Class IX

Physics

MOTION

Motion is defined as anything which is moving, which changes its position wrt fixed reference point.

Any thing which remains stationary wrt fixed reference point is called as Rest.

Difference between :

Vector Quantity	Scalar Quantity
① Those quantities which have both magnitude and direction	① Those quantity which have only magnitude.
② They cannot be added or subtracted by rules of airthmetics.	② They can be added or subtracted.
③ eg: Force, displacement, velocity etc.	③ eg: distance, Speed, time etc.

We use a symbol → over the variable eg: force $F \Rightarrow \vec{F}$

Distance	Displacement
Total path covered by a body.	The shortest path covered by the body.
It is Scalar quantity.	It is vector quantity.
SI unit is meter (m)	SI unit is meter (m)
Distance can never be zero.	Displacement can be zero.
Distance is always positive.	Displacement can be both positive and negative.

ODOMETER - Device used to measure distance travelled by any body.

UNIFORM MOTION -

When a body travels equal distance in given equal intervals of time.

NON UNIFORM MOTION. -

When a body travels unequal distance in equal time interval.

Conversion -

Km/h to m/s and viceversa -

$1\,Km = 1000\,m$

$1\,h = 60\,min = 3600\,s$

$1\,Km/h = \frac{1\,Km}{1\,h} = \frac{1000\,m}{3600\,s} = \frac{5}{18}\,m/s$

$\therefore 1\,Km/h = \frac{5}{18}\,m/s$

Similarly, $1\,m/s = \frac{18}{5}\,Km/h$

m/s to cm/s and viceversa -

$1\,m = 100\,cm$

$1\,m/s = \frac{1\,m}{1\,s} = \frac{100\,cm}{1\,s} = 100\,cm/s$

Similarly, $1\,cm/s = 0.01\,m/s$

Convert Km/min to m/s and viceversa

$1\,Km = 1000\,m$

$1\,min = 60\,s$

$1\,Km/min = \frac{1\,Km}{1\,min} = \frac{1000\,m}{60\,s} = \frac{50}{3}\,m/s$

Similarly, $1\,m/s = \frac{3}{50}\,Km/min$

SPEED -

The distance travelled per unit time.

Denoted by v.

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

$$v = \frac{s}{t}$$

Speed is a scalar quantity.

SI unit is ⇒ m/s (ms^{-1}).

Distance = m

Time = s

$$v = \frac{m}{s}$$

Speedometer is a device fitted to measure Speed at every instant of time.

This speed is called Instantaneous Speed.

AVERAGE SPEED -

Ratio of total distance travelled to total time taken by the body.

$$\text{Avg Speed} = \frac{\text{Total distance}}{\text{Total time}}$$

$$v_{av} = \frac{s_1 + s_2 + \cdots + s_n}{t_1 + t_2 + \cdots + t_n}$$

SI unit is m/s.

Uniform Speed - A body moving in uniform motion has uniform speed.

VELOCITY -

Speed with direction is called velocity.

Velocity is a vector quantity.

It is defined as displacement per unit time.

$$\vec{v} = \frac{s}{t} = \frac{\text{Displacement}}{\text{Time taken}}$$

* If a body moves along a straight line path then displacement is equal to distance.

SI unit of velocity = $\frac{m}{s}$ (ms^{-1})

* If displacement is 0, then velocity is also 0.

UNIFORM VELOCITY - A body moves along a straight line path at constant speed.

NON UNIFORM VELOCITY - Also called as Variable velocity.

Velocity can be changed by either changing speed of body or its direction or both.

AVERAGE VELOCITY -

When velocity changes repeatedly during a journey.

It is the ratio of total displacement to total time taken.

$$\text{Avg Velocity} = \frac{\text{Total Displacement}}{\text{Total time}}$$

$$\vec{V}_{avg} = \frac{s}{t}$$

Velocity at an instant is called as

Instantaneous Velocity.

If velocity of a body changes uniformly with time from an initial velocity 'u' to a final velocity 'v' in the same direction

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

$$\boxed{\vec{V}_{avg} = \frac{u+v}{2}}$$

Difference between Velocity and Speed

Velocity	Speed
• It is displacement in a specified direction per unit time.	• It is distance travelled per unit time.
• It is a vector quantity.	• It is a scalar quantity.
• It can be positive, negative or zero.	• It is never zero or negative.

ACCELERATION -

It is the rate of change of velocity of the body.

$$\text{Acceleration} = \frac{\text{change in velocity}}{\text{Time}}$$

$$= \frac{\text{final velocity } (v) - \text{Initial velocity } (u)}{\text{Time taken } (t)}$$

$$\boxed{a = \frac{v-u}{t}}$$

Acceleration is a vector quantity.

Unit of $a \Rightarrow \frac{m/s}{s} = m/s^2$ or ms^{-2}.

SI unit = ms^{-2}

① When body starts from rest, it accelerates so that its velocity increases.

Final velocity (V) > Initial velocity (u).

$(V > u)$

Thus, change in velocity is +ve and acceleration is positive (+ve)

② When body moving comes to rest, its velocity decreases.

Initial velocity > final velocity

$(u > V)$

Change in velocity is -ve and acceleration is negative (-ve).

③ Negative Acc. is called Retardation (deceleration).

④ When body moves with constant velocity for given time interval

Initial velocity = Final velocity

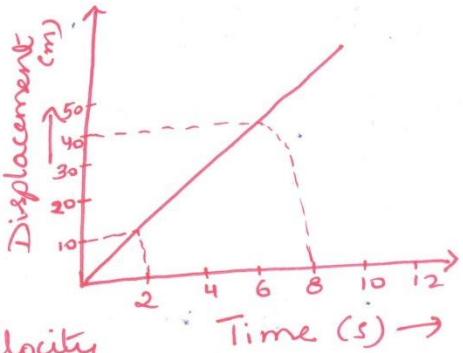
Change in velocity is Zero.

Acc. is Zero.

Graphical Representation of Motion

(a) Distance - time (Displacement-time) graph (S-t)

Velocity is obtained by finding **slope** of the graph.



Slope of graph = Velocity of body

$$= \frac{Y \text{ intercept}}{X \text{ intercept}}$$

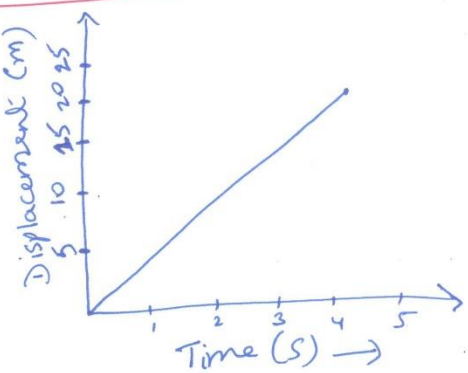
Y intercept = 40 − 10 = 30 m

X intercept = 8 − 2 = 6 s

$$\text{Slope} = \frac{30}{6} = 5 \text{ m/s}$$

(i) when body is in uniform motion.

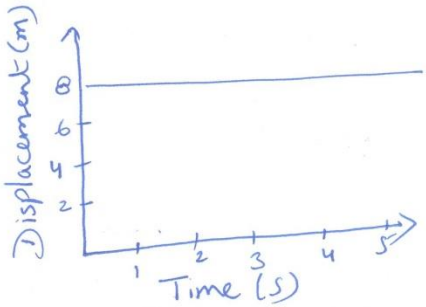
The graph is a straight line, ie, displacement is proportional to time.



The slope of this graph is Uniform Velocity

(ii) When displacement - time graph is parallel to time axis -

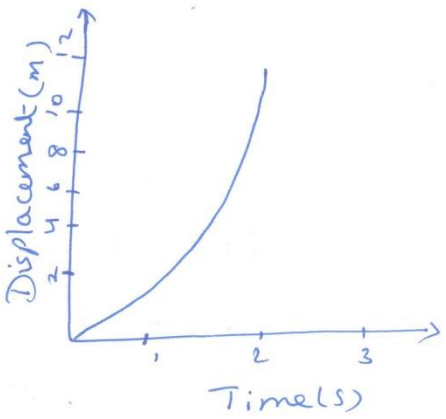
It means body is not changing its position wrt time.



The body is stationary.

(iii) When displacement - time graph is not a straight line -

It represents Variable velocity of a moving body. Hence, body has some acceleration.



(b) Velocity - Time Graphs -

The slope of such graphs give acceleration.

The acc. will be +ve if slope is +ve.

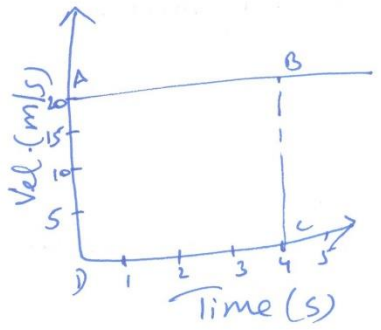
The acc. will be -ve if slope is -ve.

The area under velocity - time curve represents displacement.

Displacement = Velocity × time.

(i) When Vel - Time graph is parallel to time axis -

As slope of graph is zero, therefore, acc. is zero.



Displacement = Area of rectangle ABCD

= length × breadth

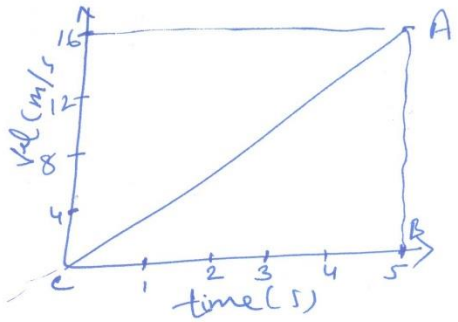
= AD × CD

= 20 × 4

= 80 m

(ii) When vel-time graph is a straight line -

When body starts from rest, its velocity increases its uniform rate.



Slope of the graph AC ie, $\frac{AB}{BC}$ gives acceleration.

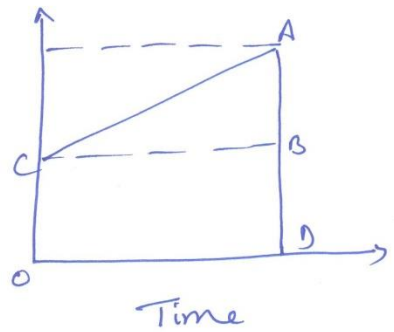
$$a = \frac{16-0}{5} = 3.2\ m/s^2$$

Area of Δ^{le} ABC gives displacement.

$$\therefore \text{Displacement} = \frac{1}{2} \times AB \times BC$$

$$= \frac{1}{2} \times 16 \times 5 = 40\ m$$

If body is initially not at rest then graph would look like,

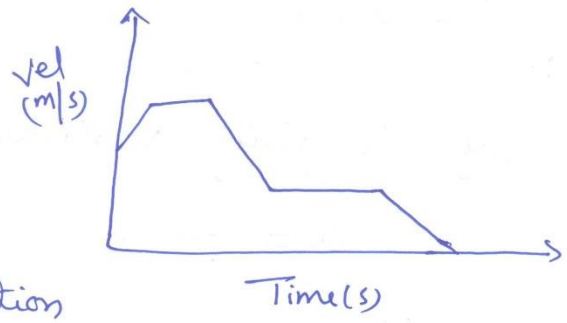


Again, Slope of AC gives acceleration

And, displacement is area of trapezium OCAD $= \frac{1}{2}$ (Sum of ||el Sides) $\times$ length

(iii) Velocity time graph in which velocity doesn't change uniformly wrt time.

Here, body has variable velocity and variable acceleration



Acc. at any instant is found by slope at that point.

EQUATION OF MOTION

I- To prove, $v = u + at$

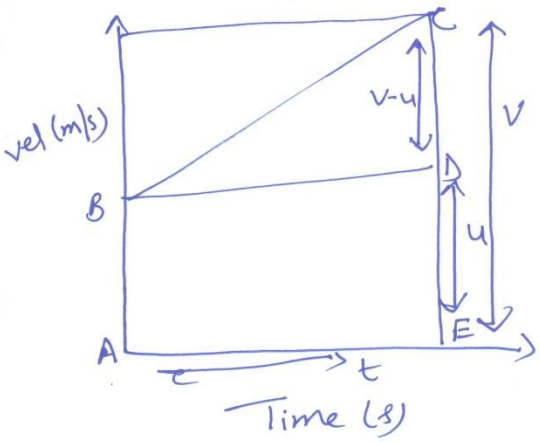
Acc. = slope of curve BC

$$= \frac{EC - DE}{BD}$$

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

$$at = v - u$$

$$\boxed{v = u + at}$$



Cases - (i) If $u = 0$ then $v = at$

(ii) If body is falling freely under gravity

$$a = +g$$

$$\boxed{V = u + gt}$$

(iii) If body is rising vertically upward

$$a = -g$$

$$\boxed{V = u - gt}$$

II - To prove $S = ut + \frac{1}{2}at^2$

Distance travelled = Area of trapezium ABCE

$$S = \frac{1}{2}(AB + CE) \times AE$$

or, S = Area of Δ^{le} + Area of rectangle

$= \frac{1}{2}$ base x altitude + length x breadth

$$= \frac{1}{2} \times (BD \times CD) + AB \times AE$$

$$= \frac{1}{2}(t \times (v-u)) + u \times t$$

$$= \frac{1}{2}(t \times at) + u \times t$$

$$\boxed{S = ut + \frac{1}{2}at^2}$$

Cases. (i) If $u=0$

$$S = \frac{1}{2}at^2$$

(ii) If $a=+g$

$$S = ut + \frac{1}{2}gt^2$$

(iii) If $a=-g$

$$S = ut - \frac{1}{2}gt^2$$

III. To prove $2aS = v^2 - u^2$

S = Area of trapezium

$$= \frac{1}{2}(AB+CE) \times AE$$

$$= \frac{1}{2}(u+v) \times t$$

We Know,

$v = u + at$

$v - u = at$

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

Sub $\Rightarrow$

$$S = \frac{1}{2}(v+u)\left(\frac{v-u}{a}\right)$$

$$= \frac{1}{2a}(v+u)(v-u)$$

$$\boxed{2aS = v^2 - u^2}$$

Case $\rightarrow$ (i) if $u=0$, $v^2 = 2as$

Uniform Circular motion -

When a body exhibits circular motion with a constant speed, it is known as Uniform circular motion.

In circular motion only magnitude of velocity remains constant while direction keeps on changing.

$$\text{Angular velocity} = \frac{\text{Angular displacement}}{\text{Time taken}}$$

$$\omega = \frac{l}{rt}$$

$$\text{Linear velocity} = \text{Radius} \times \text{Angular velocity}$$

$$= r \times \frac{l}{r \times t}$$

where, $l = 2\pi r$

Sub.

$$\boxed{v = \frac{2\pi r}{t}}$$

Numericals -

(1) A car initially at rest, picks up a velocity of 72 Km/h in $\frac{1}{4}$ min. Calculate (i) acceleration
(ii) distance covered by car.

2) A stone dropped from the top of a tower, takes 4sec to reach ground level. Calculate (i) final velocity of stone
(ii) height of tower (take $g = 10 m/s^2$)

3) If a train accelerating uniformly at $5 m/s^2$ attains a velocity of 90 Km/h after the start. find its displacement and time for which it is accelerating.

(18)

(4) A circular track has circumference of 314m. A cyclist moves along the Circumference and completes one round in half an hour. Find his distance and ~~dis~~ displacement in 45 minutes.