SHARJAH INDIAN SCHOOL – BOYS WING
FORCE AND LAWS OF MOTION (Class IX)

First Law of Motion

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.

Inertia

The tendency of undisturbed objects to stayat rest or to keep moving with the same velocity is called inertia. This is why, the firstlaw of motion is also known as the law of inertia.
[Refer Text Book for more examples on inertia]

Inertia and Mass

The mass of an object is a measure of its inertia

Second Law of Motion

The second law of motion states that the rate of change of momentum of an object is proportional to the applied unbalanced force in the direction of force

MATHEMATICAL FORMULATION OF SECOND LAW OF MOTION

Suppose an object of mass, m is moving along a straight line with an initial velocity, u. It is uniformly accelerated to velocity, v in time, t by the application of a constant force, F throughout the time, t. The initial and final momentum of the object will be, $p_1 = mu$ and $p_2 = mv$ respectively.
The change in momentum $(p_2 - p_1) = mv - mu = m(v - u)$.
The rate of change of momentum $= m(v-u)/t$
Or, the applied force,

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$$F \propto \frac{m \times (v-u)}{t}$$

$$F = \frac{km \times (v-u)}{t}$$

$$= kma$$

where k is the constant of proportionality. In S.I unit k =1

Thus, $F = ma$

Define 1 Newton.

One Newton is defined as the amount of force that produces an acceleration of 1 ms^{-2} in an object of 1 kg mass.

Prove Newton's First Law of Motion from the Second Law of Motion

The first law of motion can be mathematically stated from the mathematical expression for the second law of motion as follows:

$$F = ma$$

$$F = \frac{m(v-u)}{t}$$

$$Ft = mv - mu$$

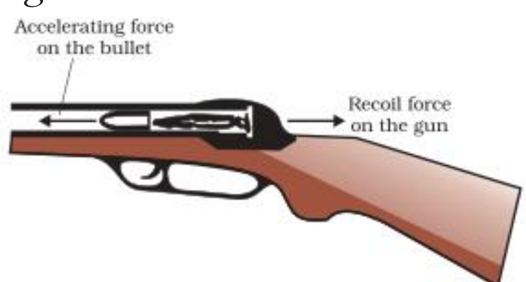
That is, when $F = 0$, $v = u$ for whatever time, t is taken. This means that the object will continue moving with uniform velocity, u throughout the time, t. If u is zero then v will also be zero. That is, the object will remain at rest. This is First Law of Motion.

Newton's third law of motion

To every action there is an equal and opposite reaction.

The action and reaction always act on two different objects. Hence they do not cancel each other.

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.
For example, when a gun is fired, it exerts a forward force on the bullet. The bullet exerts an equal and opposite reaction 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.

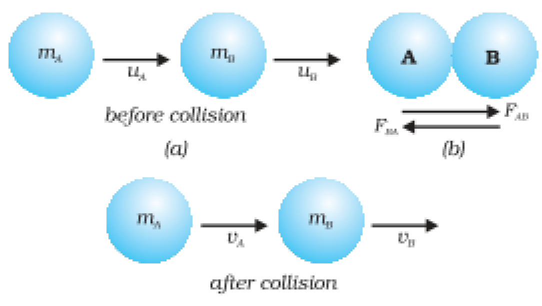
[Refer Text Book for more examples]

Law of Conservation of momentum

It states that the sum of momenta of the two objects before collision is equal to the sum of momenta after the collision provided there is no external unbalanced force acting on them. This is known as the law of conservation of momentum.
Thus the total momentum of the two objects is unchanged or conserved by the collision.

Proof

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. During collision which lasts for a time t, the ball A exerts a force F_{BA} on ball B and the ball B exerts a force F_{AB} on ball A. Suppose v_A and v_B are the velocities of the two balls A and B after the collision, respectively.



The momenta of ball A before and after the collision are $m_A u_A$ and $m_A v_A$, respectively. The rate of change of its momentum (or F_{AB}, the action) during the collision will be

$$F_{AB} = m_A \frac{(v_A - u_A)}{t}$$

Similarly, the rate of change of momentum of ball B (= F_{BA}, the reaction) during the collision will be

$$F_{BA} = m_B \frac{(v_B - u_B)}{t}$$

According to the third law of motion,

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

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

i.e., $m_A v_A - m_A u_A = -m_B v_B + m_B u_B$
On rearranging we get, $m_A u_A + m_B u_B = m_A v_A + m_B v_B$
This is the law of conservation of momentum.