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CLASS – 11

PHYSICS

Chapter – 2

Motion in a Straight Line

Part – 2

Acceleration

Alok Gaur

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OVERVIEW

1. Instantaneous Velocity and Speed
2. Acceleration
3. Motion Under Gravity and Graphs
4. Uses of Differential and Integral Calculus in Physics

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ACCELERATION

The rate of change of velocity of a body with time is called acceleration.

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

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

a = ~~speed~~ / Time

a = velocity / Time

vector

$v_i = u$

$v_f = v$

- It is vector quantity.
- Unit : metre. sec^{-2}

SI

- Dimension : $[M^0L^1T^{-2}]$

$\Delta V = 0$

$a = 0$

TYPES OF ACCELERATION

1. Uniform acceleration
2. Non-uniform acceleration
3. Average acceleration
4. Instantaneous acceleration

(i) Uniform acceleration :

It's velocity changes by equal amounts in equal intervals of time.

(ii) Non-uniform acceleration :

It's velocity changes by unequal amount in equal intervals of time.

(iii) Average acceleration :

In time Interval

$$\text{Avg Acceleration} = \frac{\Delta v}{\Delta t}$$

at $t = t \Rightarrow v = v_1$

at $t = t_2 \Rightarrow v = v_2$

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

$$\boxed{a_{avg} = \frac{\Delta v}{\Delta t}}$$

(iv) Instantaneous acceleration :

At the instantaneous time, the value of acceleration is called instantaneous acceleration.

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

$\Delta t \to 0$

$$a = \frac{dv}{dt} \quad \text{Or} \quad a = \frac{d^2x}{dt^2}$$

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

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

[differentiation of velocity with respect to time.]

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

accel. → Double differentiation of x with respect to time

$$a = \frac{d}{dt}\left(\frac{dx}{dt}\right) \qquad a = \frac{dv}{dt} \cdot \frac{dx}{dx}$$

$$\therefore \quad a = \frac{d^2x}{dt^2} \qquad \boxed{a = v\frac{dv}{dx}}$$

$x = (3t^3 + 2t^2 + 1)\ m$

find acceleration at $t = 2$ sec

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

$V = \frac{dx}{dt} = \frac{d}{dt}[3t^3 + 2t^2 + 1]$

$= 3(3t^2) + 2(2t) + 0$

$V = 9t^2 + 4t$

$a = \frac{dv}{dt} = \frac{d}{dt}(9t^2 + 4t)$

$a = 9(2t) + 4(1)$

$a = 18t + 4$

at $t = 2$ sec

$a = 18(2) + 4$

$\boxed{a = 40\ m/s^2}$

Ans

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Note

velocity ↑

- Positive acceleration : Increase velocity with time

velocity ↓

- Negative acceleration : Decrease velocity with time (Retardation or deceleration)

$v = +ve$
$a = +ve$ ↑ accel.

$v = +, -$
$a = -, +$ ↓ retarding

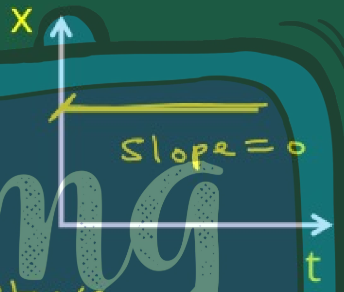
Position time graph :

x-t

slope of x-t graph = velocity

x-t slope = v

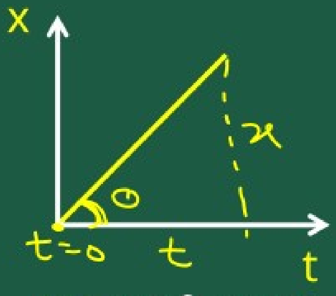
$\tan\theta =$



Distance $s = 0$

velocity → $v = 0$

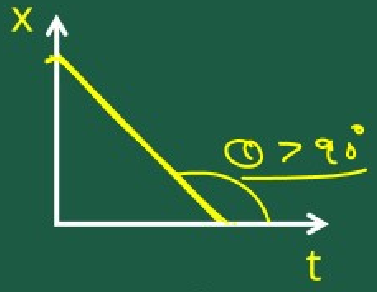
Accel. → $a = 0$



v = +ve & const.

$a = 0$

$\tan\theta = \dfrac{x}{t} = v$



v = −ve & const.

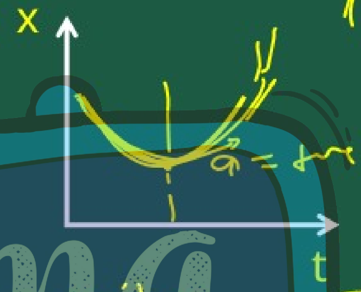
$a = 0$

Slope = −ve

Slope of straight line = constant

$\theta < 90^\circ$ → slope = +ve

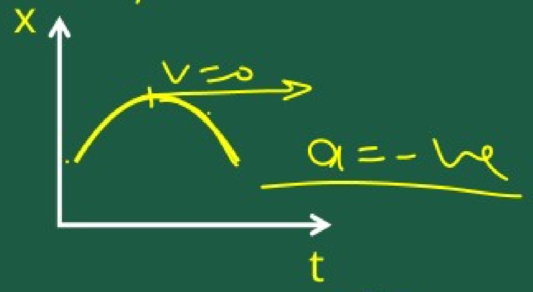
$\theta > 90^\circ$ → slope = −ve



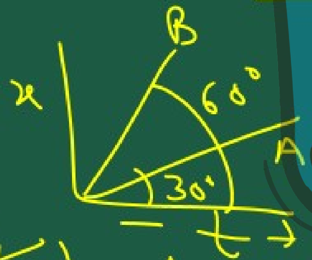
velocity

s = First –ve & ing ↓
then +ve & ing ↑
a = +ve &
may be a, b or const.

a(t) = +ve ↑ ↓ Const



v = Firstly +ve & ing ↓
then –ve & ing ↑
a = –ve &
may be a, b or const.



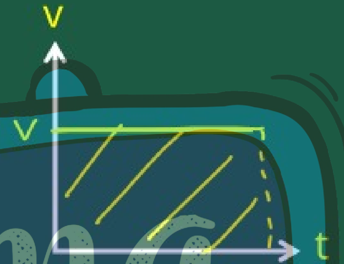
$V_A = \tan 30° = \frac{1}{\sqrt{3}}$

$V_B = \tan 60° = \sqrt{3}$

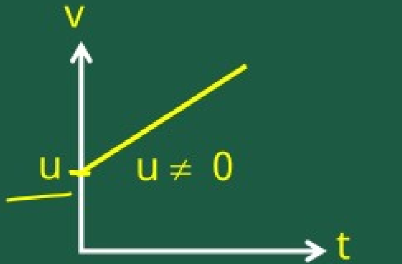
Velocity time graph :

Slope of v-t graph $= \tan\theta = \frac{v}{t} = a$

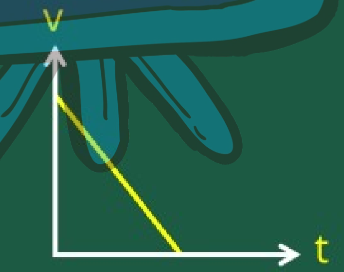
area covered by v-t graph $= v \times t = x$



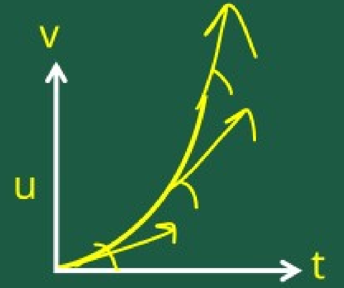
v = const. & +ve
a = zero



v = +ve & ing ↑
a = +ve & const.



v = +ve & ing ↓
a = –ve & const.



v = +ve & ing
a = +ve & ing

KINEMATICS EQUATION FOR UNIFORMLY ACCELERATION

$s, t, u, v, \underline{\underline{a}}$

$a =$

Let at $t_1 = 0 \Rightarrow v_1 = u$

at $t_2 = t \Rightarrow v_2 = v$

I K.E

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

$a = \frac{v - u}{t - 0} = \frac{v - u}{t}$

$v - u = at$

$v = u + at$

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

Let suppose initial velocity u at time t = 0, and final velocity at time t

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

$$v - u = at$$

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

- This equation represents the first equation of motion.

$$V_{avg} = \frac{u+v}{2}$$

$$S = V_{avg} \times t$$

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

Using $v = u + at$

$$S = \left[\frac{u+(u+at)}{2}\right]t$$

$$V_{ay} = \frac{u+v}{2}$$

II k.E

$$S = v \times t$$

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

$$S = \frac{ut + vt}{2}$$

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

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

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

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

$$V = u + at$$

$$v^2 = (u + at)^2$$

$$v^2 = u^2 + 2uat + a^2t^2$$

$$v^2 = u^2 + 2a\left[ut + \frac{1}{2}at^2\right]$$

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

III k'E

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

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

- This equation represents the second equation of motion.

$v = u + at$

taking square from both sides

$v^2 = (u + at)^2$

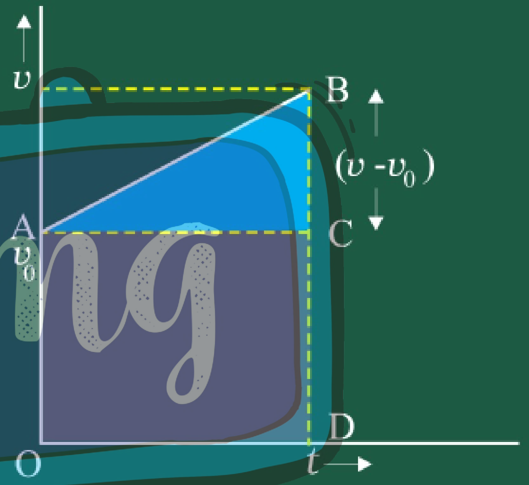
$$v^2 = (u^2 + 2uat + a^2t^2)$$

$$v^2 = u^2 + 2a\left(ut + \frac{1}{2}at^2\right)$$

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

- This equation represents the third equation of motion.

Using graphical method :



slope of v – t curve = $\tan\theta$

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

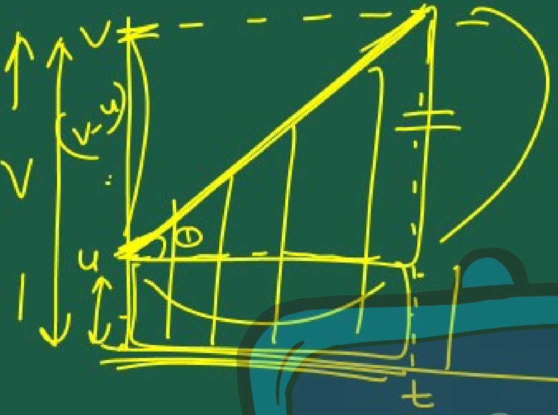
$$v - u = at$$

$$v = u + at$$

Let

at $t = 0 \Rightarrow u$

at $t = t \Rightarrow v$



Area of v-t graph $= x = s$

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

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

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

Slope of v-t graph $= a$

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

$v - u = at$

$v = u + at$

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

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

$s = \left[u + \frac{1}{2}(v-u)\right]t$

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

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

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

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

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

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The area under this curve is :

Area between instants 0 and t = Area of triangle ABC + Area of rectangle OACD

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

$$\because v - u = at$$

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

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

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$$s = V_{arg}\ t$$

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

$$2as = (v+u)(v-u)$$

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

$$\boxed{V^2 = u^2 + 2as}$$

LEARNING OUTCOMES

1. To study : Acceleration
2. To study : Derive kinematic equations for uniformly accelerated motion

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ASSESSMENT

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1 The acceleration of a moving body is found from –

A. Area under v – t graph

B. Area under x – t graph

C. slope of v – t graph

D. slope of x – t graph

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ASSESSMENT

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2 If the initial velocity of the car is 5m/s, and the final velocity is 10m/s in 5 sec, then the acceleration is .... (in m/sec^2)

A 0.1

B 1

C 5

D 10

$u = 5\ m/s$, $v = 10\ m/s$

$t = 5\ sec$, $a = ?$

$v - u = at$

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

$a = \frac{10-5}{5} = \frac{5}{5}$

$a = 1\ m/s^2$