9 Force and Laws of Motion

IMPORTANT NOTES

1. **Force,** generally denotes push or pull.
2. **Force,** is defined as an external agent which changes or tends to change the state of rest or uniform motion of the body or changes the direction of the body or deforms the body.
3. **Effects of force :**
   (i) A force can produce motion in stationary bodies.
   (ii) A force can stop moving bodies.
   (iii) A force can change the speed and direction of motion of bodies.
   (iv) A force can bring about change in dimensions of a body.
4. **Balanced forces :** Equal forces acting in the opposite directions, which do not change the state of rest or uniform motion of an object are said to be balanced forces.
5. **Unbalanced forces :** Unequal forces acting in opposite directions, which change the state of rest or uniform motion of an object are said to be unbalanced forces.
6. **Newton's first law of motion :** A body will continue in its state of rest or uniform motion in a straight line, unless compelled by some external force to change its state of rest or uniform motion.
7. **Inertia :** The property of matter, due to which it is incapable of changing its state of rest or uniform motion on its own is called inertia.
8. **Law of inertia :** The tendency of a body to continue in its state of rest or uniform motion in a straight line, even when some external force is applied, is called law of inertia.
9. **Inertia of rest :** The tendency of a body to continue in its state of rest, even when some external force is applied on it is called inertia of rest.
10. **Inertia of motion :** The tendency of a body to continue in its state of uniform motion in a straight line, even when some external force is applied on it is called inertia of motion.
11. **Momentum :** The force possessed by a body due to the combined effect of mass and velocity is called momentum. Mathematically, it is the product of mass and velocity i.e. $\boldsymbol{p = mv}$.
12. **Units of momentum :** Momentum is a vector quantity. Its unit in SI system is newton-second (N-s).
    1 N-s = 1 kg ms^{-1}
13. **Law of conservation of momentum :** In a given system, the sum total of momenta is a constant quantity and hence cannot be increased or decreased by applying an external force.
14. **Newton's second law of motion :** The rate of change of momentum of a body is directly proportional to the impressed force and takes in the same direction in which the force acts.
15. **Mathematically**, force is the product of mass and acceleration.
    $$F = ma$$
16. **Absolute units of force :** In C.G.S. system, absolute unit of force is dyne and in SI system is newton.
17. **Newton :** A force which produces an acceleration of 1 ms^{-2} in a body of mass one kilogram is called one newton.
    $$1N = 1\ kg \times 1ms^{-2}$$
18. **Gravitational** unit of force is known as **kilogram force (kgf)**.
19. **Kilogram force (kgf) :** A force which produces 9.8 ms^{-2} acceleration due to gravity of earth in a mass of one kilogram is called kilogram force.
    $$1\ kgf = 1\ kg \times 9.8\ ms^{-2} = 9.8\ N.$$
20. **Impulse or impulsive force :** When a force of large magnitude acts on a body for a very short interval of time, then the collective effect of force and time is called impulsive force.
21. **Unit of impulsive force :** SI unit of impulsive force is newton-second (N-s).
22. **Newton's third law of motion :** "To every action, there is an equal and opposite reaction."

I. VERY SHORT ANSWER QUESTIONS (1 Marks)

PREVIOUS YEARS' QUESTIONS

1. State Newton's first law of motion. **[2010 (T-I)]**

2. An athelete always runs some distance before taking a jump. Why? **[2010 (T-I)]**

3. Define 1 kg weight and express it in newton. **[2010 (T-I)]**

4. What is the mass of an object whose weight is 196 N? **[2010 (T-I)]**

5. Two similar vehicles are moving with the same velocity on the roads such that one of them is loaded and the other one is emply. Which of the two vehicles will require larger force to stop it ? Give reaons. **[2010 (T-I)]**

6. Is it possible that the train in which you are sitting appears to move while it is at rest? **[2010 (T-I)]**

7. Why do passengers in a bus tend to fall backward when it starts suddenly. **[2010 (T-I)]**

8. Which one has greater inertia : a stone of mass 1 kg or a stone of mass 5 kg ? **[2010 (T-I)]**

9. Name the physical quantity which is determined by the rate of change of linear momentum. **[2010 (T-I)]**

OTHER IMPORTANT QUESTIONS

1. Define the term 'force'.

2. Name two effects a force can bring about, other than moving or stopping a body.

3. What do you understand by the term inertia?

4. What determines the magnitude of inertia of a body?

5. Which has more inertia, a table tennis ball or a rubber ball of the same size?

6. What do you understand by the term momentum?

7. State two factors which determine the momentum of a body.

8. Is momentum a scalar or a vector quantity?

9. State the SI unit of momentum.

10. A body P has mass 2 *m* and velocity 5 *v*. Another body Q has mass 8 *m* and velocity 1.25 *v*. Which of the two has more momentum?

11. The magnitude of a physical quantity is 8.5 Ns. Name the physical quantity.

12. State the law of conservation of momentum.

13. State Newton's third law of motion.

14. State two factors which determine the force possessed a body.

15. Name and define the unit of force in SI system.

16. A force of 36 N acts on a body of mass 12 kg. What is the acceleration of the body?

17. A body is acted by a force of 15 kgf. What is force acting on a body in SI system?

Take 'g' = 9.8 m/s^2.

18. What is the mass of a body having a force of 5.7 kgf?

II. SHORT ANSWER QUESTIONS – I (2 Marks)

PREVIOUS YEARS' QUESTIONS

1. What would happen if a fielder stops the fast moving ball suddenly? Justify your answer. **[2010 (T-I)]**

2. (a) Why does the rider fall in the forward direction when a running horse stops suddenly?

(b) Why is it easier to stop a tennis ball in comparison to a cricket ball moving with the same speed ? **[2010 (T-I)]**

3. A bullet of mass 25 g is fired horizontally with a velocity of 100 m/s from a gun of mass 5 kg. Calculate the recoil velocity of the gun. **[2010 (T-I)]**

4. Why do we jerk wet clothes before spreading them on line? **[2010 (T-I)]**

5. Give reasons for :

(a) When a carpet is beaten with a stick, dirt comes out of it.

(b) It is difficult for a fireman to hold a hose which ejects large amount of water at high velocity. **[2010 (T-I)]**

6. (a) State Newton's third law of motion.

(b) In collision between a heavier body and a lighter body, how do the forces experienced by the two bodies compare ? **[2010 (T-I)]**

7. Which is having higher value of momentum ?

A bullet of mass 10 g moving with a velocity of 400 m/s or a cricket ball of mass 400 g thrown with the speed of 90 km/hr. **[2010 (T-I)]**

8. 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 ? **[2010 (T-I)]**

9. Calculate the force required to produce an acceleration of 2 ms^{-2} in a body of mass 10 kg. **[2010 (T-I)]**

10. It is difficult to balance our body when we accidentally slip on a peel of banana. Explain why? **[2010 (T-I)]**

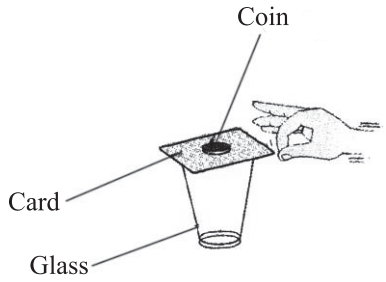
11. A bullet of mass 50 g is horizontally fired with a velocity of 35 m/s form a pistol of mass 4 kg. Calculate the recoil velocity of the pistol. **[2010 (T-I)]**

12. It is dangerous to jump out of a moving bus. Explain why ? **[2010 (T-I)]**

13. While catching a fast moving ball, fielder gradually pulls his hand backwards. Give reasons. **[2010 (T-I)]**

14. Give a simple experiement to illustrate the inertia of rest. **[2010 (T-I)]**

15.

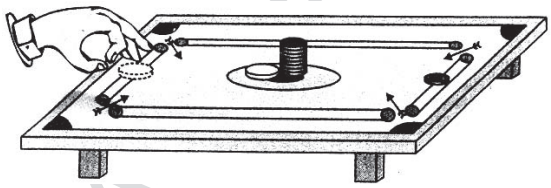


In the above experimental set-up, a student given the card a sharp, fast horizontal flick with a finger.

(a) What will happen to the coin?

(b) Write reasons for your answer. **[2010 (T-I)]**

16.



In the figure above, a pile of similar coins is hit very strongly at the bottom of the pile by a striker. What will happen to the :

(i) Lowest coin (ii) Rest of the coins

(iii) Why ? **[2010 (T-I)]**

OTHER IMPORTANT QUESTIONS

1. Why do fruits fall down from the branches of a tree, when the branches are shaken vigorously? Explain.

2. Why is it dangerous to jump out of a moving vehicle? How can the danger be minimised?

3. Why are we not hurt at all, while diving in a deep water tank from a height of 10 m?

4. Why are long jump athletes made to jump in sand pits?

5. Why are glass or porcelain articles packed in straw or foam?

6. Why is it difficult to climb up a greased pole?

7. Why does a balloon fully inflated with air rise up vertically for some distance when punctured from below?

8. Why does a boatman tie his boat to a pillar, before allowing the passengers to step on the river bank?

9. Why is it difficult to walk on sandy or marshy soil?

10. Why does a truck driver put solid bricks or a wooden plank under the wheel of his truck which is struck in the soft mud?

III. SHORT ANSWER QUESTIONS – II (3 Marks)

PREVIOUS YEARS' QUESTIONS

1. A man pushes a box of mass 50 kg with a force of 80 N. What will be the acceleration of the box due to this force? What would be the acceleration if the mass were doubled ? **[2010 (T-I)]**

2. (a) State Newton's third law of motion.

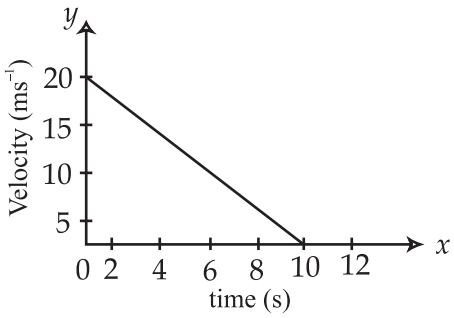
(b) In the following table the mass and speed of two bodies are given. Which body has more momentum? Justify your answer. **[2010 (T-I)]**

Body	Mass (kg)	Speed (m/s)
A	1	10
B	2	9

3. A bullet of mass 20 g is horizontally fired from a pistol of mass 2 kg with a horizontal velocity of 150 m/s. Calculate the recoil velocity of the pistol. **[2010 (T-I)]**

4. The velocity-time graph of a ball of mass 20 g moving along a straight line on a level ground is given below. How much force does the ground exert on the ball to bring it to rest?

[2010 (T-I)]



5. 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 40,000 N and the track offers a friction force of 5,000 N then calculate:

(a) the net accelerating force

(b) the acceleration of the train

(c) the force of the wagon 1 on rest of the wagons. **[2010 (T-I)]**

6. (a) State the law of inertia.

(b) A body of mass 5 kg is moving with a uniform velocity of 10 m/s. It is acted upon by a force of 20 N. What will be its velocity after 1s? **[2010 (T-I)]**

7. State the action and reaction in the following:

(a) moving rocket

(b) firing of a bullet from a gun

(c) a person walking on the floor **[2010 (T-I)]**

8. Two balls A and B of masses 'm' and '2 m' are in motion with velocities '2 v' and 'v' respectively. Compare

(i) their inertia

(ii) their momentum and

(iii) the force needed to stop them in the same time. **[2010 (T-I)]**

9. 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 moves at a velocity of 1.67 ms^{-1}. Determine the velocity of the second object. **[2010 (T-I)]**

10. A truck starts from rest and rolls down a hill with a constant acceleration. It travels a distance of 400 m in 20 seconds. Find the acceleration. Find the force acting on it if its mass is 7 metric tonne. [**Hint** 1 metric tonne = 1000 kg].

[2010 (T-I)]

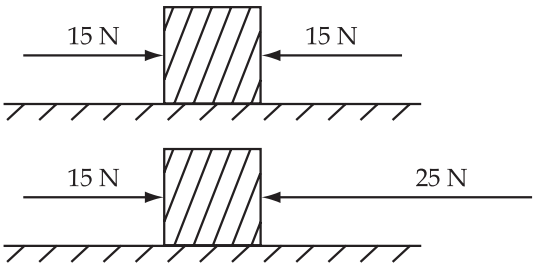
11. According to the third law of motion when we push on an object, the object pushes back on us with an equal and opposite force. If the object is a massive truck parked along the road side, it will probably not move. A student justifies this by answering that the two opposite and equal forces cancel each other. Comment on this logic and explain why the truck does not move.

[2010 (T-I)]

12. State Newton's second law of motion. Write its mathematical expression. How can you state first law from it ? **[2010 (T-I)]**

13. (a) State first law of motion.

(b) Look at the diagrams given below and answer the following questions.



In which case will the object move and in which direction? Give reason in support of your answer. **[2010 (T-I)]**

14.

Look at the diagram above and answer the following questions : **[2010 (T-I)]**

(a) When a force is applied through the free end of the spring balance A, the reading on the spring balance A is 15 gwt. What will be the measure of the reading shown by spring balance B?

(b) Write reasons for your answer.

(c) Name the force which balance A exerts on balance B and the force of balance B on balance A.

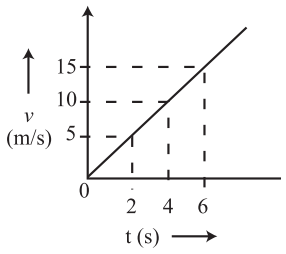
15. The motion of a body of mass 5 kg is shown in the *v-t* graph.

Find from graph

(a) its acceleration

(b) the force acting on the body

(c) the change in momentum of the body in 2 seconds after start



[2010 (T-I)]

OTHER IMPORTANT QUESTIONS

1. A cyclist and a person on a bike are acted upon by the same force. If the acceleration produced by the cyclist is 2/5 that of the biker, calculate the ratio of the mass of the cyclist and the biker.

2. A force of 100 N gives a body of mass m_1 an acceleration of 5 ms^{-2}. The same force can give an acceleration of 40 ms^{-2} to another body of mass m_2. If both the bodies are tied together and acted upon by the same force as above, what acceleration is produced in the combination?

3. A cannon of mass 0.5 t recoils with a velocity of 0.8 m/s, while firing a shell of mass 4 kg. Calculate the velocity at which the shell leaves the cannon.

4. A cricket player holds a cricket ball of mass 0.1 kg by moving his hands backward by 0.75 m. If the initial velocity of the ball is 108 kmh^{-1}, calculate the retarding force applied by the player.

5. A railway wagon of mass 0.5 t and moving with a velocity of 10 kmh^{-1} is hit from behind by another railway wagon of mass 1.5 t and moving with 15 kmh^{-1}, such that after collision they move together. Calculate the final velocity of the wagon.

6. A bullet of mass 0.03 kg and moving with velocity '*x*' hits a target with a force of 187.5 N. If the bullet penetrates 0.80 m in the target, find the value of '*x*'.

7. A golfer hits a ball at rest, such that the contact between the ball and the golf stick is 0.1 s. If the golf ball covers a linear distance of 200 m in 2 s, calculate the magnitude of the force applied, assuming there is no friction and the mass of the golf ball is 50 g.

8. Calculate the force required to stop a car of mass 1000 kg and a loaded truck of mass 10,000 kg in 2 seconds, if they are moving with the same velocity of 5 ms^{-1}.

IV. LONG ANSWER QUESTIONS (5 Marks)

PREVIOUS YEARS' QUESTIONS

1. (a) State Newton's 1st and 3rd law of motion.

(b) A car of mass 1800 kg moving with a speed of 10 m/s is brought to rest after a covering a distance of 50 m. Calculate the force acting on the car. **[2010 (T-I)]**

2. (a) State Newtons's second law of motion. Use this law to find a method to measure force acting on an object.

(b) From a rifle of mass 4 kg a bullet of mass 50 g is fired horizontally with an initial velocity of 40 ms^{-1}. Calculate the initial recoil velocity of the rifle. **[2010 (T-I)]**

3. (a) How much momentum will an object of mass 10 kg transfer to the floor, if it falls from a height of 0.8 m? ($g = 10\ m/s^2$).

(b) Explain why is it difficult for a fireman to hold a hose, which ejects large amount of water at a high velocity. **[2010 (T-I)]**

4. (a) Using Newton's law of motion, derive the relation between force and acceleration.

(b) Define one newton.

(c) Which would require a greater force to accelerate a 1/2 kg mass at 5 m/s^2 or a 4 kg mass at 2 m/s^2? Give reason. **[2010 (T-I)]**

5. (a) Define inertia. There are three solids ball, made up of aluminium, steel and wood, of same shape and volume. Which of them would have highest inertia ? Why ?

(b) Describe in brief an activity to illustrate the property of inertia of rest. **[2010 (T-I)]**

6. (a) Define S.I. unit of force.

(b) Mention any two effects of force.

(c) A body of mass 60 kg has a momentum of 300 kg m/s. Calculate its velocity.

(d) Why does a carpet beaten with a stick releases dust? **[2010 (T-I)]**

7. (a) Action and reaction are equal and opposite but even then they do not cancel each other. Why?

(b) Explain why it is dangerous to jump out of a moving bus?

(c) A machine gun can fire 50 g bullets with a velocity of 150 m/s. A 60 kg stone is moving towards the machine gun velocity of 10 m/s. How many bullets must be fired from the gun to just stop the stone in its tracks? **[2010 (T-I)]**

8. (a) Explain why it is difficult to walk on sand?

(b) Why does the recoil of a heavy gun on firing not so strong as a light gun using the same cartridges?

(c) A constant force acts on an object of 5 kg for a period of 2 s. It increases the velocity of the object from 3 m/s to 7 m/s. Find the magnitude of the applied force. Now, if the force were applied for a period of 5 s, what would be the final velocity of the object? **[2010 (T-I)]**

9. (a) It is mass of a body is doubled, what happens to its acceleration when acted upon by the same force ?

(b) It is easier to stop a tennis ball than a cricket ball moving with the same speed. Why?

(c) A girl of mass 40 kg jumps with a horizontal velocity of 5 ms^{-1} on to a stationary cart with frictionless wheels. The mass of the cart is 3 kg. What is her velocity as the cart starts moving? **[2010 (T-I)]**

10. (a) What happens to a person travelling in a bus when the bus takes a sharp turn?

(b) A cricketer moves his hands backwards on catching a fast moving ball. Why ?

(c) A bullet of mass 0.02 kg is fired by a gun of mass 100 kg. If the speed of the bullet is 80 ms^{-1}. Calculate the recoil speed of the gun? **[2010 (T-I)]**

11. (a) State Newton's first law of motion and also deduce it using second law.

(b) A steam engine of mass 3×10^4 kg pulls two wagons each of mass 2×10^4 kg with an acceleration of 0.2 ms^{-2}, neglecting frictional forces, calculates the : **[2010 (T-I)]**

(i) force exerted by the engine.

(ii) force experienced by each wagon.

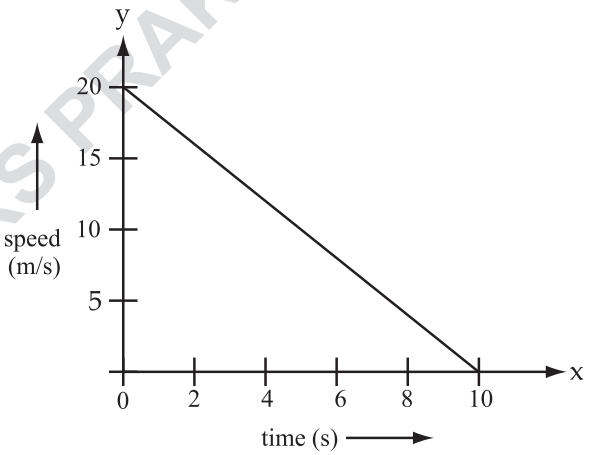
12. (a) In a high jump event the athletes are made to fall on a sand bed or on a cushioned bed. Why?

(b) Define momentum. State its S.I. unit.

(c) An object of mass 10 kg is accelerated uniformly from rest to a velocity of 8 m/s in 6 s, calculate the final momentum of the object. **[2010 (T-I)]**

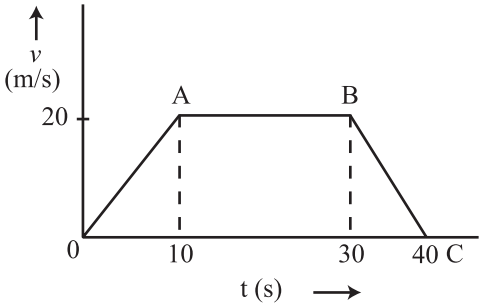
13. (a) State Newton's second law of motion. Give its mathematical expression and hence define the unit of force.

(b) The velocity-time graph of a ball of mass 20 g moving along a stright line on a long table is given in fig. How much force does the table exert on the ball to bring it to rest. **[2010 (T-I)]**



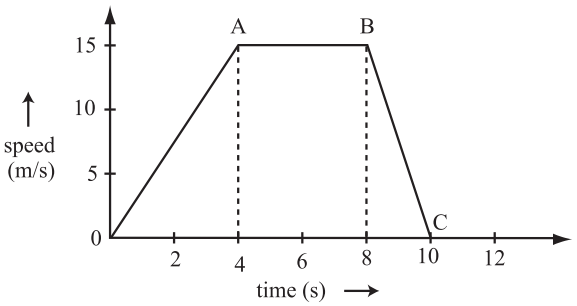
14. (a) Define force and give its S.I. unit.

(b) For a mass of 2 kg of v-t graph is given. Find the force experienced by the mass in OA, AB and BC. **[2010 (T-I)]**



15. (a) Define force and its S.I. unit.

(b) The speed-time graph of a car of 1000 kg mass is given below. From the graph answer the following: **[2010 (T-I)]**



(i) When is the maximum force acting on the car? Why?

(ii) What is the retarding force?

(iii) For how long is there no force acting?

16. (a) State second law of motion. Give its mathematical expression.

(b) How will you define unit of force using this law ?

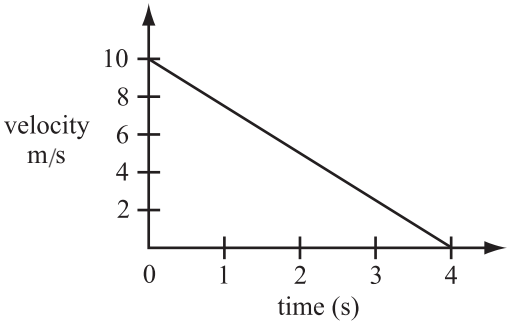
(c) Calculate the mass of a body. When a force of 525 N produce an acceleration of 3.5 m/s^2. **[2010 (T-I)]**

17. (a) Define inertia. Name the physical quantity that measures it.

(b) It is necessary to run along with the moving bus in the same direction of the bus, while alighting from bus. Give reason.

(c) Calculate the magnitude of force required to produce an acceleration of 2 m/s^2 in a body of mass 12.5 kg. **[2010 (T-I)]**

18. The velocity-time graph of a ball of mass 25 g moving on road is as given below:



(a) How much force does the road exert on the ball to bring it to rest?

(b) What is the direction of the force exerted by the road?

(c) Define one unit of force. **[2010 (T-I)]**

19. An object of mass 200 kg is accelerated uniformly from a velocity of 10 m/s to 20 m/s in two seconds,

Calculate :

(a) initial momentum

(b) Final momentum of the object

(c) Magnitude of the force exerted on the object

(d) Does momentum have direction ? If yes, how is it specified?

(e) Name two factors on which change of momentum depends. **[2010 (T-I)]**

OTHER IMPORTANT QUESTIONS

1. (i) A horse develops a momentum of 3000 Ns, while running at 15 m/s. Calculate the mass of the horse.

(ii) A bullet of mass 10 g is fired with a rifle. The bullet takes 0.003 s to move through the barrel and leaves with a velocity of 300 ms^{-1}. What is the force exerted on the bullet by the rifle?

(iii) Calculate the momentum of an electron of mass 9×10^{-31} kg, moving with a velocity of 6×10^7 m/s.

(iv) What will be the acceleration of a body of mass 5 kg, if a force of 200 N is applied on it?

(v) A boy of mass 30 kg while running, develops a momentum of 180 Ns. Calculate the velocity of the boy.

2. Give reasons :

(i) It difficult to balance our body, when we accidentally step on a peel of a banana.

(ii) Pieces of bursting cracker fall in all possible directions.

(iii) A glass pane of a window is shattered, when a flying pebble hits it.

(iv) It is easier to stop a tennis ball than a cricket ball moving at the same speed.

(v) A javelin thrower is marked foul, if an athlete crosses over the line marked for the throw. Athletes often fail to stop themselves before the line.

3. (i) What do you understand by the term force?

(ii) State the law of conservation of momentum.

(iii) Define Newton.

(iv) What do you understand by unbalanced force?

(v) Define the term impulse.

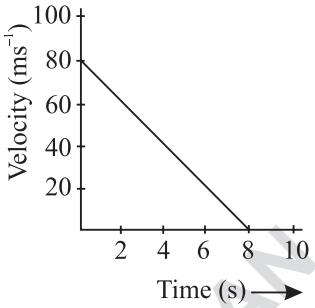
4. (i) A car of mass 1000 kg moving with a velocity of 40 kmh^{-1} collides with a tree and comes to stop in 5 s. What will be the force exerted by the car on the tree?

(ii) Why do droplets of water come out when a wet cloth is jerked?

5. (i) State Newton's second law of motion and prove $F = ma$.

(ii) Quicksand consists of very smooth and tiny grains of sand. What could happen, if a man or a heavy animal steps over a patch of such sand in a desert?

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



ASSIGNMENTS FOR FORMATIVE ASSESSMENT

A. Science Quiz

1. The inertia of _____ is responsible for the rider falling in the forward direction, when his horse stops suddenly.

2. It is difficult to walk on sandy beaches, because there is not enough _____ from the ground.

3. A truck whose rear wheel in stuck in mud can be pulled out by placing a thick _____ , _____ under the wheel.

4. Rockets rise up on the priniciple of _____ momentum.

5. The heavier is the gun, the _____ is its recoil velocity.

6. The unit of force in SI system is _____ .

7. The unit of momentum in SI system is ____.

8. Seat belts are provided in cars to arrest the inertia of _____.

9. Fruits fall off a tree when hit with a stone on account of inertia of _____ .

10. Weight is the _____ force acting on a body.

B. Group Discussions

1. Discuss the following in class with respect to momentum and third law of motion.

(i) When a cyclist moving at 18 km h^{-1} hits a wall, it is the cycle which gets damaged. However, if a truck moving at 18 km h^{-1}, hits the same wall, the wall gets damaged.

(ii) If you hit someone with a pistol bullet he may get slightly hurt. However, the same bullet when fired from the pistol, can kill the person.

(iii) When a bullet is fired from a rifle, it is the bullet which causes damage but not the recoiling gun.

(iv) A truck and a car is running at the same speed. The truck driver has to apply brakes from a greater distance as compared to the car driver, if they see an obstacle at the same time and from the same place.

2. Discuss the following situation in class.

(i) Why does one slip over a banana peel?

(ii) Why is it difficult to run on a 'kacha road' on a rainy day?

(iii) Why can a person run fast on a hard ground, but cannot swim that fast in water?

(iv) Why are paddles or screws provided to powered boats?

(v) Why do athletes wear shoes with nails under their soles?

(vi) How does a lawn sprinkler work?

(vii) The head of a hammer can be tightened onto the wooden handle by banging the bottom of the handle against a hard surface.

(viii) To dislodge ketchup from the bottom of a ketchup bottle, it is often turned upside down and thrusted downward at high speed and then abruptly halted.

C. Activities

Activity 1

To find the effect of mass on the force (momentum) possessed by a body.

Materials Required

A ball of plastic (about 1 cm diameter), a ball of wood (about 1 cm diameter), a ball of glass (about 1 cm diameter) and a ball of iron or steel (about 1 cm diameter), an aluminium or plastic tray having a rim, kneaded mud, a rolling pin.

Procedure

1. Feel the weight of each ball with your hand. You will notice that the plastic ball is the lightest, followed by the wooden ball, glass ball and the heaviest is the steel ball.
2. Put wet mud in the plastic or aluminium tray. Roll the mud with a rolling pin, such that a smooth and even surface is formed.
3. Place the tray close to your feet. Take the plastic ball and hold it in line with your chin or nose. Gently allow the ball to drop in the mud tray. Notice that a small depression is created in the mud.
4. Repeat the procedure with the wooden ball, glass ball and iron ball. You will notice that the depth of depression increases as the balls get heavier.

Conclusions:

From the above activity, it can be concluded that force possessed by a falling body (or momentum) depends upon its mass. From the above statement it implies, that momentum of a body is directly proportional to its mass.

Activity 2

To find the effect of velocity on the force (momentum) possessed by a body.

Materials Required

A glass marble, a plastic or wooden tray, kneaded mud, a metre scale, a 15 cm plastic ruler.

Procedure

1. With help of metre scale, mark 50 cm, 80 cm, 110 cm, 140 cm, and 170 cm with a pencil on a wall.
2. Put the wet mud in the plastic or aluminium tray. Roll the mud with a rolling pin, such that a smooth and even surface is formed.
3. Place the mud tray along the wall on which markings 50 cm –170 cm are made.
4. Place the plastic rule along 50 cm mark and align a marble with it. Gently release the marble.
5. The marble makes a depression in the mud.
6. Repeat the procedure by slightly shifting the mud tray and allowing the marble to fall from 80 cm, 110 cm, 140 cm and 170 cm respectively. You will note that the depth of depression caused by the marble increases with height.

Conclusion

As the height from which the marble is made to drop increases its velocity correspondingly increases. Furthermore, with the increase in velocity, the depressions caused in mud becomes larger. From this it implies that force (momentum) possessed by the marble increases with the increases in velocity of the object. Thus, we can say

Force (momentum) $\propto$ velocity.

Activity 3

To demonstrate Newton's Third Law of Motion.

Materials Required

Rubber balloon, plastic tube or straw, thread, toy car.

Procedure

1. Tie the plastic tube to the balloon with the help of the thread. Blow air into it and inflate the balloon. Close the mouth of the tube with your thumb so that air does not escape.
2. Fix the inflated balloon on top of the toy car with the help of cellotape, keeping your thumb at the open end of the plastic tube so that air does not escape.

   Release the thumb and observe what happens.

Conclusions

(a) The balloon will move in a direction opposite to the direction in which air escapes.

(b) The car moves due to the reaction force exerted by the air on the balloon.

D. Experiment

Objective

To verify Newton's third law of motion.

Materials Required

Two spring balances preferably marked in newton's or dynes and without zero error, a 3 cm long nail and a hammer, a single fixed pulley, a set of slotted weights 50 g each, a light but strong thread.

Fig 1 : *Action and reaction forces are equal and opposite*

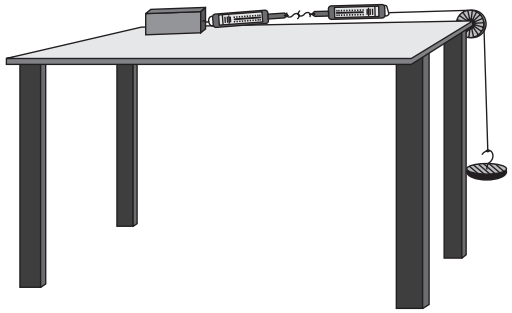


Fig 2 : *The experimental set up*

Procedure

1. Check each spring balance and make sure that they have no zero error.
2. Find the range and least count of each spring balance.

Note :- If the spring balance is marked in terms of mass (in grams), then in order to get force, multiply the mass with g = 9.8 ms^{-2}. (Please convert mass from grams to kilograms by dividing it 1000).

3. Hammer a nail in the wooden table. Fix the spring balances to the nail as shown in Fig 2.
4. Tie a string to the suspension ring of the balance A and pass it over the pulley.
5. To the other end of the string attach the hook of 50 g slotted weight.
6. Read the magnitude of mass/force from the spring balance A and B and record it.
7. Each time increase 50 g weight from the suspended slotted weight, read and record the reading for at least five times.

	Action force of spring balance A on B			Reaction force of spring balance B on A		
	Mass in(g)	Mass in (kg)	Force in (N) = mg	Mass in(g)	Mass in (kg)	Force in (N) = mg
1						
2						
3						
4						
5						

Conclusions

Action force of spring balance A is equal to reaction force of spring balance B on A. From this data it implies :

1. Action and reaction forces act on two different bodies.
2. Action and reaction are always equal, but act in opposite directions.

Class IX Chapter 9 – Force and Laws of Motion Science

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-rupees coin and a one-rupee coin?

Answer:

Inertia is the measure of the mass of the body. The greater is the mass of the body; the greater is its inertia and vice-versa.

(a) Mass of a stone is more than the mass of a rubber ball for the same size. Hence, inertia of the stone is greater than that of a rubber ball.

(b) Mass of a train is more than the mass of a bicycle. Hence, inertia of the train is greater than that of the bicycle.

(c) Mass of a five rupee coin is more than that of a one-rupee coin. Hence, inertia of the five rupee coin is greater than that of the one-rupee coin.

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.

Answer:
The velocity of the ball changes four times.

As a football player kicks the football, its speed changes from zero to a certain value. As a result, the velocity of the ball gets changed. In this case, the player applied a force to change the velocity of the ball. Another player kicks the ball towards the goal post. As a result, the direction of the ball gets changed. Therefore, its velocity also changes. In this case, the player applied a force to change the velocity of the ball. The goalkeeper collects the ball. In other words, the ball comes to rest. Thus, its speed reduces to zero from a certain value. The velocity of the ball has changed. In this case, the goalkeeper applied an opposite force to stop/change the velocity of the ball. The goalkeeper kicks the ball towards his team players. Hence, the speed of the ball increases from zero to a certain value. Hence, its velocity changes once again. In this case, the goalkeeper applied a force to change the velocity of the ball.

Question 3:

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

Answer:

Some leaves of a tree get detached when we shake its branches vigorously. This is because when the branches of a tree are shaken, it moves to and fro, but its leaves tend to remain at rest. This is because the inertia of the leaves tend to resist the to

and fro motion. Due to this reason, the leaves fall down from the tree when shaken vigorously.

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?

Answer:

Due to the inertia of the passenger
Every body tries to maintain its state of motion or state of rest. If a body is at rest, then it tries to remain at rest. If a body is moving, then it tries to remain in motion. In a moving bus, a passenger moves with the bus. As the driver applies brakes, the bus comes to rest. But, the passenger tries to maintain his state of motion. As a result, a forward force is exerted on him. Similarly, the passenger tends to fall backwards when the bus accelerates from rest. This is because when the bus accelerates, the inertia of the passenger tends to oppose the forward motion of the bus. Hence, the passenger tends to fall backwards when the bus accelerates forward.

Question 1:

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

Answer:

A horse pushes the ground in the backward direction. According to Newton's third law of motion, a reaction force is exerted by the Earth on the horse in the forward direction.

As a result, the cart moves forward.

Question 2:

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

Answer:

Due to the backward reaction of the water being ejected

When a fireman holds a hose, which is ejecting large amounts of water at a high velocity, then a reaction force is exerted on him by the ejecting water in the backward direction. This is because of Newton's third law of motion. As a result of the backward force, the stability of the fireman decreases. Hence, it is difficult for him to remain stable while holding the hose.

Question 3:

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.

Answer:

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

Bullet is fired with an initial velocity, $v_2 = 35\ \text{m/s}$

Initially, the rifle is at rest.

Thus, 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

$$4v_1 + 1.75 = 0$$

$$v_1 = -\frac{1.75}{4} = -0.4375 \text{ m/s}$$

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

Question 4:

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.

Answer:

Mass of one of the objects, m_1 = 100 g = 0.1 kg

Mass of the other object, m_2 = 200 g = 0.2 kg

Velocity of m_1 $v_1 = 2$ m/s before collision,

Velocity of m_2 $v_2 = 1$ m/s before collision,

Velocity of m_1 $v_3 = 1.67$ m/s after collision,

Velocity of m_2 after collision v_4 =

According to the law of conservation of momentum:

Total momentum before collision = Total momentum after collision

$$\therefore m_1 v_1 + m_2 v_2 = m_1 v_3 + m_2 v_4$$
$$(0.1)2 + (0.2)1 = (0.1)1.67 + (0.2)v_4$$
$$0.4 = 0.167 + 0.2\,v_4$$
$$\therefore v_4 = 1.165 \text{ m/s}$$

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

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.

Answer:
Yes. Even when an object experiences a net zero external unbalanced force, it is possible that the object is travelling with a non-zero velocity. This is possible only when the object has been moving with a constant velocity in a particular direction. Then, there is no net unbalanced force applied on the body. The object will keep moving with a non-zero velocity. To change the state of motion, a net non-zero external unbalanced force must be applied on the object.

Question 2:

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

Answer:

Inertia of an object tends to resist any change in its state of rest or state of motion. When a carpet is beaten with a stick, then the carpet comes to motion. But, the dust particles try to resist their state of rest. According to Newton's first law of motion, the dust particles stay in a state of rest, while the carpet moves. Hence, the dust particles come out of the carpet.

Question 3:

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

Answer:

When the bus accelerates and moves forward, it acquires a state of motion. However, the luggage kept on the roof, owing to its inertia, tends to remain in its state of rest. Hence, with the forward movement of the bus, the luggage tends to remain at its

original position and ultimately falls from the roof of the bus. To avoid this, it is advised to tie any luggage kept on the roof of a bus with a rope.

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.

Answer:

(c) A batsman hits a cricket ball, which then rolls on a level ground. After covering a short distance, the ball comes to rest because there is frictional force on the ball opposing its motion.

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

Hence, this force is responsible for stopping the cricket ball.

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

Answer:

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

Distance travelled, s = 400 m

Time taken, t = 20 s

According to the second equation of motion:

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

Where,

Acceleration = a

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

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

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

1 metric tonne = 1000 kg (Given)

∴ 7 metric tonnes = 7000 kg Mass of truck, m = 7000 kg

From Newton's second law of motion:

Force, F = Mass × Acceleration

F = ma = 7000 × 2 = 14000 N

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

Question 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? Answer:

Initial velocity of the stone, u = 20 m/s

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

Distance covered by the stone, s = 50 m

According to the third equation of motion: v^2 = $u^2 + 2^{as}$ Where,

Acceleration, a

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

-4 m/s^2

The negative sign indicates that acceleration is acting against the motion of the stone.

Mass of the stone, m = 1 kg

From Newton’s second law of motion:

Force, F = Mass × Acceleration

F = ma

F = 1 × (− 4) = −4 N

Hence, the force of friction between the stone and the ice is −4 N.

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 accelerating force; (b) the acceleration of the train; and (c)the force of wagon 1 on wagon 2.

Answer:

(a) 35000 N (b) 1.944 m/s^2 (c) 28000 N

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

Frictional force offered by the track, F_f = 5000 N

Net accelerating force, $F_a = F - F_f = 40000 - 5000 = 35000$ N Hence, the net accelerating force is 35000 N.

(b)Acceleration of the train = a

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

Net accelerating force on the wagons, F_a = 35000 N

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

Mass of a wagon = 2000 kg

Number of wagons = 5 ∴ m =

2000 × 5 = 10000 kg

Mass of the engine, m′ = 8000 kg Total

mass, M = m + m′ = 18000 kg

From Newton's second law of motion:
$F_a = Ma$

$$a = \frac{F_a}{M} = \frac{35000}{18000} = 1.944 \text{ m/s}^2$$

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

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

Acceleration of the wagons = 3.5 m/s^2

Thus, force exerted on all the wagons except wagon 1 = 8000 × 3.5 = 28000 N

Therefore, the force exerted by wagon 1 on the remaining four wagons is 28000 N.

Hence, the force exerted by wagon 1 on wagon 2 is 28000 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 m s^{-2}?

Answer:

Mass of the automobile vehicle, m = 1500 kg

Final velocity, v = 0 (finally the automobile stops)

Acceleration of the automobile, a = −1.7 ms^{-2} From Newton's

second law of motion:

Force = Mass × Acceleration = 1500 × (−1.7) = −2550 N

Hence, the force between the automobile and the road is −2550 N, in the direction opposite to the motion of the automobile.

Question 9:

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

(a) $(mv)^2$ (b) mv^2 (c) ½ mv^2 (d) mv

Answer:
(d) mv

Mass of the object = m

Velocity = v

Momentum = Mass × Velocity

Momentum = 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?

Answer:

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

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 m s^{-1} before the collision during which they stick together. What will be the velocity of the combined object after collision?

Answer:

Mass of one of the objects, m_1 = 1.5 kg

Mass of the other object, m_2 = 1.5 kg

Velocity of m_1 before collision, v_1 = 2.5 m/s

Velocity of m_2, moving in opposite direction before collision, v_2 = −2.5 m/s

(Negative sign arises because mass m_2 is moving in an opposite direction) After collision, the two objects stick together.

Total mass of the combined object = $m_1 + m_2$

Velocity of the combined object = v

According to the law of conservation of momentum:

Total momentum before collision = Total momentum after collision $m_1v_1 + m_2$

$v_1 = (m_1 + m_2)\ v$

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

$3.75 - 3.75 = 3\ v \quad v = 0$

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

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.

Answer:

The truck has a large mass. Therefore, the static friction between the truck and the road is also very high. To move the car, one has to apply a force more than the static friction. Therefore, when someone pushes the truck and the truck does not move, then it can be said that the applied force in one direction is cancelled out by the frictioal force of equal amount acting in the opposite direction.

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

Question 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 at 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.

Answer:

Mass of the hockey ball, m = 200 g = 0.2 kg

Hockey ball travels with velocity, v_1 = 10 m/s

Initial momentum = mv_1

Hockey ball travels in the opposite direction with velocity, v_2 = −5 m/s

Final momentum = mv_2

Change in momentum = $mv_1 - mv_2$ = 0.2 [10 − (−5)] = 0.2 (15) = 3 kg m s^{-1} Hence, the change in momentum of the hockey ball is 3 kg m s^{-1}.

Question 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.

Answer:

Now, it is given that the bullet is travelling with a velocity of 150 m/s.
Thus, when the bullet enters the block, its velocity = Initial velocity, u = 150 m/s

Final velocity, v = 0 (since the bullet finally comes to rest)

Time taken to come to rest, t = 0.03 s

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

Acceleration of the bullet, a

0 = 150 + (a ×0.03 s)

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

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

According to the third equation of motion: $v^2 = u^2 + 2^{as}$ 0

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

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

Hence, the distance of penetration of the bullet into the block is 2.25 m.

From Newton's second law of motion:

Force, F = Mass × Acceleration Mass of the

bullet, m = 10 g = 0.01 kg

Acceleration of the bullet, $a = 5000\ m/s^2$

$F = ma = 0.01 \times 5000 = 50\ N$

Hence, the magnitude of force exerted by the wooden block on the bullet is 50 N.

Question 15:

An object of mass 1 kg travelling in a straight line with a velocity of 10 m s^{-1} collides with, and sticks to, a stationary wooden block of mass 5 kg. Then they both move off together in the same straight line. Calculate the total momentum just before the impact and just after the impact. Also, calculate the velocity of the combined object.

Answer:

Mass of the object, $m_1 = 1$ kg

Velocity of the object before collision, $v_1 = 10$ m/s Mass of the stationary wooden block, $m_2 = 5$ kg Velocity of the wooden block before collision, $v_2 = 0$ m/s

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

$= 1\ (10) + 5\ (0) = 10$ kg m s^{-1}

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

Total mass of the combined system $= m_1 + m_2$
Velocity of the combined object $= v$

According to the law of conservation of momentum:

Total momentum before collision = Total momentum after collision $m_1 v_1 + m_2 v_2 = (m_1 + m_2)\ v$

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

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

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

Total momentum just before the impact = 10 kg m s^{-1}

Total momentum just after the impact = $(m_1 + m_2)$ v $= 6 \times \frac{5}{3} = 10 \text{ kg m s}^{-1}$

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

= Question 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.

Answer:

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 take by the object to accelerate, t = 6 s

Initial momentum = mu = 100 × 5 = 500 kg m s^{-1}

Final momentum = mv = 100 × 8 = 800 kg m s^{-1}

Force exerted on the object, F = $\frac{mv - mu}{t}$

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

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

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

Force exerted on the object is 50 N.

Question 17:

Akhtar, Kiran and Rahul were riding in a motorocar 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.

Answer:

According to the law of conservation of momentum:

Momentum of the car and insect system before collision = Momentum of the car and insect system after collision

Hence, the change in momentum of the car and insect system is zero.

The insect gets stuck on the windscreen. This means that the direction of the insect is reversed. As a result, the velocity of the insect changes to a great amount. On the other hand, the car continues moving with a constant velocity. Hence, Kiran's suggestion that the insect suffers a greater change in momentum as compared to the car is correct. The momentum of the insect after collision becomes very high because the car is moving at a high speed. Therefore, the momentum gained by the insect is equal to the momentum lost by the car.

Akhtar made a correct conclusion because the mass of the car is very large as compared to the mass of the insect.

Rahul gave a correct explanation as both the car and the insect experienced equal forces caused by the Newton's action-reaction law. But, he made an incorrect statement as the system suffers a change in momentum because the momentum

before the collision is equal to the momentum after the collision.

Question 18:

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

Answer:

Mass of the dumbbell, m = 10 kg

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

Acceleration in the downward direction, a = 10 m/s^2

Initial velocity of the dumbbell, u = 0

Final velocity of the dumbbell (when it was about to hit the floor) = v

According to the third equation of motion: $v^2 = u^2 + 2as$ $v^2 = 0 + 2$

(10) 0.8 v = 4 m/s

Hence, the momentum with which the dumbbell hits the floor is

= mv = 10 × 4 = 40 kg m s^{-1}

Question 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?

Answer:

(a) There is an unequal change of distance in an equal interval of time.

Thus, the given object is having a non – uniform motion. Since the velocity of the object increases with time, the acceleration is increasing.

(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.

Question 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) Answer:

Mass of the motor car = 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 m/s^2

Let the force applied by the third person be F.

From Newton's second law of motion:

Force = Mass × Acceleration

F = 1200 × 0.2 = 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.

Question 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?

Answer:
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:

$$\text{Force, } F = \frac{m(v-u)}{t} = \frac{0.5(0-50)}{0.01} = -2500 \text{ N}$$

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.

Question 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.

Answer:

Mass of the motor car, m = 1200 kg

Initial velocity of the motor car, v = 90 km/h = 25 m/s

Final velocity of the motor car, u = 18 km/h = 5 m/s

Time taken, t = 4 s

According to the first equation of motion: v

= u + at 25 = 5 + a (4) a = 5 m/s^2

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

= 1200 (25 − 5) = 24000 kg m s^{-1}

Force = Mass × Acceleration

= 1200 × 5 = 6000 N

Acceleration of the motor car = 5 m/s^2
Change in momentum of the motor car = 24000 kg m s^{-1} Hence, the

force required to decrease the velocity is 6000 N.

Question 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?

Answer:

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 collision)

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:

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

$$F_{Truck} = \frac{M(v'-v)}{t} = -Mv$$

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

(b) Initial momentum of the car = mv

Final momentum of the car = 0

Change in momentum = mv

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 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.