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Reference Frames - Newton's laws of Motion - Galilean Invariance

Let us try to understand the some important terms.

(i) Particle :- A particle is ideally a piece or a quantity of matter having practically no linear dimensions but only a position.
such idealised particles or point bodies are, of course, just a hypothetical assumption and have no real existence.

(ii) Event :- An event stands for the anything that occurs suddenly or instantaneously at a point in space. It involves both, a position and a time of occurence.

(iii) Observer : A person or an equipment which can locate, record, measure or interpet an event is called an observer.

Rest and motion :-
In relative reference frame, a particle is taken to be at rest or in motion in relation to the observer.

Reference frame :- A system of coordinate axes which defines the position of a particle or an event in two or three dimensional space is called a frame of reference.
The simplest frame of reference is cartesian system of coordinates, in which the position of

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Particles given by:

$$\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$$

So that, velocity of the particle is given by:

$$\vec{v} = \frac{d\vec{r}}{dt} \Rightarrow \frac{dx}{dt}\hat{i} + \frac{dy}{dt}\hat{j} + \frac{dz}{dt}\hat{k}$$

and its acceleration, $\vec{a} = \frac{d\vec{v}}{dt} = \frac{d^2\vec{r}}{dt^2}$

A reference frame with such four coordinates x, y, z and t is referred to as a space-time frame. The four axes defining a four dimensional continuum called space-time.

Newton's law & their limitations

1) First law: A body must continue in its state of rest or of uniform motion along a straight line unless acted upon by an external force.
2) Second law: It states that rate of change of momentum is proportional to the force and takes place in the direction of force
3) Third law: To every action, there is an equal and opposite reaction.

Obviously, the first law states that

If $F=0$ then $\vec{a}=0$

whereas, second law gives

$$\vec{F} = \frac{d\vec{p}}{dt} = \frac{d}{dt}(m\vec{v}) \text{ and}$$

again, If $\vec{F}=0$ then $\vec{a}=0$.