Class – IX (Science)

Chapter – How Forces Affect Motion

Revise, Reflect, Refine Solution

1. **Using a horizontal force F, a table is moved across the floor at a constant velocity. How much is the frictional force exerted by the floor on the table?**

Solution:

Since the velocity is constant, the acceleration is zero.

According to Newton's Second Law,

$$F_{\text{net}} = ma$$

Since $a = 0$,

$$F_{\text{net}} = 0$$

Therefore, the applied force F must be balanced by the frictional force f.

$$F - f = 0$$
$$f = F$$

Thus , frictional force exerted by the floor on the table is equal in magnitude to F.

2. **For a ball moving on a smooth frictionless surface, choose the appropriate option that will make the following statements physically correct.**
   - **(i) If no net force is applied on the ball, the velocity of the ball will remain the same/increase/decrease.**
   - **(ii) If a net force is applied on the ball in the direction of its motion, the magnitude of the velocity of the ball will remain the same/increase/decrease.**
   - **(iii) If a net force is applied on the ball in a direction opposite to the direction of its motion, the magnitude of the velocity of the ball will remain the same/increase/decrease.**

Solution:

(i) No net force is applied

When the net force is zero, there is no acceleration.

Therefore, the velocity remains unchanged.

(ii) Net force is applied in the direction of motion

A force in the direction of motion produces acceleration in the same direction.

Therefore, the speed (magnitude of velocity) increases.

(iii) Net force is applied opposite to the direction of motion

A force opposite to the direction of motion produces acceleration opposite to the velocity.

Therefore, the speed decreases.

3. Two blocks P and Q on a smooth horizontal surface are shown in Fig. 6.36a and Fig. 6.36b. Two forces of magnitudes 4 N and 5 N are acting in opposite directions on block P, while block Q is moving with a constant velocity.

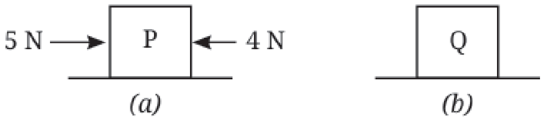

Fig. 6.36

Which of the following statement is correct?

(i) P experiences a net force and Q does not experience a net force.
(ii) P does not experience a net force and Q experiences a net force.
(iii) Both P and Q experience a net force.
(iv) Neither P nor Q experiences a net force.

Solution:

Net force on P:

$$F_{\text{net}} = 5 - 4 = 1\,\text{N}$$

Thus, block P experiences a net force of **1 N towards the right**.

For Block Q

Block Q is moving with a **constant velocity**.

According to Newton's First Law, if an object moves with constant velocity, its acceleration is zero.

$$F_{\text{net}} = ma = m \times 0 = 0$$

Therefore, block Q does **not** experience any net force.

4. **While practising for the snake boat race (*Vallum kali* in Kerala), 100 oarsmen are rowing a boat together. Out of these, 95 row backwards to propel the boat forward. But by mistake, 5 oarsmen row in the opposite direction. If each oarsman applies a horizontal force of 200 N, what is the net force on the snake boat? (Ignore drag forces, air friction, etc.)**

Solution:

Force in the forward direction:

$$F_{\text{forward}} = 95 \times 200$$
$$F_{\text{forward}} = 19000 \text{ N}$$

Force in the opposite direction:

$$F_{\text{backward}} = 5 \times 200$$
$$F_{\text{backward}} = 1000 \text{ N}$$

Net force:

Since the forces act in opposite directions,

$$F_{\text{net}} = F_{\text{forward}} - F_{\text{backward}}$$
$$F_{\text{net}} = 19000 - 1000$$
$$F_{\text{net}} = \mathbf{18000 \text{ N}}$$

5. **When a net force acts on an object, we observe that the object accelerates:**

(i) opposite to the direction of force, with acceleration proportional to the force acting on the object.
(ii) opposite to the direction of force, with acceleration proportional to the mass of the object.
(iii) in the direction of force, with acceleration inversely proportional to the force acting on the object.
(iv) in the direction of force, with acceleration proportional to the force acting on the object.

Solution:

According to **Newton's Second Law of Motion**,

$$F = ma$$

or

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

This shows that:

- Acceleration is **in the direction of the net force**.
- Acceleration is **directly proportional to the force** acting on the object.
- Acceleration is **inversely proportional to the mass** of the object.

Therefore, the correct statement is:

(iv) in the direction of force, with acceleration proportional to the force acting on the object.

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6. The position-time graph for four objects A, B, C and D moving along a straight line are given in Fig. 6.37. A net force acts on:

(i) Object A
(ii) Object B
(iii) Object C
(iv) Object D

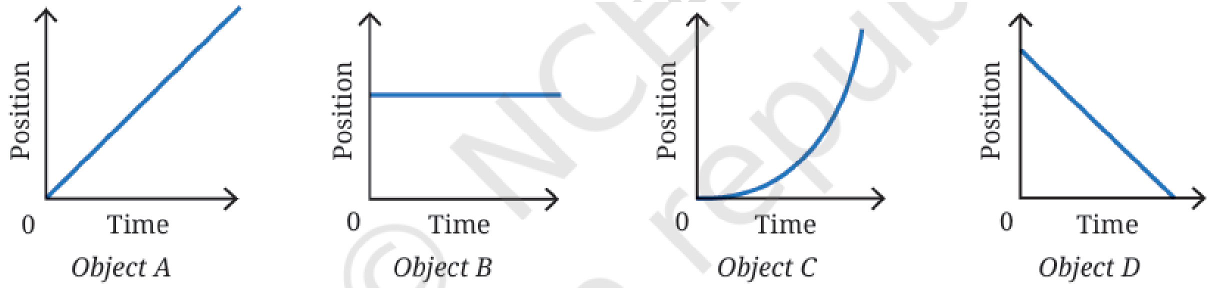


Fig. 6.37

Solution:

In a **position–time graph**, the **slope** represents velocity.

- Constant slope → Constant velocity → Acceleration = 0 → Net force = 0
- Changing slope → Velocity changing → Acceleration ≠ 0 → Net force acts

Object A

- Straight line with constant positive slope.
- Velocity is constant.
- Acceleration = 0.
- **Net force = 0**

Object B

- Horizontal line.
- Position remains constant (object at rest).
- Velocity = 0, Acceleration = 0.
- **Net force = 0**

Object C

- Curved graph with increasing slope.
- Velocity increases with time.
- Acceleration is present.
- **Net force acts**

Object D

- Straight line with constant negative slope.
- Constant negative velocity.
- Acceleration = 0.
- **Net force = 0**

7. A sailor jumps out from a small boat to the shore (Fig. 6.38). As the sailor jumps forward, will the boat move? If yes, in which direction and why?

Fig. 6.38: A sailor jumping forward

Solution:

According to Newton's Third Law of Motion:

For every action, there is an equal and opposite reaction.

- **Action:** The sailor exerts a backward force on the boat.
- **Reaction:** The boat exerts an equal forward force on the sailor, helping him jump toward the shore.

Since the boat is free to move on water (where friction is very small), it recoils backward.

8. During a high jump event, a landing mat or sand bed is placed for the athlete to fall upon (Fig. 6.39). Explain the reason behind it.

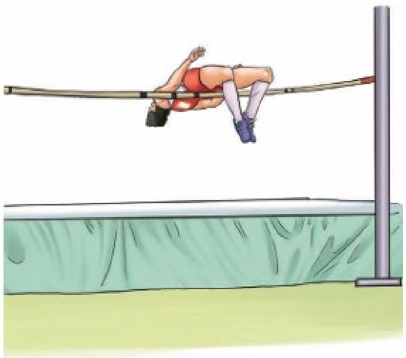


Fig. 6.39: A landing mat for a high jump event

Solution:

A landing mat or sand bed is placed so that the athlete can come to rest safely without getting injured.

When the athlete lands, his momentum must reduce to zero. The change in momentum is the same whether he lands on a hard surface or a soft mat. However, a soft landing mat or sand bed increases the time taken to stop.

From the relation:

$$F = \frac{\Delta p}{\Delta t}$$

where F is the force, Δp is the change in momentum, and Δt is the time taken.

Since the landing mat increases the stopping time (Δt), the force exerted on the athlete decreases. Therefore, the impact is less severe and the chances of injury are greatly reduced.

9. **A hand cart loaded with vegetables collides with an identical but empty hand cart. During the collision:**

(i) the loaded cart exerts a force of larger magnitude on the empty cart.
(ii) the empty cart exerts a force of larger magnitude on the loaded cart.
(iii) neither cart exerts a force on the other.
(iv) the loaded cart and the empty cart both exert an equal magnitude of force on each other.

Solution:

This question is based on Newton's Third Law of Motion:

For every action, there is an equal and opposite reaction.

During the collision:

- The loaded cart exerts a force on the empty cart.
- Simultaneously, the empty cart exerts an equal and opposite force on the loaded cart.

Although the masses of the carts are different, the forces they exert on each other are always equal in magnitude and opposite in direction.

10. **The acceleration–mass graph for the acceleration produced by a force on objects of different masses is plotted in Fig. 6.40. Plot the force–mass graph for this case.**

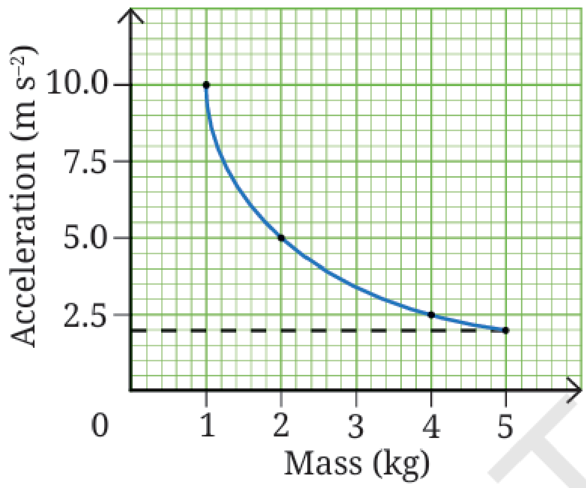


Fig. 6.40

Solution:

From **Newton's Second Law**:

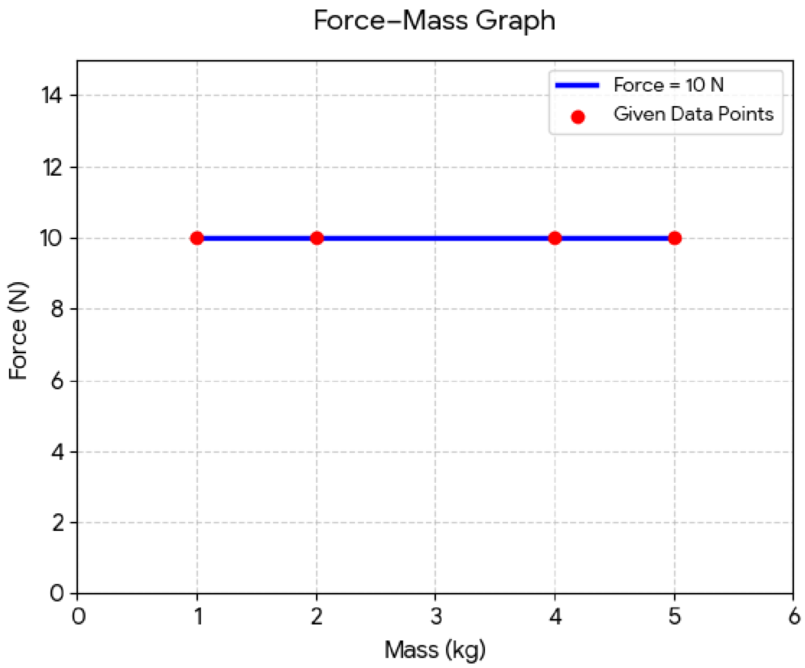
$$F = ma$$

We can calculate force as follows:

Mass (kg)	Acceleration (m s^{-2})	Force (N)
1	10	1X10 = 10
2	5	2X5 = 10
4	2.5	4X2.5 = 10
5	2	5X2 = 10

Thus, the force is **constant (10 N)** for all masses.

Since force remains constant as mass changes, the force–mass graph is a **horizontal straight line** parallel to the mass axis at $F = 10$ N



11. The velocity–time graph of an object of mass 10 kg moving along a straight line is shown in Fig. 6.41. Calculate the force acting on the object by using the graph.

Solution:

Given:

- Mass of the object, $m = 10$ kg
- From the velocity–time graph:
  - At $t = 0$ s, $v = 10$ m s^{-1}
  - At $t = 8$ s, $v = 30$ m s^{-1}

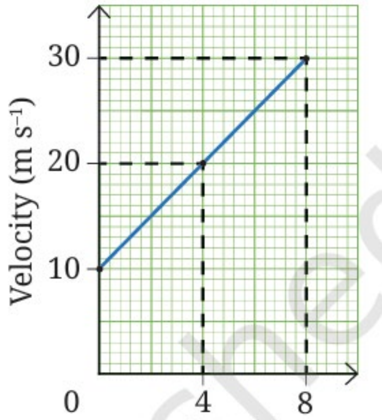


Fig. 6.41

Step 1: Calculation of acceleration

Acceleration is the slope of the velocity–time graph.

$$a = \frac{\Delta v}{\Delta t}$$
$$a = \frac{30 - 10}{8 - 0}$$
$$a = \frac{20}{8} = 2.5 \text{ m s}^{-2}$$

Step 2: Calculation of force

Using Newton's Second Law:

$$F = ma$$
$$F = 10 \times 2.5$$
$$\boldsymbol{F = 25 \text{ N}}$$

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12. A bullet of mass 50 g moving with a speed of 100 m s^{-1} enters a heavy stationary wooden block and stops after penetrating a distance of 50 cm. Estimate the stopping force acting on the bullet (assume that the bullet undergoes constant acceleration within the block).

Solution:

Given:

- Mass of bullet, $m = 50\ g = 0.05\ kg$
- Initial velocity, $u = 100\ m\ s^{-1}$
- Final velocity, $v = 0$

- Distance penetrated, $s = 50\ cm = 0.5\ m$

Using the equation of motion:

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

Substituting the values:

$$0 = (100)^2 + 2(a)(0.5)$$
$$0 = 10000 + a$$
$$a = -10000\ m\,s^{-2}$$

(The negative sign indicates retardation.)

Now, using Newton's second law:

$$F = ma$$
$$F = (0.05)(10000)$$
$$F = \mathbf{500\ N}$$

13. An ace footballer converted a penalty shot by kicking the football with a speed of 108 km h^{-1}. The estimated force they imparted was 800 N. The mass of the football was 0.4 kg. Calculate the time of contact between their foot and the ball.

Solution:

Given:

- Speed of football, $v = 108 \text{ km h}^{-1} = 108 \times \frac{5}{18} = 30 \text{ m s}^{-1}$
- Force applied, $F = 800$ N
- Mass of football, $m = 0.4$ kg
- Initial velocity, $u = 0 \text{ m s}^{-1}$(ball initially at rest)

Calculation of acceleration:

Using

$$F = ma$$

$$a = \frac{F}{m}$$
$$a = \frac{800}{0.4}$$
$$a = 2000 \text{ m s}^{-2}$$

Calculation of time of contact

Using

$$v = u + at$$
$$30 = 0 + 2000t$$
$$t = \frac{30}{2000}$$
$$t = \mathbf{0.015\ s}$$

14. An object of mass 2 kg moving with a constant velocity of 10 m s^{-1} encounters a rough patch where the force of friction on the object is 7 N. At the same time, an additional constant force of 3 N opposing the motion is applied on the object. After entering the rough patch, how much distance does the object travel before coming to rest?

Solution:

Given:

- Mass of object, $m = 2\ kg$
- Initial velocity, $u = 10\ m\ s^{-1}$
- Final velocity, $v = 0\ m\ s^{-1}$
- Frictional force $= 7\ N$
- Additional opposing force $= 3\ N$

Calculation of the net retarding force

$$F = 7 + 3 = 10\ N$$

Calculation of the acceleration

Using

$$F = ma$$

$$a = \frac{F}{m} = \frac{10}{2} = 5\ m\ s^{-2}$$

Since the force opposes the motion,

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

Calculation of the distance travelled before stopping

Using

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

$$0 = (10)^2 + 2(-5)s$$
$$0 = 100 - 10s$$
$$10s = 100$$
$$s = \mathbf{10\, m}$$

15. A tractor pulls a harrow (a ploughing tool) of mass m_1 with a net force F resulting in an acceleration of a_1. The same tractor pulls a trolley of mass m_2 with a force F producing an acceleration of a_2. If the tractor now pulls the trolley with the harrow placed on it (with the same force F), then obtain an expression for the resulting acceleration in terms of a_1 and a_2. Ignore friction.

Solution:

Given:

When the tractor pulls the harrow alone:

$$F = m_1 a_1$$
$$m_1 = \frac{F}{a_1}$$

When the tractor pulls the trolley alone:

$$F = m_2 a_2$$
$$m_2 = \frac{F}{a_2}$$

Combined system

When the harrow is placed on the trolley, the total mass is

$$m = m_1 + m_2$$
$$m = \frac{F}{a_1} + \frac{F}{a_2}$$
$$m = F\left(\frac{1}{a_1} + \frac{1}{a_2}\right)$$

Let the resulting acceleration be a.

Applying Newton's second law:

$$F = ma$$
$$F = F\left(\frac{1}{a_1} + \frac{1}{a_2}\right) a$$

Cancelling F,

$$1 = \left(\frac{1}{a_1} + \frac{1}{a_2}\right) a$$
$$a = \frac{1}{\frac{1}{a_1} + \frac{1}{a_2}}$$
$$\boldsymbol{a = \frac{a_1 a_2}{a_1 + a_2}}$$

16. When the pole of a bar magnet is brought close to a magnetic compass, the bar magnet and the compass needle (which is also a magnet) exert a magnetic force on each other. As per Newton's third law of motion, both the forces are equal in magnitude and opposite in direction. However, the compass needle moves, whereas the bar magnet does not move (Fig. 6.42). Explain why.

Solution:

According to Newton's Third Law, the bar magnet and the compass needle exert equal and opposite magnetic forces on each other.

However, the motion produced by a force depends not only on the force but also on the mass (inertia) of the object.

Using Newton's second law:

$$F = ma$$

- The compass needle has a very small mass and is mounted on a pivot, so even a small force can produce a noticeable acceleration and rotation.
- The bar magnet has a much larger mass and is usually held firmly in the hand or placed on a surface. Therefore, the same force produces negligible acceleration, so it does not appear to move.