kg m s}^{-1}$ ...(1)

(*ii*) Final momentum = mass × final velocity

$= 100 \times 8$

$= 800 \text{ kg m s}^{-1}$ ...(2)

(*iii*) $\text{Force} = \dfrac{\text{Change in momentum}}{\text{Time taken}}$

$= \dfrac{800 - 500}{6}$

$= \dfrac{300}{6}$

$= 50 \text{ N}$

Q.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 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 large 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. (*a*) Kiran's suggestion that the insect suffered a greater change in momentum as compared to the change in momentum of the motorcar is wrong.

(*b*) Akhtar's suggestion that since the motorcar was moving with a larger velocity, it exerted a larger force on the insect, is also wrong.

(*c*) Rahul's explanation that both the motorcar and the insect experienced the same force and same change in their momentum is correct. Both experience the same force because the action (force) and reaction (force) are always equal and opposite. Moreover, the magnitude of change in their momenta is also the same (though the change in momenta occur in opposite directions).

Q.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 m s^{-2}.

Ans. We will first calculate the final velocity of falling dumb-bell (just before touching the floor).

Here, Initial velocity, $u = 0$ (Falls from rest)

Final velocity, $v = ?$ (To be calculated)

Acceleration, $a = 10$ m s^{-2}

And, Distance, $s = 80$ cm

(or Height) $= \frac{80}{100}$ m

$= 0.8$ m

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

So, $v^2 = (0)2 + 2 \times 10 \times 0.8$

$v^2 = 16$

$v = \sqrt{16}$

$v = 4$ m s^{-1}

Momentum = mass × velocity

$= 10$ kg × 4 m s^{-1}

$= 40$ kg m s^{-1}

Now, the momentum of falling dumb-bell just before touching the floor is 40 kg m s^{-1}. So, the dumb-bell will transfer an equal amount of momentum (40 kg m s^{-1}) to the floor.

NCERT Additional Exercise

Q.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*) We can see from the given time (t) values and the distance (s) values that at time (t) = 0 s, distance (s) = 0 m, and at time (t) = 1 s, distance (s) = 1 m.

But, when time (t) = 2 s, then distance (s) = 8 m

We know that: $(2)^3 = 2 \times 2 \times 2 = 8$

Again, when time (t) = 3 s, then distance (s) = 27 m

So, $(3)^3 = 3 \times 3 \times 3 = 27$, and so on.

Thus, from the given distance and time values, we conclude that:

$$\text{distance} \propto (\text{time})^3$$

or $$s \propto t^3$$

So, in this question, the 'distance' travelled by the object is proportional to the 'cube of time'. Now:

(*i*) when the distance travelled is proportional to time ($s \propto t$), then the object has constant velocity (or uniform velocity) and hence acceleration in that case would be zero (This is because $s = ut + \frac{1}{2}at^2$, so when a = 0, then $s = ut$ or $s \propto t$). But since in this question, $s \propto t^3$, so the acceleration in this case cannot be zero).

(*ii*) when the distance travelled is proportional to the square of time ($s \propto t^2$), then the object has constant acceleration (This is because $s = ut + \frac{1}{2}at^2$, that is, $s \propto t^2$). But since in this question, $s \propto t^3$, so the acceleration in this case cannot be constant.

(*iii*) The data given in this question shows that the distance travelled is proportional to the cube of time ($s \propto t^3$), therefore, the conclusion drawn is that the acceleration is increasing uniformly with time.

(*b*) We know that Force = mass × acceleration or $F = m \times a$. In other words $F \propto a$ or acceleration is proportional to the force applied. Now, since the acceleration of the object in this case is increasing uniformly with time, therefore, the forces acting on the object must also be increasing uniformly with time.

Q.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).

Ans. Suppose each person applies a force F to push the motorcar.

So, Total force applied by two persons $= F + F$

$$= 2F \quad ...(1)$$

Since this force ($2F$) gives a uniform velocity to the motorcar along a level road (where work is done only against the force of friction), so the force $2F$ can be taken as being equal to the force of friction f between the motorcar and the road. That is,

$$\text{Force of friction,} \quad f = 2F \quad ...(2)$$

Now, when three persons apply force to push the motorcar, then:

Total force applied by three persons $= F + F + F$

$$= 3F \quad ...(3)$$

Now, the total force applied by three persons is 3F whereas the opposing force of friction is f. So,

$$\text{Force that produces acceleration} = 3F - f \quad ...(4)$$

But from equation (2), we have $f = 2F$. So,

$$\text{Force that produces acceleration} = 3F - 2F$$

or $$\text{Force that produces acceleration} = F$$

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

or, $$F = m \times a$$

$$F = 1200 \times 0.2 \text{ N}$$

$$F = 240 \text{ N}$$

Thus, each person pushes the motorcar with a force of 240 newtons.

Q.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?

Ans. Here, $$\text{Mass, } m = 500 \text{ g}$$

$$= \frac{500}{1000} \text{ kg}$$

$$= 0.5 \text{ kg}$$

We will now calculate the acceleration.

Now, Initial velocity, $u = 50\ \text{m s}^{-1}$

Final velocity, $v = 0$ (The hammer stops)

Acceleration, a =? (To be calculated)

And, Time, $t = 0.01$ s

Now, $v = u + at$

So, $0 = 50 + a \times 0.01$

$0.01\,a = -50$

$$a = -\frac{50}{0.01}$$

$a = -5000\ \text{m s}^{-2}$

We know that: Force, $F = m \times a$

So, $F = 0.5 \times (-5000)$ N

$F = -2500$ N

Thus, the force of the nail on the hammer is 2500 newtons. The negative sign indicates that this force is opposing motion.

Q.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. (*a*) *Calculation of acceleration*

Here, Initial velocity, $u = 90$ km/h

$$= \frac{90 \times 1000\ \text{m}}{60 \times 60\ \text{s}}$$

$= 25$ m/s

Final velocity, $v = 18$ km/h

$$= \frac{18 \times 1000\ \text{m}}{60 \times 60\ \text{s}}$$

$= 5$ m/s

Acceleration, a =? (To be calculated)

And, Time, $t = 4\ s$

Now, $v = u + at$

$5 = 25 + \text{a} \times 4$

$4\,a = 5 - 25$

$4\,a = -20$

$$a = -\frac{20}{4}$$

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

Thus, the acceleration of the motorcar is, – 5 m/s^2. It is actually negative acceleration or retardation.

(*b*) *Calculation of change in momentum*

$$\begin{aligned} \text{Change in momentum} &= mv - mu \\ &= 1200 \times 5 - 1200 \times 25 \\ &= 6000 - 30000 \\ &= -24000 \text{ kg. m/s} \end{aligned}$$

Thus, the change in momentum is 24000 kg. m/s

(c) *Calculation of magnitude of force*

$$\text{Force,} \quad F = m \times a$$
$$F = 1200 \times (-5)$$
$$F = -6000 \text{ N}$$

Thus, the magnitude of force required is 6000 newtons. The negative sign shows that this force is opposing the motion.

Q.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. (*a*) As the action (force) and reaction (force) are equal and opposite, both the vehicles experience the same force on collision.

(*b*) Since the change in momentum of truck is equal and opposite to the change in momentum of car, both the vehicles experience equal change in momentum.

(*c*) As the force on each vehicle is the same but the mass of car is smaller than the truck, therefore, the car experiences the greater acceleration (or greater retardation) $\left(\text{because } a = \dfrac{F}{m}\right)$.

(*d*) Since the car is much lighter than the truck, therefore, the car is likely to suffer more damage during the collision than the truck (The car has greater retardation than the truck).