## Chapter 39 Relativity

→ Introduction to the special theory of relativity and its consequences.

### 39.1 Classical relativity

**→ Galilean relativity : Ideas of relativity embodied in Newtonian mechanics.**

- **Frame of reference :**

  Definition : i) A reference frame extends infinitely far in all directions.

  ii) The experimenters are at rest in the reference frame.

- An ***Inertial Reference Frame*** (IRF) is one in which Newton's laws hold.

- **Principle of Galilean relativity** :

  $\Rightarrow$ The law of mechanics must be the same in all inertial frames of reference.

- **Galilean transformation :** Find the relationship between space-time coordinates in two inertial reference frames $S$ and $S'$.

1) Space - Time transformation :

$$x' = x - vt$$
$$y' = y$$
$$z' = z$$
$$t' = t$$

2) Velocity transformation :

$$u_x' = u_x - v$$

## 39.3 Einstein's principle of relativity

Special relativity : Deals only with inertial reference frames.
(*i.e.*, $v$ = constant relative to one another, no acceleration)

General relativity : Noninertial (accelerating) reference frames.

↳ *Einstein's theory of gravitation*

### Special theory of relativity

- **Two postulates of the special theory of relativity :**

1) *All* the laws of physics must be same in all inertial reference frames.

2) The speed of light is always same, $c = 3\times10^8$ m/s, in every inertial reference frames, and is independent of the relative motion of the light source and the observer. → The universality of the speed of light $c$.

## 39.4 The Lorentz transformation equations

→ Correct transformation equation for $0 < v < c$.

1) Space–time transformation for $S'$:

$$x' = \gamma (x - vt)$$
$$y' = y$$
$$z' = z$$
$$t' = \gamma [\, t - (v/c^2)\, x \,]$$

Velocity transformation :

$$u_x' = ( u_x - v ) / [\, 1 - (u_x v/c^2) \,]$$

with relativistic gamma factor :

$$\gamma = \gamma(v) = ( 1 - v^2/c^2 )^{-1/2}$$

2) Space–time transformation for $S$ :

$$x = \gamma (x' + vt)$$
$$y = y'$$
$$z = z'$$
$$t = \gamma [\, t' + (v/c^2)\, x' \,]$$

Velocity transformation :

$$u_x = ( u_x' + v ) / [\, 1 + (u_x' v/c^2) \,]$$

## 39.5 Consequences of the special theory of relativity

- **Central points of relativity :**

(1) There's no absolute inertial frame of reference.

(2) Observers in different inertial frames always measure different time intervals with their clocks and different distances with their meter sticks.

The observers in different IRF may come to different conclusion about the time and space for the same event.

**39.5.1. Relativity of Simultaneity.**

**39.5.2. Time Dilation.**

**39.5.3. Length Contraction.**

**39.5.4. Four-Dimensional Space-Time.**

## 39.5.1. Relativity of Simultaneity.

## 39.5.2. Time Dilation :

$\Rightarrow$ How two observers in two different inertial frames determine the time interval between two events.

$\rightarrow$ *Moving clocks run slow* : Clocks moving relative to an observer are measured by that observer to run more slowly as compared to clocks at rest.

- Time dilation formula : $\Delta t = \gamma \, \Delta t_p$

  with proper time interval $\Delta t_p$ (the time interval between the two events in a reference frame where the two events occur at the same point in space).