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)]**

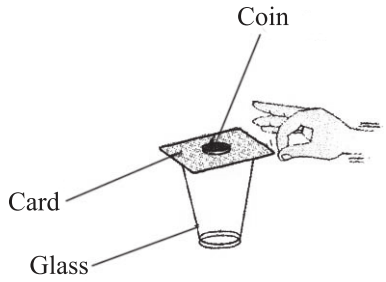
11. A bullet of mass 50 g is horizontally fired with a velocity of 35 m/s form a pistol of mass 4 kg. Calculate the recoil velocity of the pistol. **[2010 (T-I)]**

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.

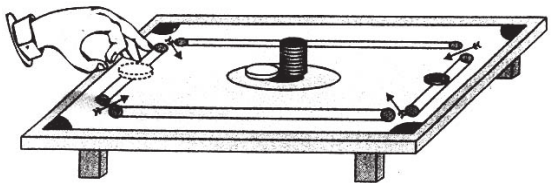


In the above experimental set-up, a student given the card a sharp, fast horizontal flick with a finger.

(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)]**

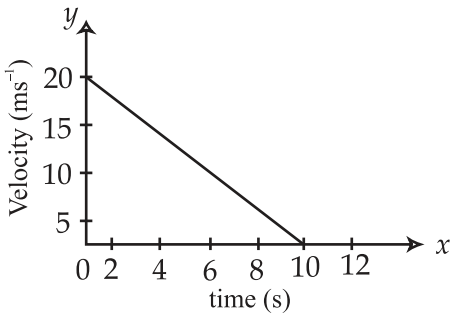
2. (a) State Newton's third law of motion.

(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)]**

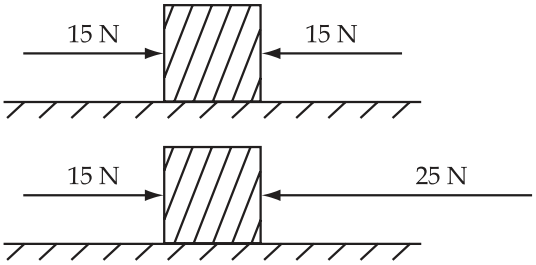
10. A truck starts from rest and rolls down a hill with a constant acceleration. It travels a distance of 400 m in 20 seconds. Find the acceleration. Find the force acting on it if its mass is 7 metric tonne. [**Hint** 1 metric tonne = 1000 kg]. **[2010 (T-I)]**

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.

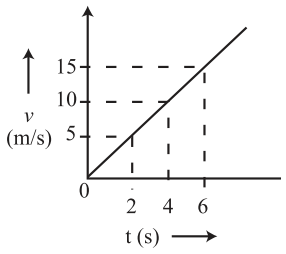
15. The motion of a body of mass 5 kg is shown in the *v-t* graph.

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.

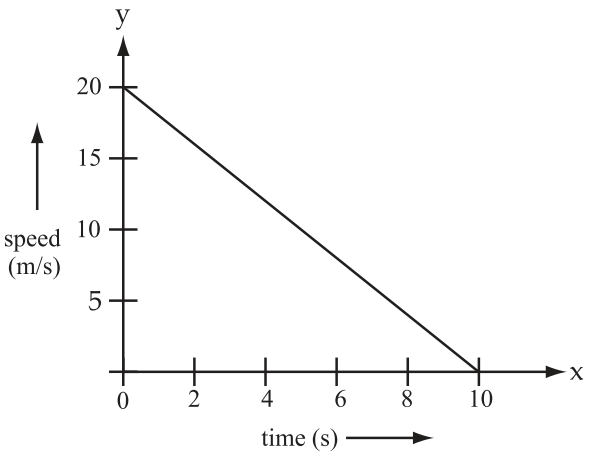
12. (a) In a high jump event the athletes are made to fall on a sand bed or on a cushioned bed. Why?

(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)]**

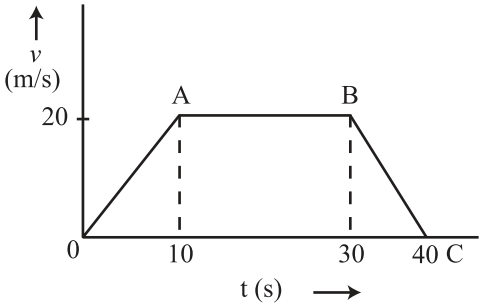
13. (a) State Newton's second law of motion. Give its mathematical expression and hence define the unit of force.

(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)]**



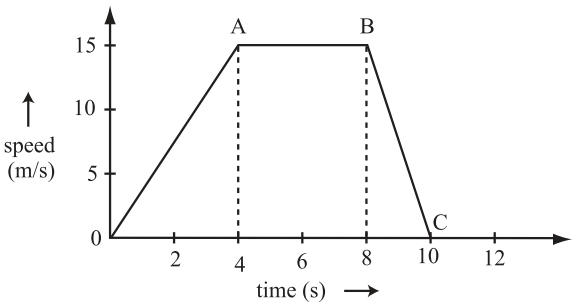
14. (a) Define force and give its S.I. unit.

(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 ?

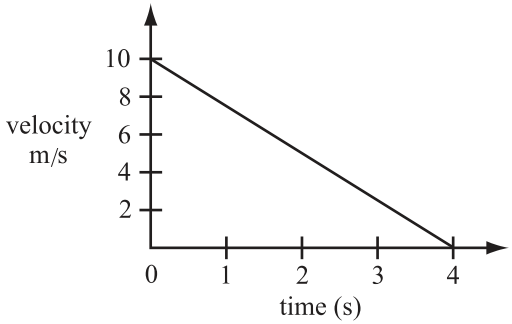
(c) Calculate the mass of a body. When a force of 525 N produce an acceleration of 3.5 m/s^2. **[2010 (T-I)]**

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.