Chapter 9

Force and Laws of Motion

Intext Questions

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Question 1:Which of the following has more inertia?

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

(b) A bicycle and a train?

(c)A five-rupee coin and a one-rupee coin?

Solution:Inertia of an object is the measurement of its mass. (a) A stone of same size as that of rubber ball will have a greater mass because the stone will have more inertia.

(b) A train has much greater mass than that of a bicycle, so the train will have more inertia.

(c) A five-rupee coin has more mass than a one-rupee coin, so five-rupee coin will have greater inertia.

Question 2:In the following example, try to identify the number of times the velocity of the ball changes: "A football player kicks a football to another player of his team who kicks the football towards the goal.

The goalkeeper of the opposite team collects the football and kicks it towards a player of his own team." Also identify the agent supplying the force in each case.

Solution:Given below are the number of times at which the velocity of the ball changes.Whenever a force will be applied on the ball then the velocity of the ball will change.

a) When first player kicks the ball towards another player of his team then the velocity of ball will change because first player applies some force on the ball.

b) When another player kicks the ball towards the goal, then the velocity of ball will change, here again the force is applied on the ball.

c) When goalkeeper of the opposite team collects the ball, then the velocity of ball will change, it becomes zero. Here the goalkeeper applies some force on the ball to stop.

d) When the goalkeeper kicks the ball towards his own team, the velocity of the ball changes because goalkeeper applies some force on the ball.

Question 3:Explain why some of the leaves may get detached from a tree if we vigorously shake its branch?

Solution:We know that the leaves are attached to the tree and are in a state of rest initially. But when the tree is vigoursly shaken, the branches of the tree comes in the state of motion but the leaves tend to maintain their state of rest, as a result the leaves get detached from the tree and fall down.

Question 4:Why do you fall in the forward direction when a moving bus brakes to a stop and fall backwards when it accelerates from rest?

Solution:Initially when the bus is at rest our body also follows the same state. But all of a sudden when the bus starts to move the lower part of our body tends to move with the motion of the bus, but the upper part rejects this state of motion and continues to be in a state of rest. This results in a sudden jerk backwards when a bus moves. Also, a person standing in a bus will be in a state of motion, and when the brakes are applied the lower part of our body comes to the state of rest but our upper part is in a state of motion. Hence, we tend to fall forward when the bus applies brakes.

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Question 1:If action is always equal to the reaction, explain how a horse can pull a cart?

Solution:Inorder to pull the cart horse pushes the ground with its foot in the backward direction by pressing the ground. As a reaction of this force, the ground pushes the horse in forward direction. As a result the cart is pulled by the horse in the forward direction.

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

Solution:From Newton's Third Law, we know that every action has an equal and opposite reaction. So when a fireman holds a hose-pipe which is ejecting a large amount of water at a high velocity experiences a backward push due to the force of water flowing in the forward direction.

Hence, making it clear that due the action of force in the forward direction the force is applied on the pipe in the backward direction, thus making the fireman difficult to hold the hose-pipe.

Question 3:From a rifle of mass 4 kg, a bullet of mass 50g is fired with an initial velocity of 35 ms-1. Calculate the initial velocity of the rifle.

Solution: Mass of gun $M = 4$ kg

Mass of bullet $m = 50$ g

$= 50 \times 10^{-3}$ kg

Initial velocity of bullet, $v = 35\ ms^{-1}$

Let recoil velocity of the gun be $v\ ms^{-1}$

Before firing the bullet both gun and bullet were in rest so total mom
zero. After firing

$$\text{Momentum of bullet} = mv$$

$$\text{Momentum of gun} = Mv$$

Total momentum of bullet and gun after firing $= mv + Mv$

Since, there is no external force applied on the system.

So, total momentum after firing = total momentum before firing

$$mv + Mv = 0$$

$$Mv = -mv$$

$$\Rightarrow \qquad v = -\frac{mv}{M}$$

$$= \frac{50 \times 10^{-3} \times 35}{4} = -0.44 ms^{-1}$$

Here negative sign shows that the recoil velocity of the gun is in the direction opposite to the velocity of the bullet.

Question 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 - t, 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.

Solution: Before collision,

$$m_1 = 100\,g = \frac{100}{1000} = 0.1\text{ kg}$$

$$m_2 = 200\,g = \frac{200}{1000} = 0.2\text{ kg}$$

$$v_1 = 2\text{ms}^{-1}$$

$$v_2 = 1\text{ms}^{-1}$$

After collision,

$$m_1 = 100g = 0.1\text{ kg}$$

$$m_2 = 200g = 0.2\text{ kg}$$

$$v_1' = 1.67\text{ms}^{-1}$$

(Since,

1kg = 1000g)

Let velocity of second object after collision is v2ms-1. Since, there is no external force on the system.

Exercises

Question 1:An object experiences a net zero external unbalanced force. Is it possible for the object to be travelling with a non-zero velocity? If yes, state the conditions that must be placed on the magnitude and direction of the velocity. If no, provide a reason.

Solution:According to the Newton's 1st law of motion, no net force is required to move an object which is moving with a constant velocity. So, when an object experiences a net zero external unbalanced force, then it can move with a non-zero velocity. Also, if an object is initially at rest not net force acts upon it, thus the object may not move at all.

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

Solution:When a carpet is beaten with a stick, then the fibers of the carpet attain the state of motion while the dust particles remain in rest due to inertia of rest. Therefore, the dust particles fall down.

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

Solution:It is advised to tie any luggage kept on the roof of a bus because when the bus stops suddenly, it readily comes in the state of rest but the luggage remains in the state of motion. So, due to inertia of motion, the luggage will move forward and would fall down from the roof of the bus.

If the bus starts suddenly, then bus comes in the state of motion but luggage remains in the state of rest. Due to inertia of rest, the luggage moves in the backward direction and will fall down.

Question 4:A batsman hits a cricket ball which then rolls on a level ground. After covering a short distance, the ball comes to rest. The ball slows to a stop because

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

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

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

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

Solution:(c) because the ball slows down to rest as the force of friction acting between the ground and the ball opposes the motion of the ball.

Question 5:A truck starts from rest and rolls down a hill with a constant acceleration. It travels a distance of 400 m in 20 s. Find its acceleration.

Find the force acting on it if its mass is 7 tons.
(Hint: 1 ton = 1000 kg).

Solution:The truck starts from rest, so initial velocity u = 0,

Distances= 400 m, t= 20 s, m= 7 tons = 7 × 1000 = 7000 kg,

From 2nd equation of motion,

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

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

$$400 = 200a$$

$$\Rightarrow \quad a = 2\text{ms}^{-2}$$

From Newton's 2nd law of motion, force acting on the truck

$$F = ma$$

$$= 7000 \times 2 = 14000\text{N}$$

$$= 1.4 \times 10^4\,\text{N}$$

Question 6:A stone of size 1 kg is thrown with a velocity of 20 ms ? 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?

Solution:Mass of stone m = 1 kg, initial velocity u = 20 ms-1, Final velocity v= O (Therefore, the stone comes to rest), distance covered s= 50 m.

From third equation of motion,

$v2 = u2 + 2as$

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

$100a=-400\ a=-4ms-2$

Here negative sign shows that there is retardation in the motion of stone.

Force of friction between stone and ice = Force required to stop the stone

$= ma$

$= 1 \times -4 = -4N$ OR $4N$

Question 7:A 8000 kg engine pulls a train of 5 wagons, each of 2000 kg, along a horizontal track. If the engine exerts a force of 40000 N and the track offers a friction force of 5000 N, then calculate:

(a)The net acceleration force,

(b)The acceleration of the train and

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

Solution:(a) Net accelerating force = Force exerted by engine–Friction force (Here frictional force is subtracted because it opposes the motion)

= 40000 –5000 = 35000 N

= 3.5×10^4N

(b) From Newton's second law of motion,

Accelerating force = Mass of the train × Acceleration of train

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

Mass of train = Mass of engine + Mass of all wagons

= 8000 + 5 × 2000

= 8000 + 10000 = 18000 kg

$$\text{Acceleration} = \frac{35000}{18000} = \frac{35}{18} = 1.95\,ms^{-2}$$

(c) Force of wagon 1 on wagon 2

= Mass of the engine × Acceleration

= 800 × 1.95 = 15600 N

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

Solution:Mass, m= 1500 kg, Acceleration, a= –1.7 ms-2

From Newton's second law of motion,

F ma

= 1500 × (–1.7)

= –2550 N

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

(a) (mv)2

(b) mv

(c) m2v

(d) mv

Answer: -(d) because the momentum of an object of mass m moving with a velocity v.

p = mv

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

Solution:The cabinet will move across the floor with constant velocity, if there is no net external force is applied on it.

Here a horizontal force of 200 N is applied on the cabinet, so for the net force to be zero, an external force of 200 N should be applied on the cabinet in opposite direction.

Thus, the frictional force = 200N

(Frictional force always acts in the direction opposite to direction of motion.)

Question 11:Two objects, each of mass 1.5 kg, are moving in the same straight line but in opposite directions. The velocity of each object is 2.5 ms-1before the collision during which they stick together. What will be the velocity of the combined object after collision?

Solution:Mass of first object, m1= 1.5 kg

Mass of second object,m2= 1.5 kg

velocity of first object before collision, u1= 2.5 ms-1
velocity of second object before collision,u2= -2.5 ms-1

(Here negative sign is taken because second object is moving in the direction opposite to the direction of motion of first object).

Mass of combined object after collision

M= m1+ m2 (Since, they stick together)

= 1.5 + 1.5 = 3kg

Let velocity of combined object after collision be vms-1.

Here there is no external force, so from law of conservation of momentum.
Momentum after collision = Momentum before collision

mv= m1u1+ m2u2

3xv=1.5 x 2.5 + 1.5(-2.5)=0

v=0

Question 12:According to the third law of motion, when we push on an object, the object pushes back on us with an equal and opposite force. If the object is a massive truck parked along the roadside, it will probably not move. A student justifies this by answering that the two opposite and equal forces cancel each other.

Comment on this logic and explain why the truck does not move.

Solution:The logic given by the student is not correct because two equal and opposite forces cancel each other only in the case if they act on the same body. According to Newton's third law, action and reaction force always act on two different bodies, so they cannot cancel each other. When a massive truck is pushed, then the truck may not move because the force applied is not sufficient to move the truck.

Question 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 5ms -1. Calculate the

change of momentum

occurred in the motion of the hockey ball by the force applied by the hockey stick.

Solution: Mass of hockey ball

m= 200 g = 0.2 kg

Initial velocity, u= 10ms -1

Final velocity, v= –5ms -1

(Since, final velocity of the ball is in the direction opposite to the direction of initial velocity.)
Change in momentum of the ball = Final momentum – Initial momentum

= mv–mu

= m(v–u)

= 0.2 (–5–10)

= 0.2 ×–15 = –3 kg ms–1

Question 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.

Solution:

Mass of bullet, $m = 10\text{ g} = \frac{10}{1000}\text{kg} = 0.001\text{kg}$

Initial velocity, $u = 150\text{ ms}^{-1}$

Final velocity, $v = 0$ (Since, the bullet

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

From equation of motion,

$$v = u + at$$

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

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

$$= -5000\text{ ms}^{-2}$$

Magnitude of the force applied by the bullet on the block, $F = ma$

$$= 0.01 \times -$$

Question 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.

10 = 1.67ms-1

Solution:

Mass of object, $m_1 = 1$ kg, Velocity, $u = 10$ ms^{-1}

Mass of wooden block, $m_2 = 5$ kg, Velocity, $u_2 = 0$ (Since, w

Total momentum just before the impact = Momentum of object + Mo

$$= 1 \times 10 + 5 \times 0 = 10 \text{ kg ms}^{-1}$$

According to law of conservation of momentum,

Momentum after impact = Momentum before impact

$$(m_1 + m_2)v = 10$$

where, v = velocity of combined object

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

v = ---- 6

Question 16:An object of mass 100 kg is accelerated uniformly from a velocity of 5 ms-1 to 8ms-1in 6 s. Calculate the initial and final momentum of the object. Also, find the magnitude of the force exerted on the object.

Solution:

Mass of the object, m= 100 kg,

Initial velocity, u= 5 ms-1

Final velocity, v= 8 ms-1

(i) Initial momentum =mu= 100 x 5=500 kg-ms-1

Final momentum = mv = 100 x 8 = 800 kg-ms-1

(ii) From Newton's second law,

Force exerted on the object = Rate of change of momentum

Change in momentum

= --------------------------

Time

Final momentum- Initial momentum

= ---

Time

$$= \frac{800-50}{6} = \frac{300}{6} = 50N$$

Question 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 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 of these suggestions.

Solution:The explanation given by Rahul is correct, as there is no external force on the system, so both the insect and motorcar experienced the same force and a change in momentum.

Question 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?

Solution: m= 10 kg,u= 0 (Since the dumb-bell falls from rest)

Distance covered, s= 80cm = 0.8m

a= 10 ms-2

From equation of motion, v2=u2+ 2as

v2= 0 + 2 × 10 × 0.8 = 16

$$v = \sqrt{16} = 4 \text{ ms}^{-1}$$

Momentum of dumb-bell just before it touches the floor

$$p = mv$$

$$= 10 \times 4$$

$$= 40 \text{ kg-ms}^{-1}$$

When the dumb-bell touches the floor, its velocity becomes zero. Thus, the total momentum of the dumb-bell is transferred to the floor.
Hence, the momentum transferred to floor = 40 kg-ms-1.