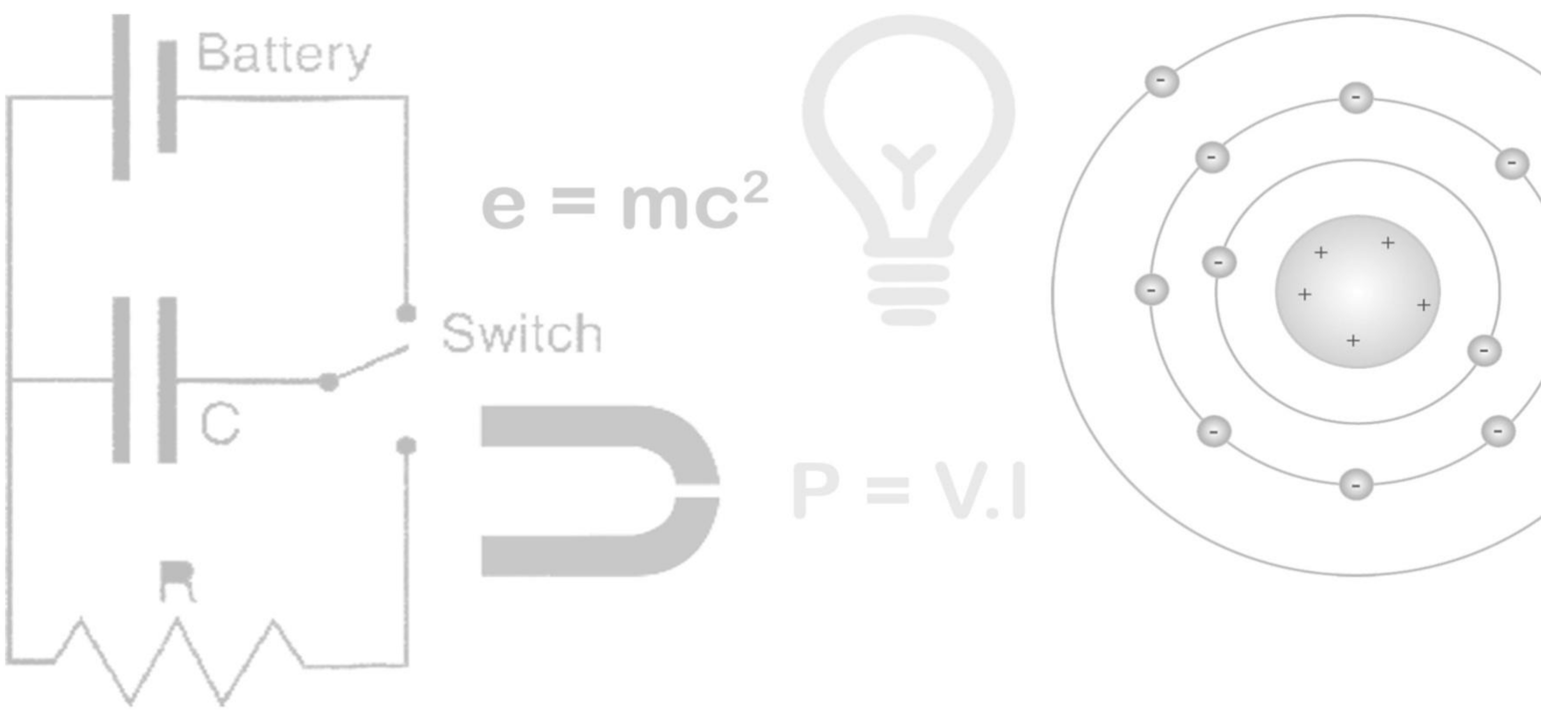
PHYSICS



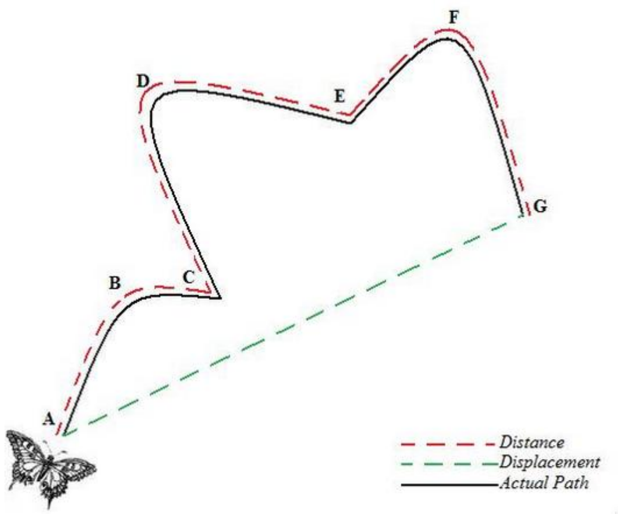
Motion

Rest and Motion

- If the position of an object does not change as time passes, then it is said to be at **rest**. If the position of an object changes as time passes, then it is said to be in **motion**.
- An object can be at rest with respect to one thing and in motion with respect to some other thing at the same time. So, the states of **rest and motion are relative** only.
- To locate the position of an object, we have to choose some suitable **reference point** called the **origin**.

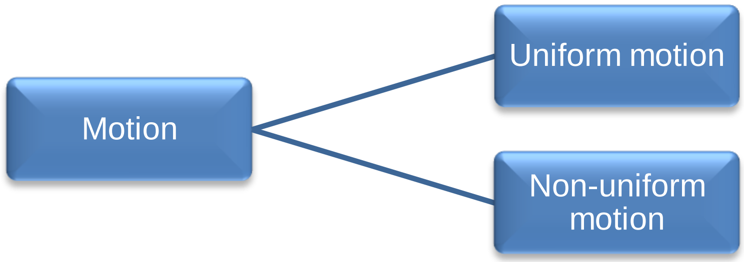
Distance and Displacement

- The **distance** travelled by an object is the length of the actual path traversed by the object during motion. It is a **scalar** quantity.
- The **displacement** of an object in motion is the shortest distance between the initial position and the final position of the object. It is a **vector** quantity.



- The distance travelled by an object in motion can never be zero or negative.
- The displacement of an object can be positive, zero or negative. Never can the distance travelled be less than the displacement.
- Both distance and displacement have the same units.

Uniform and Non-uniform Motion



- An object is said to be in **uniform motion** if it travels equal distances in equal intervals of time, howsoever small the intervals may be.
- An object is said to have **non-uniform motion** if it travels unequal distances in equal intervals of time.

Speed

- **Speed** of a body is defined as the distance travelled by the body in unit time. The SI unit of speed is **metre/second** (m/s).

$$\text{Speed} = \frac{\text{Distance travelled}}{\text{Time taken}}$$

- If 's' is the distance travelled by a body in time 't', then its speed 'v' is given as $v = \frac{s}{t}$
- Speed of a body is a **scalar** quantity. It can be zero or positive but can never be negative.
- If a body covers equal distances in equal time intervals, howsoever small the intervals may be, then it is said to have **uniform speed** (or **constant speed**).
- If a body covers unequal distances in equal time intervals, however small the intervals may be, then it is said to have **non-uniform speed** (or **variable speed**).
- For bodies moving with non-uniform speed, we describe the rate of motion in terms of their **average speed**.

$$\text{Average speed} = \frac{\text{Total distance travelled}}{\text{Total time taken}}$$

Velocity

- **Velocity** of a body is defined as the distance travelled by the body in unit time in a given direction.
- The SI unit of velocity is the same as that of speed, i.e. metre/second (m/s).

$$\text{Velocity} = \frac{\text{Distance travelled in a given direction}}{\text{Time taken}}$$

$$\text{or,} \quad \text{Velocity} = \frac{\text{Displacement}}{\text{Time taken}}$$

$$\text{i.e.} \quad \vec{v} = \frac{\vec{s}}{t}$$

where $\vec{v}$ is velocity and $\vec{s}$ is displacement of the body in time t.

- Velocity of a body is a **vector** quantity. It can be positive, negative or zero.
- A body is said to be moving with **uniform velocity** (or **constant velocity**) if it travels along a straight line, covering equal distances in equal intervals of time, howsoever small these intervals may be.
- A body is said to be moving with **non-uniform velocity** (or **variable velocity**) if it covers unequal distances in a particular direction in equal intervals of time or if the direction of motion of the body changes.
- When the velocity of a body is changing at a uniform rate over a period of time, the **average velocity** for that time period is given by the arithmetic mean of the initial and final velocity of the body.

$$\text{Average velocity} = \frac{\text{Initial velocity + Final velocity}}{2}$$

$$\text{or} \qquad \vec{v}_{av} = \frac{u+v}{2}$$

where 'u' is initial velocity, 'v' is final velocity and $\vec{v}_{av}$ is average velocity.

Acceleration

- **Acceleration** of a body is defined as the rate of change of its velocity with time.

$$\text{Acceleration} = \frac{\text{Change in velocity}}{\text{Time taken}}$$

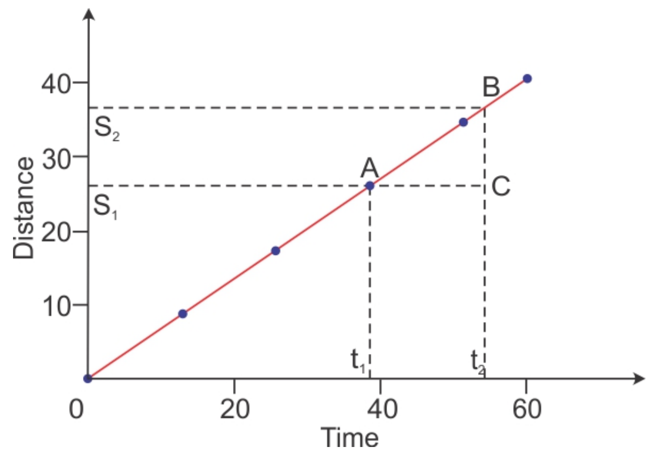
$$= \frac{\text{Final velocity - Initial velocity}}{\text{Time taken}}$$

$$\text{or, } a = \frac{v - u}{t}$$

  where 'u' is initial velocity, 'v' is final velocity, 'a' is acceleration of the body and 't' is time taken for change in velocity.
- Acceleration is a **vector** quantity. It can be positive, negative or zero. The SI unit of acceleration is metre per second square (m/s^2).
- If the velocity of a body increases, then the acceleration is positive. If the velocity of a body decreases, then the acceleration is negative. **Negative acceleration** is called **retardation**.
- If acceleration occurs in the direction of velocity, then it is taken as positive and negative when it is opposite to the direction of velocity.
- A body is said to possess **uniform acceleration** if it travels in a straight line and its velocity increases or decreases by equal amounts in equal intervals of time.
- A body is said to possess **non-uniform acceleration** if its velocity changes by unequal amounts in equal intervals of time.

Distance–Time Graph

- The distance–time graph of **a body moving with uniform speed** is a straight line.



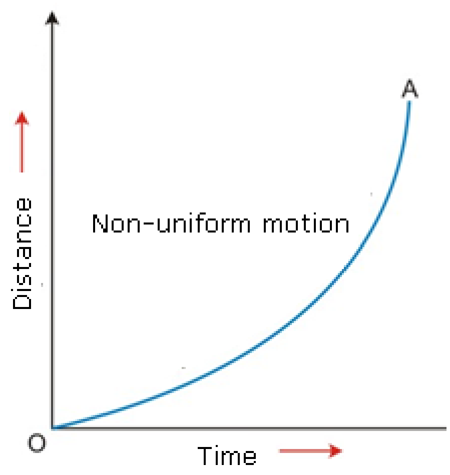
- **Speed** of a body can be obtained from the **slope of the distance–time graph**.

- Let s_1 and s_2 be the distance travelled by the object in time t_1 and t_2, respectively. Here $(s_2 - s_1)$ gives the distance travelled by the body in time interval $(t_2 - t_1)$.

$$\text{Speed} = \frac{\text{Distance travelled}}{\text{Time taken}}$$

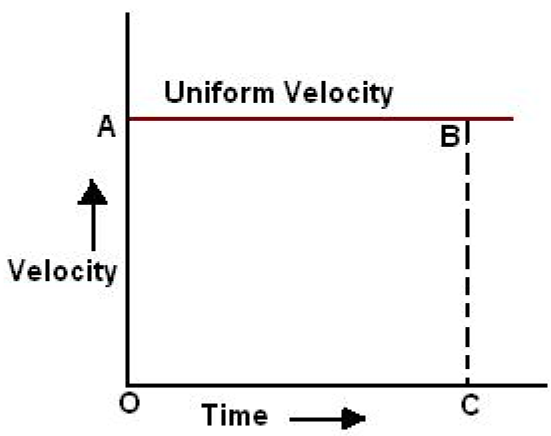
$$v = \frac{s_2 - s_1}{t_2 - t_1}$$

- The distance–time graph of **a body moving with non-uniform speed** is a curved line with a variable slope indicating variable speed.



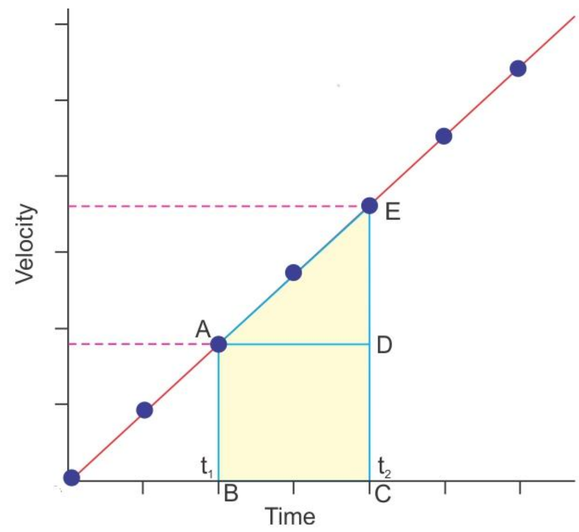
Velocity–Time Graph

- The velocity–time graph of **a body moving with uniform velocity** is a straight line parallel to the time axis.



- The magnitude of **displacement** or **distance** travelled by the body is equal to the **area enclosed by the velocity–time graph and time axis.**
Distance travelled = Speed × Time taken
= OA × OC
= Area of rectangle OABC

- The velocity–time graph of **a body moving with uniform acceleration** is a straight line inclined to the time axis.



- The **slope of the velocity–time graph** represents the **acceleration** of the body.

$$\text{Acceleration} = \frac{\text{Change in speed}}{\text{Time taken}} = \frac{ED}{AD}$$

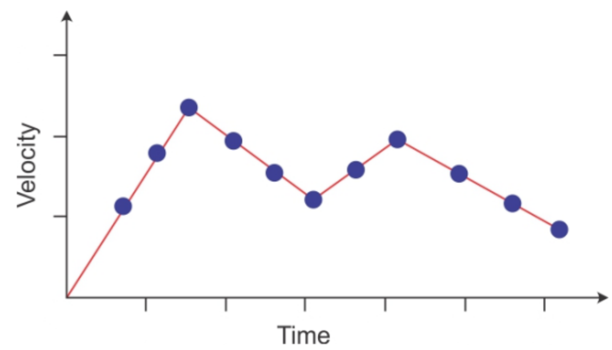
- The **area enclosed by the velocity–time graph and time axis** gives the **distance** travelled by the body.

Distance travelled = Area of ABCDE

= Area of triangle ADE+ Area of rectangle ABCD

$$= \frac{1}{2} \times AD \times DE + AB \times BC$$

- The velocity–time graph of **a body moving with non-uniform acceleration** can have any shape, indicating variable speed.



Equations of Motion

- The three equations of motion of a body moving along a straight line with **uniform acceleration are**

$$v = u + at$$

$$s = ut + (1/2)\,at^2$$

$$v^2 - u^2 = 2as$$

where '**u' is initial velocity** of the body which moves **with uniform acceleration 'a'** for time t, '**v' is final velocity** and '**s' is distance** travelled by the body in time t.

Uniform Circular Motion

- When a body moves along a circular path with a uniform speed, its motion is called **uniform circular motion.**
- Examples: Motion of the Moon around the Earth, a cyclist moving in a circular track at constant speed
- In uniform circular motion, although the speed remains constant, the direction of motion and velocity change continuously. Thus, uniform circular motion is an **accelerated motion**.
- The external force needed to make a body travel in a circular path is known as **centripetal force**.
- The circumference of a circle of radius 'r' is given by $2\pi r$. If a body takes 't' seconds to go once round the circular path of radius 'r', then its velocity 'v' is given by $v = \frac{2\pi r}{t}$.