If $'F'$ is the force applied on a body whose momentum at time $'t'$ is $'p'$, then from Newton's 2nd law,

$$Force\ (F) \propto Rate\ of\ change\ of\ momentum\ \left(\frac{dp}{dt}\right)$$

$$or, F \propto \frac{dp}{dt}$$

$$or, F = k\frac{dp}{dt}; \qquad \text{k is proportionality constant and its value is one}$$

$$\therefore F = \frac{dp}{dt} - - - - - (1)$$

We have, $p = mv$, then eq. (1) becomes,

$$F = \frac{d(mv)}{dt}$$

$$or, F = m\frac{dv}{dt} + v\frac{dm}{dt} \qquad \text{[differential form of Newton's 2nd law]}$$

Since, mass is constant, $\frac{dm}{dt} = 0$, then

$$or, F = m\frac{dv}{dt}$$

$$or, F = ma, \qquad a = \frac{dv}{dt}\ is\ acceleration\ of\ a\ body$$

$$\therefore \boldsymbol{F_{net} = ma}$$

If we know the mass (m) and acceleration (a) of a body, we can calculate the net force acting on the body.

- Newton's 2nd law of motion gives the quantitative (measurement) of force. (significance of 2nd law)
- The force is a vector quantity. It SI unit is $kgm/s^2\ or\ Newton\ (N)$. Its dimension is $[M^1L^1T^{-2}]$
- If $m = 1kg$ and $a = 1m/s^2$ then $F = 1N$. Hence, $1N$ force is defined as the that force which produces an acceleration of $1m/s^2$ when applied on a body of mass $1kg$.
- $\boldsymbol{1N = 10^5 dyne}$

Questions:

1. A body of mass $5kg$ at rest is acted by a force. After $5\ sec$, the body covers $50m$ displacement. Calculate the force acting on the body.
2. A force of $10N$ in applied at 60^0 to above the horizontal. Find the acceleration of $5kg$ body which moves in horizontal direction.

Newton's 3rd law:

Statement: "To every action, there is an equal and opposite reaction". i.e. $\boldsymbol{Action = -Reaction}$

- The action and reaction always act on ***two different bodies.*** Hence, they never cancel each other.
- The forces always exist in pairs. (Significance of Newton's 3rd law)
- Action-reaction pairs are of the same nature.
- This law cannot be applied to a single body. There should be an interaction between two bodies. In an interaction between two bodies in contact, the force applied by one body on the other creates a reaction force which is equal and opposite to the action.

Some Applications of Newton's 3rd law:

- While walking, a person pushes the ground in the backward direction, and the ground in return pushes the person in the forward direction, thus making him walk.
- When a bullet is fired from a gun, the gun recoils. In rocket propulsion, the burnt fuel moves downward and the rocket moves upward.
- When a man jumps from a boat, the boat moves backwards away from him. While it is difficult to walk in sand or ice. This is because we cannot push the ground sufficiently hard. As a result, the reaction force is not sufficient to help us move forward.