Force Laws Motion Acceleration

Definition of Force

A force is a physical quantity which, when acts on an object, will change the state of motion, direction or shape of the object.

Balanced Forces

When two or more forces act on an object simultaneously, even then the object may not change its state of rest or motion or shape. Such forces acting on the object are known as balanced forces. The resultant of all the forces acting on a body is zero.

Unbalanced Forces

When two or more forces act on an object simultaneously, then the object may change its state of rest or motion or shape. These forces acting on the object are known as unbalanced forces. The resultant of all the forces acting on a body is not zero.

Newton's First Law of Motion

A body at rest will remain at rest and a body in motion will remain in uniform motion unless acted upon by an unbalanced force.

Momentum

The momentum of an object is the product of its mass and velocity and has the same direction as that of the velocity. Its SI unit is kilogram meter per second (kg m/s).

Newton's Second Law of Motion

The rate of change of momentum of a body is directly proportional to the force and takes place in the same direction as the applied force.

Force as Mass Times Acceleration

Force is also defined as the product of mass and acceleration.

SI Unit of Force

The SI unit of force is kilogram meter per second squared (kg m/s^2). This is also known as Newton and represented by the symbol N.

Definition of One Newton

A force of 1 Newton produces an acceleration of 1 meter per second squared (1 m/s^2) on an object of mass 1 kilogram.

Force of Friction

The force of friction always opposes the motion of an object.

Action and Reaction Forces

Action and reaction forces result from the interaction between two objects. They act on two different bodies but are equal in magnitude and opposite in direction.

Newton's Third Law of Motion

For every action, there is an equal and opposite reaction, but action and reaction act on different bodies.

Solved Examples

Example 1: A force of 10 N is applied on a body of mass 2 kg. Calculate the acceleration produced.

Solution:

Given, Force, F = 10 N; Mass, m = 2 kg

Using Newton's second law, F = m × a

Acceleration, a = F / m = 10 N / 2 kg = 5 m/s²

Therefore, the acceleration produced is 5 m/s².

Example 2: A body of mass 5 kg is moving with a velocity of 3 m/s. Calculate its momentum.

Solution:

Given, Mass, m = 5 kg; Velocity, v = 3 m/s

Momentum, p = m × v = 5 kg × 3 m/s = 15 kg m/s

Therefore, the momentum of the body is 15 kg m/s.

Example 3: A force of 20 N acts on a body of mass 4 kg. Find the acceleration and the change in velocity after 3 seconds.

Solution:

Given, Force, F = 20 N; Mass, m = 4 kg; Time, t = 3 s

Acceleration, $a = F / m = 20 \text{ N} / 4 \text{ kg} = 5 \text{ m/s}^2$

Change in velocity, $\Delta v = a \times t = 5 \text{ m/s}^2 \times 3 \text{ s} = 15 \text{ m/s}$

Therefore, the acceleration is 5 m/s^2 and the velocity changes by 15 m/s after 3 seconds.

Practice Set

- **Level 1 (Easy):** Define balanced and unbalanced forces with examples.
- **Level 2 (Moderate):** Explain Newton's first law of motion with a real-life example.
- **Level 3 (Challenging):** A force of 15 N acts on a 3 kg object initially at rest. Calculate the velocity of the object after 4 seconds.

Answer Key

Level 1: Balanced forces are forces that cancel each other out and do not change the state of motion of an object, e.g., a book resting on a table. Unbalanced forces cause a change in motion, e.g., pushing a stationary box.

Level 2: Newton's first law states that an object remains at rest or in uniform motion unless acted upon by an unbalanced force. For example, a passenger falls forward when a bus suddenly stops because their body tends to remain in motion.

Level 3: Given, F = 15 N, m = 3 kg, initial velocity u = 0, time t = 4 s

Acceleration, $a = F / m = 15 / 3 = 5\ m/s^2$

Final velocity, $v = u + at = 0 + 5 \times 4 = 20\ m/s$

Therefore, the velocity after 4 seconds is 20 m/s.

Inertia Conservation Momentum

Definition of Inertia

Inertia is the property by virtue of which an object tends to remain in the state of rest or uniform motion unless acted upon by an unbalanced force.

Mass and Inertia

The mass of a body is a measure of its inertia.

Inertia of Rest and Motion

Inertia of rest is the inherent property of a body that prevents it from changing its state of rest. Inertia of motion is the tendency of a body to oppose any change in its state of uniform motion.

Conservation of Momentum

The momentum of a system remains constant if no external forces act on it.

Effects of Momentum

Momentum can produce motion in a stationary body, stop a moving body, change the speed and direction of a body's motion, and bring about change in a body's dimensions.

Solved Examples

Example 1: A gun of mass 5 kg fires a bullet of mass 0.1 kg with a velocity of 200 m/s. Calculate the recoil velocity of the gun.

Solution:

Given, Mass of gun, m1 = 5 kg; Mass of bullet, m2 = 0.1 kg; Velocity of bullet, v2 = 200 m/s; Recoil velocity of gun = v1

Using conservation of momentum: m1 × v1 + m2 × v2 = 0 (initial momentum is zero)

Therefore, v1 = - (m2 × v2) / m1 = - (0.1 × 200) / 5 = -4 m/s

The negative sign indicates recoil in the opposite direction.

Therefore, the recoil velocity of the gun is 4 m/s backward.

Example 2: A moving body of mass 3 kg and velocity 4 m/s collides with a stationary body of mass 2 kg. If they move together after collision, find their common velocity.

Solution:

Given, m1 = 3 kg, v1 = 4 m/s; m2 = 2 kg, v2 = 0; final velocity = v

Using conservation of momentum: m1 × v1 + m2 × v2 = (m1 + m2) × v

12 + 0 = 5 × v

v = 12 / 5 = 2.4 m/s

Therefore, the common velocity after collision is 2.4 m/s.

Practice Set

- **Level 1 (Easy):** Define inertia and give an example of inertia of rest.
- **Level 2 (Moderate):** State the law of conservation of momentum with an example.
- **Level 3 (Challenging):** A bullet of mass 0.05 kg is fired with a velocity of 300 m/s from a gun of mass 2 kg. Calculate the recoil velocity of the gun.

Answer Key

Level 1: Inertia is the property of an object to resist change in its state of rest or motion. Example: Passengers fall backward when a bus suddenly starts.

Level 2: The law of conservation of momentum states that the total momentum of a system remains constant if no external forces act on it. Example: When a gun fires a bullet, the momentum of the bullet and gun system remains constant.

Level 3: Given, mass of bullet m = 0.05 kg, velocity v = 300 m/s, mass of gun M = 2 kg, recoil velocity V

Using conservation of momentum: $M \times V + m \times v = 0$

$V = - (m \times v) / M = - (0.05 \times 300) / 2 = -7.5$ m/s

The recoil velocity of the gun is 7.5 m/s backward.

Quick Reference Table

Common Mistakes and Misconceptions

Glossary