CHAPTER 8

MOTION

Rest

A body is said to be in state of rest when its position does not change with respect to a reference point.

Motion

A body is said to be in motion when it changes its position with respect to a fixed position with time.

Motion can be of different types depending upon the type of path by which the object is going through.

i) Circular motion - in circular path

ii) Linear motion – in a straight line path
iii) Oscillatory motion /vibratory motion – to and fro motion with respect to a mean position

Vector quantity: Physical quantities which are having both magnitude as well as direction are called vector quantities.

Eg: Displacement, Force, Velocity, Acceleration, Weight

Scalar quantity: Physical quantities which are having only magnitude are called scalar quantities.

Eg: Distance, Speed, Mass

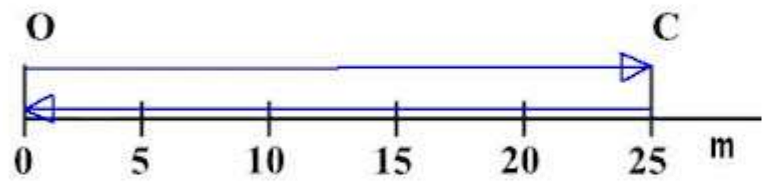
Distance:

The actual path travelled by a body is the distance travelled.

It is a scalar quantity.

Its SI unit is Metre.

Distance travelled cannot be zero or negative.



In the above fig: Distance travelled by the body from O to C and back to O is 25 + 25 = 50 m

Displacement:

The shortest distance between the initial position and final position of a body is its displacement.

It is a vector quantity.

Its SI unit is Metre.

Displacement can be zero, Positive or negative.

In the above figure: Displacement = 0

***Uniform motion*:**

When an object travels equal distances in equal intervals of time, however small the intervals may be, the motion of the object is said to be uniform.

Eg: *A car travels 10km in every 10 minutes*

***Non- uniform motion*:**

When an object travels unequal distances in equal intervals of time, the motion is said to be non-uniform.

Eg: *A body falling freely under gravity.*

Speed:

Speed of a body is defined as the distance travelled in unit time.

$$\text{SPEED} = \frac{\text{DISTANCE TRAVELLED}}{\text{TIME TAKEN}}$$

If **s** is the distance travelled by the body in time **t** its speed **v = s/t**

Speed is a scalar quantity.

Its SI unit is metre/ second (m/s)

Speed of vehicles like car or bus is expressed as km/h

The speed can be zero or positive. It can never be negative

***Uniform speed*:** When a body travels equal distances in equal intervals of time, however small the intervals may be, the speed of the body is said to be uniform.

Non- uniform speed or variable speed: When a body covers unequal distances in equal intervals of time, the speed of the body is said to be non- uniform or variable.

Average speed:

The Average Speed of a body is obtained by dividing the total distance travelled by the total time taken.

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

Velocity:

Velocity of a body is the displacement in unit time. Or

Speed of a body in a particular direction

Velocity = $\frac{\textbf{Displacement}}{\textbf{Time}}$ i.e. v = s/t

S I unit of velocity is same as that of speed (m/s)

It is a vector quantity.

It can be zero, positive or negative.

***Uniform velocity or Constant velocity*:** When a body has equal displacements in equal intervals of time, however small the intervals may be, the velocity of the body is said to be uniform or constant.

Eg: *When a train travels along a straight line, covering 60km in every hour.*

Velocity of a body can be changed in any one of the following ways.

i) By changing the **speed** of the body

ii) By changing the **direction** of motion of the body

iii) By changing both, the **speed and direction** of motion.

Non-uniform velocity:

Velocity of a body is said to be **variable (non-uniform)** when it has unequal displacements in equal intervals of time**.**

Average velocity:

CASE I : When a body is moving along a **straight line at a variable speed**, its velocity is variable. (Non-uniform).In this case the magnitude **of average velocity is equal to average speed.**

Average velocity = $\frac{\textbf{Total displacement}}{\textbf{total time}}$

CASE II: When velocity of a body is changing at a uniform rate over a period of time, then the average velocity of the body is the arithmetic mean of initial velocity and final velocity of the body.

If u is the initial velocity and v is the final velocity, then

Average velocity, $\mathbf{v_{av} = (u + v)/2}$

Acceleration:

Rate of change of velocity of a body with time is called acceleration. OR

Change in velocity of body in unit time is called acceleration.
It is represented by **a**

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

Consider a body moves along a straight line. Let **u** be the initial velocity and it changes to **v** in time t.

Acceleration a = $\mathbf{\frac{v-u}{t}}$

It is a vector quantity.

Its SI unit is **metre/second^2 (m/s^2)**
It can be zero, positive or negative.

***Negative acceleration (retardation*)**: When the velocity of a body decreases, it is called negative acceleration.

When the body is moving with uniform velocity, acceleration is zero. I.e**. v= u**

When the velocity of the body increases with time, acceleration is positive i.e**. v> u**

Eg: *When an object is dropped from a height.*

When the velocity of a body decreases, it is called negative acceleration. Negative acceleration (retardation) i.e. **v< u**

Eg: When an object is thrown vertically upward

Uniform acceleration:

When the velocity of the body moving along a straight line changes by equal amounts in equal intervals of time, the acceleration is said to be uniform.

Eg: *Motion of a body falling freely under the action of gravity.*

Motion of a ball rolling down a smooth inclined plane.

Non-uniform acceleration:

When the velocity of a body changes by unequal amounts in equal intervals of time, the acceleration is said to be non- uniform.

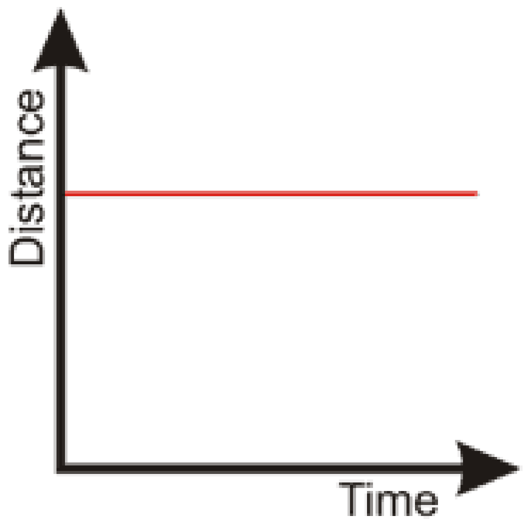
GRAPHICAL REPRESENTATION OF MOTION:

To describe motion, we can draw distance-time graph and velocity- time graph. From the nature of graphs, we can study the nature of motion.

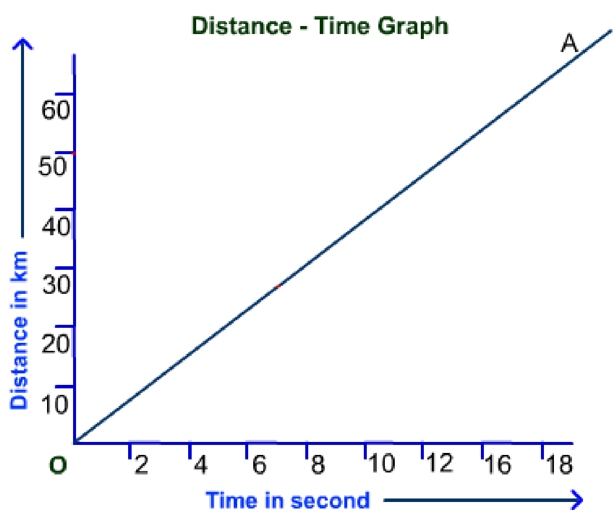
Distance- time graph:

The distance – time graph represents the change in the position of a body with time. In this graph, we take time along the X-axis and the distance along the Y- axis. Three cases arise**:**

Case I When a body is at rest, the distance – time graph will be a **line parallel to the X-axis (Time a xis)**.

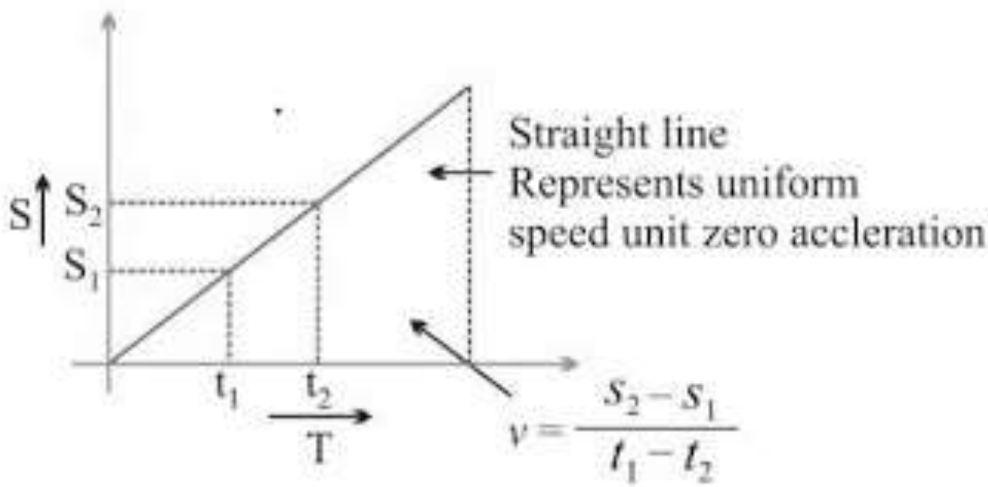


Case II: When the body is in uniform motion, the graph will be a **straight line passing through the origin**. Here, Distance travelled by the body is directly proportional to the time taken.

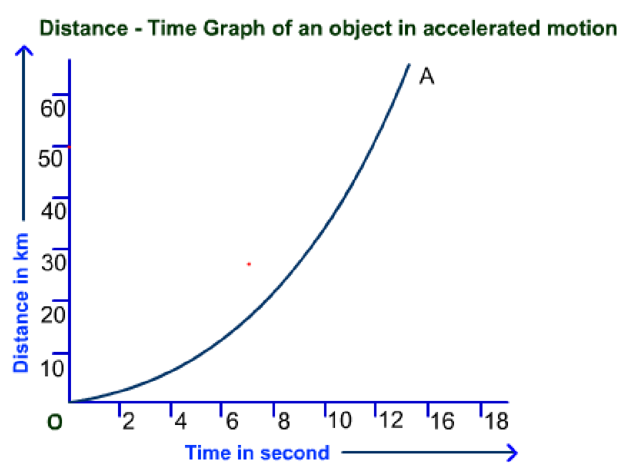


We can find the position of body and speed of body at any instant using this graph.

(i) s/t graph for uniform motion:



Case III: When the body is in non- uniform motion or accelerated motion, the graph will be a curved line.

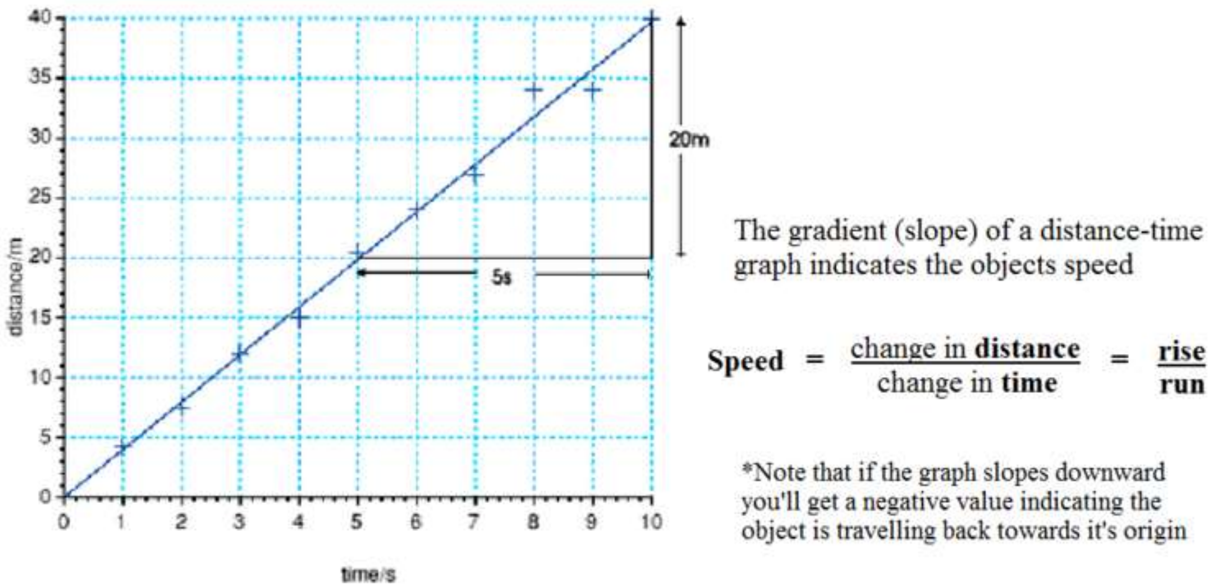


Uses of distance- time graph:

i) To determine the type of motion a body has.

ii) To compare the speed

iii) To determine the speed of the body. **Speed of the body = slope of the distance – time graph.**



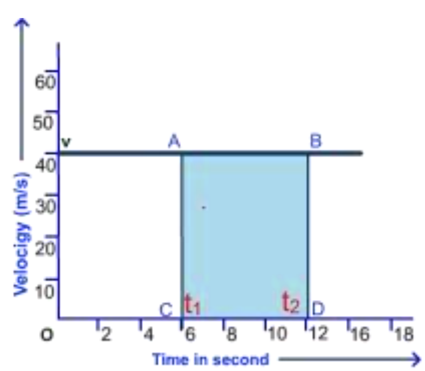
Speed = ($s_2 - s_1$) / ($t_2 - t_1$) =20/5 =4m/s

Velocity –time graph:

For a body moving along a straight line, the variation of velocity with time is represented by a velocity – time graph. There are three cases.

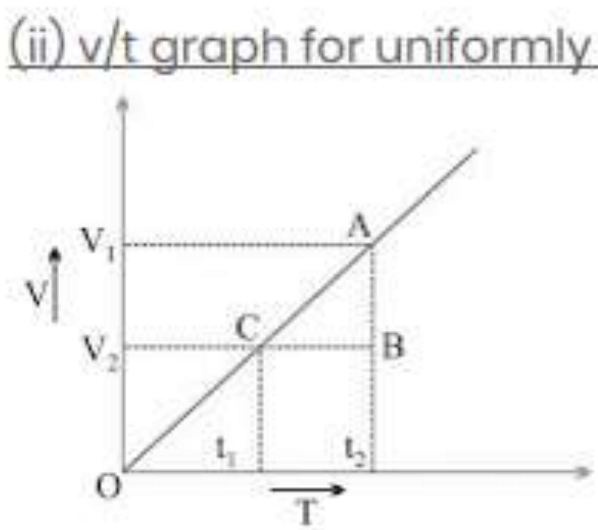
Case I: When a body is moving with **a uniform velocity.**

The velocity- time graph will be **a straight line parallel to the X-axis (time axis).**



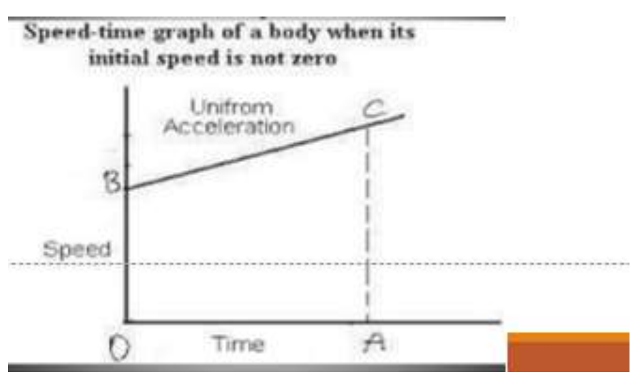
Velocity - Time Graph of an object moving with constant velocity

Case II: a) When the body is moving with a uniform acceleration, velocity- time graph is a straight line passing through the origin (Initial velocity =0)

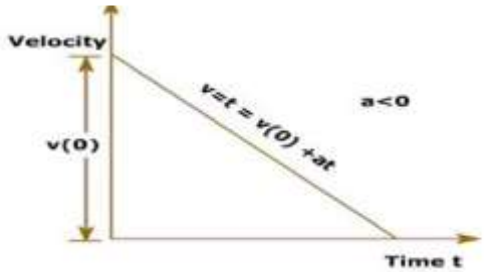


$$a = \frac{v_2 - v_1}{t_2 - t_1}$$

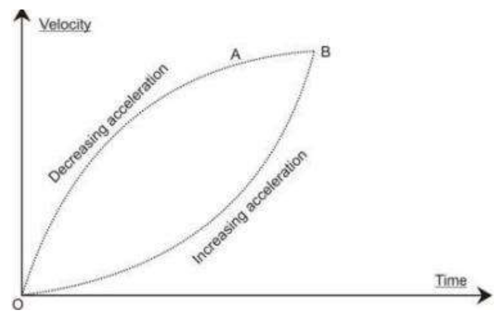
b) When initial velocity is not zero



Case II: c) When a body moves with uniform **retardation (negative acceleration**

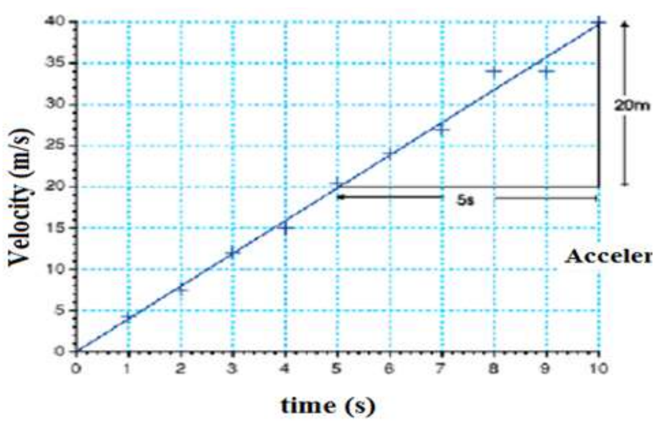


Case III: When the body is moving with non- uniform acceleration (variable) the velocity –time graph is **a curved line.**



Velocity – time graph can be used to

i) Identify **the type of motion** a body has
ii) To compare the acceleration produced in two bodies
iii) Determine **the acceleration** of the body.



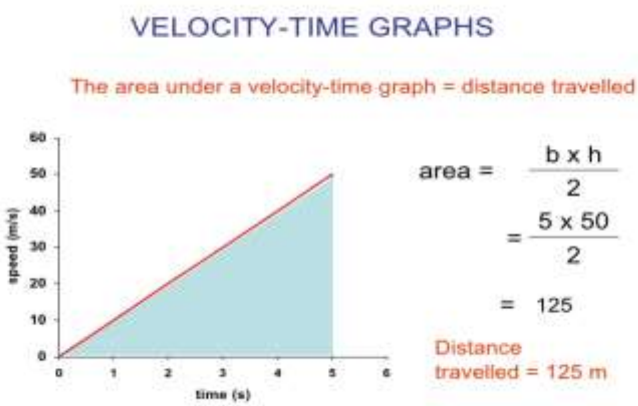
Acceleration = Slope of v- t graph

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

$$= (\mathbf{v_2 - v_1}) / (\mathbf{t_2 - t_1})$$

$$= 20/5 = 4\text{m/s}^2$$

iv v-t graph can be used to **calculate displacement or distance travelled by** a body. Distance travelled is equal to **the area enclosed by the velocity- time graph and the time axis.**

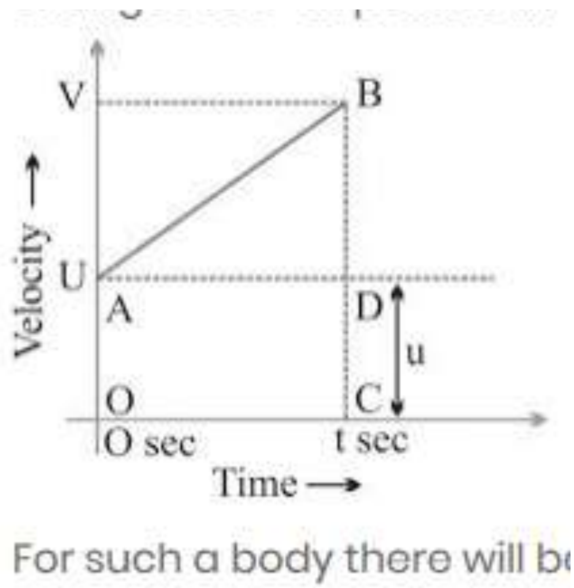


DERIVATION OF EQUATIONS OF MOTION BY

GRAPHICAL METHOD

When a body is moving along a straight line with uniform acceleration, we can establish relation between velocity of the body, acceleration of the body and the distance travelled by the body in a particular time by a set of equations. These equations are called equations of motion.

Equation for velocity – time relation



Suppose a body is moving along a straight line with a uniform acceleration a. Let u be the initial velocity of the body. Let its velocity changes to v in time t and it covers a distance s

Let OC= AD =t; OA = CD = u BC = v

Acceleration a =slope of BD

a =BD/AD

a = (BC – CD) /AD

a = (v- u)/ t

On cross multiplying

v – u = at

v= u+ at

Equation for position –time relation

Suppose a body is moving along a straight line with a uniform acceleration a. Let u be the initial velocity of the body .Let its velocity changes to v in time t and it covers a distance s.

Let OC= AD = t OA = CD = u BC = v

Distance travelled s = Area of OABC

s = Area of △ABD+ Area of rectangle OADC=1/2×AD×AB+ (OA×OC)

$s=1/2\times (v-u)\, t + ut$; But $v-u = at$

$s = ½\, at\, .t + ut$

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

$$\mathbf{s = ut + 1/2\, at^2}$$

Equation for position- velocity relation

Suppose a body is moving along a straight line with a uniform acceleration a. Let u be the initial velocity of the body .Let its velocity changes to v and it covers a distance s in time t.

Let OC= AD = t OA = CD = u; BC = v

Distance travelled = Area of trapezium OABC

$s = ½ \times OC \times (OA + BC)$

$s= ½ \times t \times (u + v)$

From 1st Eqn .of motion $t = (v- u)/a$

$$s = ½ \frac{(v-u)\,(v+u)}{a}$$

$$s = \frac{v^2 - u^2}{2a}$$

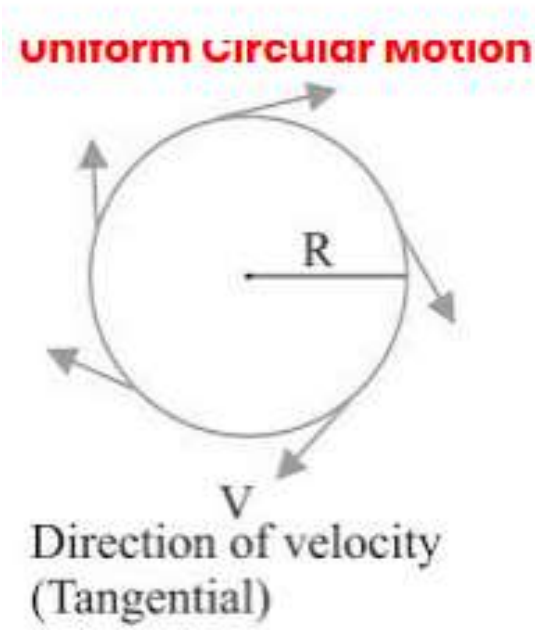
On cross multiplying $\mathbf{v^2 - u^2 = 2as}$

Uniform Circular Motion

When a body travels equal distances in equal intervals of time, over a circular path, the motion of the body is said to be uniform

.

In uniform circular motion, only the speed of the body is constant. But the **direction of motion of the body is changing continuously**. Hence uniform circular motion is **an accelerated motion.**



Direction of velocity is along the tangent to the circle at that point.

Direction of acceleration is along the radius towards the centre of the circle