

Chapter - 2nd

Motion in Straight line (Motion in 1-Dimensional)

Kinematics =

{ $\begin{matrix} \text{Kine} \\ \downarrow \\ \text{motion} \end{matrix} + \begin{matrix} \text{matics} \\ \downarrow \\ \text{math} \end{matrix} \}$

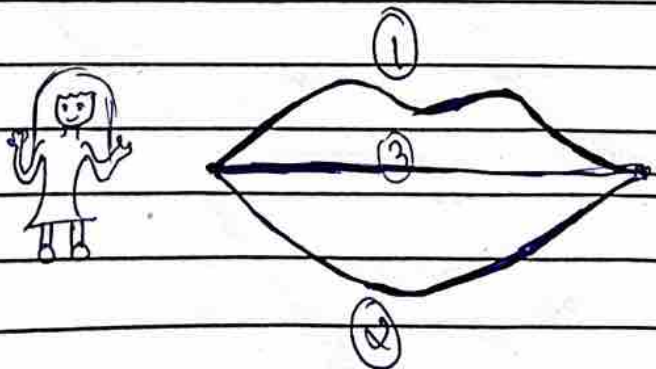
- 1] Distance
- 2] Displacement
- 3] Speed
- 4] Velocity
- 5] Acceleration

Distance $\rightarrow$ Displacement

Length of actual path $\rightarrow$ Shortest path b/w the points

Dist = (1) (2) (3)

Displace = (3)



Unit of Distance - metre.

Unit - metre

Dimension $[L]$

Dimension $[L]$

It is a Scalar Quantity

It is a vector quantity?

Que

Find the distance and displacement in each case:-

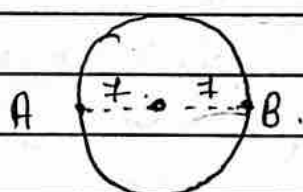
$$28 + 29 = 57$$

$$24 + 30 = 54$$

$$31 + 1 = 32 \text{ m}$$

$$4 \text{ m}$$

$$3 \text{ m}$$



$$\text{Distance} = 4 + 3$$

$$= 7$$

$$\text{Distance} = 2\pi r = \pi r$$

$$2$$

$$= 22 \times 7$$

$$\text{Displa} = \sqrt{3^2 + 4^2}$$

$$= 22 \text{ m}$$

$$= \sqrt{9 + 16}$$

$$\text{Displacement} = 7 + 7 = 14 \text{ m}$$

$$= \sqrt{25}$$

$$= 5 \text{ m}$$

A car moving along in a straight highway from point P to Q to Point R and to point S then back to point Q and finally to the point P as shown in the figure below.

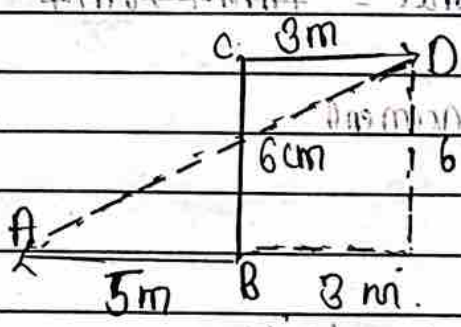
- (i) Find the Distance travelled by a car.
- (ii) Find the Displacement.



Distance = $3 + 5 + 7 + 7 + 5 + 5$
 32 km

Disp = $3 + 5$
 $= 8 \text{ km}$

Given



Distance = $5 + 6 + 3$
 $= 14 \text{ m}$

Displacement =

$$H^2 = 6^2 + 8^2$$

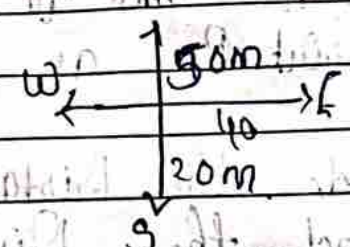
$$H^2 = 36 + 64$$

$$H^2 = 100$$

$$H = 10 \text{ m}$$

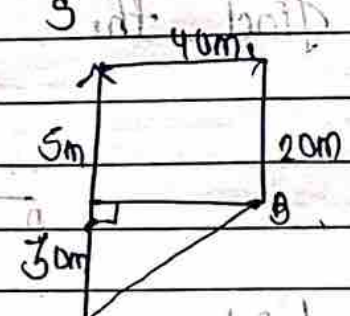
Ques A man has to go 50m in the North, 40m due east and 20m due to south to reach the field?

What distance he has to walk to reach the field?



What is the Displacement?

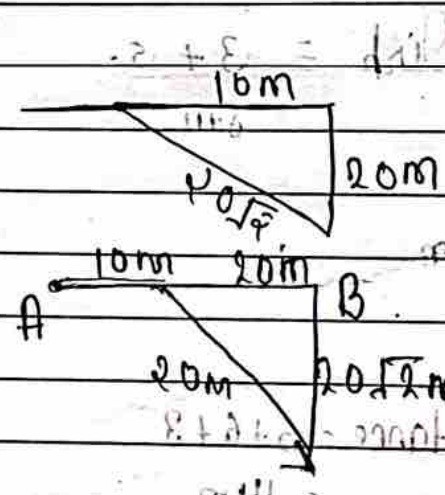
Distance = $50 + 40 + 20$
= 110m



Displacement = $\sqrt{30^2 + 40^2}$
= 50m

Distance = 10m + 20m +

Displacement



total displacement

$H^2 = P^2 + B^2$

$B^2 = P^2 + H^2$ $H^2 = P^2$ $P = H$ $\text{total} = 10 + 20 = 30m$

$B^2 = (20\sqrt{2})^2 - (20)^2$

$B^2 = 400 \times 2 - 400 = 400$

$B^2 = 800 - 400 = 400$

$B = \sqrt{400}$

$B = 20m$

If initial position of object (2, 6, 9) and final position (8, -2, 19) then find Displacement & Distance.

$$A = x_1, y_1, z_1$$

$$B = x_2, y_2, z_2$$

$$2, 6, 9$$

$$[8, -2, 19]$$

$$\text{Displ} = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2}$$

$$\sqrt{(8 - 2)^2 + (-2 - 6)^2 + (19 - 9)^2}$$

$$\sqrt{(6)^2 + (-8)^2 + (10)^2}$$

$$\sqrt{36 + 64 + 100}$$

$$\sqrt{200}$$

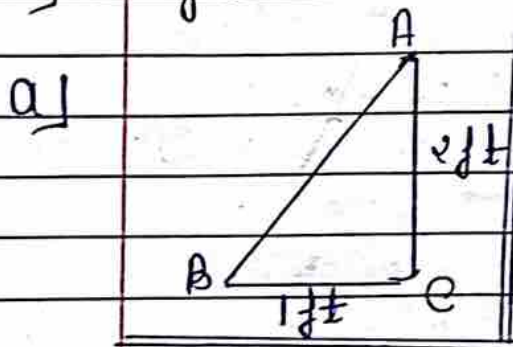
$$10\sqrt{2} \text{ units.}$$

of Cannon board (4 ft x 4 ft square) you the queen is in the centre. The queen, hit by the striker, moves to the front edge, rebounds and goes in in

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the hole behind the striking line. Find the magnitude of displacement of the queen

- a) From the centre to the front edge.
b) From the front edge to the hole and.
c) From the centre to the hole.

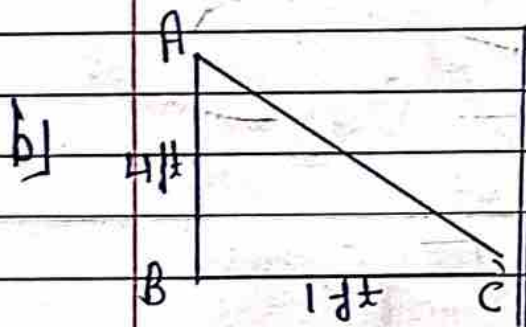
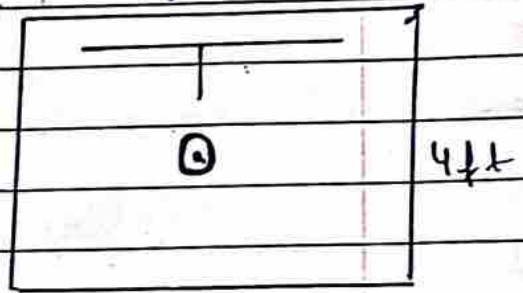


$$AB^2 = BC^2 + AC^2$$

$$AB^2 = 1^2 + 2^2$$

$$AB^2 = 5$$

$$AB = \sqrt{5} \text{ ft}$$

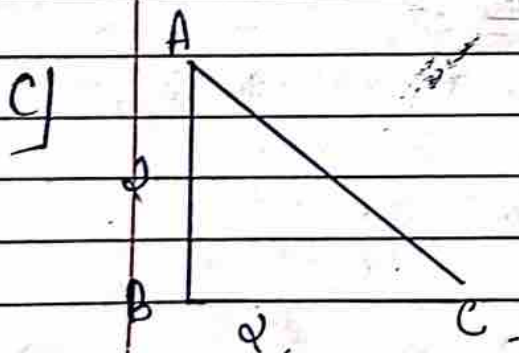


$$AC^2 = AB^2 + BC^2$$

$$AC^2 = 4^2 + 1^2$$

$$AC^2 = 16 + 1$$

$$AC = \sqrt{17} \text{ ft}$$



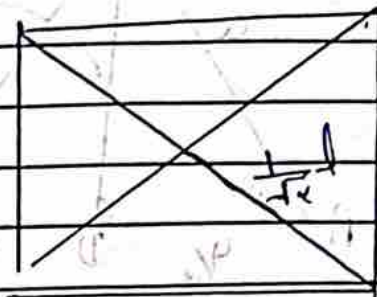
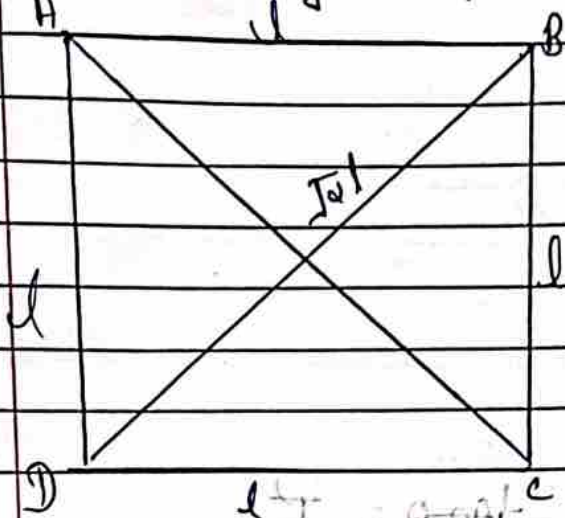
$$AC^2 = 2^2 + 2^2$$

$$= 4 + 4$$

$$= 8$$

$$AC = 2\sqrt{2} \text{ ft}$$

A square of length l

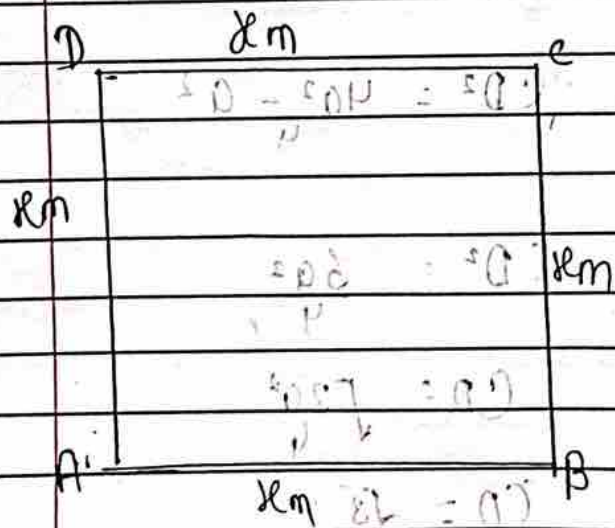


$$AC^2 = l^2 + l^2$$

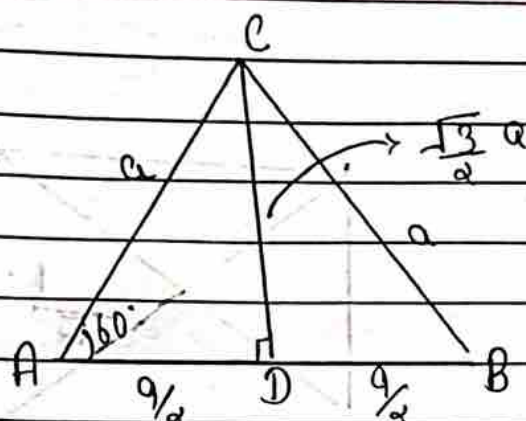
$$AC^2 = 2l^2$$

$$BD = AC = \sqrt{2}l^2 = \sqrt{2}l$$

A boy is moving on a square path of side 2 km

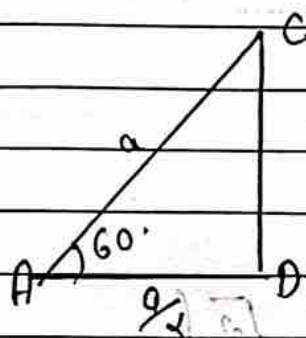


Path	Dist	dir
A-B	2	2
A-C	$2\sqrt{2}$	$\sqrt{2}2$
A-D	32	2
A-A	42	0



Perpendicular bisector

$$CD = ?$$



$$\tan \theta = \frac{P}{B}$$

$$\tan \theta = \frac{P}{B}$$

$$\sin 60^\circ = \frac{CD}{a}$$

$$\frac{\sqrt{3}}{2} = \frac{CD}{a}$$

$$\frac{\sqrt{3}}{2} a = CD$$

$$\tan 60^\circ = \frac{CD}{a/2}$$

$$a^2 = CD^2 + \left(\frac{a}{2}\right)^2$$

$$a^2 - \frac{a^2}{4} = CD^2$$

$$\frac{\sqrt{3}}{2} a = CD$$

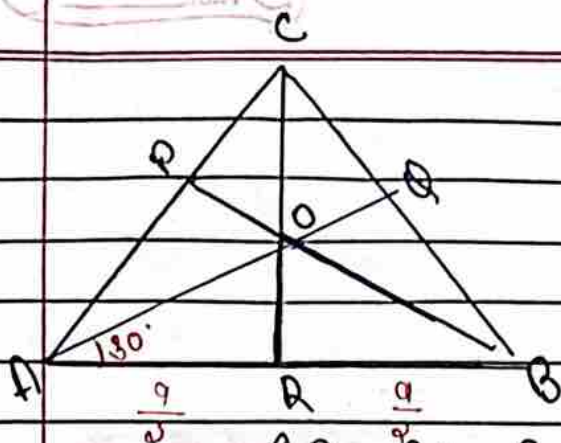
$$CD^2 = \frac{4a^2 - a^2}{4}$$

$$\frac{\sqrt{3}}{2} a = CD$$

$$CD^2 = \frac{3a^2}{4}$$

$$CD = \frac{\sqrt{3}a}{2}$$

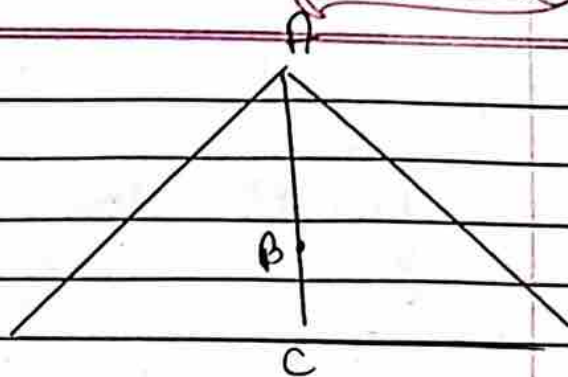
$$CD = \frac{\sqrt{3}}{2} a$$



$$AO = CO = BO$$

$$OR = OP = OQ$$

$$OR = ?$$



$$AC = \frac{\sqrt{3}}{2} a$$

$$AB = \frac{a}{\sqrt{3}}$$

$$BC = \frac{a}{2\sqrt{3}}$$

$$BC = \frac{a}{2\sqrt{3}}$$

$$\tan 30^\circ = \frac{OR}{\frac{a}{2}}$$

$$= \frac{1}{\sqrt{3}}$$

$$AB = \frac{a}{\sqrt{3}}$$

$$\frac{1}{\sqrt{3}} = \frac{OR}{\frac{a}{2}}$$

$$= 2:1$$

$$\frac{a}{2\sqrt{3}} = OR$$

$$CO = CR - OR$$

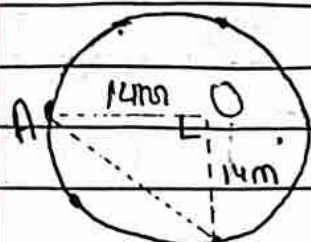
$$= \frac{\sqrt{3}}{2} a - \frac{a}{2\sqrt{3}}$$

$$= \frac{2 \times 3a - 2a}{4\sqrt{3}}$$

$$= \frac{4a}{4\sqrt{3}}$$

$$= \frac{a}{\sqrt{3}}$$

Find distance and displacement in following figure



$$\text{Displacement} = 2R \sin \frac{\theta}{2}$$

$$= 2 \times 14 \times \sin(90^\circ)$$

$$= 2 \times 14 \sin 45^\circ$$

$$= 2 \times 14 \times \frac{1}{\sqrt{2}}$$

$$\text{Dist} = \frac{2\pi r}{4} - \frac{\pi r}{2}$$

$$= \frac{2\pi}{4} \times \frac{14}{2}$$

$$= 22 \text{ cm}$$

$$= 14\sqrt{2}$$



$$\text{Dist} = 20$$

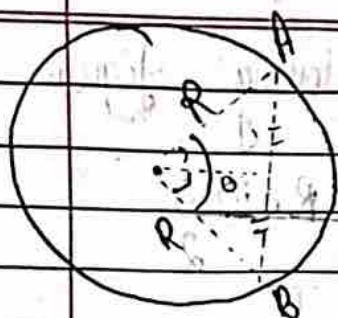
$$\text{Dist} = \frac{3}{4} (2\pi r) = r \times \frac{3\pi}{2}$$

$$= \frac{3}{2} \pi r$$

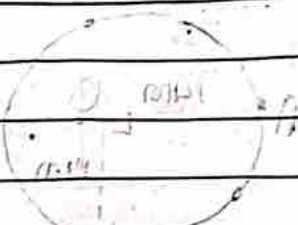
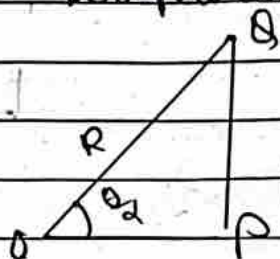
$$= \frac{3}{2} \pi r$$

$$= \frac{3}{2} \pi r$$

$$\text{Disp} = \sqrt{2}r$$



Displacement



$$\text{Distance} = (2\pi r) \theta$$

$$\sin \theta = \frac{P}{R}$$

$$= r\theta \rightarrow \text{in radian}$$

$$\sin \frac{\theta}{2} = \frac{PB}{R}$$

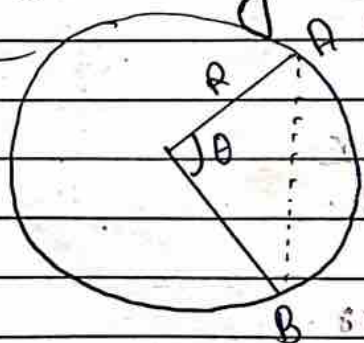
$$PB = R \sin \left(\frac{\theta}{2} \right)$$

then,

$$AB = 2 PB$$

$$AB = 2 R \sin \left(\frac{\theta}{2} \right)$$

Summary



$$\text{Distance} = (2\pi r) \theta$$

$$\text{Displ} = 2 R \sin \left(\frac{\theta}{2} \right)$$

$$2\pi R = \text{circumference}$$

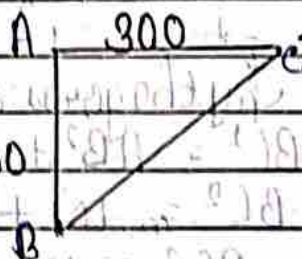
$$2\pi R = \text{displacement}$$

Que 1 Assertion (A): Rest (of a body) is a relative term.
Reason (R): Motion of a body may be absolute term.

Que-2 The ratio of displacement to distance is:
May be 1. A

Que-3 The numerical ratio of displacement to the distance covered is always
Equal to or less than 1.

Que-4 An aeroplane flies 400m north and 300m south-east and then flies 1200m upwards. The net displacement is



$BD^2 =$
 $BC^2 = AB^2 + AC^2$
 $BC^2 = 400^2 + 300^2$
 $BC^2 = 80000 + 90000$
 $BC^2 = 170000$
 $BC = 412.31$
 $BC = 412.31 \text{ m}$

It is a vector quantity and it has both magnitude and direction. It is a physical quantity which can be measured.

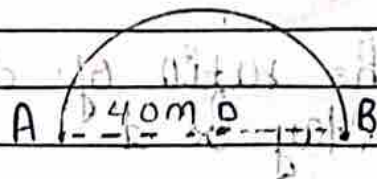
Que-5 A person runs on a semicircular track of radius 40m. If he starts at one end of the track and reaches the other end, then the magnitude and displacement of person is

$$\text{Distance} = 2\pi r$$

$$\pi r$$

$$\pi \times 40 = 40\pi \text{ m}$$

$$\text{Displacement} = 2 \times 40 = 80 \text{ m}$$



Que-6 A man goes 10m towards North then 20m towards east, the Displacement is

By Pythagoras theorem

$$BC^2 = AB^2 + AC^2$$

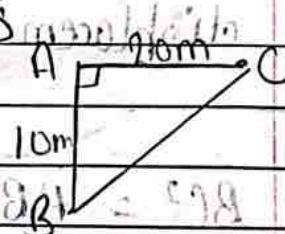
$$BC^2 = 10^2 + 20^2$$

$$BC^2 = 100 + 400$$

$$BC^2 = 500$$

$$BC = \sqrt{500}$$

$$BC = 10\sqrt{5} \text{ m} = 22.5 \text{ m}$$



Que-7 A hall has the dimensions 10m x 10m x 10m. A fly starting from one corner ends up at the diagonally opposite corner. The magnitude of displacement nearly

Speed

Rate of change in distance is called Speed.

Denote: - $u \rightarrow$ initial velocity
 $v =$ final speed.

Arg. Speed = $\frac{\text{total dist.}}{\text{total time}}$

$$\text{Unit} = \frac{\text{metre}}{\text{Sec.}} = \text{ms}^{-1}$$

$$\text{Dimension} = [L T^{-1}]$$

Velocity

Rate of change in Displacement is called Velocity.

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

Arg. velocity = $\frac{\text{total dist.}}{\text{total time}}$

instantaneous velocity

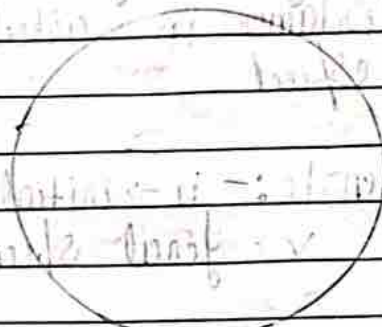
$$V_{\text{inst}} = \frac{ds}{dt}$$

$$\text{Unit} = \frac{\text{m}}{\text{s}} = \text{ms}^{-1}$$

$$\text{Dimension} = [L T^{-1}]$$

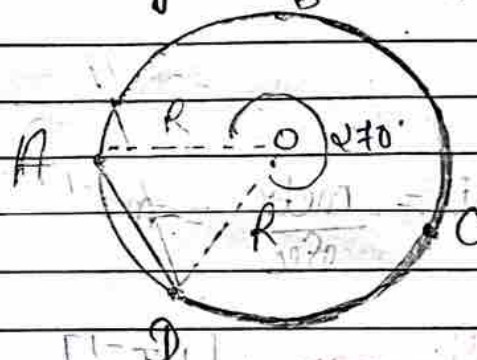
8] A particle moves along a circular path of radius r . The distance and displacement of the particle after one complete revolution are respectively)

Ans $2\pi r, 0$



Ques-9 A body is moving along the circumference of a circle of radius R and complete $3/4$ of the revolution, then the ratio of the displacement to distance is.

Distance $= 3 \times \frac{1}{4} \times 2\pi R$
 $= \frac{3}{2} \times 2\pi R$
 $= 3\pi R$



Displacement $= AC$

$\theta = 270^\circ$, $2R \sin \frac{\theta}{2} = 2R \sin \frac{270^\circ}{2}$

$= 2R \sin 135^\circ$

$= 2R \sin \frac{\sqrt{2}}{2}$

$2R \times \frac{\sqrt{2}}{2}$

$R\sqrt{2}$

Que - A boy completes one round of a circular track of radius 20m in 50s. The displacement at the end of 4m 10 second will be.

$$4m\ 10\ sec = 114 \times 60 + 10\ seconds$$

$$= 240 + 10$$

$$= 250\ seconds$$

$$50\ s = 1\ round$$

$$250\ s = \frac{250}{50} = 5\ rounds$$

$$Displacement = 0$$

Que - A particle is moving along a circle such that it completes one revolution in 40s.

To 2 min 20s the ratio of Dist / Displacement is :-

$$2\ min\ 20\ s = 2 \times 60 + 20\ s$$

$$= 140\ s$$

$$= 140\ s$$

$$1\ revolution = 40\ s$$

$$2\ revolutions = 80\ s$$

$$3\ revs = 120\ s$$

$$20\ s\ remaining = 3.5$$

$$3.5\ revs = 140\ s$$

$$Displacement = 0$$

$$Dist = 3.5 \times 2\pi r$$

$$= 7\pi r$$

$$\frac{Dist}{Displacement} = \frac{7\pi r}{0}$$

$$= \frac{7}{0}$$

Acceleration: Rate of change in velocity with respect to time is called Acceleration.

It is denoted by $a^{\rightarrow}$

It is a vector quantity.

$$a = \frac{\text{velocity}}{\text{time}}$$

$$\text{Avg } a^{\rightarrow} = \frac{\Delta v}{\Delta t}$$

$$\text{Unit } a^{\rightarrow} = \frac{\text{m/s}}{\text{s}} = \frac{\text{m}}{\text{s}^2} = \text{ms}^{-2}$$

$$\text{Dimension} = [L T^{-2}]$$

Instantaneous = $\frac{dv}{dt}$

① Uniform Speed: When obj travels same distance in equal time interval.

2) Non-uniform Speed: When obj travels different distances in equal time interval.

3) Uniform motion: When obj moves with uniform (Speed / velocity).

no change in speed

$$\vec{a} = 0$$

Uniform accelerated motion: - Body moves with constant $a \rightarrow$

ex: Acceleration due to gravity (gravitational accel)

$$g = 9.8 \text{ m/s}^2$$

$$g = 10 \text{ m/s}^2$$

non-Uniform accelerated motion: - Body moves with variable acceleration

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

Instantaneous Speed: - Speed of an object at any instant is called instantaneous speed

ex: The speedometer of vehicle shows instantaneous speed

Sign of Displacement, velocity and acceleration: -

1) Sign of displacement: -

$$x_A = +3 \text{ m} \Rightarrow +ve \Rightarrow \text{Origin} \rightarrow \text{right} \rightarrow +x$$

$$x_B = -2 \text{ m} \Rightarrow -ve \Rightarrow \text{Origin} \rightarrow \text{left} \rightarrow -x$$

2) Sign of velocity :- Direction of motion.

(+ve)	(-ve)
→	←

$V_A = +2 \text{ m/s} \Rightarrow +ve \rightarrow$ Right direction

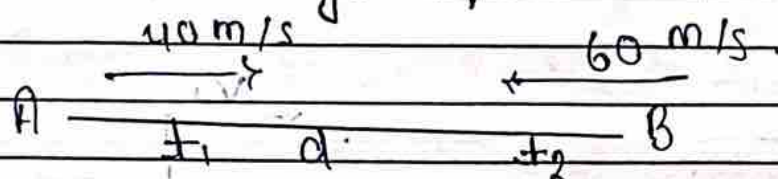
$V_B = -2 \text{ m/s} \Rightarrow -ve \rightarrow$
Opposite direction.

3) Sign of Acceleration :- Speed / Break

$a^+ = +ve \rightarrow$ Speed up $\uparrow \uparrow$

$a^- = -ve \rightarrow$ Speed down $\downarrow \downarrow$ - Break $\rightarrow$
Retardation

Q-1 A train travels from city A to B with a constant speed of 40 m/s and returns back to A with a constant speed of 60 m/s . Find its average speed and average velocity.



Average speed = $\frac{\text{total distance}}{\text{total time}}$

Let total dist = $2d$ (constant)
 with dist $\rightarrow$ (1)

$$\frac{t_1 + t_2}{b + b} =$$

Speed = $\frac{\text{dist}}{\text{time}}$ Avg Speed = $\frac{2d}{\frac{d}{40} + \frac{d}{60}}$

$$\text{time} = \frac{\text{dist}}{\text{Speed}} = \frac{2d}{d \left(\frac{1}{40} + \frac{1}{60} \right)}$$

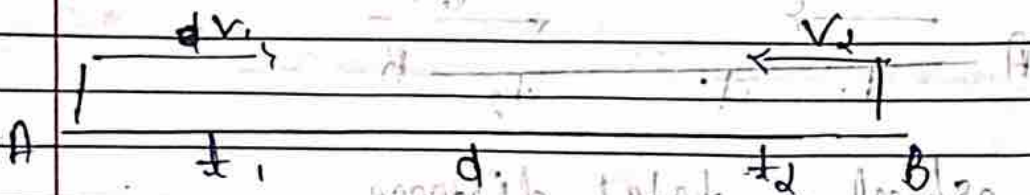
$$t_1 = \frac{d}{40} \quad t_2 = \frac{d}{60} = \frac{2}{\frac{60+40}{40 \times 60}}$$

$$t_1 = \frac{d}{40} \quad t_2 = \frac{d}{60} = \frac{2 \times 40 \times 60}{100}$$

Put in eq (1)

$$= 48 \text{ m/s}$$

Average velocity = $\frac{\text{total dist}}{\text{total time}}$



Average Speed = $\frac{\text{total dist}}{\text{total time}}$

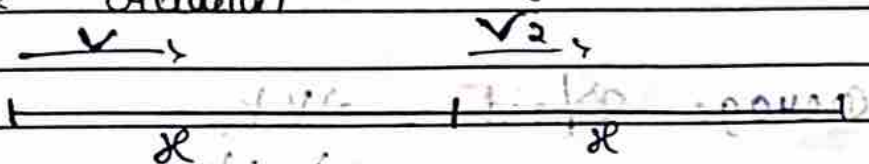
$$\begin{aligned}
 &= \frac{d + d}{\frac{d}{v_1} + \frac{d}{v_2}} \\
 &= \frac{2d}{d \left(\frac{1}{v_1} + \frac{1}{v_2} \right)} \\
 &= \frac{2}{\frac{1}{v_1} + \frac{1}{v_2}} = \frac{2v_1 v_2}{v_1 + v_2}
 \end{aligned}$$

2) m s⁻¹

→

→

A person is travelling in a straight line moves with a constant velocity v_1 for a certain distance x and with a constant velocity v_2 for next equal distance. The average velocity v is given by the relation



$$v = \frac{2v_1 v_2}{v_1 + v_2} \quad \text{or} \quad \frac{1}{v} = \frac{1}{v_1} + \frac{1}{v_2}$$

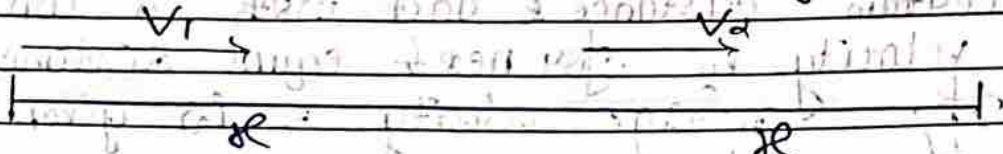


$$\frac{2x}{v} = \frac{x}{v_1} + \frac{x}{v_2}$$

$$\frac{2}{v} = \frac{1}{v_1} + \frac{1}{v_2}$$

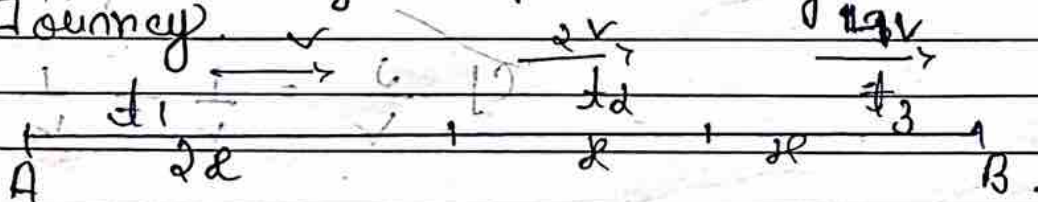
$$v = \frac{2v_1 v_2}{v_1 + v_2}$$

Que-3 A particle covers half of its total distance with speed v_1 and the rest of half distance with speed v_2 . Its average speed during the complete journey is



$$\text{Average Speed} = \frac{2v_1v_2}{v_1+v_2}$$

Que-4 A particle covers half its journey with a constant speed of v , half the remaining part of journey with a constant speed of $2v$ and the rest of the journey with a constant speed of $4v$. Find its average speed during the entire journey.



$$\frac{v+2v}{2} = \frac{3v}{2}$$

$$\frac{3v+4v}{2} = \frac{7v}{2}$$

$$\frac{7v \cdot \frac{3v}{2}}{7v} = \frac{21v}{2}$$

Average Speed =

$$\frac{\text{total dist}}{\text{total time}}$$

$$= \frac{2x + x + x}{t_1 + t_2 + t_3}$$

①

$$\text{time} = \frac{\text{dist}}{\text{Speed}}$$

$$t_1 = \frac{2x}{v}$$

$$t_2 = \frac{x}{2v}$$

$$t_3 = \frac{x}{4v}$$

Put in eq ①

$$\frac{4x}{\frac{2x}{v} + \frac{x}{2v} + \frac{x}{4v}}$$

$$= \frac{4x}{x \left(\frac{2}{v} + \frac{1}{2v} + \frac{1}{4v} \right)}$$

$$= \frac{4}{\frac{11}{4v}} = \frac{4 \times 4v}{11} = \frac{16v}{11}$$

$$\frac{21m8 + 9 + 1}{4v}$$

Ques. If the displacement is given by $x = 2t^2 + t + 5m$.
The velocity at $t = 2s$ is.

$$x = 2t^2 + t + 5$$

$$v = \frac{dx}{dt}$$

$$v = \frac{d}{dt} (2t^2 + t + 5)$$

$$v = 2 \times 2t + 1 + 0$$

$$v = 4t + 1$$

$$\text{at } t = 2 \text{ sec.}$$

$$v = 4 \times 2 + 1$$

$$v = 8 + 1$$

$$v = 9 \text{ m/s}$$

$$\frac{1}{v_P} = \frac{1}{v_Q} + \frac{1}{v_R}$$
$$\frac{1}{9} = \frac{1}{11} + \frac{1}{v_R}$$
$$\frac{1}{9} - \frac{1}{11} = \frac{1}{v_R}$$
$$\frac{11 - 9}{9 \times 11} = \frac{1}{v_R}$$
$$\frac{2}{99} = \frac{1}{v_R}$$
$$v_R = \frac{99}{2} = 49.5 \text{ m/s}$$

Two Cars P and Q start from a point at the same time in a straight line and their position are represented by $x_p(t) = at + bt^2$ and $x_q(t) = ft - t^2$. At what time do the cars have same velocity?

$$x_p = at + bt^2$$

$$v_p = a + 2bt$$

$$x_q = ft - t^2$$

$$v_q = f - 2t$$

$$\text{If } v_p = v_q$$

$$a + 2bt = f - 2t$$

$$2bt + 2t = f - a$$

$$t(2b + 2) = (f - a)$$

$$t = \frac{f - a}{2(b + 1)}$$

$$t = \frac{(f - a)}{2(b + 1)}$$

A particle moves along a straight line OX. At a time t (in second), the distance x (in m) of the particle O is given by $x = 40 + 12t - t^3$. How long would the particle travel before comes to the rest?

$$x = 40 + 12t - t^3$$

$$v = 0 + 12 - 3t^2$$

$$v = 12 - 3t^2$$

In rest

body travel in 2 sec

$$v = 0$$

$$12 - 3t^2 = 0$$

$$3t^2 = 12$$

$$t^2 = 4$$

$$t = \sqrt{4}$$

$$t = 2$$

$$t = 2 \text{ sec}$$

$$t^2 - 4 = 0$$

$$(t-2)(t+2) = 0$$

$$t = 2$$

$$t = 2$$

$$x = 40 + 12t - t^3$$

$$x = 40 + 12 \times 2 - 2^3$$

$$x = 40 + 24 - 8$$

$$x = 56 \text{ m}$$

$$x = 56 \text{ m}$$

$$x = 56 \text{ m}$$

$$x = 56 \text{ m}$$

$$x = 56 \text{ m}$$

$$x = 56 \text{ m}$$

$$x = 56 \text{ m}$$

$$x = 56 \text{ m}$$

$$x = 56 \text{ m}$$

Instantaneous Acceleration

$$a = \frac{dv}{dt}$$

$$a = \frac{d(dx/dt)}{dt}$$

$$a = \frac{d^2x}{dt^2}$$

$$a = \frac{v}{dx} \frac{dv}{dx}$$

A particle is moving so that its displacement S is given by $S = t^3 - 6t^2 + 3t + 4$ m. Its velocity at the instant when its acceleration is zero will be.

$$S = t^3 - 6t^2 + 3t + 4 \quad \text{and } a = 0$$

$$v = \frac{ds}{dt}$$

$$v = 3t^2 - 12t + 3 + 0$$

$$v = 3t^2 - 12t + 3 \quad \text{--- (1)}$$

$$a = \frac{dv}{dt}$$

$$a = 6t - 12$$

$$6t - 12 = 0$$

$$6t = 12$$

$$t = 2 \text{ sec.}$$

by eq (1)

$$v_{t=2} = 3 \times (2)^2 - 12(2) + 3$$

$$= 12 - 24 + 3$$

$$= -12 + 3 = -9$$

$$\therefore \text{Velocity} = -9 \text{ m/s}$$

The motion of a particle along a straight line is described by equation $x = 8 + 12t - t^3$. where x is in meter and t in sec. the retardation of particle when its velocity becomes zero is.

$$x = 8 + 12t - t^3$$

$$v = 0 + 12 - 3t^2$$

$$v = 12 - 3t^2 \quad \text{--- (1)}$$

and

$$a = 0 - 6t$$

$$a = -6t \quad \text{--- (2)}$$

$$12 - 3t^2 = 0$$

$$12 - 3t^2 = 0$$

$$t^2 = 4$$

$$t = \pm 2$$

$$t = 2$$

$$t = 2$$

$$t = 2$$

$$a = -6t$$

$$a = -12$$

$$a = -12$$

$$a = -12 \text{ m/s}^2$$

The x and y co-ordinates of the particle at any time are $x = 5t - 2t^2$ and $y = 10t$ respectively, where x and y are in meter and t in sec. The acceleration of the particle at $t = 2$ s is,

$$x = 5t - 2t^2$$

$$v = \sqrt{v_x^2 + v_y^2}$$

$$v_x = 5 - 4t$$

$$a_x = 0 - 4$$

$$a_x = -4 \text{ m/s}^2$$

$$y = 10t$$

$$v_y = 10$$

$$a_y = 0$$

Then

$$\text{at } t = 2 \text{ sec}$$

$$a = -4 \text{ m/s}^2$$

For motion of an object along the x -axis, the velocity v depends on the displacement x as $v = 3x^2 - 2x$, then what is the acceleration at $x = 2$ m.

$$v = 3x^2 - 2x$$

Diff. w.r.t. x .

$$\frac{dv}{dx} = (6x - 2)$$

$$a = v \left(\frac{dv}{dx} \right)$$

$$a = (3x^2 - 2x)(6x - 2)$$

$$\text{at } x = 2$$

$$a = (3(2)^2 - 2(2))(6(2) - 2)$$

$$a = (12 - 4)(12 - 2)$$

$$a = 8 \times 10$$

$$a = 80 \text{ m/s}^2$$

A particle of unit mass undergoes one-dimensional motion such that its velocity varies according to $v(x) = \beta x^{-2n}$, where β, n are constants and x is the position of the particle.
 $a = ?$

$$v = \beta x^{-2n}$$

W. w. to x .

$$\frac{dv}{dx} = \beta (-2n) x^{-2n-1}$$
$$= -2n\beta x$$

$$a = v \left(\frac{dv}{dx} \right)$$

$$a = \beta x^{-2n} (-2n\beta x^{-2n-1})$$

$$= -2n\beta^2 x^{-4n-1}$$

$$= -2n\beta^2 x^{-4n-1} \text{ m s}^{-2}$$

If the velocity of a particle is $v = At + Bt^2$, where A and B are constants, then the distance travelled by it between 1s and 2s is

$$v = At + Bt^2$$

$$x = \int v dt$$

$$= \int_1^2 (At + Bt^2) dt$$

$$= \left[\frac{At^2}{2} + \frac{Bt^3}{3} \right]_1^2$$

$$= \left(\frac{A \cdot 2^2}{2} + \frac{B \cdot 2^3}{3} \right) - \left(\frac{A \cdot 1^2}{2} + \frac{B \cdot 1^3}{3} \right)$$

$$= \left(\frac{4A}{2} + \frac{8B}{3} - \frac{A}{2} - \frac{B}{3} \right)$$

$$= \frac{3A}{2} + \frac{7B}{3}$$

Velocity vs Displacement

$$v = \frac{dx}{dt}$$

$$dx = v dt$$

taking integral in both.

$$\int dx = \int v dt$$

$$x = \int v dt$$

Acceleration vs velocity

$$a = \frac{dv}{dt}$$

$$dv = a dt$$

taking integral in both.

$$\int dv = \int a dt$$

$$v = \int a dt$$

If velocity of particle is given by as $v = t + 1$
 find displacement of particle at the end
 of 4s, if initially particle is at origin

$$v = t + 1$$

$$x = \int v dt$$

$$x = \int (t + 1) dt$$

$$x = \frac{t^2}{2} + t + c$$

$$x = \frac{t^2}{2} + t \quad \text{--- (1)}$$

$$t = 4 \text{ sec}$$

$$t = 0, \quad x = 0$$

by eq (1)

$$0 = 0 + 0 + c$$

$$c = 0$$

$$\text{at } t = 4 \text{ sec.}$$

$$x = \frac{4^2}{2} + 4 = \frac{16}{2} + 4 = 12 \text{ m}$$

If acceleration of particle is given by $a = 3t^2$,
find velocity of particle at $t = 3s$,
if initial particle is at rest.
 $t = 0$ $v = 0$

$$a = 3t^2$$

$$v = \int a dt$$

$$v = \int 3t^2 dt$$

$$v = \frac{3t^3}{3} + C$$

$$v = t^3 + C \quad \text{--- (1)}$$

$$t = 3 \text{ sec.}$$

$$t = 0 \rightarrow v = 0$$

$$\text{in eq (1)}$$

$$v = t^3 + C$$

$$C = 0$$

$$\text{in eq (1)}$$

$$\text{at then, } v = t^3.$$

$$\text{at } t = 3 \text{ sec.}$$

$$v = (3)^3$$

$$v = 27 \text{ m/s.}$$

A particle initially at rest moves along the x-axis. Its acceleration varies with time as $a = 4t$. If it starts from the origin, the distance covered by it in 3 s is

$$d = 0, \quad v = 0$$

$$a = 4t$$

$$v = \int 4t \, dt$$

$$v = \frac{4t^2}{2} + c$$

$$v = 2t^2 + c$$

$$[\because v = 0, t = 0, c = 0]$$

$$v = 2t^2$$

$$a = 4t$$

$$x = \int v \, dt$$

$$= \int 2t^2 \, dt$$

$$x_c = \frac{2 \cdot 3}{3}$$

$$t = 0, x_c = 0 \quad \text{at } C = 0$$

$$x_c = \frac{2 \cdot 3}{3}$$

$$t = 0$$

$$x_c = ?$$

$$at \quad t = 3 \text{ sec}$$

$$x_c = \frac{\sqrt{(3)^2}}{3}$$

$$= \frac{\sqrt{2 \times 2 \times 9}}{3}$$

$$= \sqrt{2 \times 9}$$

$$= 18 \text{ m}$$

$$at \quad t = 3 \text{ sec}$$

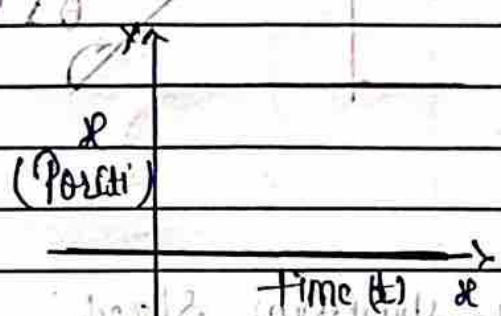
$$at \quad t = 3 \text{ sec}$$

Graph in 1-D Motion

5] Graph

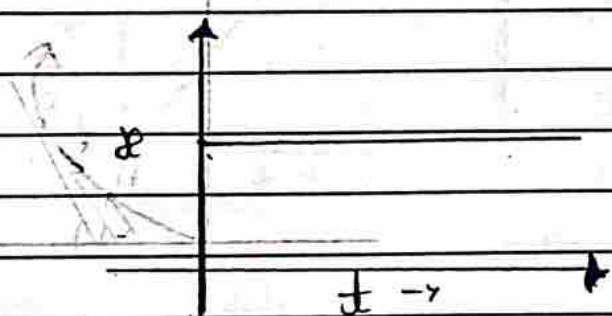
1. Position - time graph ($x-t$ graph)
2. velocity - time graph ($v-t$ graph)
3. acceleration - time graph ($a-t$ graph)

1. Position time graph



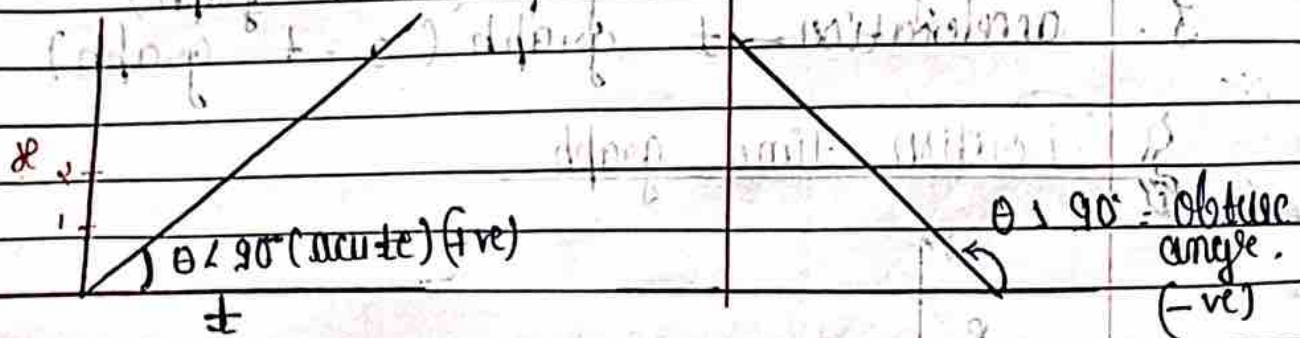
2. x -axis $\rightarrow$ time axis.

When object at rest :-

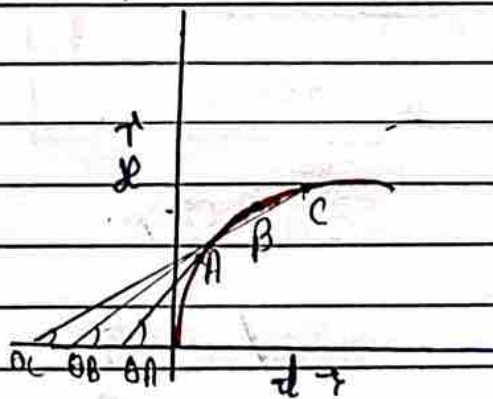


a straight line which is parallel to x -axis (time axis)

(2) When object moves with uniform speed (motion)

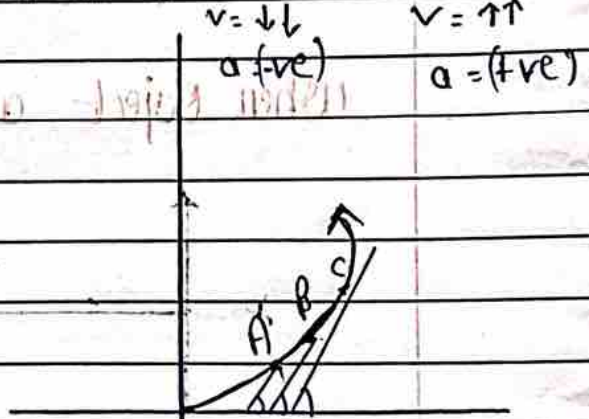


(3) When object moves with non-uniform speed



$\theta_A > \theta_B > \theta_C$

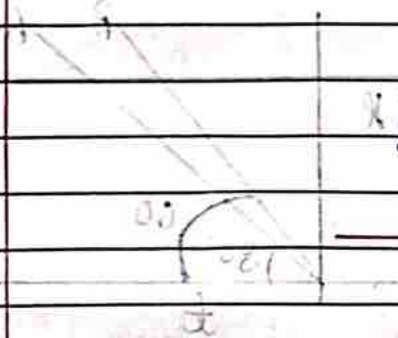
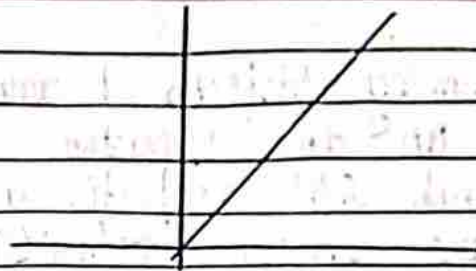
v decrease $\rightarrow$



$\theta_C > \theta_B > \theta_A$

at B slope is $a \downarrow$, $v \downarrow$ - $a = -ve$
at C slope is $a \uparrow$, $v \uparrow$ - $a = +ve$

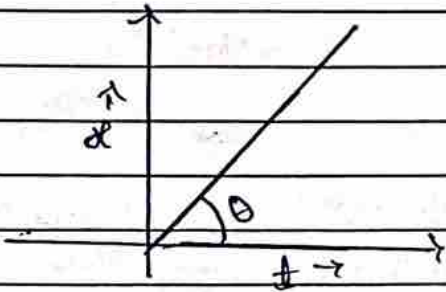
Summary:-



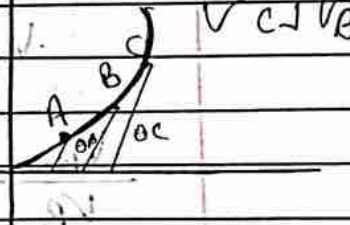
$\hat{x}$

y axis = parallel
x axis = perpendicular

Calculation of velocity from $x-t$ graph = gV



velocity = slope of $x-t$ graph
 $v = \tan \theta$
 $v = \frac{dx}{dt}$



Uniform motion

$v_B = \tan \theta_B$
 $v_C = \tan \theta_C$

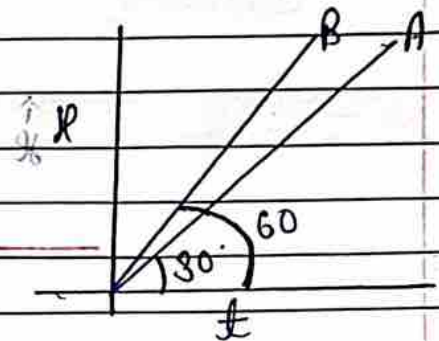
Non uniform motion

For two moving objects A and B, we get two straight lines on the position-time graph making angles 30° and 60° respectively with the time axis. Compare their velocities.

$$V_A = \frac{\Delta x}{\Delta t} = \tan \theta$$

$$V_A = \tan 30^\circ$$

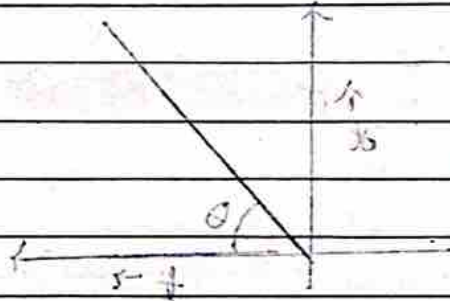
$$V_A = \frac{1}{\sqrt{3}}$$



$$V_B = \frac{\Delta x}{\Delta t} = \tan \theta$$

$$V_B = \tan 60^\circ$$

$$V_B = \sqrt{3}$$

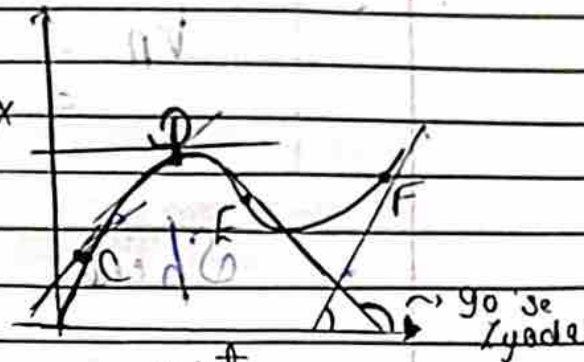


$$\frac{V_A}{V_B} = \frac{\frac{1}{\sqrt{3}}}{\sqrt{3}} = \frac{1}{3}$$

$$= \frac{1}{3} = 1:3$$

The displacement - time graph of a moving particle is shown below. The instantaneous velocity of the particle is negative at a point.

It is negative because its angle is more than 90° .

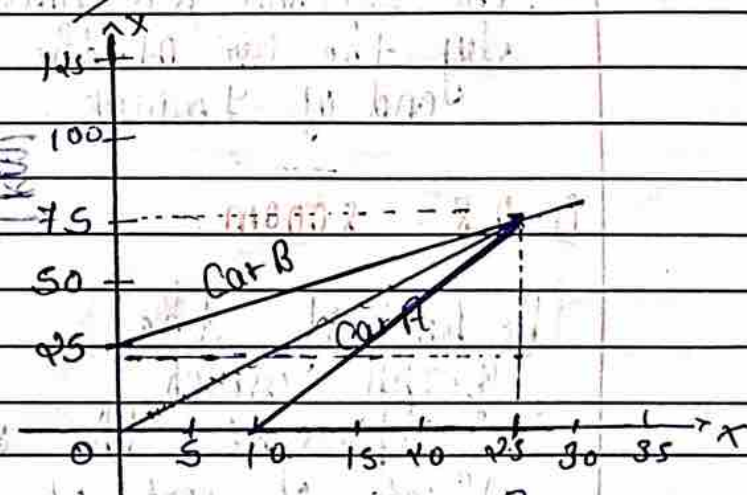
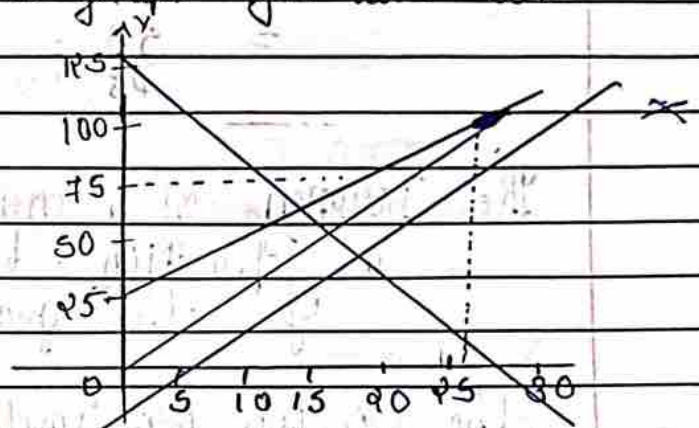


Represents the position - time graph for two cars A and B.

- 1) Which car starts moving later?
Car A.

After what time from starting, Car A will cross the Car B?

15 min



(15 min)

Speed of Car A and B.

Speed of Car A

$$v_A = \tan \theta$$

$$= \frac{P.B.}{B} = \frac{75}{15} = 5 \text{ km/min}$$

Speed of Car B

$$v_B = \tan \theta$$

$$= \frac{50}{5} = 10 \text{ km/min}$$

The Journey of a car is represented with the help of a position-time graph. The different parts of the graph termed as A, B, C, D find:

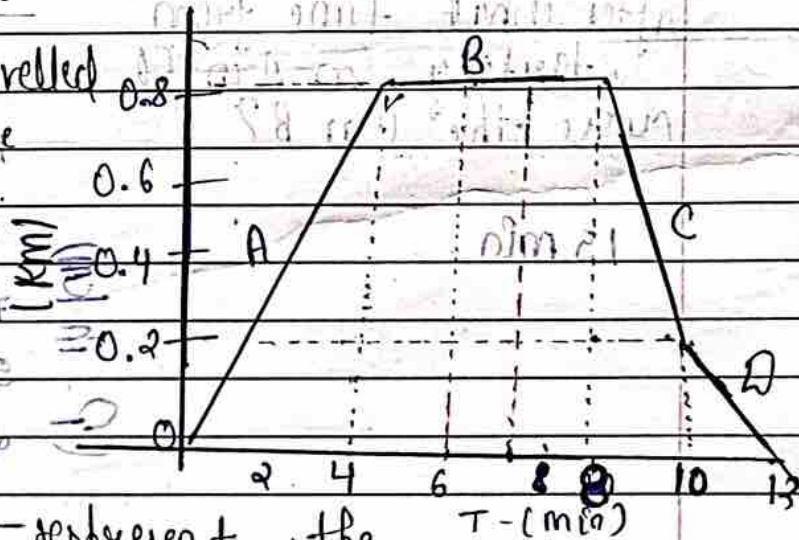
The Distance travelled by the car at the end of 4 minute.

i) $0.8 = 8000 \text{ m}$

The part of the graph which

represents the rest of the car.

Part B.



Average velocity in first 6 minutes

$$\text{Average velocity} = \frac{\text{total disp}}{\text{total time}}$$

$$= \frac{0.8}{6} = \frac{0.8}{\cancel{6} \times 60} = \frac{0.8}{60}$$

$$= \frac{0.8}{60} = \frac{0.8 \times 60}{60 \times 1}$$

$$= 8 \text{ km/h}$$

the parts of the graph which represent the uniform motion and the velocity of the car in each part.

$$V_p = \tan \theta$$

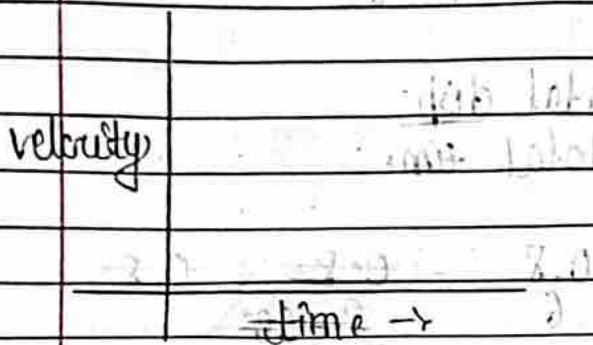
$$= \frac{p}{b} = \frac{0.8}{\frac{4}{60}} = \frac{0.8 \times 60}{4} = 12 \text{ km/h}$$

$$V_b = \tan \theta = 0$$

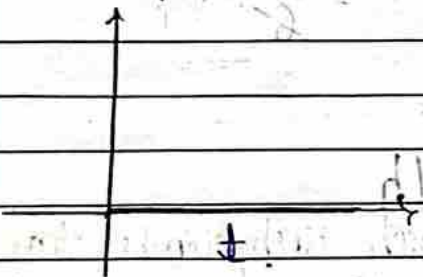
$$V_c = \tan \theta = \frac{0.6}{\frac{2}{60}} = \frac{0.6 \times 60}{2} = 18 \text{ km/h}$$

$$V_d = \tan \theta = \frac{0.2}{\frac{2}{60}} = \frac{0.2 \times 60}{2} = 6 \text{ km/h}$$

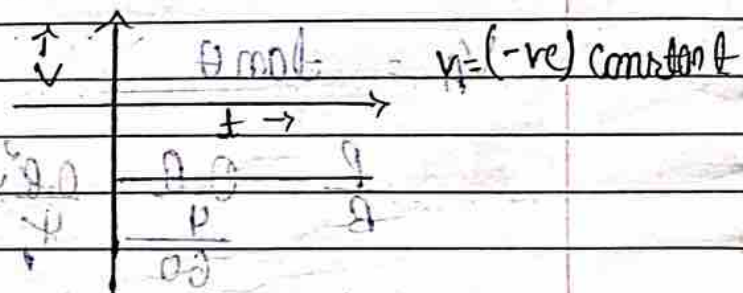
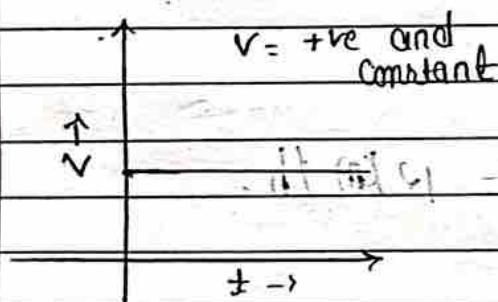
Velocity, time graph



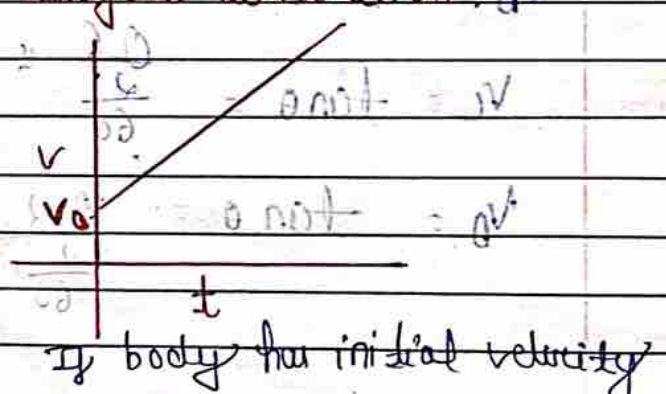
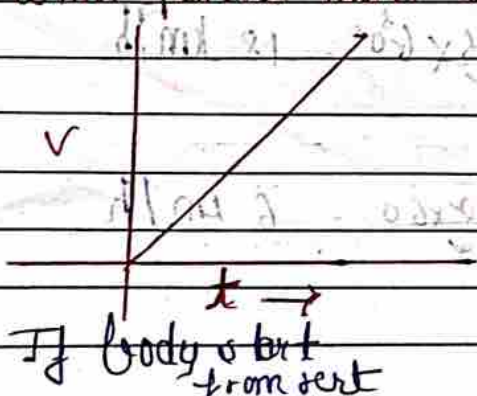
(i) when particle is at rest or $v = 0$



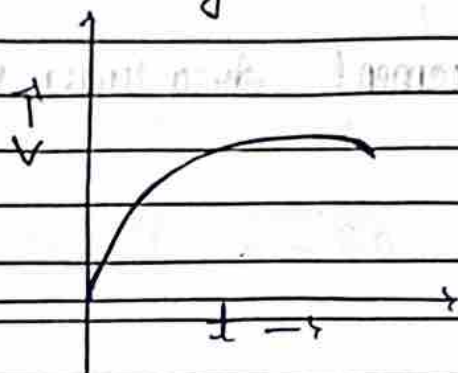
(ii) when particle is in uniform motion: - ($v = \text{constant}$)



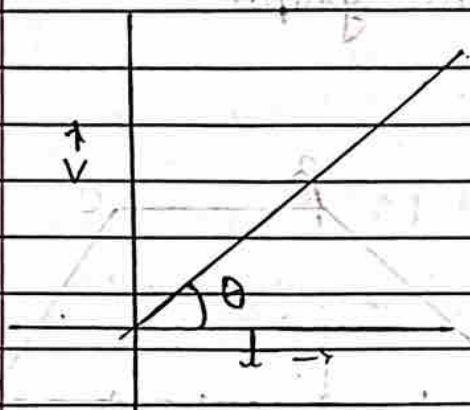
(When particle moves with uniform acceleration, $a \neq 0$)



When body moves with non-uniform accelerated motion



Calculation of acceleration from $v-t$ graph

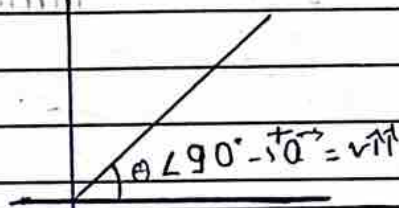


Slope of $v-t$ graph represents acceleration

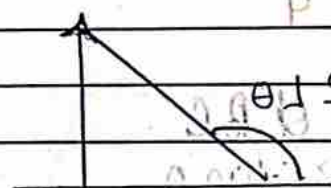
$$a = \text{slope of } v-t \text{ graph}$$

$$a = \tan \theta$$

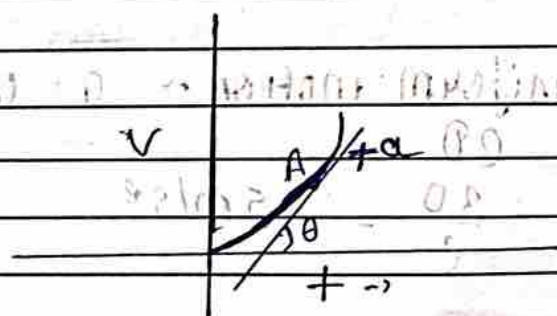
+ve acceleration



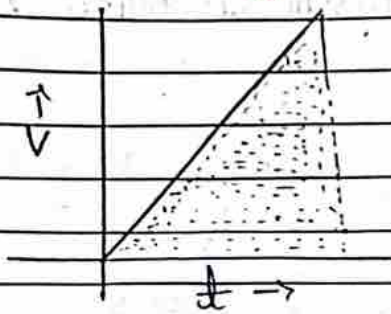
-ve acceleration



retardation



Calculation of displacement from $v-t$ graph



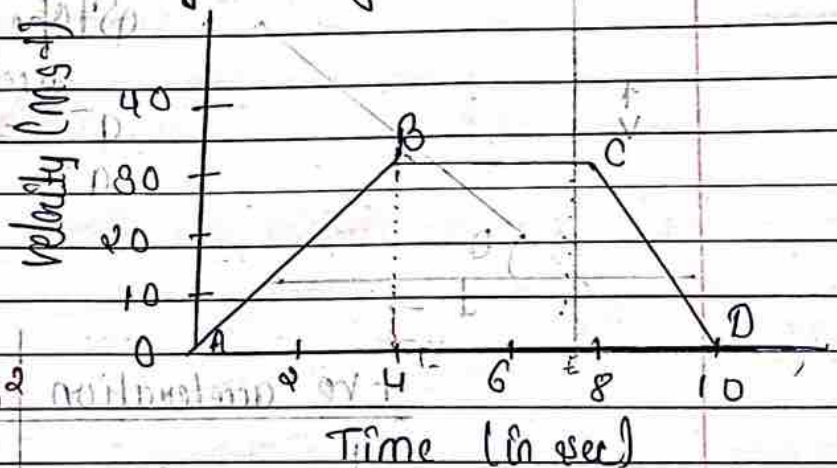
Displacement = Area under $v-t$ graph

Ex: - Fig represents the velocity time graph of an object. Calculate (i) the acceleration in the part AB, BC and CD of the graph.

2. Area under velocity time graph

a → of AB

$$a = \frac{\text{Perpendicular}}{\text{Base}}$$



$$= \frac{30}{4} = 7.5 \text{ m/s}^2$$

a → of BC

$$a \rightarrow \tan \theta$$

$$a \rightarrow \tan 0$$

$$a = 0$$

BC → uniform motion → $a = 0$

a → of CD

$$\tan \theta = \frac{30}{2} = 15 \text{ m/s}^2$$

ii) the displacement of the object in 10s?

Displacement = Area under $v-t$ graph.

$S = \text{Area of } \triangle OBE + \text{Area of } \square BCEF + \text{Area of } \triangle CDF$

$$= \frac{1}{2} \times 4 \times 30 + 4 \times 30 + \frac{1}{2} \times 2 \times 30$$

$$= 60 + 120 + 30$$

A train starting from rest from a station A travels with a uniform acceleration 100 m min^{-2} for 10 min. Then it travels with the constant velocity for 20 min. At last it travels with uniform retardation for 5 min and stops at a station B. Draw the velocity-time graph & find.

Ques. the maximum velocity acquired by the train?

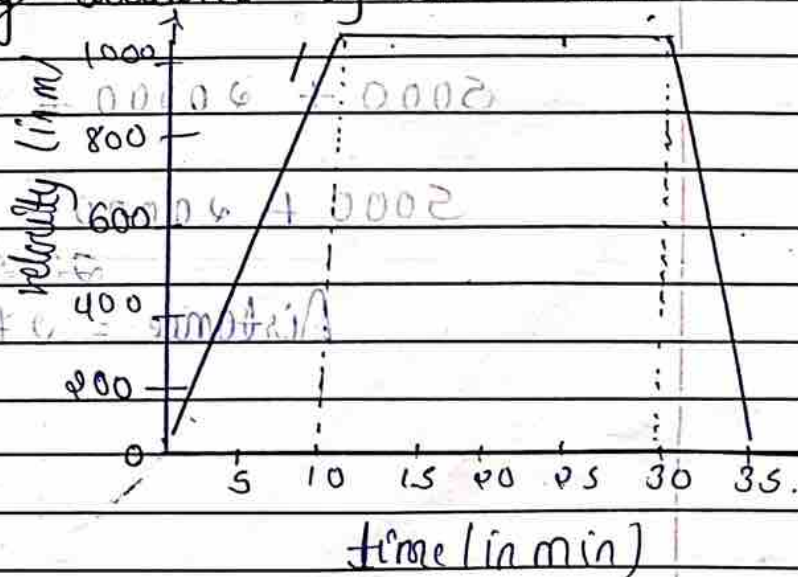
$$v_i = 0$$

$$v = ?$$

$$v = u + at$$

$$v = 0 + 100(10)$$

$$v = 1000 \text{ m/min}$$



$$t = 20 \text{ min}$$

$$v = \text{Constant} = 1000 \text{ m/min}$$

$$a = 0$$

iii

the retardation during last 5 min

$$t = 5 \text{ min}$$

$$v_i = 1000 \text{ m/min}$$

$$v_f = 0$$

(i)

Maximum velocity achieved by the train
1000 m/min

ii

the retardation during last 5 min of travel

$$a = \frac{0 - 1000}{5} = -200 \text{ m/min}^2$$

iii

the Distance between the two station

$$\frac{1}{2} \times 10 \times 1000 + 1000 \times 20 + \frac{1}{2} \times 1000 \times 5$$

$$5000 + 20000 + 2500$$

$$27500 \text{ m}$$

$$27.5 \text{ km}$$

$$\text{Distance} = 27.5 \text{ km}$$

Average velocity of train

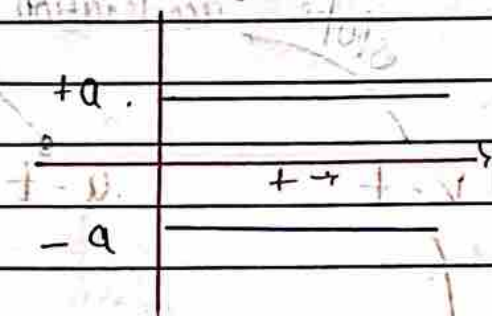
(i) Average velocity = $\frac{\text{total displacement}}{\text{total time}}$

$$= \frac{5500}{25} = 220 \text{ m/s}$$

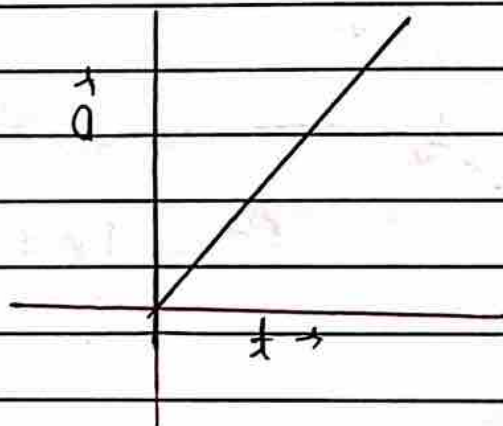
$$= 785.7 \text{ m/min}$$

Acceleration - time graph / a - t graph

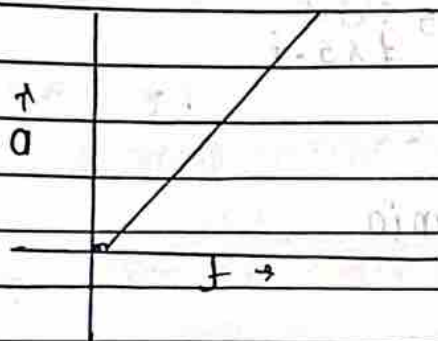
When body moves with uniform acceleration



When body moves with non-uniform accelerated motion

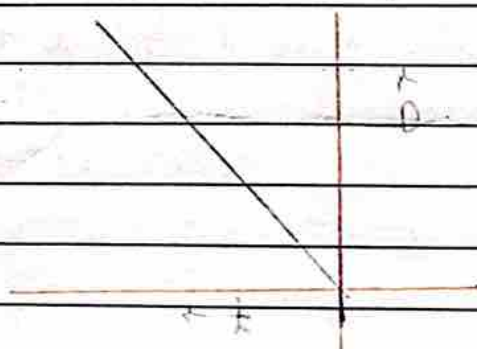
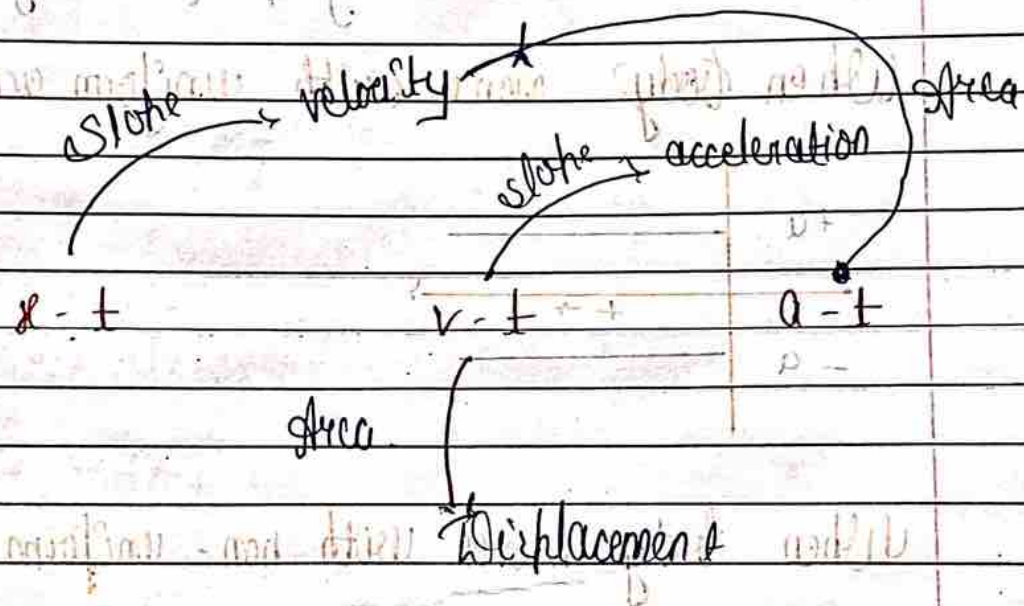


Calculation of velocity from a - t graph



velocity - area under a - t graph

Graph of a - t graph with acceleration



Eqn of motion

DATE _____
PAGE _____

$$1) v = u + at$$

$$2) s = ut + \frac{1}{2} at^2$$

$$3) v^2 = u^2 + 2as$$

$$4) S_n = u + \frac{1}{2} a(2n-1)$$

(u) = initial velocity

v = final velocity

a = acceleration

t = time

s = displacement

Eqn of Motion by graphical method

acceleration = slope of v-t graph

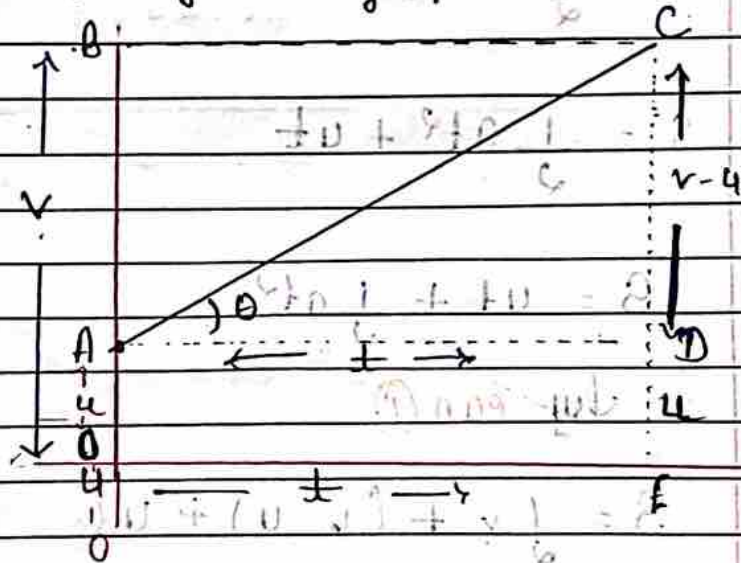
$$a = \frac{v-u}{t}$$

a = perp.
Base

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

$$at = v - u$$

$$v = u + at \quad \text{--- (1)}$$

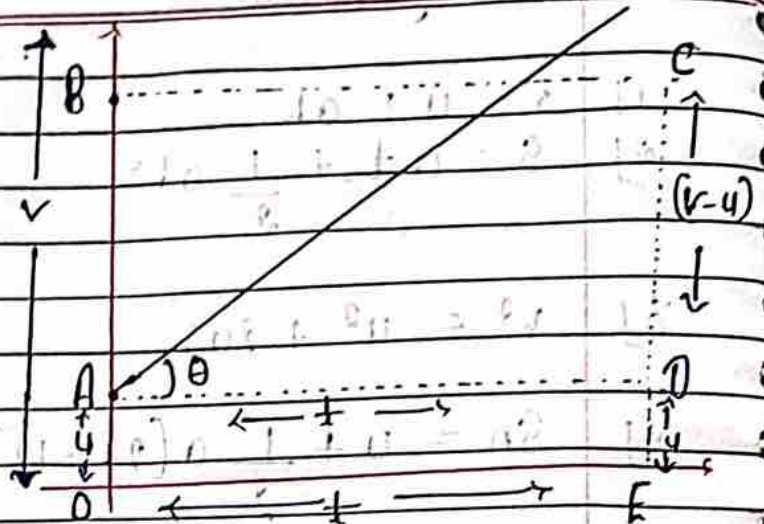


$$(u + v) t = 2s$$

Displacement = Area under $v-t$ graph

$S =$ Area of $\triangle ACD$ and
Area of $\square OADE$

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



$\therefore v = u + at$

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

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

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

By eqn (1)

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

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

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

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

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

$$\left\{ \begin{array}{l} \because v = u + at \\ v - u = at \\ t = \frac{v - u}{a} \end{array} \right.$$

Then,

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

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

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

$$v^2 = u^2 + 2as$$

Eqn by Calculus Method.

~ by the definition of acceleration

$$a = \frac{dv}{dt}$$

$$a dt = dv$$

taking integral on both side

$$\int_0^t a dt = \int_u^v dv$$

$$a \int_0^t dt = [v]_u^v$$

$$a [t]_0^t = v - u$$

$$at = v - u$$

$$v = u + at \quad \text{--- (1)}$$

By the definition of velocity

$$v = \frac{ds}{dt}$$

$$v dt = ds$$

taking integral

$$\int_0^t v dt = \int_0^s ds$$

put the value of eq(1)

$$\int_0^t (u + at) dt = [s]_0^s$$

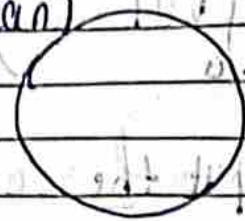
$$\left[ut + \frac{at^2}{2} \right]_0^t = s$$

$$ut + \frac{at^2}{2} = s$$

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

Length (Distance) = $s = R\theta$ (in radians)

(Displacement) = $r\theta \sin \theta$
(Chord length)



Average Speed = $\frac{\text{total distance}}{\text{total time}}$

Equation of motion

1] $v = u + at$

2] $s = ut + \frac{1}{2} at^2$

3] $v^2 = u^2 + 2as$

By the definition of acceleration:-

$$a = \frac{dv}{dt} \times \frac{ds}{ds}$$

$$a = \frac{ds}{dt} \times \frac{dv}{ds}$$

$$a = v \frac{dv}{ds}$$

$$a ds = v dv$$

Taking integral on both sides.

$$\int_0^s a \, ds = \int_u^v v \, dv$$

$$a \int_0^s ds = \left[\frac{v^2}{2} \right]_u^v$$

$$+0 + 1.0 \, \text{s}^{-2} = \frac{v^2}{2} - \frac{4^2}{2}$$

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

$$2 a s = v^2 - u^2$$

$$\boxed{v^2 = u^2 + 2 a s}$$

Ques- An object starts moving with a velocity $6 \, \text{ms}^{-1}$ and acceleration $1.5 \, \text{ms}^{-2}$. After what time will it acquire the velocity $15 \, \text{ms}^{-1}$, find the distance travelled by the object in this time.

$$u = 6 \text{ m/s}$$

$$a = 1.5 \text{ m/s}^2$$

$$t = ?$$

$$v = 15 \text{ m/s}$$

$$s = ?$$

$$v = u + at$$

$$15 = 6 + 1.5t$$

$$15 - 6 = 1.5t$$

$$9 = 1.5t$$

$$t = \frac{9}{1.5}$$

$$t = 6 \text{ sec.}$$

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

$$= 6 \times 6 + \frac{1}{2}(1.5) \times (6)^2$$

$$= 18 + 1.5 \times 18$$

$$= 18 + 27$$

$$= 45 \text{ m}$$

$$72 \quad 65$$

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

$$6 \times 6 + \frac{1}{2}(1.5) \times (6)^2$$

$$= 18 + 1.5 \times 18$$

$$= 18 + 27$$

$$36 + 27$$

An object moving with a constant acceleration travels 15 m in the 3rd second and 47 m in 6th second. Calculate its initial velocity and acceleration.

- (a) the acceleration of the object
 (b) the initial velocity of the object
 (c) the distance travelled by the object in 10th sec
 (d) the total distance travelled by the object in 10s.

$$3^{rd} \text{ Sec} = 15m$$

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

$$15 = u + \frac{1}{2} a (2 \times 3 - 1)$$

$$15 = u + \frac{1}{2} a \times 5$$

$$15 = 2u + 5a$$

$$30 = 2u + 5a$$

$$2u + 5a = 30 \text{ --- (1)}$$

$$6^{th} \text{ Sec} = 0.7m$$

$$27 = u + \frac{1}{2} a (2 \times 6 - 1)$$

$$27 = 2u + 11a$$

$$54 = 2u + 11a$$

$$2u + 11a = 54 \text{ --- (2)}$$

By eq (1) and eq (2)

$$u + 5a = 30$$

$$2u + 11a = 54$$

$$-6a = -24$$

$$(i) \quad a = 4 m/s^2$$

By eq (1)

$$2u + 5(4) = 30$$

$$2u = 10$$

$$(ii) \quad u = 5 m/s$$

iii) $S_{10} = u + \frac{1}{2} a (2 \times 10 - 1)$

$S_{10} = 5 + \frac{1}{2} \times 10 \times (19)$

$S_{10} = 5 + 2 \times 19$

$S_{10} = 5 + 38$

$S_{10} = 43 \text{ m} - 5 \times 10 \times 1 + 10 = 21$

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

$= 5 \times 10 + \frac{1}{2} \times 10 \times 10$

250 m

An object starts moving from rest with a uniform acceleration. If it travels a distance S_1 in the first t s and the distance S_2 in the next t s. Obtain the relationship between S_1 and S_2 .

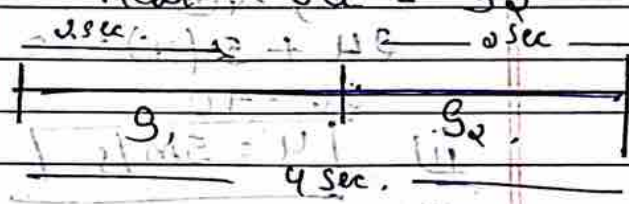
or $u = 0$

$0.2 + 0.6 = 0.8$

1st t Sec $= S_1$

$0.8 = 0.2 + 0.6$

next t Sec $= S_2$



$4 \text{ sec} = S_1 + S_2$

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

$$S_1 = 0 + \frac{1}{2} a (2)^2$$

$$S_1 = \frac{1}{2} 4a$$

$$S_1 = 2a$$

$$a = \frac{S_1}{2}$$

$$S_1 + S_2 = 0 + \frac{1}{2} a (4)^2$$

$$S_1 + S_2 = 0 + \frac{1}{2} a \times 16$$

$$S_1 + S_2 = 8a$$

$$S_1 + S_2 = 8 \times \frac{S_1}{2}$$

$$S_1 + S_2 = 4S_1$$

$$S_2 = 4S_1 - S_1$$

$$S_2 = 3S_1$$

$$S_1 = 3$$

$$S_1 = 1 = 1:3$$

$$S_2 = 3$$

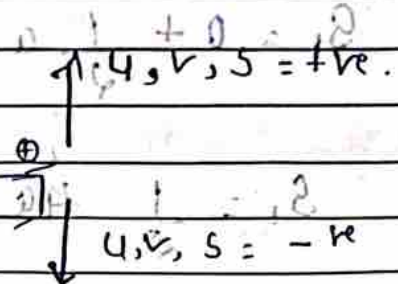
== Motion under gravity - vertical motion ==

(Acceleration due to gravity)
(Gravitational acceleration)

$$g = 9.8 \text{ m/s}^2$$

$$\approx 10 \text{ m/s}^2$$

Mean point



It always (-ve)
works towards
the centre of
earth

Time always = (+ve)

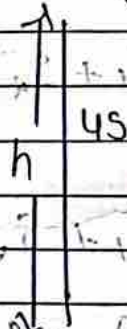
Ques. An object takes 4s in falling from the top of the tower to the ground. If acceleration during fall is constant and equal to 9.8 m/s^2 . find height of tower.

$$a = 9.8 \text{ m/s}^2$$

$$t = 4 \text{ s.}$$

$$h = ?$$

$$u = 0$$



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

$$h = 0 + \frac{1}{2} \times 9.8 \times 4^2$$

$$h = 78.4 \text{ m}$$

Que An object is made to fall from the top of a tower of height 78.4 m find

(i) Distance travelled by it in the 1st sec.

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

$$S_n = 0 + \frac{1}{2} (-9.8)(2 \times 1 - 1)$$

$$S_1 = -4.9 \times 1$$

$$S_1 = 4.9 \text{ m}$$

(ii) The time after which it strikes the ground.

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

$$S = 9.8 \cdot 0 + \frac{1}{2} (-9.8) t^2$$

$$-78.4 = -4.9 t^2$$

$$78.4 = 4.9 t^2$$

$$16 = t^2$$

$$4 = t$$

$$t = 4$$

$$t = 4 \text{ sec}$$

(iii) velocity with which it strikes the ground.

$$v = u + at$$

$$v = 0 + (-9.8)(4)$$

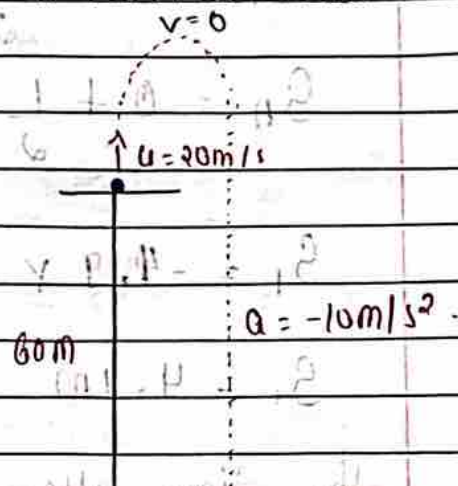
$$v = -39.2 \text{ m/s}$$

A body is thrown vertically upwards with a velocity 20 m/s from the top of a tower of height 60 m . If $g = 10 \text{ m/s}^2$, state:

(i) the Direction of acceleration in vertical motion of body.

(i) Always Downward.

(ii) the velocity and acceleration of body at the highest point of its motion.



$v = 0$, at highest point
 $a = 10 \text{ m/s}^2$

(iii) the time after which the body will reach the ground after throwing it?

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

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

$$-60 = 20t + \frac{1}{2}(-10)t^2$$

$$-60 = 20t - 5t^2$$

$$5t^2 - 20t - 60 = 0$$

$$[20t = 60]$$

$$d^2 - 4d - 12 = 0$$

$$d^2 - 6d + 2d - 12 = 0$$

$$d(d - 6) + 2(d - 6) = 0$$

$$d - 6 = 0, d + 2 = 0$$

$$d = 6, t = -2$$

$$d = 6 \text{ Sec.}$$

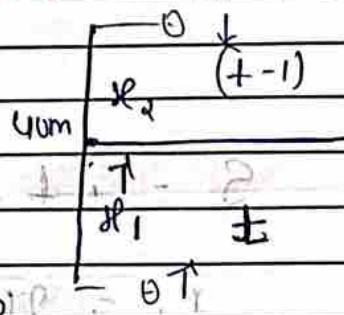
A ball A is thrown vertically upwards from the ground with a velocity 20 ms^{-1} . After 1 s another ball B is released to fall down with the same velocity from a height 40 m .
If $g = 10 \text{ ms}^{-2}$, find when and where two balls meet.

$$x_1 + (-x_2) = 40$$

$$x_1 - x_2 = 40$$

$$(ut + \frac{1}{2}at^2) - (ut + \frac{1}{2}at^2) = 40$$

~~$$ut + \frac{1}{2}at^2 - ut - \frac{1}{2}at^2 = 40$$~~



$$40t + \frac{1}{2}(-10)t^2 - (-20(t-1) + \frac{1}{2}(-10)(t-1)^2) = 40$$

$$20t - 5t^2 + 20t - 20$$

$$20t + \frac{1}{2}(-10)t^2 - (-20(t-1) + \frac{1}{2}(-10)(t-1)^2) = 40$$

$$20t - 5t^2 + 20t - 20 + 5(t^2 + 1 - 2t) = 40$$

$$20t - 5t^2 + 20t - 20 + 5t^2 + 5 - 10t = 40$$

$$40t - 10t - 15 = 40$$

$$30t = 55$$

$$30t = 55$$

$$t = \frac{55}{30} = 1.8 \text{ sec}$$

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

$$R_1 = 20 \times 1.8 + \frac{1}{2}(-10)(1.8 \times 1.8)$$

$$R_1 = 36 - 5(3.24)$$

$$R_1 = 36 - 16.20$$

$$R_1 = 19.8 \text{ m}$$