Force And Laws Of Motion

CLASS-9^{TH} CHAPTER-9^{TH}

CONTACT ME

Ranjeeta@studyiq.com - email id
Instagram – ranjeeta1208
Telegram - https://t.me/drranjeeta

what causes the motion.
Why does the speed of an object change with time?
Do all motions require a cause?
If so, what is the nature of this cause?

A ball on the ground, when given a small hit, does not move forever. Such observations suggest that rest is the "natural state" of an object. This remained the belief until Galileo Galilei and Isaac Newton developed an entirely different approach to understand motion.

Introduction to Force

- A force is an effort that changes the state of an object at rest or at motion.

- It can change an object’s direction and velocity. Force can also change the shape of an object.

What are the Effects of Force?

- In physics, motion is defined as the change in position with respect to time.

- In simpler words, motion refers to the movement of a body. Typically, motion can either be described as:

  - Change in speed
  - Change in direction

The Force has different effects and here are some of them.

- Force can make a body that is at rest to move.
- It can stop a moving body or slow it down.
- It can accelerate the speed of a moving body.
- It can also change the direction of a moving body along with its shape and size

- We ordinarily experience this as a muscular effort and say that we must push or hit or pull on an object to change its state of motion.
- The concept of force is based on this push, hit or pull.
- However, we always see or feel the effect of a force.
- It can only be explained by describing what happens when a force is applied to an object.
- Pushing, hitting and pulling of objects are all ways of bringing objects in motion.

(a) The trolley moves along the direction we push it.

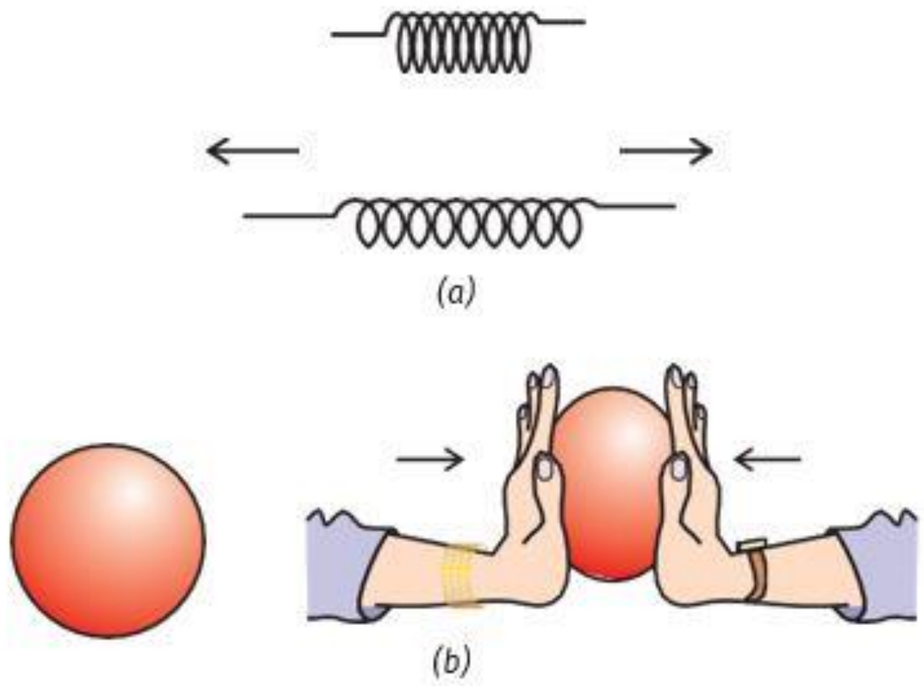
(b) The drawer is pulled.

(c) The hockey stick hits the ball forward

- They move because we make a force act on them.

- A force can be used to change the magnitude of velocity of an object (that is, to make the object move faster or slower) or to change its direction of motion.

- We also know that a force can change the shape and size of objects.



(a) *A spring expands on application of force;* *(b) A spherical rubber ball becomes oblong as we apply force on it.*

Unit of Force

- In the centimetre gram second system of unit (CGS unit) force is expressed in dyne.
- In the standard international system of unit (SI unit) it is expressed in Newton (N).

Types of Force

Force is a physical cause that can change the state of motion or the dimensions of an object. There are two types of forces based on their applications:

Contact Force

Non-Contact Force

Contact Force

Forces that act on a body either directly or through a medium are called contact forces.

Examples of contact forces are:

- Muscular Force
- Mechanical Force
- Frictional Force

Make use of the muscular force of animals like bullocks, horses, and camels to get the activities done.

The frictional force is another type of contact force, which acts between a pair of a surface in contact and tends to oppose the motion of one surface over the other.

Muscular Force

Mechanical Force

Frictional Force

Non-Contact Force

- Forces that act through spaces without making direct contact with the body are called non-contact forces.

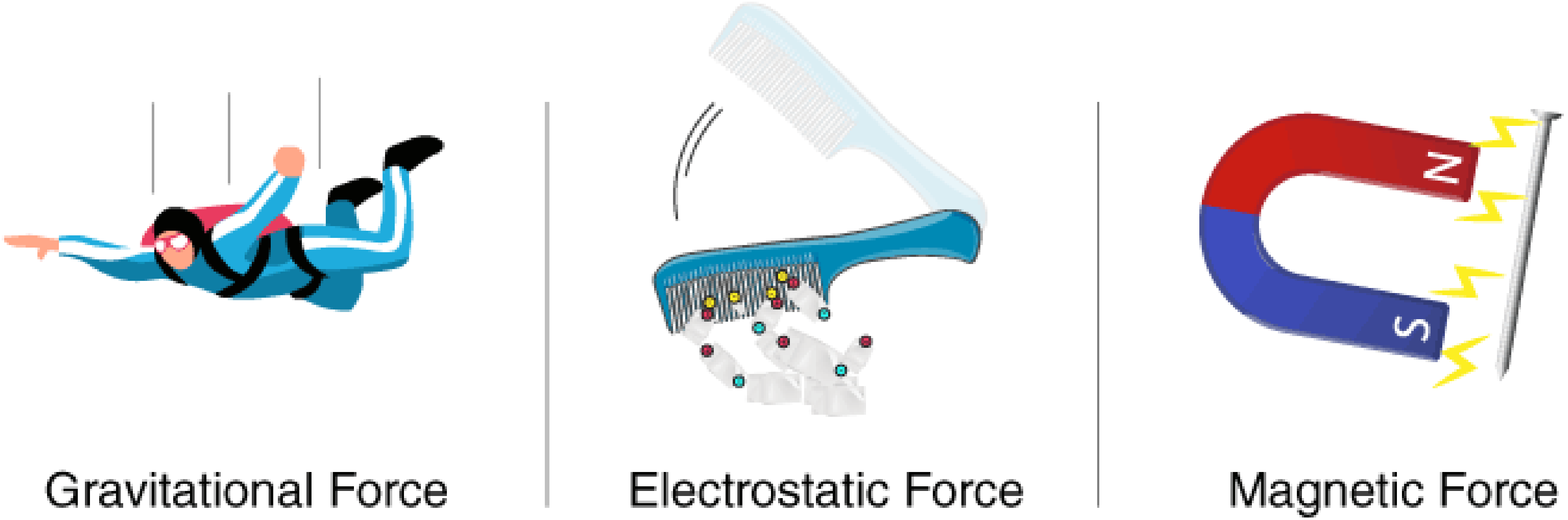
- Examples of non-contact forces are:

  - Gravitational Force
  - Electrostatic Force
  - Magnetic Force

- The force exerted by a magnet on other magnets is called magnetic force.

- Magnetic force and electrostatic force act on an object from a distance, that’s the reason they are non-contact forces.

- The strength of gravity is an attractive force that is exerted by the Earth on objects, which make them fall to the land.
- The weight of a body is the force that is pulled by the earth towards the centre.

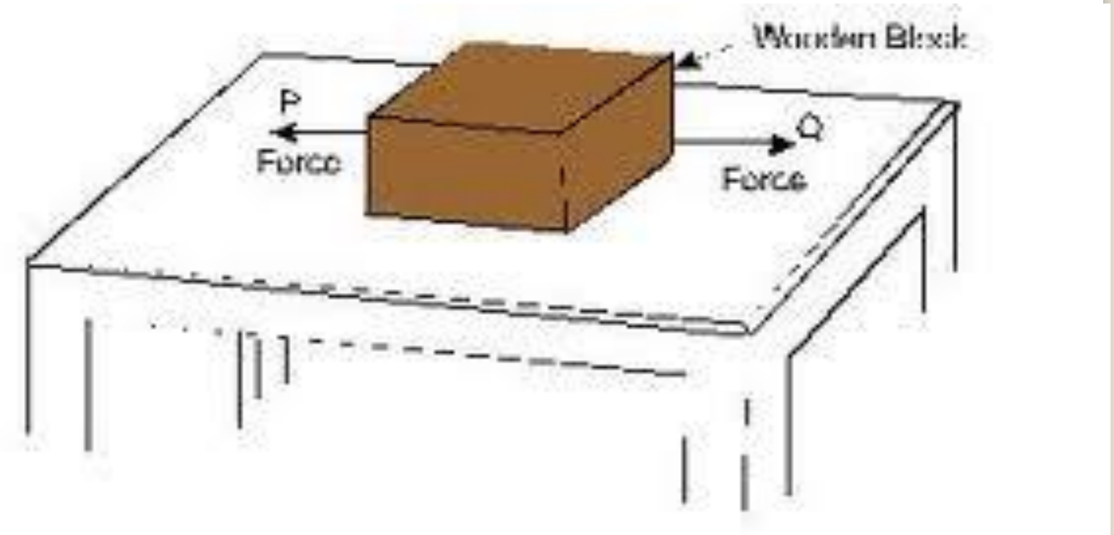


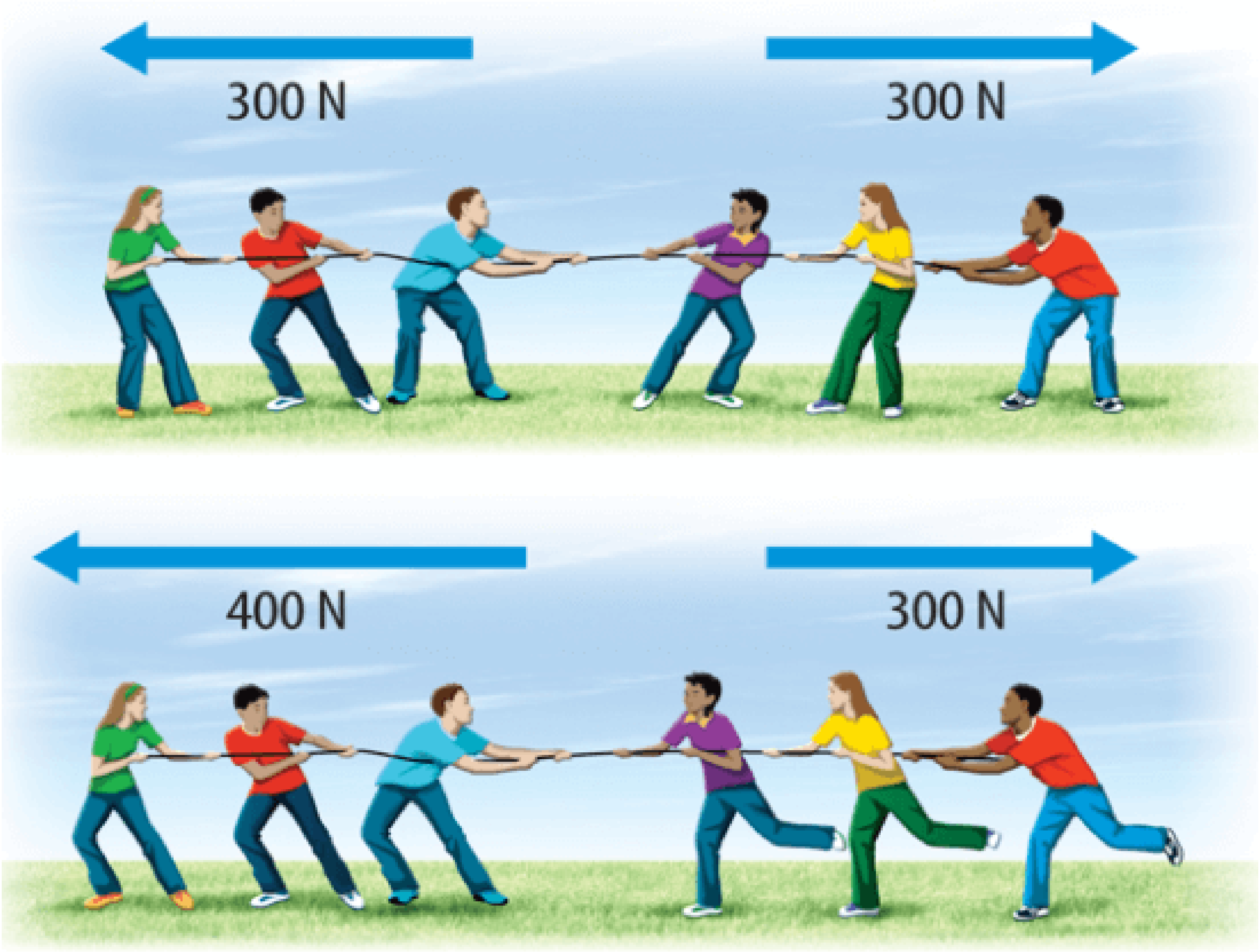
Balanced and Unbalanced Forces

- When balanced forces are applied to an object, there will be no net effective force acting on the object.

- Balanced forces do not cause a change in motion.

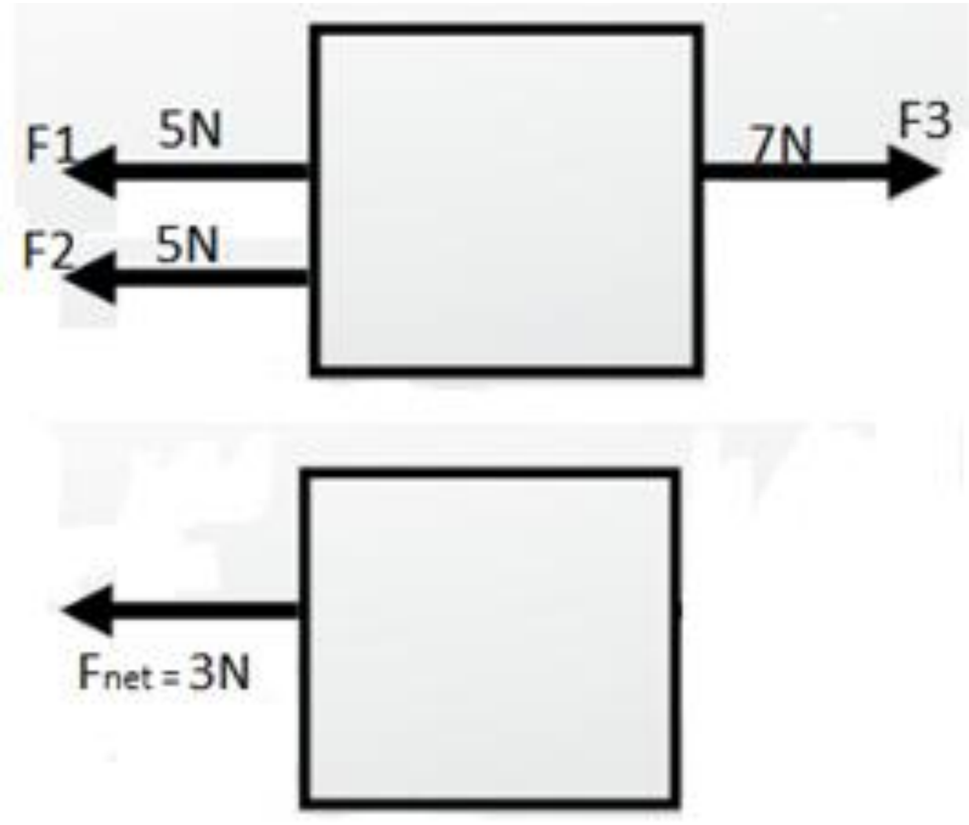
- Unbalanced forces acting on an object change its speed and/or direction of motion. It moves in the direction of the force with the highest magnitude.

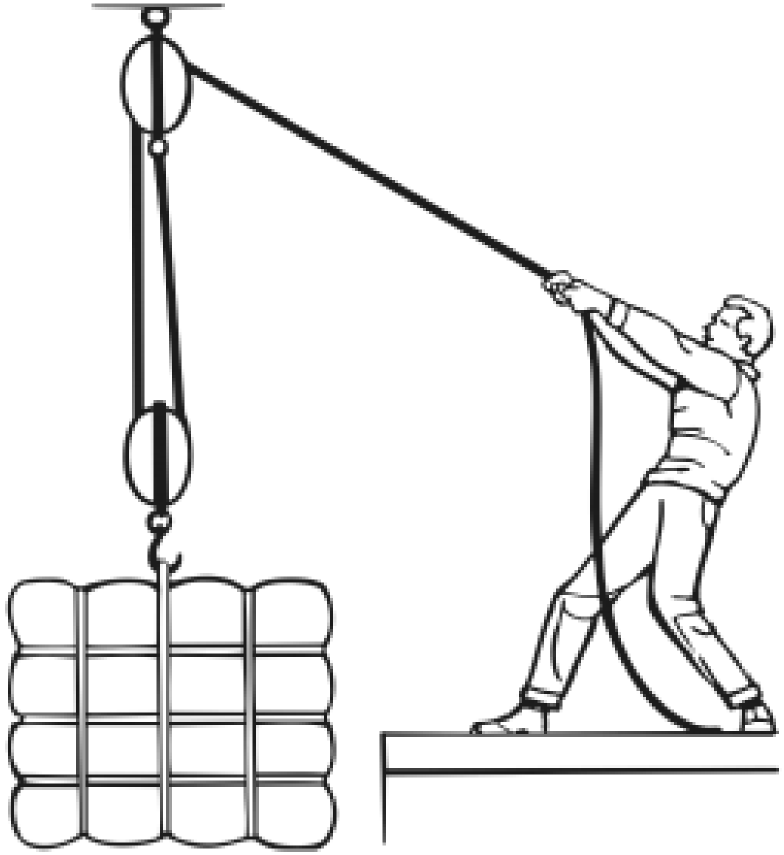



300 N
300 N
400 N
300 N

Net force

When multiple forces act on a body, they can be resolved into one component known as the net force acting on the object. For Example:





Types of forces:
In our day-to-day life we observe various types of forces around us. Some of these common types of forces are:

Gravitational force: In general, this is a force which exists because of the attraction between two bodies by the virtue of their masses. It is given by:

F = Gm1m2/r2

where,

G = Universal constant having value of 6.674×10−11Nm2/kg2

G = Universal constant having value of $6.674 \times 10^{-11} Nm^2/kg^2$

m_1, m_2 are the masses of the bodies

r is the distance between them

Electromagnetic force

- It is a force exerted by two charged particles on each other.
- Friction and Tension are the common examples of electromagnetic force.

If one of the objects exerting the force happens to be a rope, string, chain, or cable we call the force tension.

Nuclear force

- This is also known as strong force or nuclear interactions.
- Every atom has protons and neutrons. Nuclear force is responsible for binding neutrons and protons in an atom together.

- This force is many magnitudes larger than any force discussed here but it has a very short range of influence after which other forces mentioned here become dominating.

Weak force

- Sometimes a neutron changes itself to a proton, and emits an electron, and a particle called antineutrino.
- This process is called beta decay. Weak forces are responsible for such kind of decays and interactions.
- The weak force is actually a force of attraction that work at an even shorter range of 0.1 percent of the diameter of a proton.
- The forces which are responsible for such a process differ from gravitational, electromagnetic, or nuclear forces. Such forces are called weak forces.

First Law of Motion
Frictional force

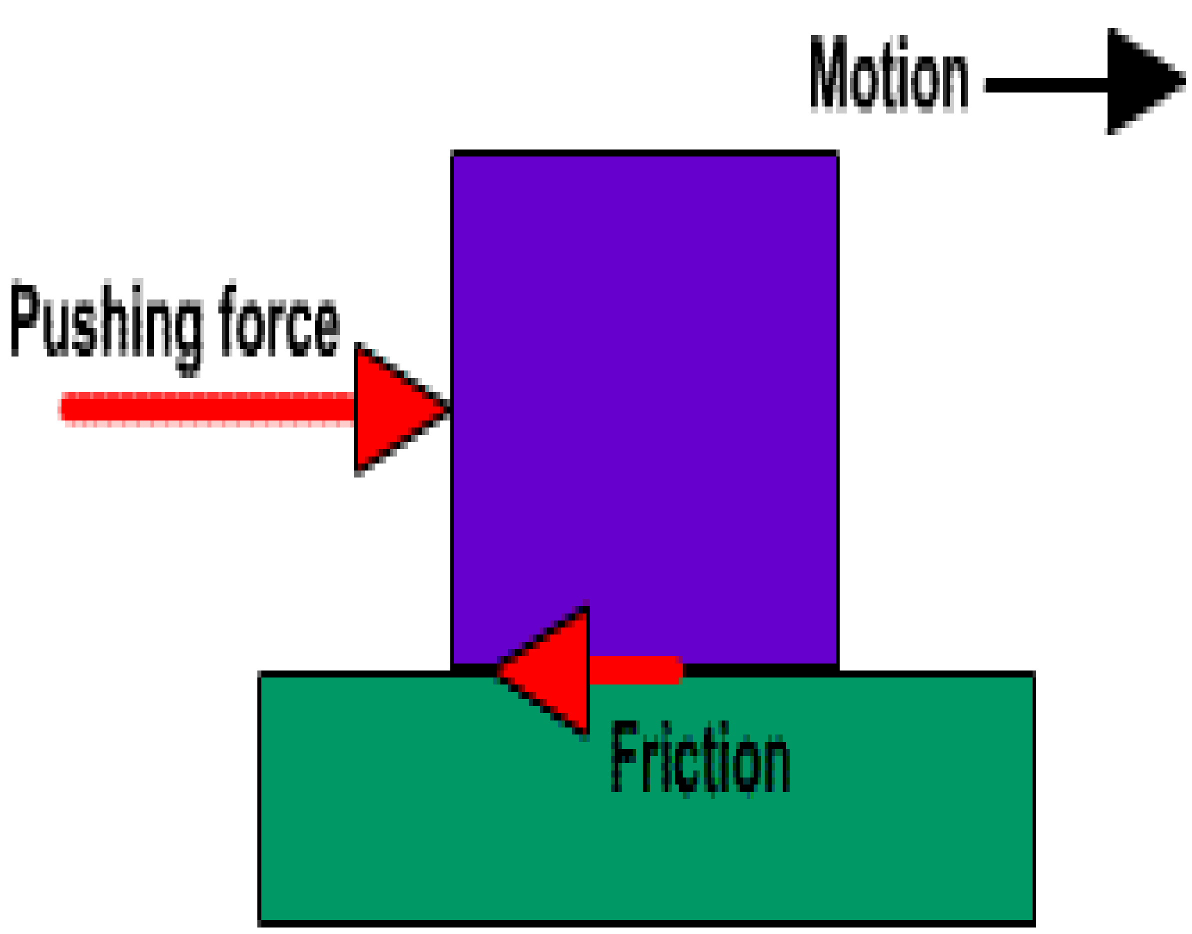
- The force that opposes relative motion is called friction. It arises between the surfaces in contact.

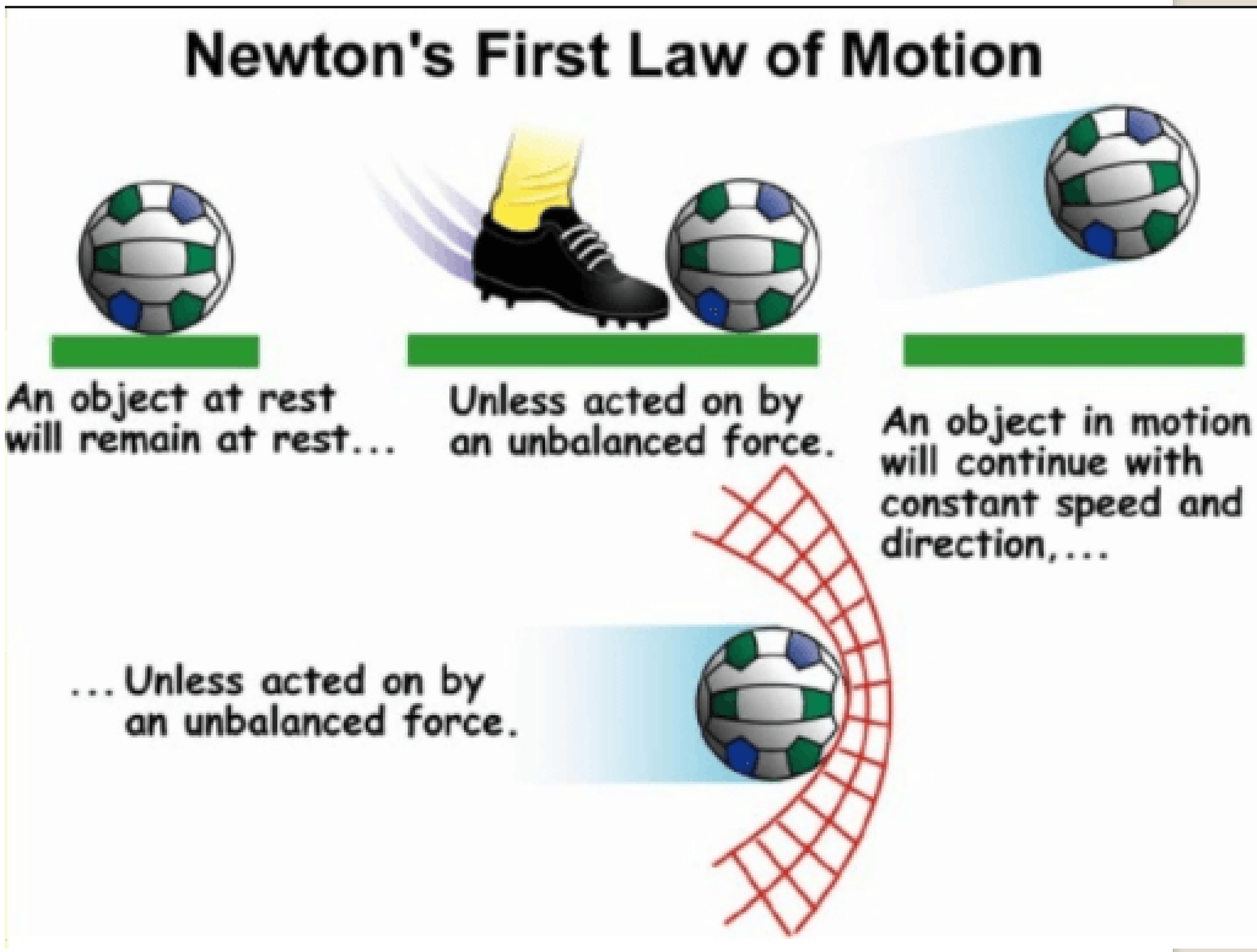
- Example: When we try to push a table and it does not move is because it is balanced by the frictional force.

- A body continues to be in the state of rest or uniform motion in a straight line unless acted upon by an external unbalanced force. The **First Law** is also called the **Law of Inertia**.

- Putting Newton’s 1st law of motion in simple words, a body will not start moving until and unless an external force acts on it.

- Once it is set in motion, it will not stop or change its velocity until and unless some force acts upon it once more.


Motion
Pushing force
Friction


Newton's First Law of Motion
An object at rest will remain at rest...
Unless acted on by an unbalanced force.
An object in motion will continue with constant speed and direction,...
...Unless acted on by an unbalanced force.

- The first law of motion is sometimes also known as the law of inertia. There are two conditions on which the 1st law of motion is dependent:

Objects at rest

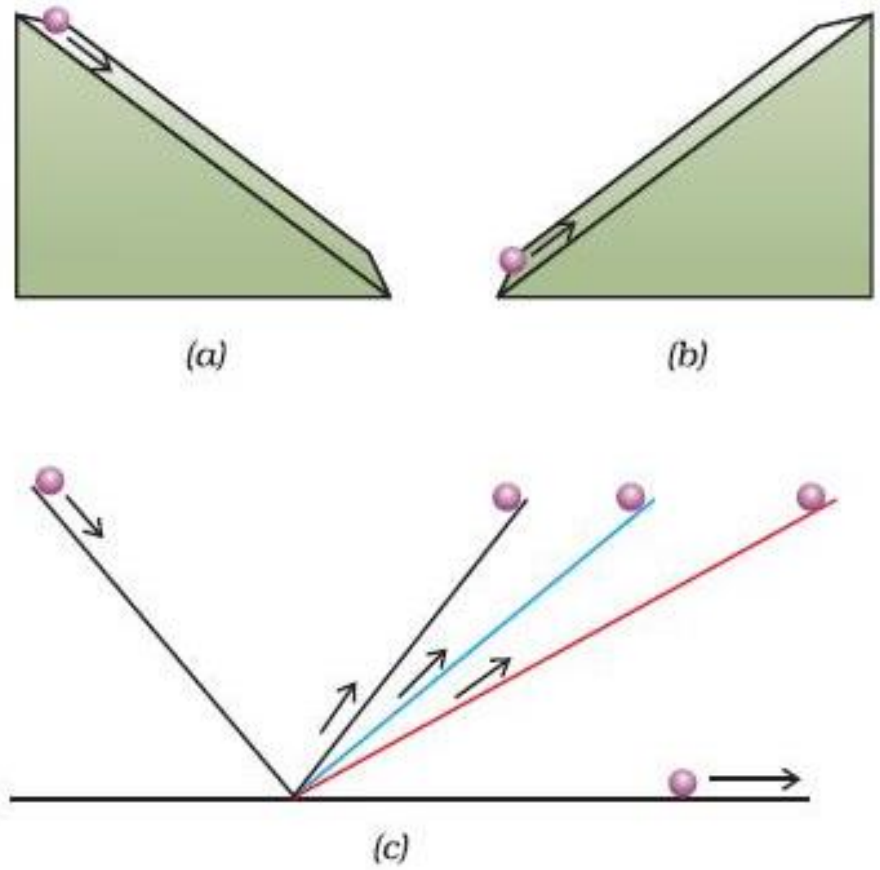
- When an object is at rest velocity ($v= 0$) and acceleration ($a = 0$) are zero.

- Therefore, the object continues to be at rest.

Objects in motion

- When an object is in motion, velocity is not equal to zero ($v \neq 0$) while acceleration ($a = 0$) is equal to zero.

- Therefore, the object will continue to be in motion with constant velocity and in the same direction.



(a) the downward motion; (b) the upward motion of a marble on an inclined plane; and (c) on a double inclined plane.

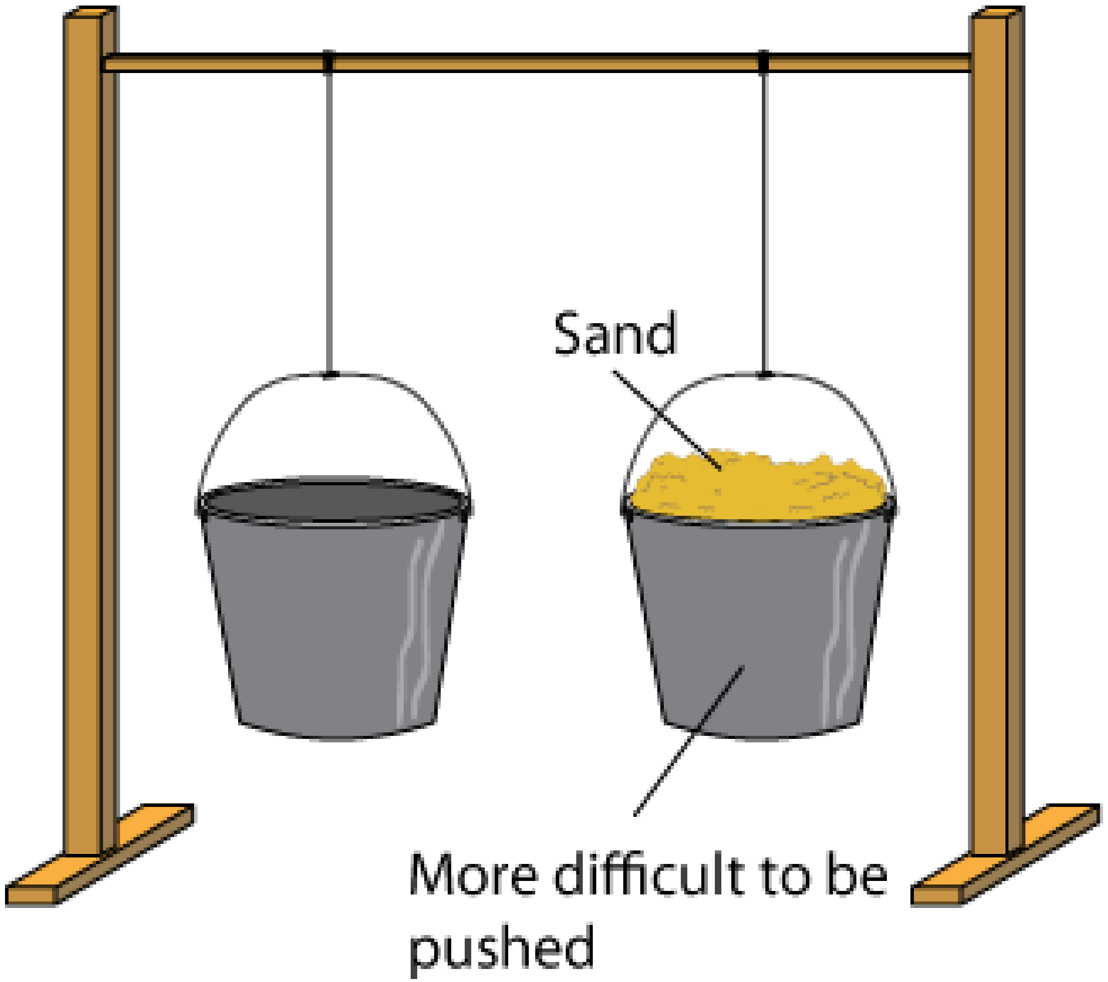
Inertia and Mass

- All objects have a tendency to resist the change in the state of motion or rest.

- This tendency is called inertia. All bodies do not have the same inertia. Inertia depends on the mass of a body.

- Mass of an object is the measure of its inertia.

- More the mass → more inertia and vice versa.


Sand
More difficult to be pushed

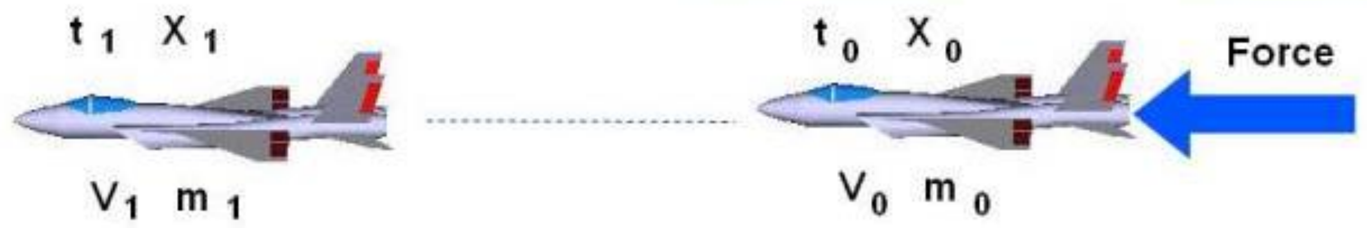
Second Law of Motion
Momentum

- Impacts produced by objects depend on their mass and velocity.

- The momentum of an object is defined as the product of its mass and velocity. p = mv. Vector quantity, has direction and magnitude.

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

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



Force = Change of Momentum with Change of Time

Difference form: $$F = \frac{m_1 V_1 - m_0 V_0}{t_1 - t_0}$$

With constant mass: $$F = m \frac{V_1 - V_0}{t_1 - t_0}$$

t = time
X = location
m = mass
V = Velocity

$$F = m\ a$$

Force = mass x acceleration

Velocity, acceleration, momentum and force are vector quantities

Conservation of Momentum
Concept of system

- The part of the universe chosen for analysis is called a system.

- Everything outside the system is called an environment.

- For example, a car moving with constant velocity can be considered a system. All the forces within the car are internal forces and all forces acting on the car from the environment are external forces like friction.

Conservation of momentum

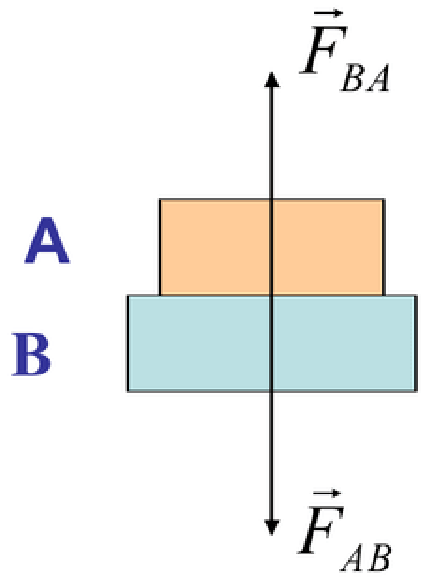
- The total momentum of an isolated system is conserved.

- Isolated system → net external force on the system is zero.

- Example: Collision of 2 balls A and B.

Newton's Third Law

For every force, or <u>action force</u>, there is an equal but opposite force, or <u>reaction force</u>.



$$\vec{F}_{AB} = -\vec{F}_{BA}$$

If object A exerts a force on object B (an "<u>action</u>"), then object B exerts a force on body A (a "<u>reaction</u>").

These two forces have the same magnitude but opposite direction.

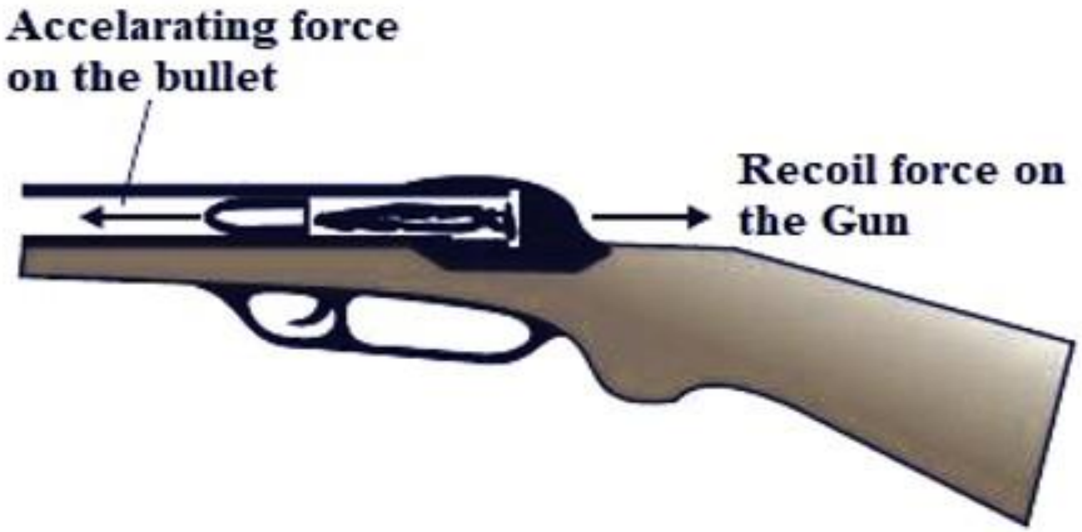
Note: these two forces act on different objects.

Third Law of Motion

- Newton’s 3rd law states that every action has an equal and opposite reaction.

- Action and reaction forces are equal, opposite and acting on different bodies.

.



A forward force on the bullet and recoil of the gun.

- The first two laws of motion tell us how an applied force changes the motion and provide us with a method of determining the force.

- The third law of motion states that when one object exerts a force on another object, the second object instantaneously exerts a force back on the first.

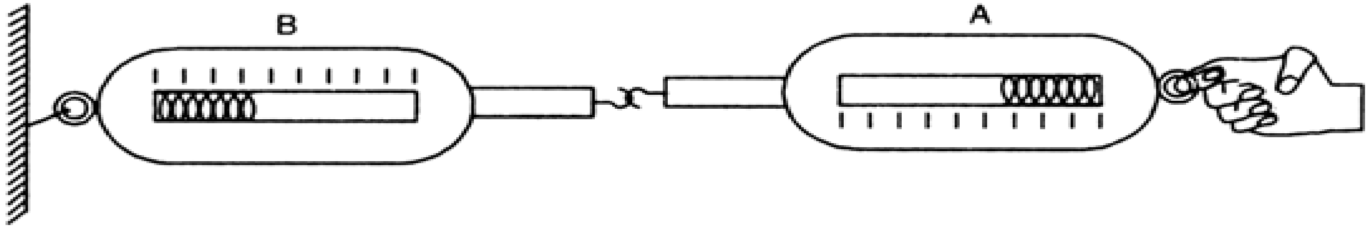
- These two forces are always equal in magnitude but opposite in direction. These forces act on different objects and never on the same object.

- In the game of football sometimes we, while looking at the football and trying to kick it with a greater force, collide with a player of the opposite team.

- Both feel hurt because each applies a force to the other. In other words, there is a pair of forces and not just one force.

- The two opposing forces are also known as action and reaction forces.

- Let us consider two spring balances connected together.
- The fixed end of balance B is attached with a rigid support, like a wall.
- -When a force is applied through the free end of spring balance A, it is observed that both the spring balances show the same readings on their scales.
- It means that the force exerted by spring balance A on balance B is equal but opposite in direction to the force exerted by the balance B on balance A.
- Any of these two forces can be called as *action* and the other as *reaction*. This gives us an alternative statement of the third law of motion i.e., to every action there is an equal and opposite reaction.
- However, it must be remembered that the action and reaction always act on two different objects, simultaneously.



Action and reaction forces are equal and opposite.

- It is important to note that even though the action and reaction forces are always equal in magnitude, these forces may not produce accelerations of equal magnitudes.

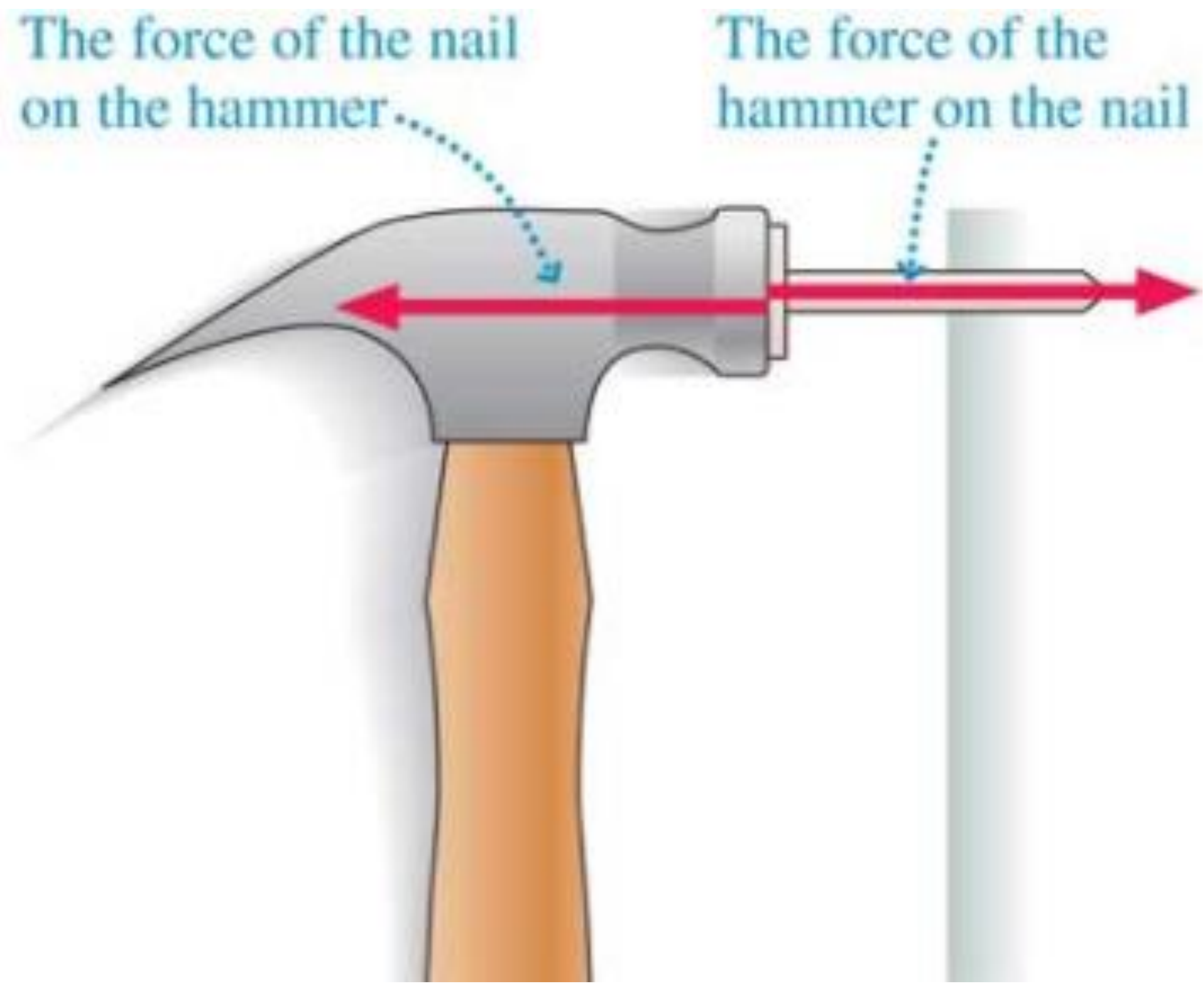
- This is because each force acts on a different object that may have a different mass.

- 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. 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.

- The third law of motion can also be illustrated when a sailor jumps out of a rowing boat. As the sailor jumps forward, the force on the boat moves it backwards.

As the sailor jumps in forward direction, the boat moves backwards.


The force of the nail on the hammer
The force of the hammer on the nail

Conservation of Momentum

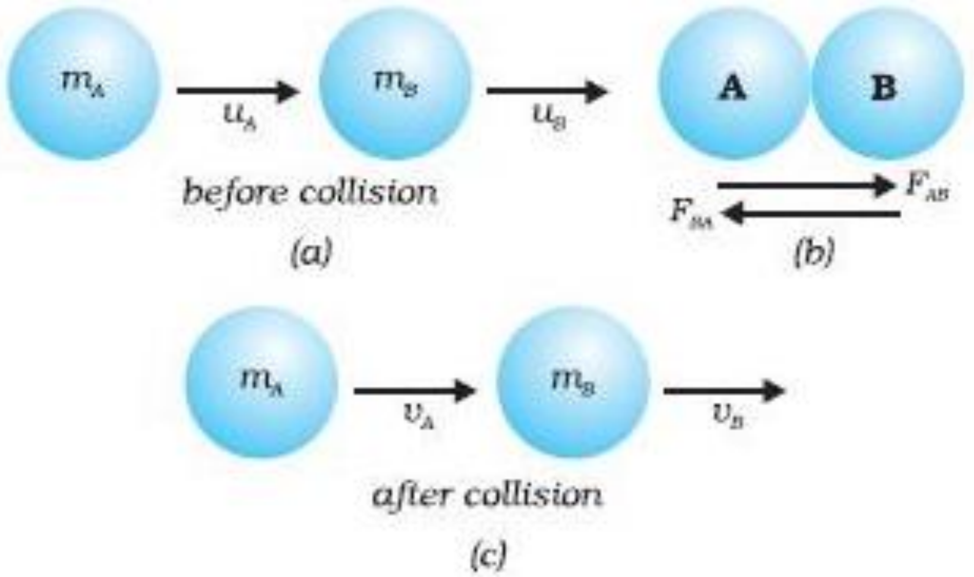
Suppose two objects (two balls A and B, say) of masses m_A and m_B are travelling in the same direction along a straight line at different velocities u_A and u_B, respectively.

And there are no other external unbalanced forces acting on them.

Let $u_A > u_B$ and the two balls collide with each other as shown in.

During collision which lasts for a time t, the ball A exerts a force F_{AB} on ball B and the ball B exerts a force F_{BA} on ball A.

Suppose v_A and v_B are the velocities of the two balls A and B after the collision, respectively.



Conservation of momentum in collision of two balls.

Change in momentum of ball A during collision $= m_A v_A - m_A u_A$

Rate of change of momentum of ball A (F_{AB}) $= m_A \dfrac{(v_A - u_A)}{t}$

Change in momentum of ball B during collision $= m_B v_B - m_B u_B$

Rate of change of momentum of ball B (F_{BA}) $= m_B \dfrac{(v_B - u_B)}{t}$

According to Newton's third law of motion the force F_{AB} exerted by ball A on ball B is equal and opposite to the force F_{BA} exerted by ball B on ball A.

Therefore $F_{AB} = - F_{BA}$

or $$m_A = \frac{(v_A - u_A)}{t} = - m_B \frac{(v_B - u_B)}{t}$$

or $$m_A v_A - m_A u_A = - m_B v_B + m_B u_B$$

or $$- m_A u_A - m_A u_A = - m_A v_A - m_B v_B$$

or $$m_A u_A + m_B u_B = m_A v_A + m_B v_B$$

Momentum of the two balls before collision is equal to the momentum of the two balls after collision.

CONSERVATION LAWS

- All conservation laws such as conservation of momentum, energy, angular momentum, charge etc. are considered to be fundamental laws in physics.

- These are based on observations and experiments. It is important to remember that a conservation law cannot be proved.

- It can be verified, or disproved, by experiments. An experiment whose result is in conformity with the law verifies or substantiates the law; it does not prove the law.

- On the other hand, a single experiment whose result goes against the law is enough to disprove it.

- The law of conservation of momentum has been deduced from large number of observations and experiments.

- This law was formulated nearly three centuries ago.

- It is interesting to note that not a single situation has been realised so far, which contradicts this law.

- Several experiences of every-day life can be explained on the basis of the law of conservation of momentum.

In 1586, he wrote his firstscientific book *'The Little Balance [La Balancitta]', in which he described* Archimedes' method of finding the relative densities (or specific gravities) of substancesusing a balance. In 1589, in his series ofessays – *De Motu, he presented his theories*about falling objects using an inclined plane to slow down the rate of descent. Galileo was also a remarkable craftsman. He developed a series of telescopes whose optical performance was much better than that of other telescopes available during those days.
Using his own telescopes and through his observations on Saturn and Venus, Galileo argued that all the planets must orbit the Sun and not the earth, contrary to what was believed at that time.

Galileo Galilei
(1564 – 1642)

THANKYOU...