Ratna Sagar

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Education, Our Mission

ICSE
Living Science
Physics

Class 10

Chapter 3 Laws of Motion

As per the latest ICSE syllabus

9

Revised and Updated

Living Science PHYSICS

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EDUCATION, OUR MISSION

LEARNING OBJECTIVES

Force

- ❖ Contact forces
- ❖Frictional force
- ❖ Normal reaction force
- ❖Tension force as applied through strings
- ❖Non-contact forces
- ❖ Gravitational force
- ❖ Electrostatic force
- ❖ Magnetic force

Effects of force

Newton's First Law of Motion

- ❖ Newton's first law of motion and inertia
- ❖ Mass and inertia
- ❖ Kinds of inertia
- ❖ Linear momentum

Newton's Second Law of Motion

Newton's Third Law of Motion

What is force?

Force is a push or a pull which changes or tends to change the state of rest or of uniform motion, the direction of motion or the shape and the size of a body.

Based on physical proximity, forces can be classified into two classes:

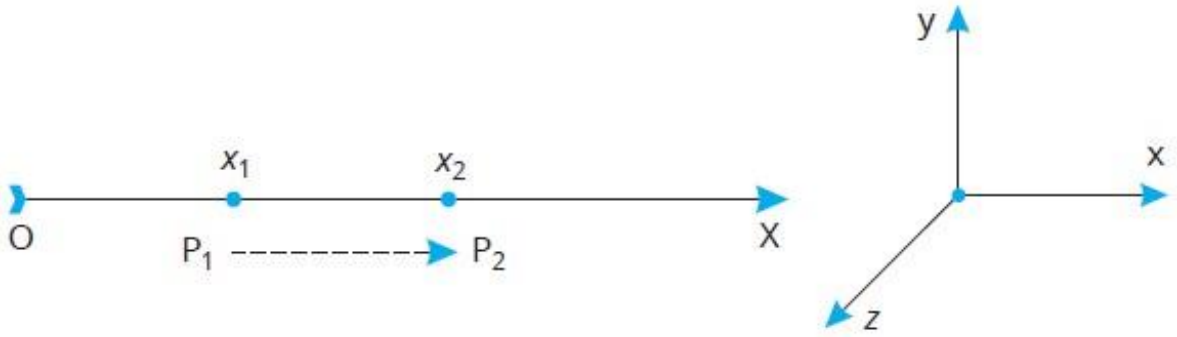
- Contact forces
- Non-contact forces (also called action-at-a-distance forces)

Rest and Motion are Relative Terms

An object can be in motion in relation to one object while it can be at rest in relation to another object at the same instant of time. We can, therefore, say that **rest and motion are relative terms**.

One-Dimensional Motion

The motion of an object is said to be one dimensional motion if only one out of the three coordinates (i.e. *x*, *y* or *z*) specifying the position of the object changes with respect to time. In such a motion, the object moves along a straight line. For example, the motion of a train along a straight railway track, the motion of an object dropped from a certain height above the ground, etc. are one dimensional motion.



a. Only one coordinate *x* changes b. Three coordinates

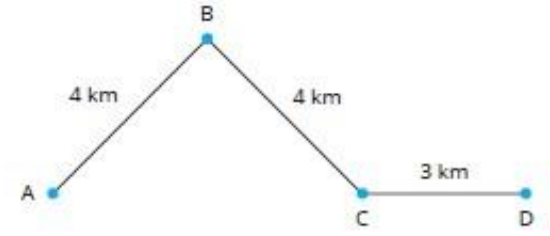
Scalar and vector quantities

A physical quantity which is described completely by its magnitude (or size) only is called a scalar quantity. Thus, a scalar quantity has only no direction. Some examples of scalar quantities are length, time, distance, area, speed, temperature, energy, power and mass.

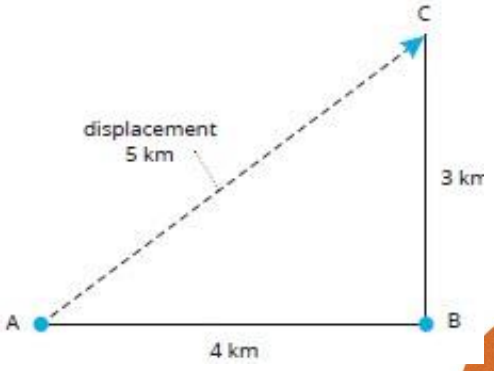
A physical quantity which requires both magnitude (or size) and direction for its complete description is called a vector quantity. Thus, a vector quantity has both magnitude and direction. Some examples of vector quantities are displacement, velocity, acceleration, force, weight and momentum.

Distance and displacement

The actual length of the path travelled (or covered) by a moving body, irrespective of its direction is called the ‘distance’ travelled by the body. The shortest distance (straight distance) between the initial and the final positions of a moving body in a particular direction is called its displacement.



Distance travelled by the person



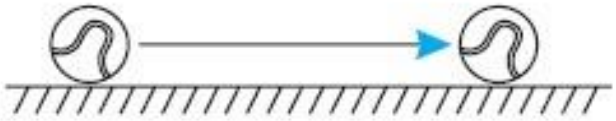
Displacement of the person

Contact Forces

Contact forces are forces which act only when objects are in physical contact with each other. There are different types of forces:

1. Frictional force

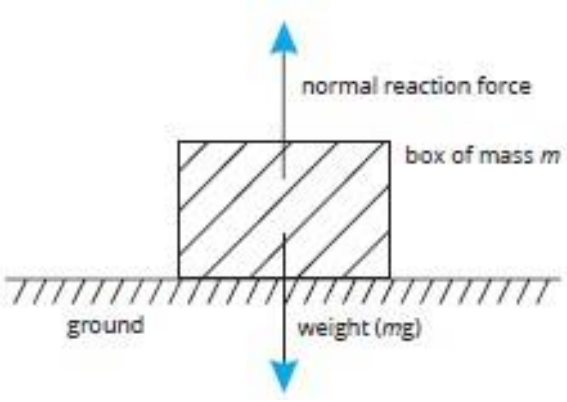
When the surface of one body is made to slide or roll over the surface of another body, a force arises which opposes the motion of the first body over the other. This force which opposes the motion is called the force of friction or frictional force.



A rolling ball stops after some time due to frictional force.

2. Normal reaction force

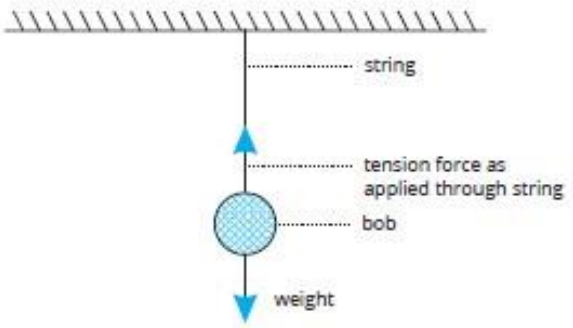
Suppose a box is resting on the ground. The box is exerting a downward force equal to its weight on the ground. The ground exerts an equal and opposite force on the box, normal to it, which is called the **normal reaction force.**



Weight of the box acting downwards is balanced by an equal and opposite normal reaction force.

3. Tension force as applied through strings

When a body like a small metal ball is suspended by a long thread from a rigid support, the weight of the small metal ball acts vertically downwards. An equal and opposite force acts on the string upwards which balances the weight of the bob. This force is called the **tension force** which is exerted through the string.



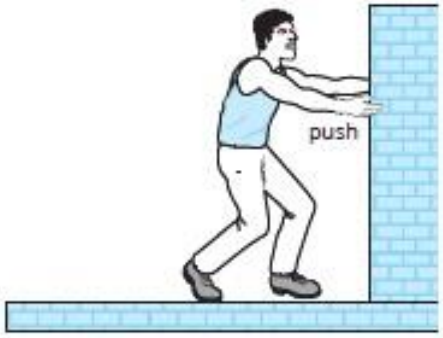
Tension force produced in a string

4. Force during collision

Due to collision, equal and opposite forces act on each body which make them move apart with different velocities after the collision.

5. Force as a pull or push

When a body is pushed or pulled, it gets displaced or tends to get displaced. Lifting a bucket or picking up a book are the acts of pull. Pushing a wall, kicking a football, throwing a stone and beating a drum are the acts of push .



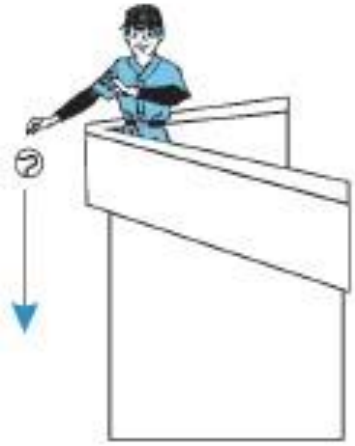
Non-contact Forces

The forces which do not involve physical contact between the objects but act through the space between them are called non-contact forces (also called action-at-a-distance forces). The gravitational force, electrostatic force and magnetic force are common examples of non-contact forces.

Gravitational force

The force of attraction exerted by the earth on all the objects is called the gravitational force.

A ball falls downwards due to the earth's gravitational force.

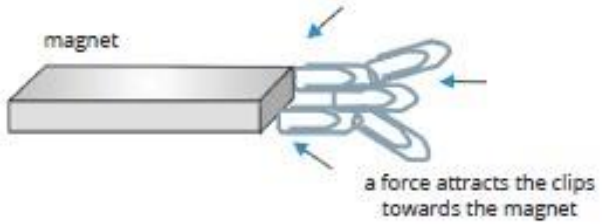


Electrostatic force

On rubbing, a comb gets charged. Since the charge is produced at the site of rubbing and remains there without any movement, it is called electrostatic charge. The force exerted by the electrostatic charge is called the electrostatic force.

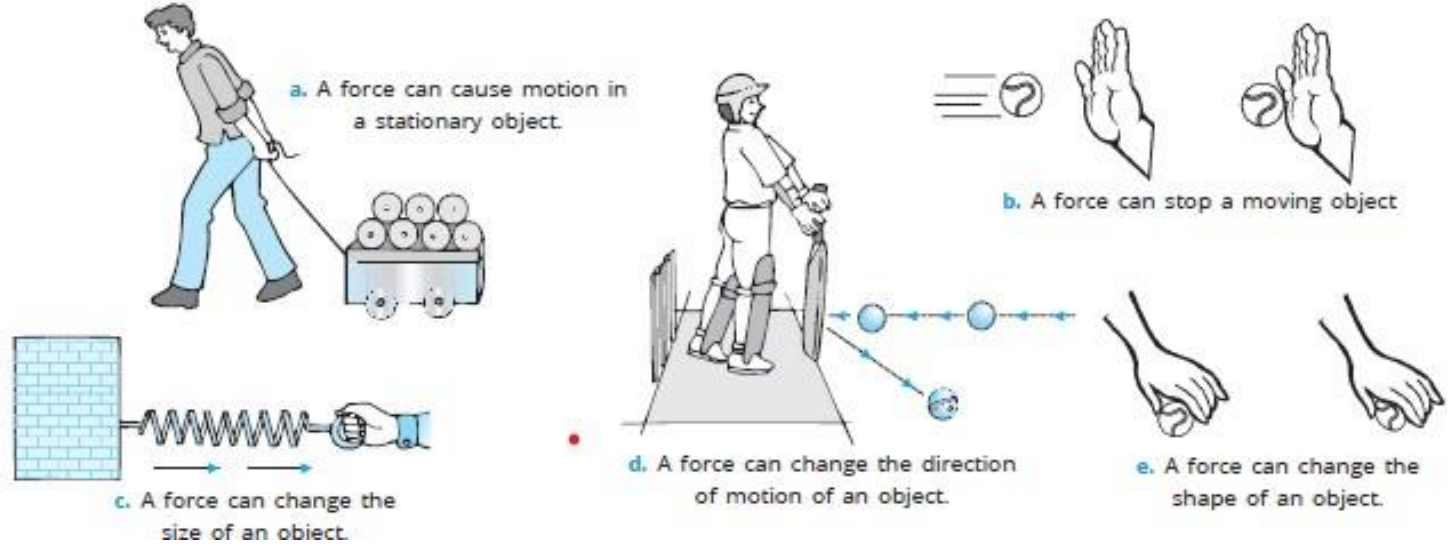
Magnetic force

The magnetic force exerts a pull on magnetic materials for example, iron, cobalt and nickel. This magnetic force acts from a distance.



Effects of Force

1. Force can cause motion in a stationary object. 2. Force can stop a moving object 3. Force can change the direction of motion of an object 4. Force can change the speed of a moving body 5. Force can change the shape and size of an object



Newton's First Law of Motion

Every body continues to be in its state of rest or of uniform motion in a straight line unless it is compelled by some external force to change that state.

Inertia

The inherent property of a body by virtue of which it resists any change in its state of rest or of uniform motion in a straight line on its own is called its inertia.

Mass and Inertia: Mass is the measure of the inertia of a body. Quantitatively, inertia of a body is measured by the mass of the body. Heavier the body, greater is the force required to change its state and greater is its inertia. The reverse is also true.

Kinds of Inertia

Inertia of a body is of the following two types: **A.** Inertia of rest **B.** Inertia of motion

Examples of Inertia of rest: 1. A passenger in a bus tends to fall backward when the bus starts suddenly 2. On shaking or giving jerks to the branches of a tree, the fruits fall down 3. Dust can be removed from a hanging carpet by shaking it or beating it with a stick 4. A bullet fired against a glass windowpane makes a hole in it but the glass pane is not cracked

Examples of Inertia of motion: 1. A passenger in a moving bus tends to fall forward when the bus stops suddenly 2. A person jumping out of a speeding bus may fall forward 3. An athlete runs a certain distance before taking a long jump 4. A cyclist does not come to rest immediately after he stops paddling

Linear Momentum

The linear momentum of a body of mass *m* moving with velocity *v* is defined as the product of its mass and velocity.
Thus, linear momentum, $p = mv$. The SI unit of momentum is kilogram metre per second which is written as kg m s–1 or kg m/s.

Newton's Second Law of Motion in Terms of Momentum

The rate of change of momentum of a body is directly proportional to the net external force applied on it and the change in momentum takes place in the direction in which the force is applied.

$$F = m(v-u)/t = ma$$

Force = mass x acceleration
The SI unit of force is **newton**. The symbol of newton is **N.**
[1 newton = 1 kg . 1 m/s^2].

Derivation of *F = ma*

When a force is applied on a body, its velocity changes. So, the force applied on a body produces an acceleration in it. The acceleration produced may be positive or negative. The acceleration produced in a body is directly proportional to the force applied on it (if mass remains constant), i.e.

Acceleration produced in a body (a) œ Force applied *a* on the body (*F*). It has also been found that the acceleration produced in a body is inversely proportional to the mass of the body, i.e.

Acceleration produced in a body (*a*) œ 1/ Mass of the body *m* .

So, Acceleration produced in a body (*a*) œ Force applied on the body (F) / Mass of the body (m)

or Force applied on the body (*F*) œ Acceleration produced in a body (*a*) x Mass of the body (*m*),

Force œ Mass x Acceleration

i.e. $F \propto m \times a$ or $F = k\,ma$

or $F = ma$ $(K=1)$

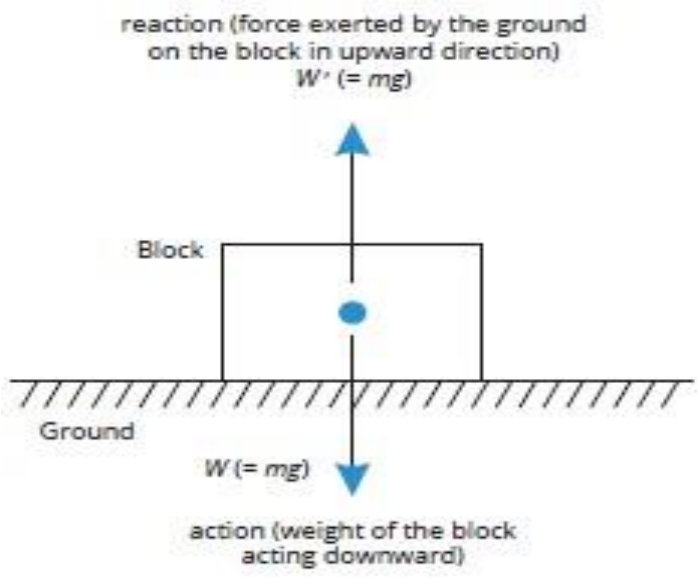
or Force = Mass x Acceleration

This is the mathematical form of Newton's second law of motion.

Newton's Third Law of Motion

To every action, there is an equal and opposite reaction; action and reaction forces act on different bodies. In other words, whenever two bodies interact with each other, the force exerted by the first body on the second (called action) is equal and opposite to that exerted by the second body on the first body (called reaction).

If a block when placed on the ground, exerts a force acting downwards equal to its weight *W* (*mg*) on the ground (due to the attraction by the earth). This is called **action**. The ground exerts an equal and opposite force *W ′* (*mg*) on the block in the upward direction. This is called **reaction.**

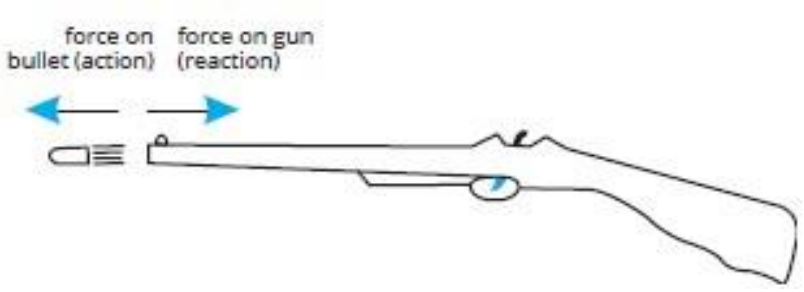


From the above example the following points must be noted carefully:

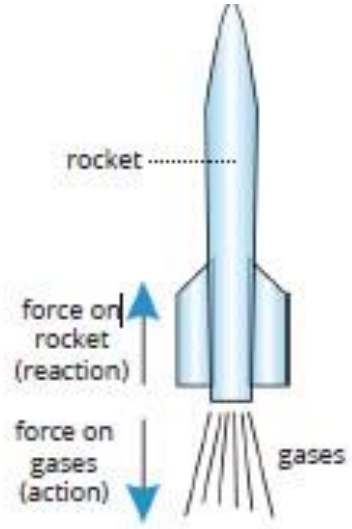
1. Both action and reaction are forces [In this case, $F = mg$].
2. Action and reaction act simultaneously but on different bodies [In this case the block and the ground are two different bodies on which action and reaction act simultaneously].
3. The magnitude of force F_{AB} applied by the body A on the body B is equal in magnitude to the force F_{BA} applied by the body B on the body A. But they are opposite in direction.
4. Action and reaction act on different bodies. For this reason, they cannot cancel each other.
5. Action and reaction forces occur in pairs only .
6. Action–reaction pair occur only if they satisfy the A-on-B and B-on-A requirement.

Examples of Newton's third law of motion

1. Action and reaction when a bullet is fired from the gun

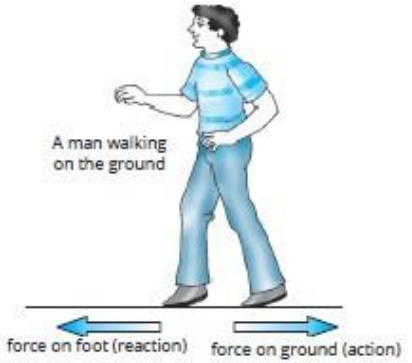


2. Action and reaction in the case of a rocket



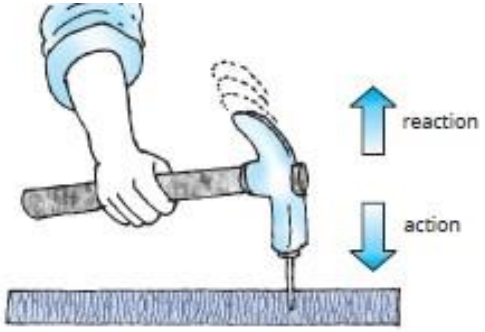
3. Action and reaction acting on a person during swimming

4. Action and reaction when we walk on the ground

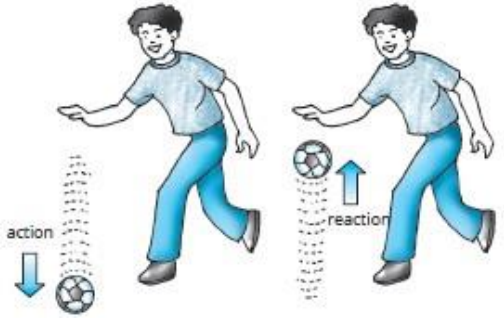


5. Action and reaction when a man steps out of a boat

6. Action and reaction when you hammer a nail into a wooden plank



7. Rebound of a rubber ball



SUMMARY...

1. Force: Force is a push or pull which changes or tends to change the state of rest or of uniform motion, the direction of motion or the shape and size of a body.

2. Contact forces: Contact forces are the forces which act only when objects are in physical contact with each other.

3. Examples of contact forces: a. Frictional force **b.** Normal reaction force **c.** Tension force **d.** Force exerted during collision **e.** Force applied as a pull or push.

4. Non-contact forces: The forces which do not involve physical contact between the surfaces are called noncontact forces.

5. Examples of non-contact forces: a. Gravitational force **b.** Electrostatic force **c.** Magnetic force.

6. Effects of force: a. Force can cause motion in a stationary object. **b.** Force can stop a moving object. **c.** Force can change the direction of motion of an object. **d.** Force can increase or decrease the speed of a moving body. **e.** Force can change the shape and size of an object.

7. Units of force: a. SI unit is newton. **b.** CGS unit is dyne. Also, 1 newton = 10^5 dynes.

8. Newton's first law of motion: Every body continues to be in its state of rest or of uniform motion in a straight line unless it is compelled by some external force to change that state.

9. Inertia: The inherent property of a body by virtue of which it resists any change in its state of rest or of uniform motion in a straight line on its own is called its inertia.

10. Linear momentum: The linear momentum of a body of mass *m* moving with velocity *v* is defined as the product of its mass and its velocity.

11. Unit of linear momentum: kg m/s (kilogram metre per second)

12. Newton's second law of motion: It states that "The rate of change of momentum of a body is directly proportional to the net external force applied on it and the change in momentum takes place in the direction in which the force is applied."

13. Mathematical form of newton's second law of motion, Force = Mass $\times$ Acceleration

14. Newton's third law of motion: It states that "To every action there is an equal and opposite reaction; action and reaction forces act on different bodies."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