Chapter 8: Force and Laws of Motion

Force and its Effects

What is Force?

In everyday life, we use muscular effort to push, hit, or pull objects to change their state of motion. The concept of force is based on this push, hit, or pull.

Effects of Force

Force can change the magnitude of velocity of an object (make it move faster or slower) or change its direction of motion. Force can also change the shape and size of objects (e.g., stretching a spring, pressing a rubber ball).

Balanced Forces

Definition

Balanced forces are forces that are equal in magnitude but opposite in direction. When balanced forces act on an object, they do not change its state of rest or of motion.

Example

If a wooden block is pulled from both sides with equal forces, the block will not move. The net force is zero.

Unbalanced Forces

Definition

When two opposite forces of different magnitudes act on an object, the forces are not balanced. The unbalanced force acts in the direction of the greater force.

Effect

An unbalanced force acting on an object brings it in motion or changes its speed or direction. To accelerate the motion of an object, an unbalanced force is required.

Friction

Opposing Force

Friction is a force that opposes motion. It arises between two surfaces in contact. For example, when you push a box on a rough floor, friction acts in the direction opposite to the push.

Balancing Push

If you push a box with a small force and it doesn't move, it's because the friction force balances the pushing force. The box only moves when the pushing force becomes bigger than the friction force.

First Law of Motion

Statement

An object remains in a state of rest or of uniform motion in a straight line unless compelled to change that state by an applied force.

Explanation

All objects resist a change in their state of motion. This tendency is called inertia. Therefore, the first law of motion is also known as the law of inertia.

Inertia

Definition

Inertia is the natural tendency of an object to resist a change in its state of motion or of rest.

Examples

When a bus starts suddenly, passengers fall backwards because their feet move with the bus but their bodies tend to remain at rest. When a bus stops suddenly, passengers fall forward because their bodies tend to continue moving.

Inertia and Mass

Measure of Inertia

Mass is a measure of inertia. Heavier or more massive objects offer larger inertia.

Comparison

It is easier to push an empty box than a box full of books. A force that can move a small cart will produce negligible change in a train. The train has more inertia than the cart.

Momentum

Definition

Momentum (p) of an object is defined as the product of its mass (m) and velocity (v). $p = mv$.

Properties

Momentum has both direction and magnitude. Its direction is the same as that of velocity. The SI unit is kilogram-metre per second (kg m/s).

Second Law of Motion

Statement

The rate of change of momentum of an object is proportional to the applied unbalanced force in the direction of force.

Significance

This law helps us measure the force acting on an object as a product of its mass and acceleration.

Mathematical Formulation of Second Law

Formula

Force (F) is proportional to the rate of change of momentum. F = ma, where m is mass and a is acceleration.

Derivation

Change in momentum = m(v - u). Rate of change = m(v - u)/t = ma. Thus, F = kma. We choose units such that k=1, so F = ma.

Unit of Force

Newton

The SI unit of force is the newton (N). One newton is defined as the amount of force that produces an acceleration of 1 m/s^2 in an object of 1 kg mass.

Calculation

1 N = 1 kg × 1 m/s^2.

Applications of Second Law

Catching a Cricket Ball

A fielder pulls his hands backwards while catching a fast-moving cricket ball. This increases the time during which the high velocity of the ball decreases to zero.

Why?

Increasing the time decreases the rate of change of momentum, which in turn decreases the force exerted by the ball on the hands, preventing injury.

Third Law of Motion

Statement

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

Different Bodies

It is important to remember that the action and reaction forces always act on two different objects, simultaneously. They never act on the same object.

Action and Reaction

Example: Walking

When you walk, you push the road backwards (action). The road exerts an equal and opposite force on your feet (reaction) to make you move forward.

Accelerations

Even though action and reaction forces are equal in magnitude, they may produce different accelerations because they act on objects with different masses.

Recoil of a Gun

Mechanism

When a gun is fired, it exerts a forward force on the bullet. The bullet exerts an equal and opposite force on the gun. This results in the recoil of the gun.

Mass Difference

Since the gun has a much greater mass than the bullet, the acceleration of the gun is much less than the acceleration of the bullet.