KINEMATICS

The branch of Mechanics that deals with the object in motion without considering the cause of motion.

Kine + Matics
↓ ↓
Motion Maths

KINEMATICS

1 Dimension
Motion of car on straight Road (Rectilinear Motion)

Two Dimension
Motion of projectile or circular motion

Three Dimension
Movement of atom

Variable of Kinematics ⇒ (I) Distance (II) Displacement (III) Speed (IV) Velocity (V) Time (VI) Acceleration (VII) Jerk

Distance

* It is the actual path length covered by body from initial point to the final point
* It is a scalar quantity
* It can be zero or positive
* Distance of a body can never predict the direction of motion
* Its SI unit will be in meter (m)

Distance ≥ displacement

Displacement

It is the shortest path length from initial to the final point

It is a vector quantity

It can be positive, zero or negative

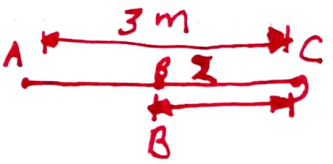
* It can also not predict the direction of motion.

Its SI unit is also meter.

Question Based Upon Displacement / Distance

Q→ Find the value of distance and displacement when a body is going from point A to B

(I) Body goes from A to C and returns back to B



Sol Distance = AC + BC = 3 + 2 = 5 m

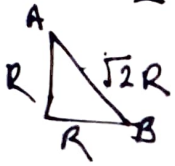
Displacement = AB = 1 m

(II) Distance = πR

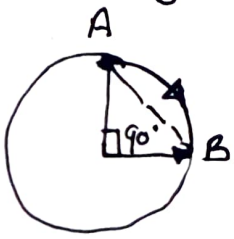
Displacement = $2R$

(III) Distance = $\frac{2\pi R}{4} = \frac{\pi R}{2}$

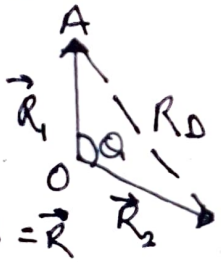
Displacement =



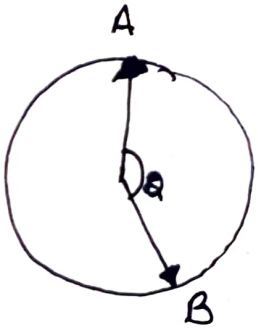
Displacement = $\sqrt{2}R$



(III) Displacement -



Displacement = AB = $\vec{R}$



Distance = $\frac{\theta}{360} \times 2\pi R$

$1 - \cos\theta = 2\sin^2\frac{\theta}{2}$

Using Δ law of vector addition

$$\vec{AO} + \vec{AB} = \vec{OB}$$

$$\vec{AB} = \vec{OB} - \vec{AO} = \vec{R}_2 - \vec{R}_1$$

$$\vec{R}_D = \vec{R}_2 - \vec{R}_1$$

$$|\vec{R}_D| = \sqrt{R_1^2 + R_2^2 + 2R_1R_2\cos\theta}$$

$|R_1| = |R_2| = R$

$$R_D = \sqrt{R^2 + R^2 + 2R^2\cos\theta}$$

$$R_D = \sqrt{2R^2 + 2R^2\cos\theta}$$

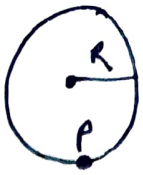
$$R_D = \sqrt{2R^2(1+\cos\theta)}$$

$$R_D = \sqrt{2R^2 \cdot 2\sin^2\frac{\theta}{2}}$$

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

Displacement

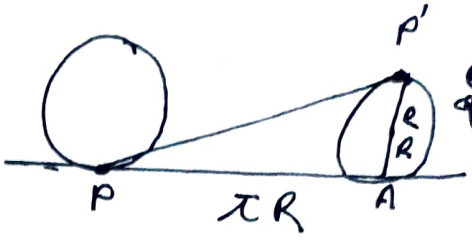
(IV) What is displacement of particle after half Rotation



Sol In $\triangle PP'A$

$PP' = \sqrt{(2R)^2 + (2R)^2}$

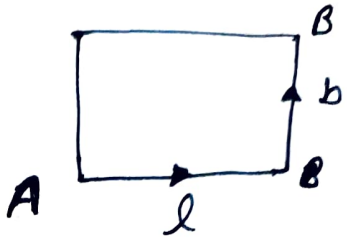
$PP' = R\sqrt{\pi^2 + 4}$



After half Rotation

(V) Distance = $l + b$

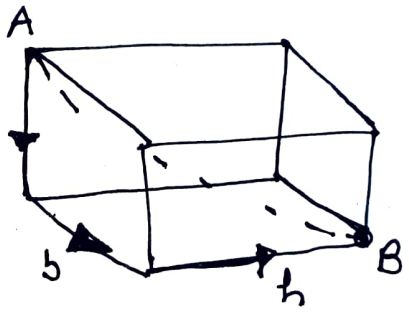
Displacement = $\sqrt{l + b}$



(VI) Distance = $l + b + h$

Displacement = $\sqrt{l^2 + b^2 + h^2}$

(Body diagonal of the cuboid)



Speed

Rate of change of distance is called speed.

It is scalar quantity

Its SI unit is m/s

Velocity

Rate of change of displacement is called velocity.

It is vector quantity

Its SI unit is m/s

Speed ≥ Velocity

Speed

- Uniform Speed
- Non Uniform speed
- Average Speed ⇒ It is the ratio of total distance travelled by body to the total time taken by the body.

Average Speed ⇒ $\frac{\text{Total distance}}{\text{total time}}$

It is generally for large time interval

Average Speed = $\frac{\Delta S}{\Delta T}$

- Instantaneous Speed ⇒ It is the speed of a body at any instant of time.

Instantaneous speed = $\frac{dS}{dt}$

$\frac{dS}{dt} = \lim_{\Delta t \to 0} \frac{\Delta S}{\Delta t}$

Velocity ⇒

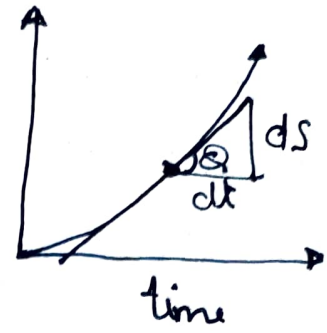
- Average Velocity ⇒ It is the total displacement by total time.

Average Velocity = $\frac{\text{total displacement}}{\text{total time}}$

Instantaneous Velocity ⇒ It is the velocity of the body at any instant of time.

Instantaneous velocity = $\frac{ds}{dt}$

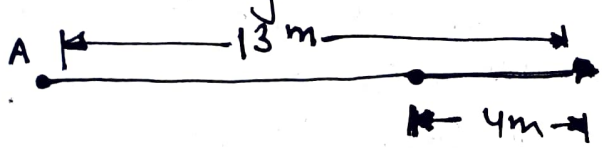
Slope of Displacement time graph gives instantaneous velocity.

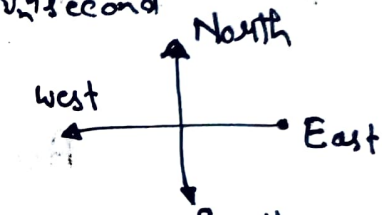


Numerical Based Upon Average Speed/Velocity

Q→ A boy walks 13 m east in 6 sec then 4 m west in 4 second. Find his average speed and velocity.

Sol





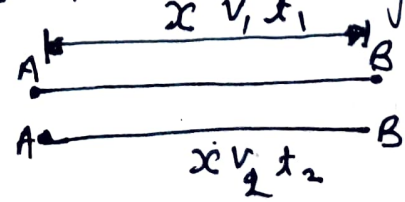
(1) Average speed = $\frac{\text{Total distance}}{\text{total time}} = \frac{13+4}{6+4} = \frac{17}{10}$

1.7 m/s

(2) Average Velocity = $\frac{9}{10}$ = 0.9 m/s

We can see Average speed > Average velocity

Q→ A man goes from A to B at v_1 speed and returns from B to A at v_2 speed. Calculate Average speed and velocity



Displacement = 0

Average velocity = 0

Distance = $x + x = 2x$

total time = $t_1 + t_2$

Distance = speed × time

$x = v_1 \times t_1$

$t_1 = \frac{x}{v_1}$ $t_2 = \frac{x}{v_2}$

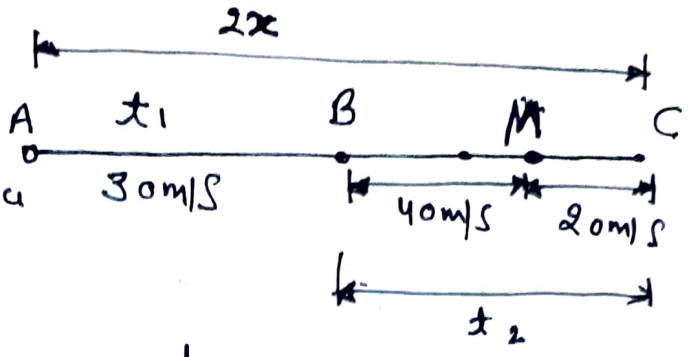
Average speed = $\frac{T.D}{T.T} = \frac{x+x}{t_1+t_2}$

$A.S = \frac{2x}{\frac{x}{v_1}+\frac{x}{v_2}} = \frac{2x}{x\left(\frac{1}{v_1}+\frac{1}{v_2}\right)} =$

$A.S \Rightarrow \frac{2v_1v_2}{v_1+v_2}$

Q→ A man covers half distance with speed 30 m/s and the second half distance for 40 m/s for half time 20 m/s for second half time.

Sol



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

Total distance = $2x$

$t_1 = \frac{x}{30}$ $\quad t_2 = \frac{x}{40+20}$

$A.S = \frac{2x}{\frac{x}{30}+\frac{x}{60}} = \frac{2x}{x(\frac{1}{30}+\frac{1}{60})}$

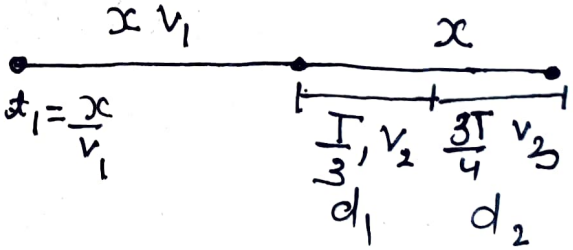
$A.S = \frac{2x}{x(\frac{1}{30}+\frac{1}{60})}$

$A.S = \frac{2\times 30\times 60}{30+60} = \frac{40}{\frac{360}{9}}$

$A.S = 40$ m/s

Q→ A bus travells first half of the distance with speed v_1 and for the next half it travells with speed V_2 for one third of the time and V_3 for the remaining time. Calculate average speed.

Sol



Average speed = $\frac{2x}{t_1+T}$

$t_1 = \frac{x}{v_1}$ $\quad x = d_1 + d_2$

$x = T\frac{V_2}{3} + \frac{3T}{4}V_3$

$x = T\left(\frac{V_2}{3} + \frac{3V_3}{4}\right) \Rightarrow x = T\left(\frac{4V_2+9V_3}{12}\right)$

$T = \frac{12x}{4V_2+9V_3}$

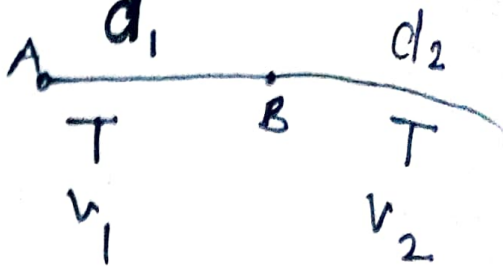
$A.S = \frac{2x}{\frac{x}{v_1}+\frac{12x}{4V_2+9V_3}}$

$A.S = \frac{2V_1(4V_2+9V_3)}{4V_2+9V_3+V_1}$

Q→ A man travells a distance with speed v_1 and v_2 two equal time periods. Find average speed.

Sol

$$\text{Average speed} = \frac{d_1 + d_2}{T + T}$$



$$d_1 = v_1 T \qquad d_2 = v_2 T$$

$$AS = \frac{v_1 T + v_2 T}{2T} = \frac{v_1 + v_2}{2}$$

NUMERICAL ON INSTANTANEOUS VELOCITY

Q→ $S = t^3 - 6t^2$ find velocity at $t = 1s$ and 3 sec.

Sol

$$S = t^3 - 6t^2$$

$$\frac{ds}{dt} = v = 3t^2 - 6t \Rightarrow$$

$$V = 3t^2 - 6t^2$$

$$V(1) = 3(1)^2 - 12(1) = -9 \text{ m/s}$$

$$V(3) = 3(3)^2 - 12(3) = -9 \text{ m/s}$$

Q→ Find the time when the body was at rest if the position of the body was given by $S = t^3 + 6t^2 + 10$

$$S = t^3 + 6t^2 + 10$$

$$\frac{ds}{dt} = v = 3t^2 + 12t + 0$$

Since we have to find out time when the body was at rest that is time when $v = 0$

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

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

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

Q→ $3t^2 + 4t + 9$ Find velocity at $t = 2$ second. And average velocity b/w 1sec to 4sec.

Sol $V = \frac{ds}{dt} = 6t + 4$

$V(2) = (6\times 2 + 4) = 12 + 4 = 16$ m/s

$S = 3t^2 + 4t + 9$

$S(1) = 3(1)^2 + 4(1) + 9 = 16$

$S(4) = 3(4)^2 + 4\times 4 + 9 = 73$

Net disp = $73 - 16 = 19$ m

total time = $4 - 1 = 3$ sec

$V_{av} = \frac{\text{total disp}}{\text{total time}} = \frac{19}{3} = 6.33$ m/s

Average velocity b/w 1 and 4 sec

$V(1) = 6\times 1 + 4 = 10$ m/s

$V(4) = 6\times 4 + 4 = 28$ m/s

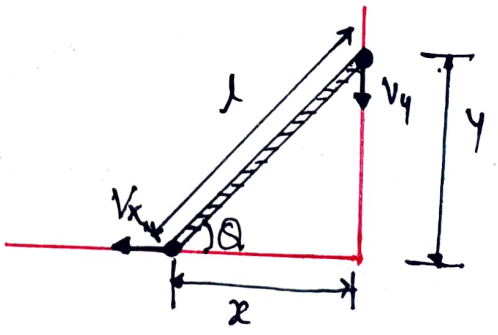
$V_{av} = \frac{V(1) + V(4)}{2} =$

Do not use this method for Calculating average ~~speed~~ velocity.

Q→ A ladder is placed along a wall. The wall and the floor are frictionless. If the bottom part of the ladder is sliding with speed v then Calculate the speed of the top of the ladder at angle θ

Sol $V_x = \frac{dx}{dt}$

$V_y = -\frac{dy}{dt}$ { since y is decreasing



Now since the length of ladder will remain Constant so

Using Pythagoras theorem

$x^2 + y^2 = l^2$

Differentiating both side w.r.t t

$2x\frac{dx}{dt} + 2y\frac{dy}{dt} = 0$

$2x V_x - 2y V_y = 0$

$2x V_x = 2y V_y$

$V_y = \frac{x}{y} V_x$

$\cot\theta = \frac{x}{y}$

$V_y = V_x \cot\theta$

Acceleration

Acceleration ⇒ Rate of change of velocity is known as acceleration.

$$\vec{a} = \frac{\vec{v}_2 - \vec{v}_1}{t_2 - t_1} = \frac{\Delta \vec{v}}{\Delta t} = \frac{m/s}{s} = m/s^2$$

m/s^2 → SI unit of acceleration.

Acceleration is a vector quantity

Acceleration

- Average Acceleration
- Instantaneous Acceleration

Average Acceleration

$$a_{av} = \frac{\Delta v}{\Delta t}$$

Instantaneous Acceleration

$$a_{in} = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t}$$

$$a_{in} = \frac{dv}{dt}$$

Slope of v-t graph gives acceleration

NUMERICAL

Q→ $v = 2t^2 - 4t$ Find acceleration at $t = 3$ sec. Also find average b/w 1 to 3 sec.

Sol $a = \frac{dv}{dt} = 4t - 4$

$a(3) = 4(3) - 4 = 8 m/s^2$

$a_{(3)} = 8 m/s^2$

$a_{(1)} = 4(1) = 4 = 0$

For average acceleration

$$\Delta a = \frac{\Delta v}{\Delta t} = \frac{v_{(3)} - v_1}{3 - 1}$$

$$\Delta a = \frac{8 - 0}{2}$$

$\Delta a = 4 m/s^2$

Q. Identify type of Motion when

(I) $x = 4t^2 + 6t$ | (II) $x = 4t^3 + 6t^2 + 1$ | (III) $x = 6t + 1$

Sol

(I) Body is moving with changing velocity But having constant acceleration

Quadratic equation

(II) Body will move with variable velocity with acceleration Changing with time

Cubic equation

(III) Moves with Constant velocity and having acceleration zero

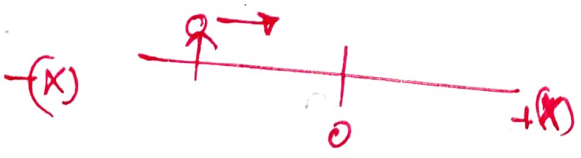
Linear equation.

☆☆ DIRECTION OF MOTION

We can not determine the direction of motion by displacement and acceleration. It can be only determined by Velocity

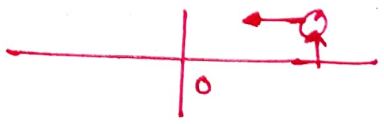
Velocity = +ve

Body will be moving in positive x direction



Velocity (-ve)

Negative x direction



Q→ $s = t^3 - 6t^2$. Find acceleration when body is at rest?

Sol $v = \frac{ds}{dt} = 3t^2 - 12t$

When body is at rest then $v = 0$

$0 = 3t^2 - 12t$

$3t^2 = 12t$

$t = 4\,sec$

acceleration

$a = \frac{dv}{dt} = \frac{d}{dt}(3t^2 - 12t)$

$a = 6t - 12$

$a_{(4)} = 6 \times 4 - 12$

$a_4 = 12\,m/s^2$

So acceleration $12\,m/s^2$ when body was at rest.

Q→ $x = 3t\,\hat{i} + 4t\,\hat{j}$. Find V at $t = 1s$
a at $t = 1s$
speed at $t = 1sec$

Sol $s_x = 3t$ $\quad s_y = 4t$

$\frac{d}{dt}(s_x) = v = 3$ $\quad \frac{ds_y}{dt} = 4$

$v_x = 3$ $\quad v_y = 4$

$V = 3\hat{i} + 4\hat{j}$

So velocity at $t = 1$

$\vec{V} = 3\hat{i} + 4\hat{j}$

$speed = |\vec{v}| = \sqrt{(3)^2 + (4)^2}$

$|\vec{v}| = \sqrt{9+16}$

$|\vec{v}| = 5$

Acceleration

$a = \frac{dv}{dt} = 0$

$a = 0$

Since velocity was constant acceleration will be zero.

Q→ $\vec{s} = t^2\,\hat{i} + (3t-1)\,\hat{j}$. Find V, a and speed at $t = 1sec$

Sol $\frac{d\vec{s}}{dt} = \vec{v} = 2t\,\hat{i} + 3\,\hat{j}$

$\vec{v}_{(1)} = 2\,\hat{i} + 3\,\hat{j}$

$speed = |\vec{v}| = \sqrt{(2)^2 + (3)^2}$

$= \sqrt{4+9}$

$|\vec{v}| = \sqrt{13}$

acceleration

$\frac{d\vec{v}}{dt} = 0$

$a = 0$

Q→ If $S = t^3 - 6t^2 + 9t$ Find velocity and acceleration at $t = 2$ sec. And also find out the direction of motion

Sol

$S = t^3 - 6t^2 + 9t$

$V = \frac{ds}{dt} = 3t^2 - 12t + 9$

$V(2) = 3(2)^2 - 12(2) + 9$

$V(2) = -3 m/s$ → Body was moving in negative direction.

$a = \frac{ds}{dt} = 6t - 6$

$a_{(2)} = 6(2) - 6$

$a_{(2)} = 6$

Direction of body can not be determined by acceleration

Q→ Find the time when the body was moving in negative direction and when the body was at rest. $S = t^3 - 6t^2 + 9t$

Sol

$V = \frac{ds}{dt} = 3t^2 - 12t + 9$

For body to be at rest

$V = 0$

$3t^2 - 12t + 9 = 0$

$t^2 - 4t + 3 = 0$

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

$t(t-3) - 1(t-3) = 0$

$(t-1)(t-3) = 0$

So body will be at rest when $t = 1$ sec, $t = 3$ sec

For body to move in negative direction

$V < 0$

$3t^2 - 12t + 9 < 0$

$(t-1)(t-3) < 0$

From above we can see that

$1 < t < 3$

So velocity will be negative when time is more than 1 sec and less than 3 sec

Displacement Of a body In n^{th} Second.

Q→ If $S = 4t^2 + 2t + 1$ then find the displacement covered by body in 3rd second

Sol The displacement in third second means the displacement covered by body b/w 2nd second 3rd second.

$S(3) = 4(3)^2 + 2(3) + 1$

$S(3) = 36 + 6 + 1$

$S(3) = 43$

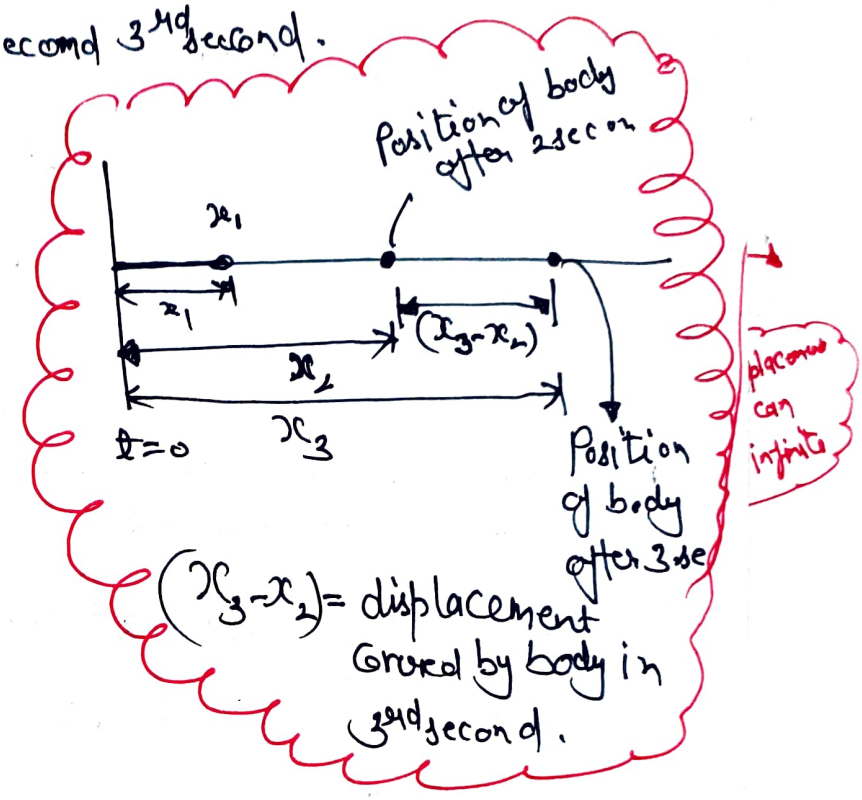
$S(2) = 4(2)^2 + 2(2) + 1$

$S(2) = 16 + 4 + 1$

$S(2) = 21 m$

$S_{3rd} = S_3 - S_2 = 43 - 21$

$S_{3rd} = 22$

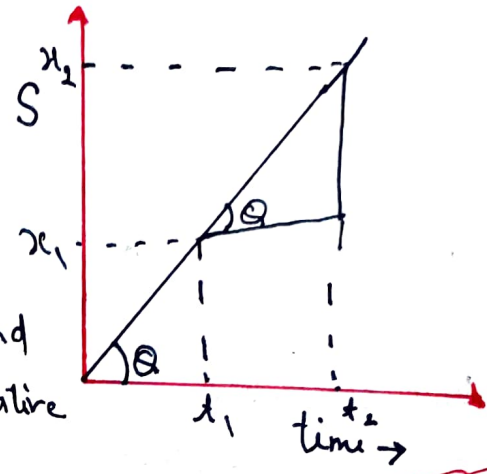


GRAPH

I Displacement V/S time

Slope of the displacement time graph gives velocity

* Slope = $\tan\theta = m = \frac{x_2 - x_1}{t_2 - t_1}$
* If slope is +ve velocity will be positive and if it is negative than velocity will be negative

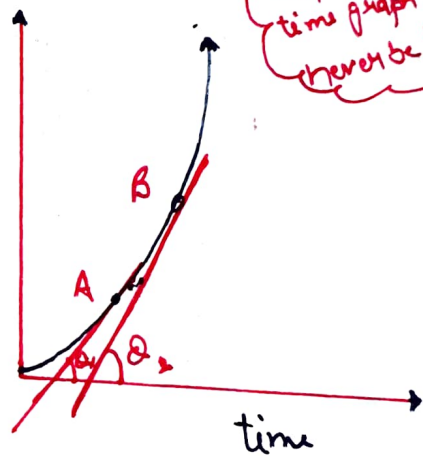


II

* This graph represent non uniform motion
* Velocity at different point will be different since slope is different at different point.

Since $\theta_1 < \theta_2$

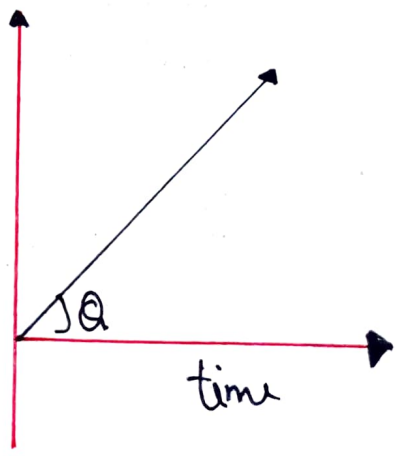
so velocity at point B is greater than velocity at point A



Slope of displacement time graph can never be infinite

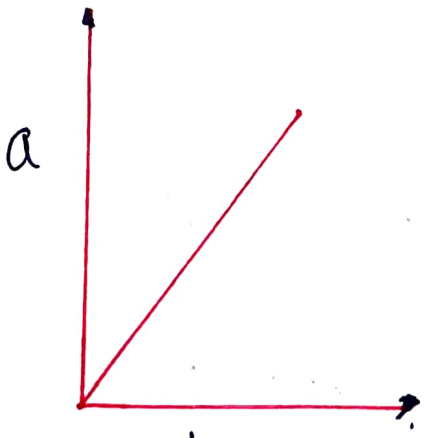
Velocity V/S time

1. The slope of velocity time graph will give acceleration
2. Area under the curve of velocity time will give you displacement covered.

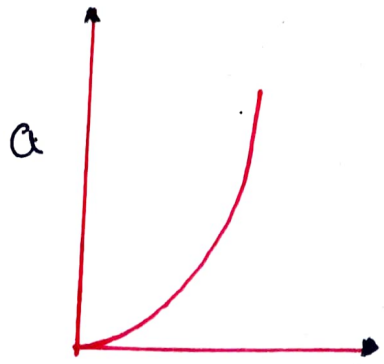


Slope of velocity time can never be infinite

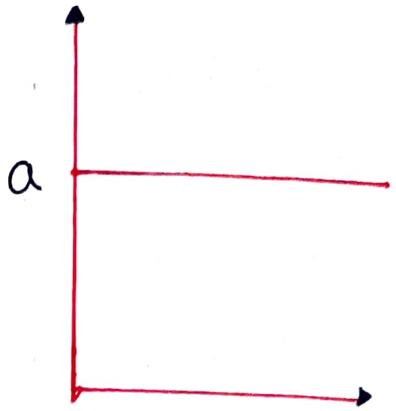
Acceleration time.



Body is under uniformly accelerated motion



Body is under Non uniformly accelerated motion

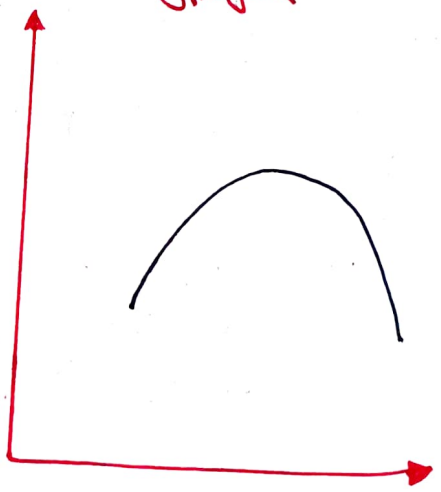


Body is moving with constant acceleration

Area of acceleration time gives change velocity

Slope of acceleration give jerk

If the graph is in upward direction then acceleration will be positive



If the acc. graph is in downward direction then acceleration will be negative

✡✡✡

if velocity and acceleration have same sign then speed will increase

if velocity and acceleration are having different sign speed will decrease.

Question Based Upon Graph

Q→1 (a) What will be the nature of velocity, acceleration and speed

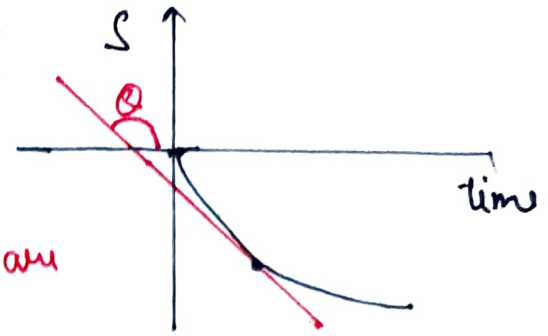
Sol

Since $\theta > 90°$

velocity will be negative

Acceleration is positive

Speed will decrease since v and a are of opposite nature.

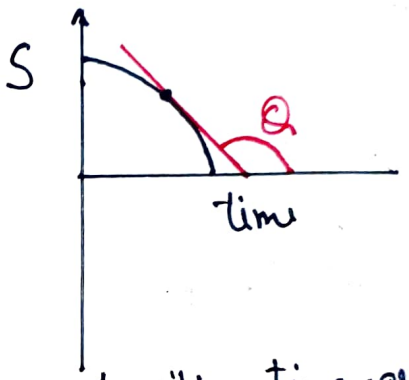


Q→1 (b) Since $\theta > 90°$

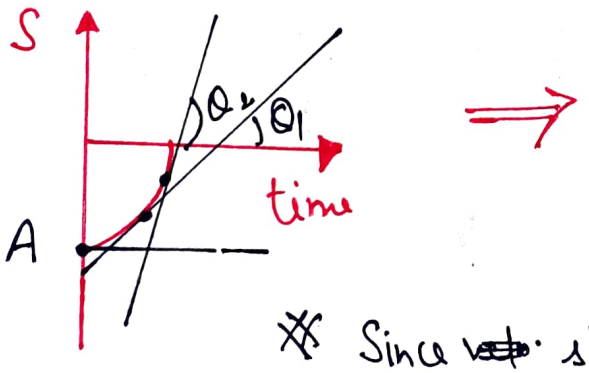
velocity = -ve

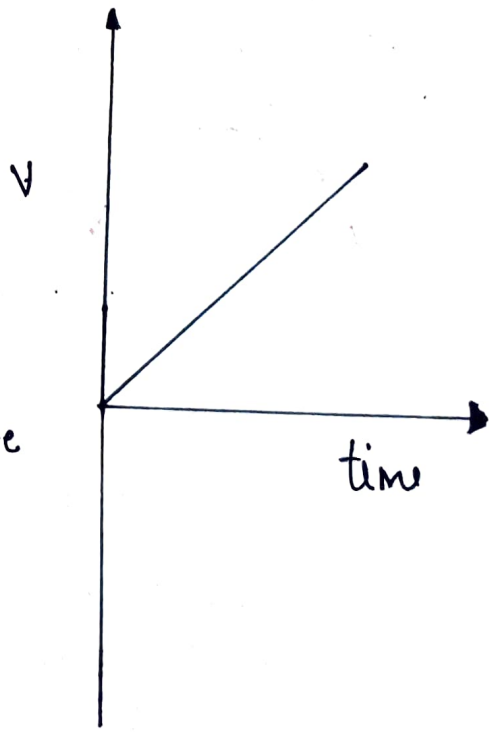
acceleration = -ve

Speed will increase.



Q→2 Draw velocity time graph ~~velocity time~~ position time graph.



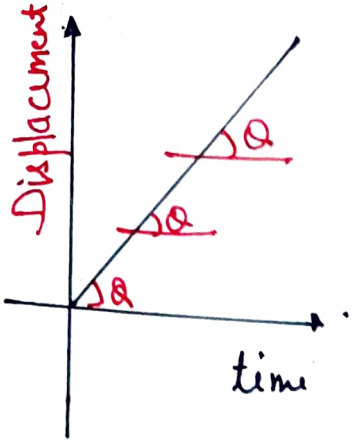


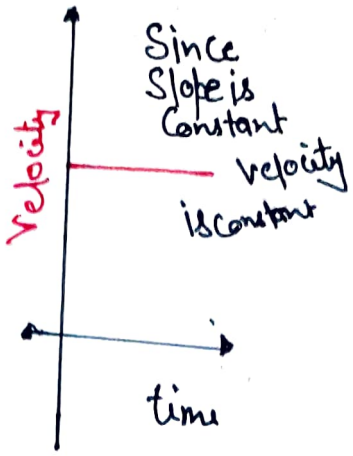
※ Since slope of the graph is positive so velocity will be positive ($\theta < 90°$)

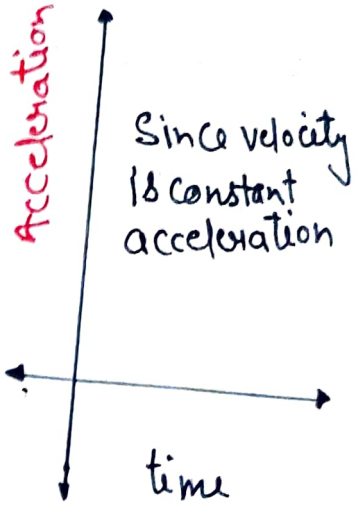
※ Since slope is increasing with time so velocity is also increasing.

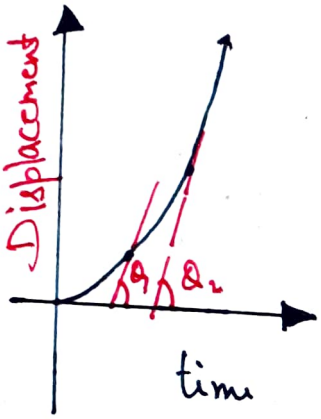
※ Since at point A of the graph slope is zero so velocity is zero

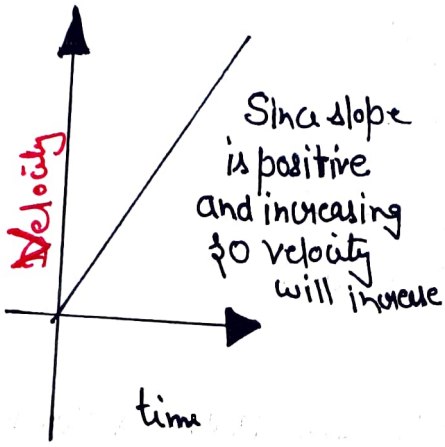
Conversion Of Graph

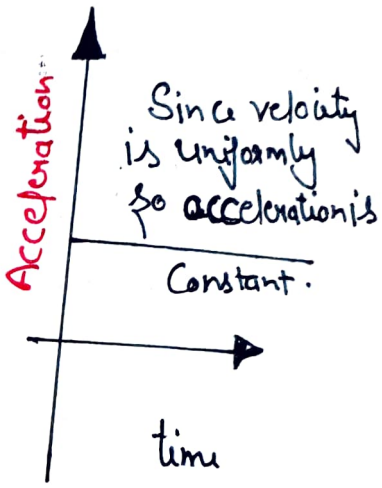






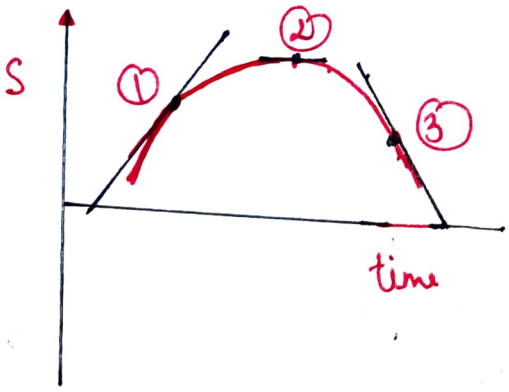


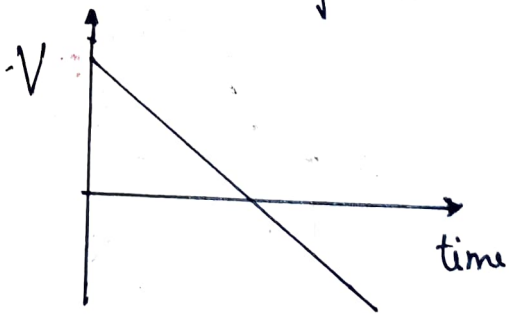




Question

Convert this graph into velocity time



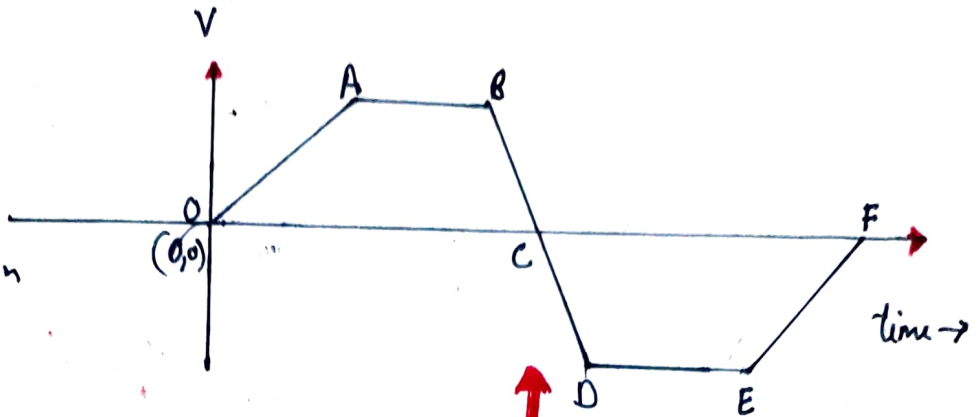


Sol at point (1) the slope is ~~neg~~ positive so the velocity is positive and slope is ~~decreasing~~ till point (II) so velocity is ~~de~~creasing

(II) at point two slope is zero so the velocity is zero.

(III) At point (3) ~~+ve~~ slope is negative and increasing so velocity is negative and increasing.

Q→ CONVERT V-T into S-T Graph



Soln

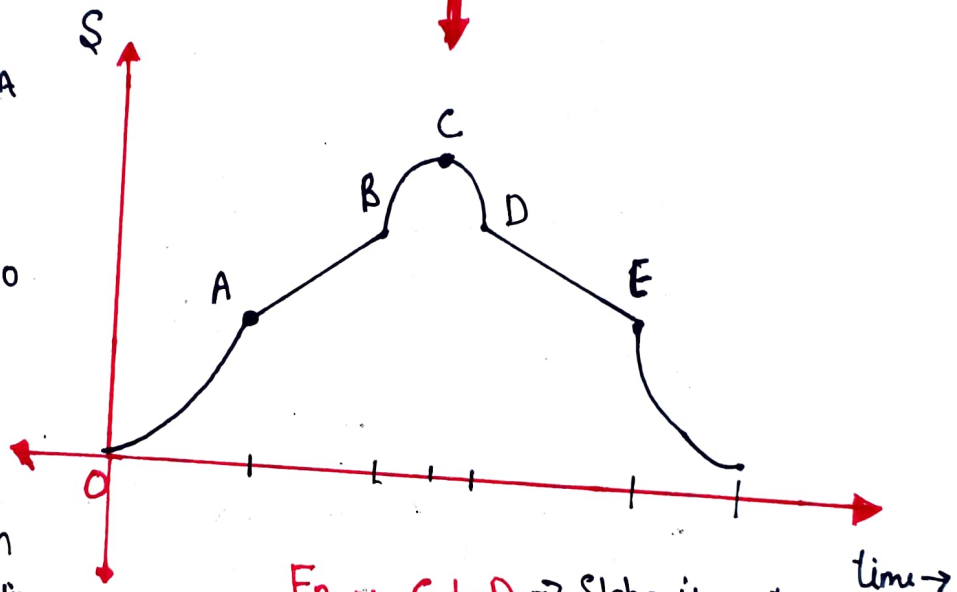
I FROM O to A

Slope of the graph is positive so acceleration is positive so

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

$y = ax^2 + bx + c$

so S-T graph should be parabolic upto point A



FROM A to B

Slope of the graph is zero

so $a = 0$

$s = ut + \frac{1}{2}(0)t^2$

$s = ut$

$y = mx + c$ so graph should be a straight line in upward direction.

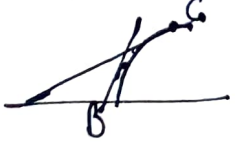
The slope of S-t graph should be constant.

FROM B to C

Slope of the graph is negative so acceleration is negative

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

so the graph must be parabolic downward and velocity must decrease. But velocity is positive



FROM C to D ⇒ Slope is negative acceleration is negative

$s = ut - \frac{1}{2}at^2$ graph will be parabolic downward

the slope of the graph must be negative as velocity is negative

FROM D to E Slope is zero so acceleration is zero

$s = ut$ so graph will be straight line and velocity should negative

FROM E TO F Slope is positive so acceleration is positive

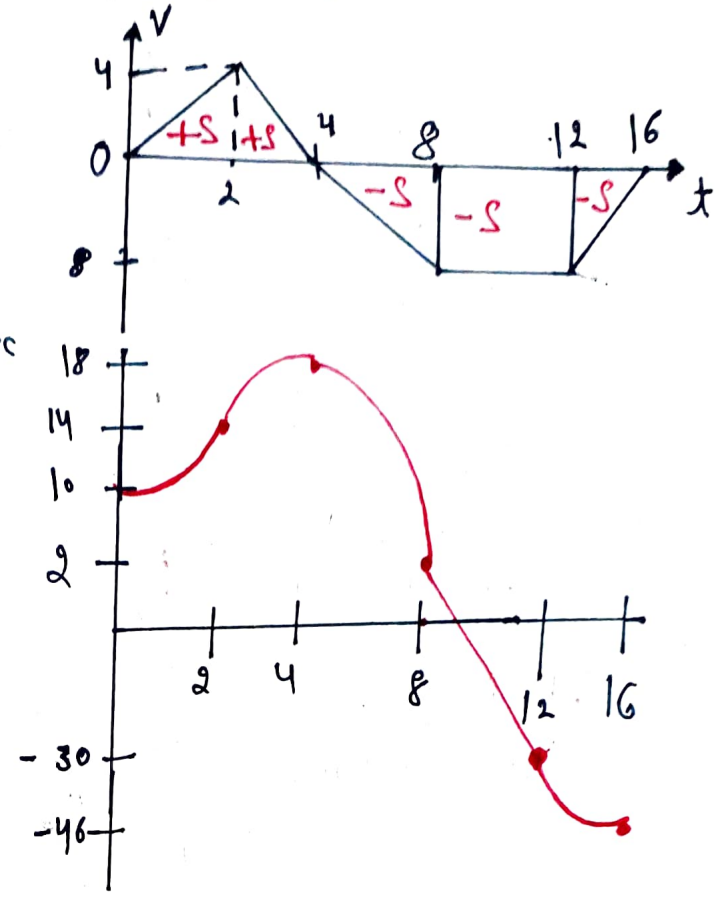
$S = ut + \frac{1}{2}at^2$ graph will be parabolic and it should have negative and decreasing slope

Q→ Velocity time graph of a particle moving along x axis is a shown. At $t=0$ $x=10$

(a) Plot x-T graph

(b) Find average velocity and average speed of the particle during Complete journey

(c) Average acceleration b/w 2 to 8 sec



Sol For Average Velocity

$$A.V = \frac{\text{Total disp}}{\text{total time}}$$

$$A.V = \frac{4+4-16-32-16}{16} = \frac{-56}{16}$$

Average velocity = -3.5 m/s

Time Interval	Area or displacement	Final X coordinate at the end of interval $X = X_i + S$
0-2	4	$x = 10+4 = 14$
2-4	4	$14+4 = 18$
4-8	-16	$18-16 = 2$
8-12	-32	$2-32 = -30$
12-16	-16	$-30-16 = -46$

Average ~~Distance~~ Speed

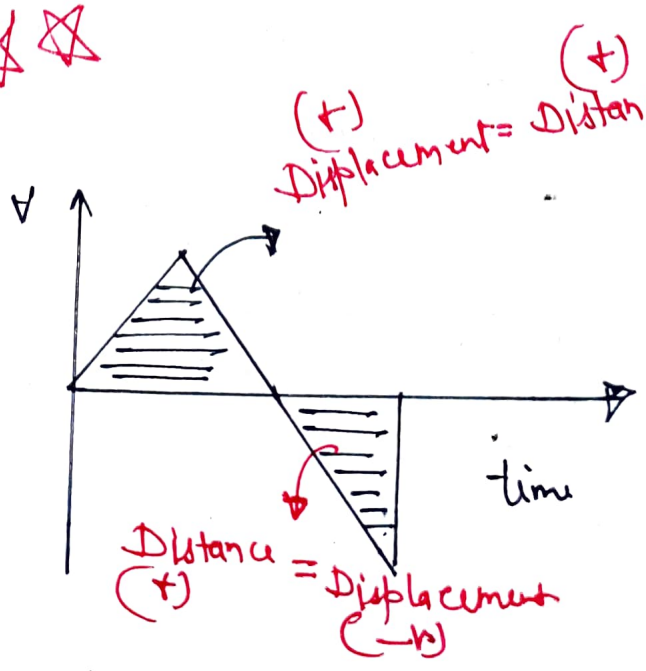
$$A.S = \frac{\text{Total distance}}{\text{total time}}$$

$$A.S = \frac{4+4+16+32+16}{16}$$

$$A.S = \frac{72}{16} = 4.5 \text{ m/s}$$

* Distance will be always positive and will be equal to area of velocity time graph

* Displacement will be positive if velocity is positive and negative if velocity is negative.



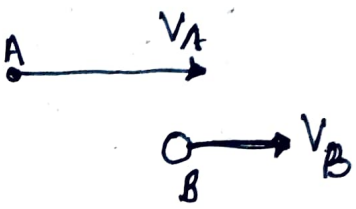
RELATIVE MOTION

RELATIVE VELOCITY ⇒ Relative Velocity is defined as rate of change of relative position of one object with respect to other.

A Relative when two objects are moving in same direction ⇒

(i) Relative Velocity of A with respect to B

$$\vec{V}_{AB} = \vec{V}_A - \vec{V}_B$$

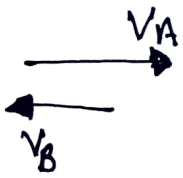


(ii) Relative Velocity of B with respect to A

$$\vec{V}_{BA} = \vec{V}_B - \vec{V}_A$$

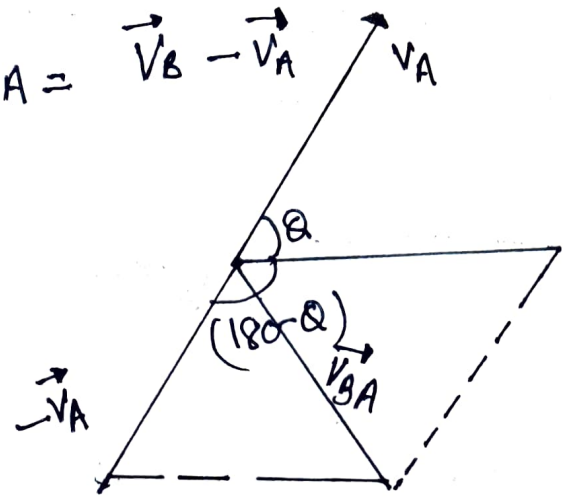
B Relative Velocity when two objects are Moving in opposite direction

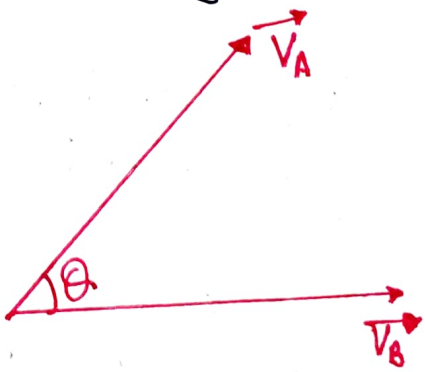
(i) $\vec{V}_{AB} = \vec{V}_A + \vec{V}_B$ (ii) $\vec{V}_{BA} = \vec{V}_B + \vec{V}_A$



C Relative Velocity when two objects are moving at angle θ

$$\vec{V}_{BA} = \vec{V}_B - \vec{V}_A$$





$$\vec{V}_{AB} = \sqrt{v_1^2 + v_2^2 + 2v_1v_2\cos(180-\theta)}$$

$$\vec{V}_{AB} = \sqrt{v_1^2 + v_2^2 + 2v_1v_2\cos 180^\circ}$$

$$\Rightarrow \vec{V}_{AB} = \sqrt{v_1^2 + v_2^2 - 2v_1v_2}$$

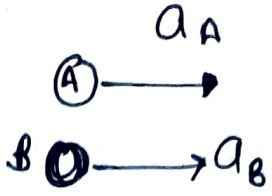
$$\vec{V}_{BA} = \sqrt{v_1^2 + v_2 - 2v_1v_2}$$

Relative Acceleration ⇒ It is defined as the rate of change of velocity of one object with respect to another object is called relative acceleration.

Case-1 When acceleration is in same direction

$$\vec{a}_{AB} = \vec{a}_A - \vec{a}_B$$

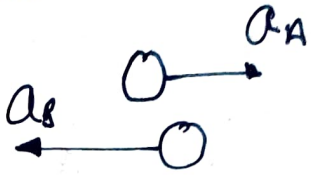
$$\vec{a}_{BA} = \vec{a}_B - \vec{a}_A$$



Case-2 When Acceleration is in opposite direction

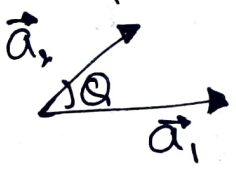
$$\vec{a}_{AB} = \vec{a}_A + \vec{a}_B$$

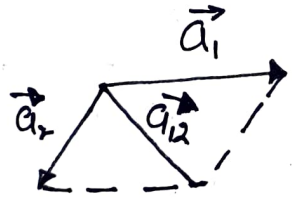
$$\vec{a}_{BA} = \vec{a}_B + \vec{a}_A$$



Case-3 When two Bodies are accelerating at some angle

$$\vec{a}_{12} = \sqrt{a_1^2 + a_2^2 - 2a_1a_2}$$





Numerical When two object are having a=0

Q→ A person(A) is in train is having 4 m/s with respect to train and the train is having speed of 10m/s with respect to ground. A person(B) is on the ground. Find :

(1) Veclocity A with respect to B

Sol $\vec{V}_{AB} = \vec{V}_{AG} - \vec{V}_{BG}$

$\vec{V}_{BG} = 0$ $V_{AT} = 4\ m/s$, $V_{TG} = 10\ m/s$

$V_{AT} = V_{AG} - V_{TG}$

$4 = V_{AG} - 10$

$V_{AG} = 14\ m/s$

$\vec{V}_{AB} = 14 - 0$

$V_{AB} = 14\ m/s$

$V_{BA} = -14\ m/s$

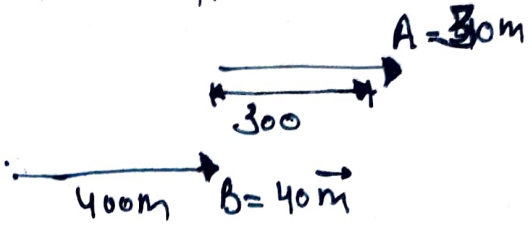
Q→ Two trains are having length 300m and 400m are moving with speed 30m/s and 40m/s. Then if they are moving on parallel track then Find

(i) Time taken to overtake (when moving in same direction)

(ii) Time taken to cross [when moving in opposite direction]

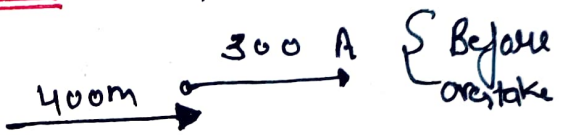
Soln ⇒ Case-1 Overtake -

The time of overtake start when the head of one train ~~is at~~ and tail of other train are at same position =



Distance to be covered for overtake = 400 + 300m = 700

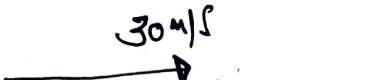
Time = $\frac{700}{V_{BA}}$



V_{BA} = 40 − 30 = 10 m/s

$T = \frac{700}{10} = 70$ sec

Case-II Cross

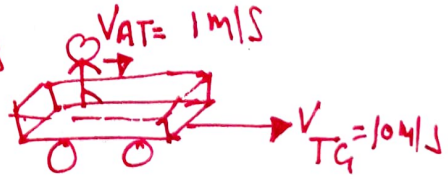


Distance = 700m $\quad \vec{V}_{AB} = 30 + 40 = 70$ m/s

time = $\frac{700}{70} = 10$s

Q→ Velocity of car with respect to Ground = $V_{CG} = 15$ m/s

Velocity of truck w.r.t Ground $V_{TG} = 10$ m/s



Velocity of person A on the truck with respect to truck = $V_{AT} = 10$m/s

Velocity monkey on the ~~Tower~~ Car = $V_{MC} = -1$m/s

Find $V_{MA} = ?$

$V_{MA} = V_{MG} - V_{AG}$

$V_{MA} = +14 - 11$

$V_{MA} = 3$ m/s

$V_{AT} = V_{AG} - V_{TG} \Rightarrow V_{AG} = V_{AT} + V_{TG}$

$V_{AG} = 1 + 10 = 11$ m/s

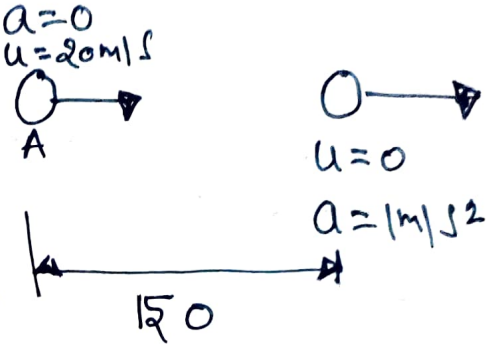
$V_{MC} = V_{MG} + V_{CG}$

$V_{MG} = V_{MC} + V_{CG}$

$V_{MG} = -1 + 15 = +14$ m/s

NUMERICAL On Relative velocity when $a \neq 0$

Q→ Two car A and B are moving in same direction. When Graphic two car was 150 m and the velocity of car A was 20 m/s and acceleration is zero while car B was at rest and start with acceleration $1 m/s^2$. When the two cars will overtake each other



Sol $u_{AB} = u_A - u_B = 20 - 0 = 20 m/s$

$u_{AB} = 20 m/s$

$a_{AB} = a_A - a_B = 0 - 1 = -1 m/s^2$

$a_{AB} = -1 m/s^2$

$s = u_{AB} t + \frac{1}{2} a_{AB} t^2$

$150 = 20t - \frac{1}{2} \times (1) t^2$

$300 = 40t - t^2$

$t^2 - 40t + 300 = 0$

$t^2 - 30t - 10t + 300 = 0$

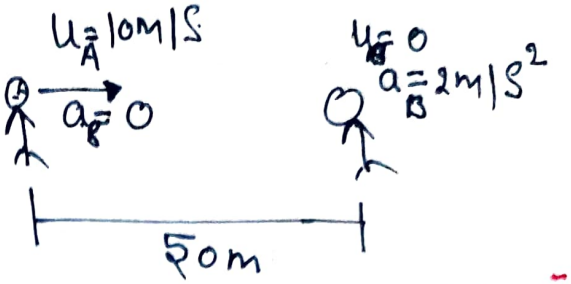
$t(t-30) - 10(t-30)$

$(t-10)(t-30)$

$t = 10 sec$ at this time car A will overtake car B

$t = 30 sec$ In this car B will overtake car A

Q→ Find the time when person A catches person B. If the person A is not being able to catch person B then find the minimum distance b/w them.



Sol

$U_{AB} = U_A - U_B = 10 - 0 = 10 m/s$

$a_{AB} = 0 - 2m/s = -2 m/s^2$

$S_{AB} = 50m$

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

$50 = 10t - \frac{1}{2}(2)t^2$

$50 = 10t - t^2$

$t^2 - 10t + 50 = 0$

$b^2 - 4ac$
$100 - 4 \times 50 \times 1$
$= -300$

So there will be no Real value of time so he will not be able to catch

To Find Minimum distance find the distance covered when relative velocity becomes zero

$V^2 - u^2 = 2as$

$0^2 - (10)^2 = -2(2)S$

$+100 = +4S$

$\boxed{S = 25m}$

Minimum distance will be $50 - 25 = 25m$

Explanation Of Above Question

Time	V_A $a=0$	V_B $a=2$	V_{AB} $= V_B - V_B$
0	10	0	10
1	10	2	8
2	10	4	6
3	10	6	4
4	10	8	2
5	10	10	0
6	10	12	-2
7	10	14	-4
8	10	16	-6

Relative velocity is decreasing with time mean distance b/w them will decrease slowly

at $t = 5$ this will be the minimum gap b/w them

After this point the gap b/w two person will increase