Force and Laws of Motion

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In the chapter we will learn about the following topics:

- Cause of Motion
- Balanced and Unbalanced Forces
- First Law of Motion
- Inertia and Mass
- Second Law of Motion
- Mathematical formulation of Second Law of Motion
- Third Law of Motion

Cause of Motion

- Two scientists discovered and deduced the cause of motion.
- Pushing, hitting and pulling of objects are all ways of bringing objects in motion.
- Force is the push or pull applied on a body.
- No person can see, taste or feel force.
- Force can change
  - the magnitude of velocity of an object. (slower or faster)
  - the direction of motion of an object.
  - change the shape and size of objects.

Balanced and Unbalanced Forces

Balanced Forces:

- Balanced forces are equal and opposite forces acting on an object from both sides. These forces cancel each other out, resulting in no change in the object's state of rest or motion.
- For example, if a wooden block is pulled from both sides with equal forces, it remains stationary because the forces are balanced.

Unbalanced Forces:

- Unbalanced forces occur when two opposite forces acting on an object have different magnitudes. In this case, the object moves in the direction of the greater force. This unbalanced force causes a change in the object's state of motion.
- For instance, if one side of the wooden block is pulled with a greater force than the other, the block moves towards the direction of the stronger force.

Q.1 Why does a wooden box not move when children push it with a small force on a rough floor?

Q.2 Why does a cycle stop moving when we stop pedalling?

Deep Concepts:

- An object moves with a uniform velocity when the pushing force and frictional force are balanced and there is no net external force on it.
- If an unbalanced force is applied on the object, there will be a change either in its speed or in the direction of its motion.
- An object will accelerate until an unbalanced force acts on it.

Q.2 If a boy throws an object with a velocity of 20 km/h, will it come to rest if no external force is being applied on it?

First Law of Motion

- Galileo observed that objects move at constant speed when no force acts on them. By studying a marble on an inclined plane, he noted its velocity increases when rolling down due to gravity and decreases when climbing up. On an ideal frictionless plane inclined on both sides, the marble reaches the same height from which it was released. If the opposite incline is gradually flattened, the marble travels further, maintaining motion indefinitely on a horizontal plane since no unbalanced force acts on it.
- In reality, friction opposes motion, because of which the marble stops after some time.
- Newton's First Law of Motion states that an object remains at rest or in uniform motion in a straight line unless acted upon by an external force.
- The tendency of an object to stay at rest or to keep moving with the same velocity is called Inertia.
- The first law of motion is also known as law of inertia.

Questions on Law of Inertia

- Why does our body tend to move forward even after the car slows down?
- Why do we tend to fall backwards when a bus suddenly starts moving?
- Why do we tend to get thrown to one side when a motorcar makes a sharp turn at high speed?
- What happens to the pile of carom coins when you attempt a sharp horizontal hit at the bottom of the pile using another carom coin or the striker?
- Why does the coin fall vertically into the glass tumbler when the card is flicked away quickly?
- Why does the water spill when we place a water-filled tumbler on a tray, and turn around as fast as we can?

Inertia and Mass

- If a body is at rest, it tends to remain at rest; if it is moving it tends to keep moving. This property of an object is called its inertia.
- Inertia is the natural tendency of an object to resist a change in its state of motion or of rest. The mass of an object is a measure of its inertia.
- A heavier object has more inertia than a lighter object.

Second Law of Motion

- Momentum is defined as the product of mass and velocity i.e. p = mv.
- The second law of motion states that the rate of change of momentum of an object is proportional to the applied unbalanced force in the direction of force.
- $F = \frac{change\ in\ momentum}{time} = \frac{Final\ momentum - Initial\ momentum}{time\ taken} = \frac{mv - mu}{t} = \frac{m(v-u)}{t} = ma$
- Unit of mass must be taken in kg, unit of velocity in m/s and acceleration in m/s^2.

Numerical Problems

1. A force acts on a 10 kg object for 4 seconds, changing its velocity from 2 m/s to 10 m/s. Calculate the magnitude of the applied force. If the same force acts for 6 seconds, what will be the final velocity?
2. An object of mass 8 kg experiences a constant force for 3 seconds, increasing its velocity from 5 m/s to 11 m/s. Determine the applied force. What would be the object's final velocity if the force was applied for 7 seconds?
3. A 6 kg body is subjected to a force over 2.5 seconds, changing its velocity from 4 m/s to 9 m/s. Find the magnitude of the force. If the same force acted for 4 seconds, what would be the final velocity?
4. A constant force is applied to a 12 kg object for 3 seconds, increasing its velocity from 1 m/s to 6 m/s. What is the magnitude of the force? If the force continues for another 5 seconds, what will be the object's final velocity?

5. An object with a mass of 15 kg has its velocity increased from 0 m/s to 5 m/s in 2 seconds under a constant force. Calculate the force involved. If the force was applied for 8 seconds instead, what would be the final velocity of the object?
6. What is the force needed to accelerate a 3 kg mass at 4 m/s²?
7. How much force is required to accelerate a 5 kg mass at 3 m/s²?
8. Determine the force necessary to accelerate a 1 kg mass at 6 m/s².
9. Calculate the force needed to accelerate a 6 kg mass at 2 m/s².
10. What force is required to accelerate a 4 kg mass at 5 m/s²?
11. A truck is travelling at a speed of 90 km/h and comes to a halt in 5 seconds after the brakes are applied. Determine the force exerted by the brakes if the truck's mass is 2000 kg.
12. A bike is moving at a velocity of 72 km/h and stops completely in 3 seconds after braking. What is the force applied by the brakes on the bike if its total mass is 150 kg?
13. A bus with a mass of 5000 kg is moving at 60 km/h and comes to rest in 6 seconds once the brakes are applied. Calculate the braking force exerted on the bus.
14. A car weighing 1200 kg is travelling at 80 km/h and takes 5 seconds to stop after the brakes are engaged. Find the force exerted by the brakes.
15. A van moving at 100 km/h comes to a complete stop in 7 seconds after applying the brakes. If the mass of the van including passengers is 1800 kg, compute the force exerted by the brakes.
16. A force of 8 N gives a mass m_1 an acceleration of 4 m/s² and a mass m_2 an acceleration of 6 m/s². What acceleration would it give if both the masses were tied together?
17. A force of 12 N causes a mass m_1 to accelerate at 3 m/s² and a mass m_2 at 9 m/s². Find the resultant acceleration when both masses are connected.
18. A force of 15 N produces an acceleration of 5 m/s² in mass m_1 and 7.5 m/s² in mass m_2. What will be the acceleration if both masses are tied together?
19. A force of 20 N provides an acceleration of 2 m/s² to mass m_1 and 4 m/s² to mass m_2. Calculate the acceleration when both masses are combined.
20. A force of 10 N results in an acceleration of 8 m/s² for mass m_1 and 12 m/s² for mass m_2. Determine the acceleration when both masses are tied together.

21. The velocity-time graph of a ball of mass 40 g moving along a straight line on a long table is given in Fig. 1. How much force does the table exert on the ball to bring it to

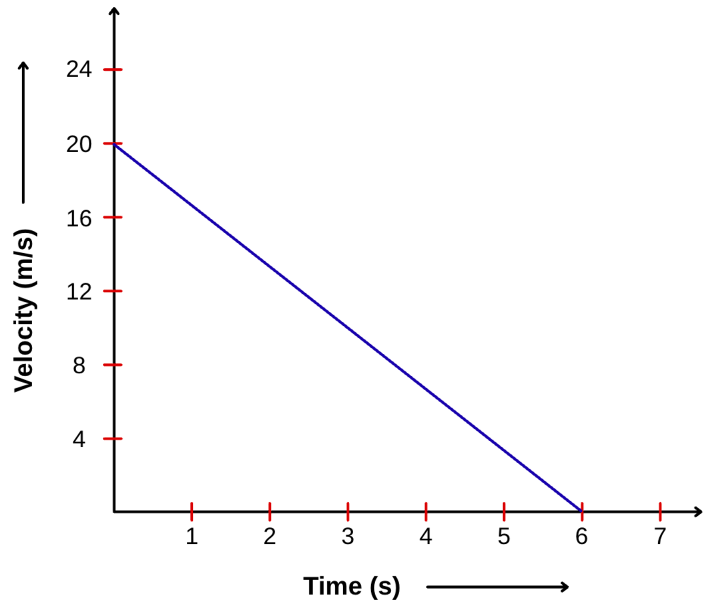


Fig. 1

rest?

22. The velocity-time graph of a car of mass 250 kg moving along a straight line on a road is given in Fig. 2. How much force does the brake exert on the car to bring it to rest?

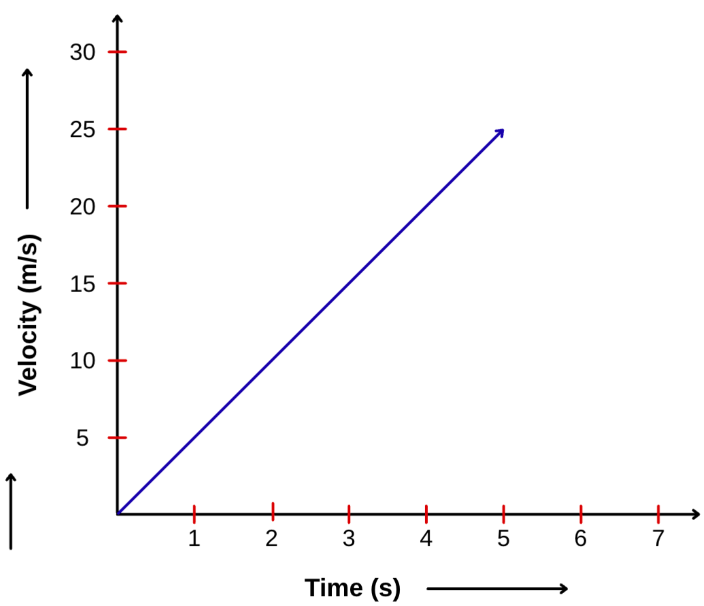


Fig. 2

23. A car of 300 kg is moving on the road and changes speed as shown in the velocity-time graph in Fig. 3. How much force should be applied by the car to attain the maximum

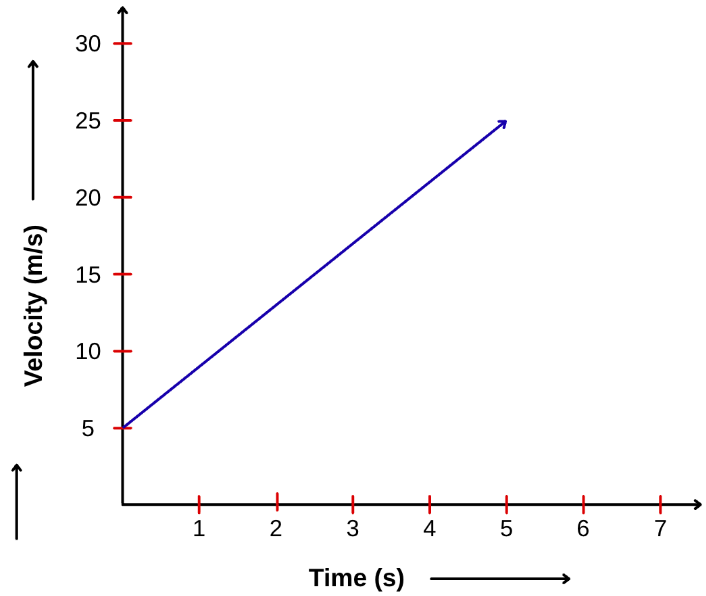
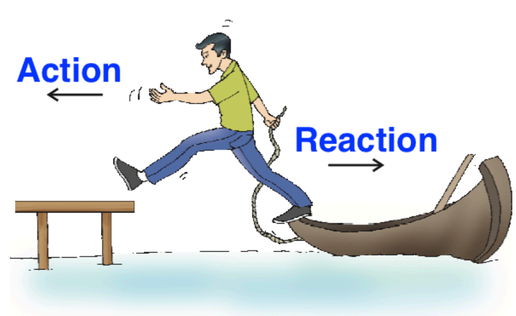


Fig. 3

speed in 5 seconds.

Third Law of Motion

- When a body exerts force on another body, the force applied by one body is called action force and the equal and opposite force applied by the other is called reaction force.
- The Third Law of Motion states that when one object exerts a force on another object, the second object instantaneously exerts an equal and opposite force back on the first.
- These two forces are always equal in magnitude but opposite in direction.
- To every action there is an equal and opposite reaction.
- The action and reaction always act on two different objects simultaneously.



1. What force causes you to move forward when you start walking, and how does it relate to the second law of motion?
2. Why do action and reaction forces, despite being equal in magnitude, not produce accelerations of equal magnitudes?
3. What causes the recoil of a gun when it is fired, and why is the gun's acceleration much less than that of the bullet?
4. Why does the boat move backwards when a sailor jumps forward out of it?
5. How does placing two children one on a cart and one on another cart demonstrate the second law of motion?

For the answers of the questions given in this summary, please visit https://perfectworksheet.com/**force-and-laws-of-motion**-class-9-notes/