Motion In A Straight Line

Chapter - 2

Class - 11 Physics

By- Jyoti Sharma Physics

Motion In A Straight Line

Mechanics

Statics | Kinematics | Dynamics

Mechanics – Branch of physics which deals with the condition of rest or motion of the objects around us.

Statics: Deals with study of objects at rest or in equilibrium.

Kinematics: Deals with study of motion of objects without considering the cause of motion. (i.e force) (Study of position, velocity, acceleration etc.)

Dynamics: Deals with the motion of objects by considering the forces that cause the motion. (* Includes the cause of motion, i.e force)

Rest And Motion

An object is said to be in rest if its position does not change with time (w.r. to surroundings) i.e. table, chair in the room.

An object is said to be in motion if its position changes with time. i.e. a car is moving etc.

Rest and motion are relative terms

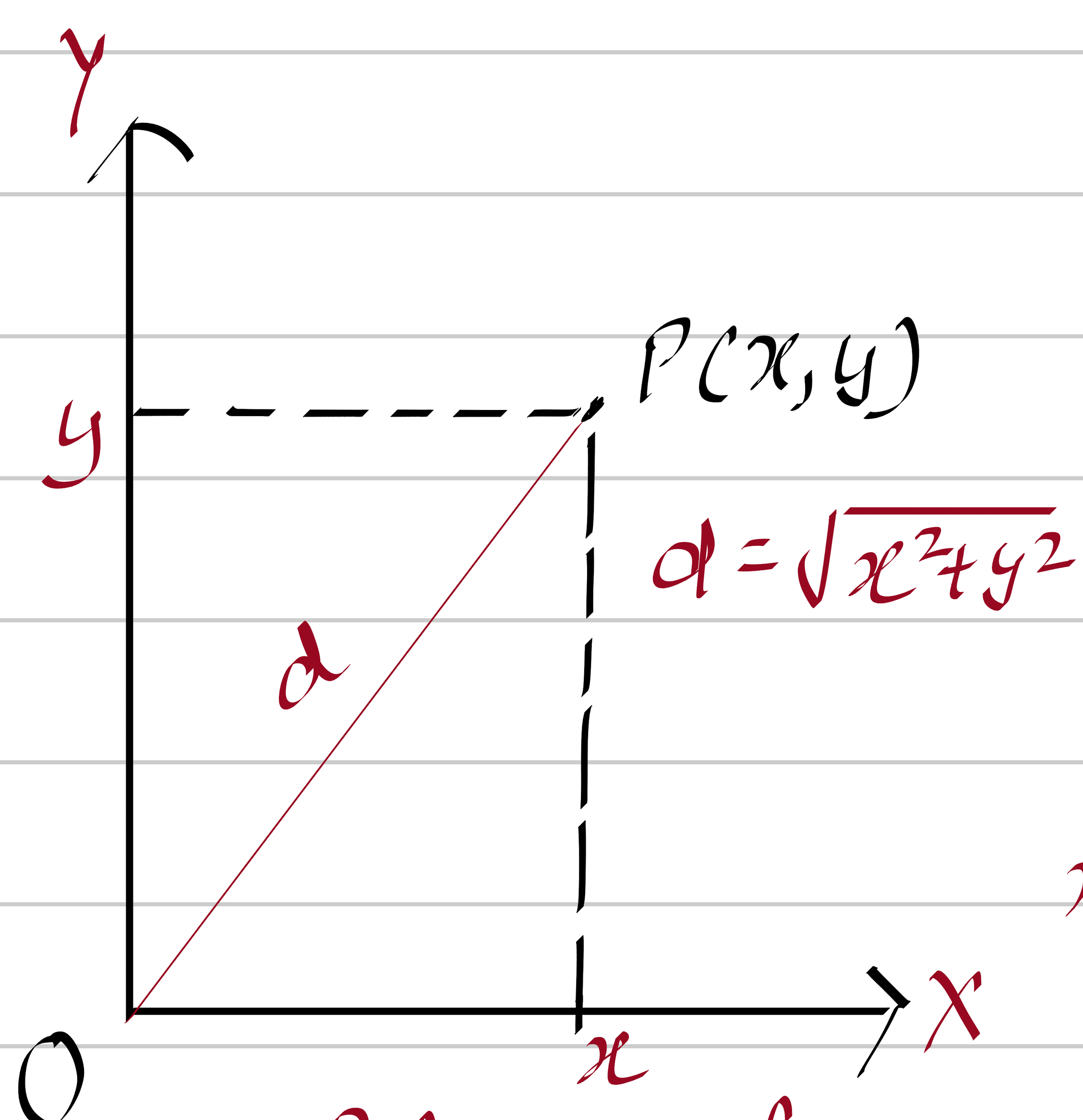
An object may be at rest w.r. to one object and at the same time it may be in motion relative to other object. e.g If you are in a moving bus then w.r.t other passengers you are in rest but w.r.t the people outside the bus you are in motion.

Hence rest and motion are relative terms.

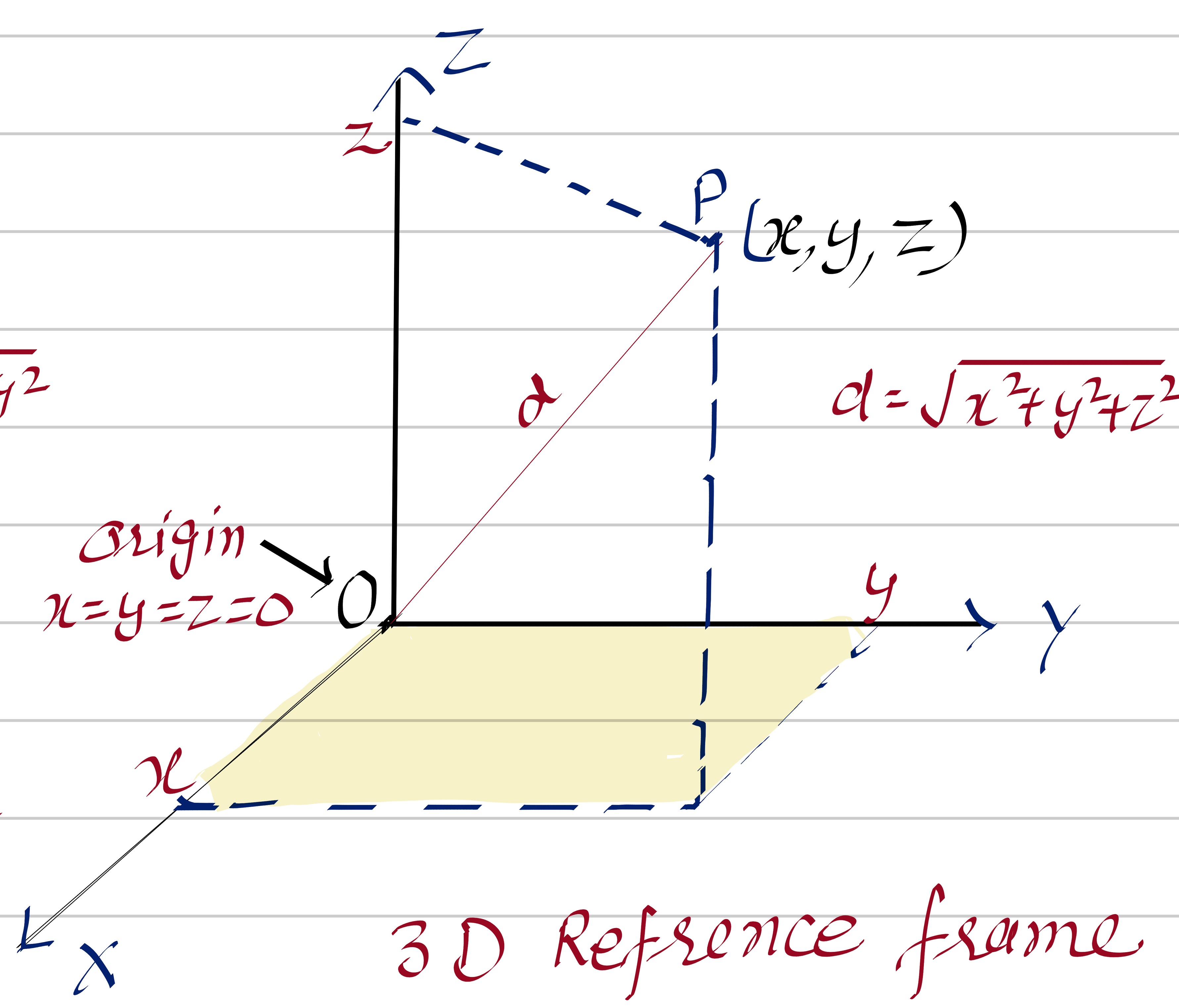
* No object in the universe is in a state of absolute rest.

* Motion is universal.

<u>Reference Frame:</u> A frame with respect to which an observer observes the position and motion of an object is known as reference frame.
To describe the motion mathematically with respect to a frame of reference, a system of coordinates axis (x, y and z axis) is taken.



2 D Reference frame



3 D Refrence frame

<u>Position of a particle:</u> Position of a particle refers to its location in the space at an instant of time.
To locate the position of a particle with respect to a frame we take three mutually perpendicular coordinate axex x, y and z axis attached to this frame of reference.

<u>Types of frame of reference:</u>

Inertial	Non inertial
→ zero acceleration (either at rest or in uniform motion)	→ Non zero acceleration
→ Newton's laws are valid	→ Newton's laws are not valid
→ e.g. car moving with constant speed.	e.g An accelerating lift

* Motion is universal.

Point object approximation:

- Objects in motion are treated as point objects.
- When object's size is small compared to the distance it moves, then object may be regarded as a point object.

e.g. Earth is considered as a point object for its motion around the sun.

A bus is regarded as a point object for its motion between two villages.

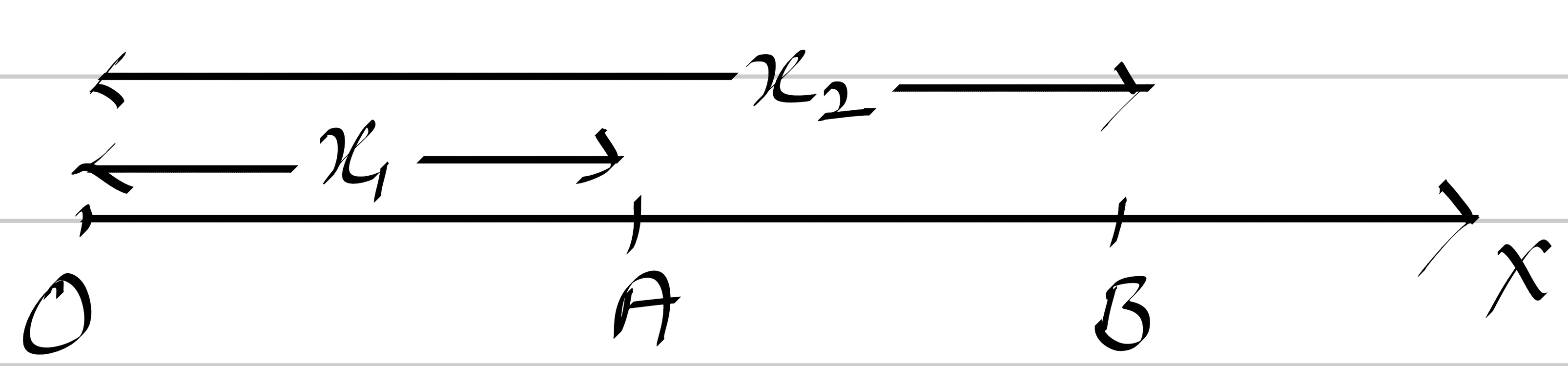
Motion in one, two and three dimensions

One dimensional motion (1D)

- Motion along a straight line.
- Only one coordinate (usually x or y) is needed

e.g. A car moving on a straight road.

- This motion is also called rectilinear or linear motion.



$OA = x_1$

$OB = x_2$

Motion of a freely falling body (vertical motion only) is also example of 1D.

Two dimensional motion (2D)

- Motion occurs in a plane, needs two coordinates (x and y) to describe the motion.

e.g. Circular motion, Projectile motion, a ball rolling on floor, motion of coins on a carom board etc.

Three dimensional motion (3D)

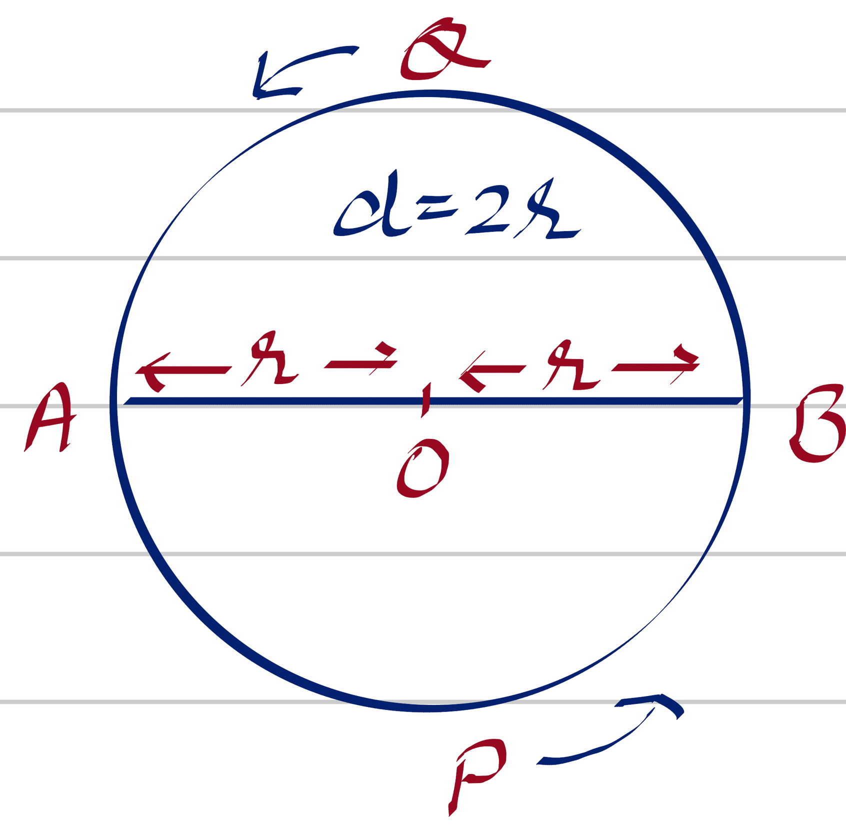
Motion that occurs in space, all three coordinates (x, y, z) are needed.

e.g. Motion of an aeroplace, motion of any flying insect, bird etc.

Distance and Displacement

	Distance	Displacement
1.	It is the total path length travelled by an object.	It is the shortest path between initial and final positions.
2.	It is a scalar quantity	It is a vector quantity.
3.	It is always +ve	It can be +ve, -ve or '0'.
4.	It does not give information about direction.	It indicates direction of motion.
5.	It is greater or equal to displacement.	It can be less or equal to distance but cannot be greater than distance
6	SI unit - m/s	SI unit - m/s

* For given figure



(1) If a particle moves from 'A' to 'B' via 'P'

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

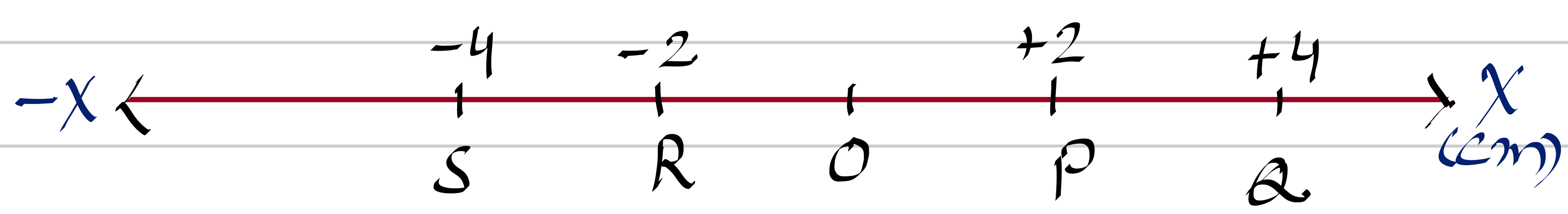
$$\text{Displacement} = r + r = 2r = d$$

(1) If a particle moves from 'A' to 'A' along the circumference (via 'P' and 'Q')

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

$$\text{Displacement} = 0 \text{ (zero)}$$

* For given figure



(1) If a particle moves from 'O' to Q

Distance = 4 cm

Displacement = 4 cm

(II) If a particle moves from 'O' to 'Q' and then 'Q' to 'O'

Distance = $4+4 = 8$ cm

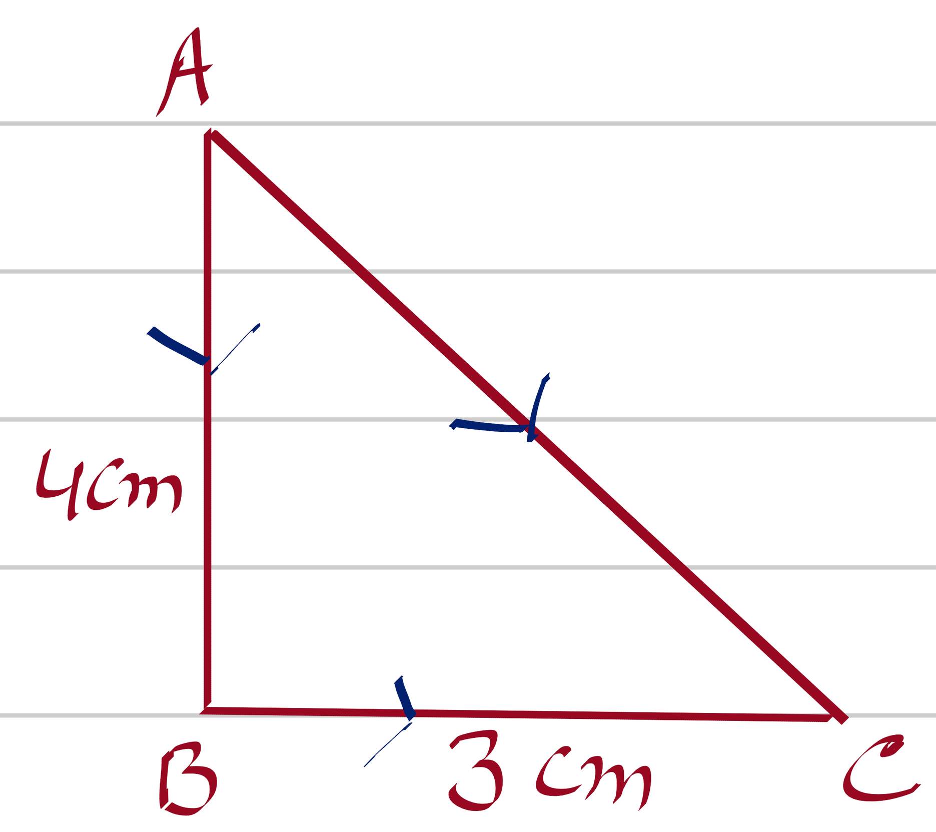
Displacement = $4-4 = 0$

(III) If a particle moves 'O' to 'P' and then 'P' to 'S'

Distance = $2+2+4 = 8$ cm

Displacement = $2-2-4 = -4$ cm

* For given figure



An object is moving from point 'A' to 'B' and then 'B' to 'C'

Distance = $4+3 = 7$ Cm

Displacement = AC

$= \sqrt{AB^2 + BC^2}$

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

$= \sqrt{25}$

$= 5$ cm

Speed and velocity

Speed: Speed is the rate of change of distance with respect to time. It is scalar quantity. It magnitude only.

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

Velocity: Velocity is the rate of change of displacement with respect to time. It is a vector quantity. It has magnitude and direction both.

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

* The speed of an object in a given direction is called velocity.

* SI unit of speed and velocity is m/S

	Speed	Velocity
1.	Scalar quantity	vector quantity
2.	Always postive or zero.	Has both magnitude and direction.
3.	Based on total distance travelled	Based on displacement
4.	Cannot be less than velocity.	Cannot be greater then speed.
5.	e.g. 40 Km/h	e.g 40 Km/h north

	Average Speed	Average Velocity
1.	It is equal to total distance travelled divided by total time.	It is defined as the total displacement divided by total time taken.
2.	Av. Speed = $\frac{\text{Total distance}}{\text{total time}}$	Av. Velocity = $\frac{\text{Displacement}}{\text{time}}$
3.	It has magnitude only	It has magnitude and direction both
4.	It cannot be zero or -ve	It can be +ve, -ve or zero

* Average velocity depends on displacement, not total path.
* It shows net change in position, not how much distance is covered.

Formulas of average velocity

1. $$\boxed{V_{av} = \frac{\text{Displacement}}{\text{time interval}} = \frac{\Delta x}{\Delta t} = \frac{x_2 - x_1}{t_2 - t_1}}$$

2. For uniform velocity,

$$v_{av} = v = \text{Constant}$$

3. For same direction,

$$\boxed{v_{av} = \frac{2 v_1 v_2}{v_1 + v_2}}$$

$$\boxed{v_{av} = \frac{S + S}{\frac{S}{v_1} + \frac{S}{v_2}} = \frac{2 v_1 v_2}{v_1 + v_2}}$$

4. For multiple velocities over equal time intervals

$$\boxed{v_{av} = \frac{v_1 + v_2 + \cdots v_n}{n}}$$

5. From position-time graph (x-t graph)

v_{av} = Slope of the straight line

Average Speed Formulas

1. $$\boxed{\text{Average speed} = \frac{\text{Total distance}}{\text{total time taken}} = \frac{S_1 + S_2 + \cdots}{t_1 + t_2 + \cdots}}$$

2. For two equal distances ($S_1 = S_2$) with different velocities v_1 and v_2

$$\boxed{v_{av} = \frac{2v_1 v_2}{v_1 + v_2}}$$

3. If S_1 distance is covered with v_1 speed and S_2 with v_2 speed, then

$$\boxed{v_{av} = \frac{S_1 + S_2}{\frac{S_1}{v_1} + \frac{S_2}{v_2}}}$$

4. For different speed v_1 and v_2 for time t_1 and t_2,

$$\boxed{v_{av} = \frac{v_1 t_1 + v_2 t_2}{t_1 + t_2}}$$

5. For equal time and different speed,

$$\boxed{v_{av} = \frac{v_1 + v_2}{2}}$$

Instantaneous velocity and speed

Average velocity tells how fast an object moves over a time interval, but not how fast it moves at a particular instant. So we define instantaneous velocity.

Instantaneous velocity is the velocity of an object at a particular instant of time.

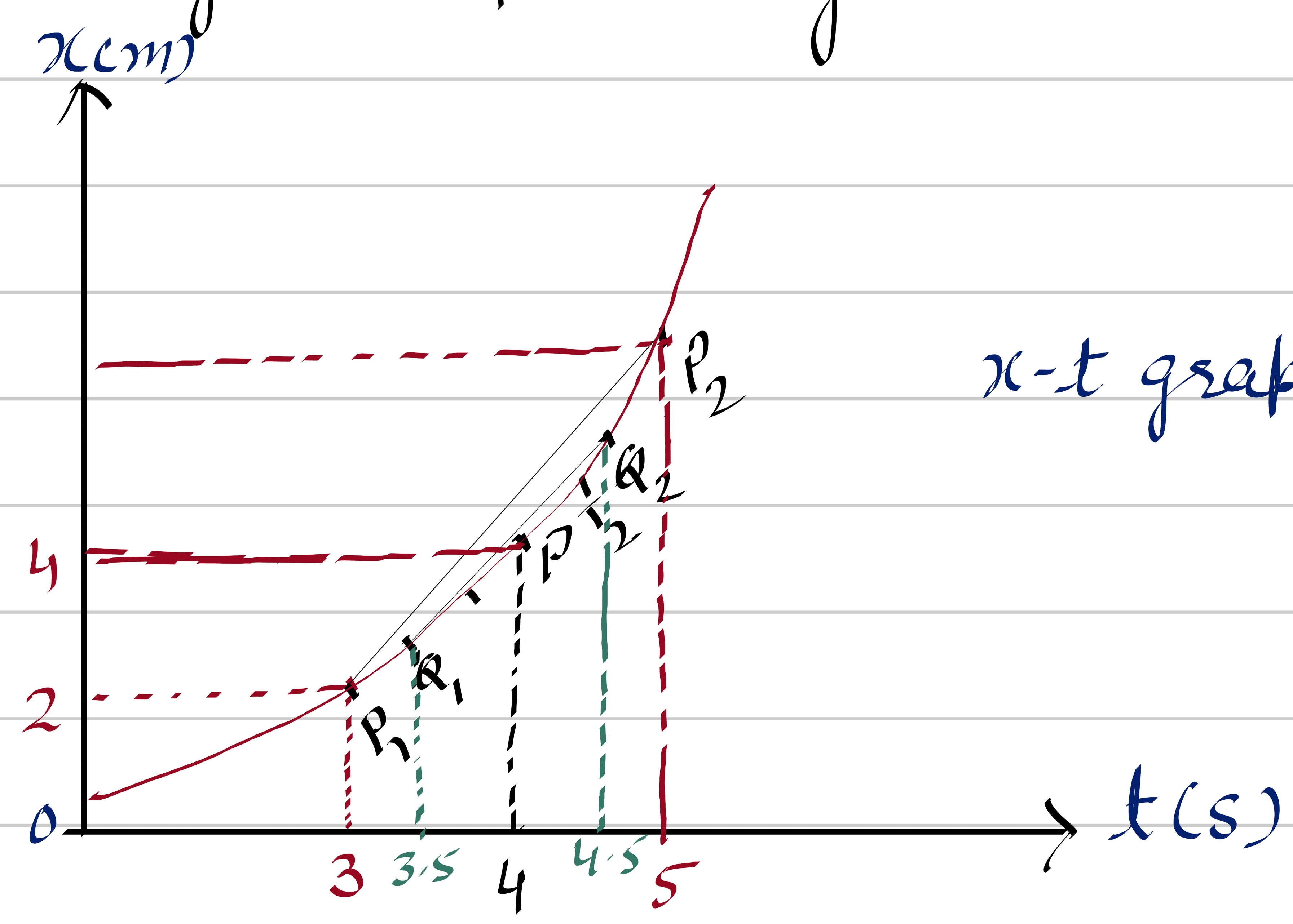
It is defined as the limit of average velocity as the time interval Δt becomes infinitesimally small.

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

or $\boxed{v = \frac{dx}{dt}}$ = derivative of position x with respect to time t.

It is the rate of change of position with respect to time at that instant.

Understanding Graphically: (NCERT book, table 2.1)



→ The instantaneous velocity is the slope of the tangent at that point.

→ Example - Suppose we want velocity at $t = 4$ sec

→ Take a small interval $\Delta t = 2s$ centred at $t = 4s$. i.e from $t = 3s$ to $t = 5s$

→ The slope of line P_1P_2 (chord) gives average velocity over this interval.

→ As $\Delta t \to 0$ chord P_1P_2 becomes tangent to the curve at point 'P', giving instantaneous velocity.

Making interval smaller

→ Decrease the value of Δt from 2 sec to 1 sec.

→ The new line joining points Q_1 and Q_2 corresponds to $t = 3.5s$ to $4.5s$

→ Again slope of Q_1Q_2 gives average velocity over a smaller interval. (closer approximation)

When $\Delta t \to 0$

- As Δt approaches to zero the chord becomes a tangent to the curve at point 'P'
- The slope of tangent gives the instantaneous velocity at $t = 4$ s.
- Graphically it becomes difficult to show when $\Delta t \to 0$
- Numerical methods are used to get more accurate values.

Table 2.1 (Numerical method)

- In the given graph, $x(t) = 0.08t^2$
- The table calculates Δx and $\frac{\Delta x}{\Delta t}$ for different values of Δt centred at $t = 4$ s.
  - $t_1 = 4 - \frac{\Delta t}{2}$, $t_2 = 4 + \frac{\Delta t}{2}$
  - Then find $x(t_1)$ and $x(t_2)$.
  - Find $\Delta x = x(t_2) - x(t_1)$
  - Find $\frac{\Delta x}{\Delta t}$ (average velocity)

Table 2.1, Limiting value of $\frac{\Delta x}{\Delta t}$ at $t = 4$ Sec

Δt (s)	t_1 (s)	t_2 (s)	$x(t_1)$ (m)	$x(t_2)$ (m)	Δx (m)	$\Delta x/\Delta t$ (ms^{-1})
2.0	3.0	5.0	2.16	10.00	7.84	3.92
1.0	3.5	4.5	3.43	7.29	3.86	3.86
0.5	3.75	4.25	4.21875	6.14125	1.9225	3.845
0.1	3.95	4.05	4.93039	5.3114	0.38402	3.8402
0.01	3.995	4.005	5.100824	5.139224	0.384	3.8400

Observation of table

- As Δt becomes smaller, $\frac{\Delta x}{\Delta t}$ becomes closer to a fixed value.

→ Limiting value of instantaneous velocity at $t = 4s$ is approx., $v = 3.84$ m/s

Final summery:

→ Instantaneous velocity = Slope of tangent on x-t graph

→ Graphical method becomes harder when $\Delta t \to 0$, so numerical method is used.

→ In this case instantaneous velocity at 4 sec is 3.84 m/s.

Instantaneous speed and uniform motion

→ For uniform motion, velocity at all instant is the same as the average velocity.

→ Instantaneous speed or simply speed is the magnitude of instantaneous velocity.

→ e.g. A velocity of +24.0 m/s and -24.0 m/s both have a speed of 24.0 m/s.

☆ → Instantaneous speed at any instant is equal to the magnitude of instantaneous velocity at that instant. This is because at any instant the speed is just the absolute value (+ve) of instantaneous velocity.

Acceleration: The rate of change of velocity with time is called acceleration.

Acceleration over a time interval,

$$a = \frac{v_2 - v_1}{t_2 - t_1} = \frac{v - u}{\Delta t}$$

or

$$a = \frac{\Delta v}{\Delta t}$$

u → Initial velocity (at $t = 0$)

v → final velocity (after time t')

It is vector quantity.

SI unit → m/s^2

In Galileo's time, it was thought that velocity change could be related to distance but his experiments showed:

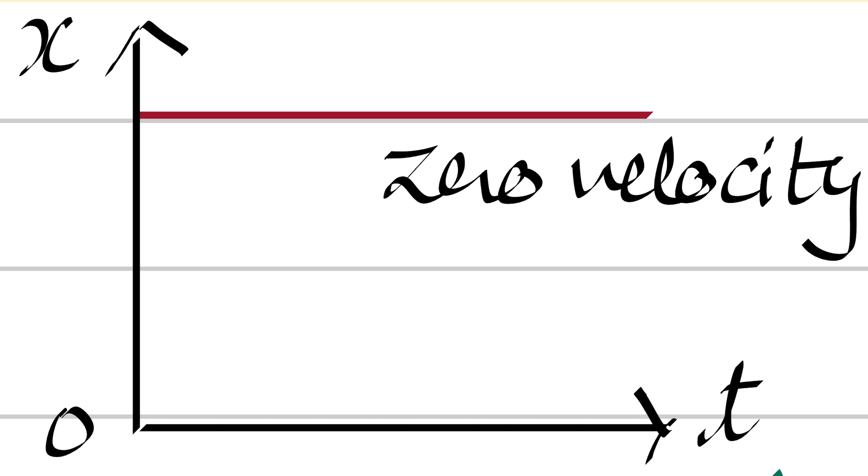
→ Rate of change of velocity for free fall remains constant with time but is not constant with distance.

1D Kinematics Graph

1. Position time graph (x-t graph)

(1) Distance-time graph / Position-time graph

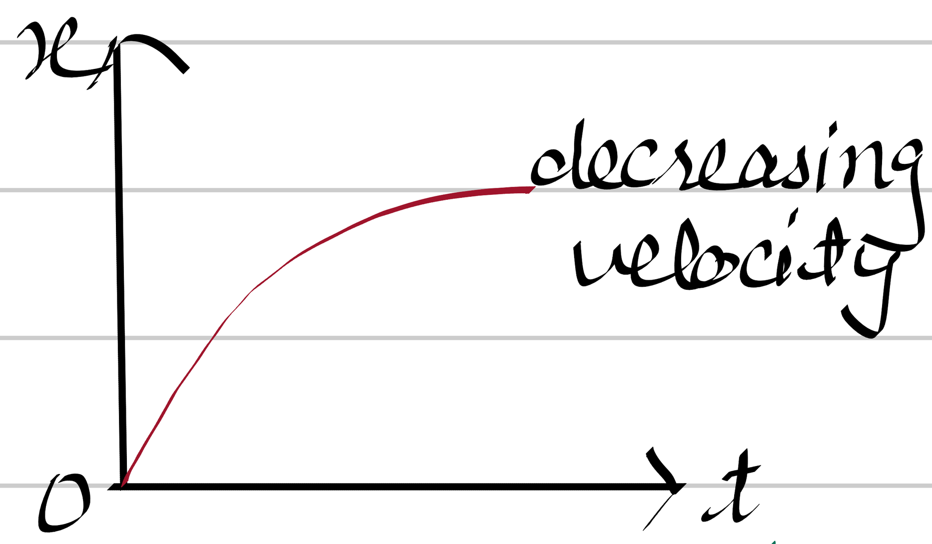
(For 1D motion distance-time and displacement-time graph are same)



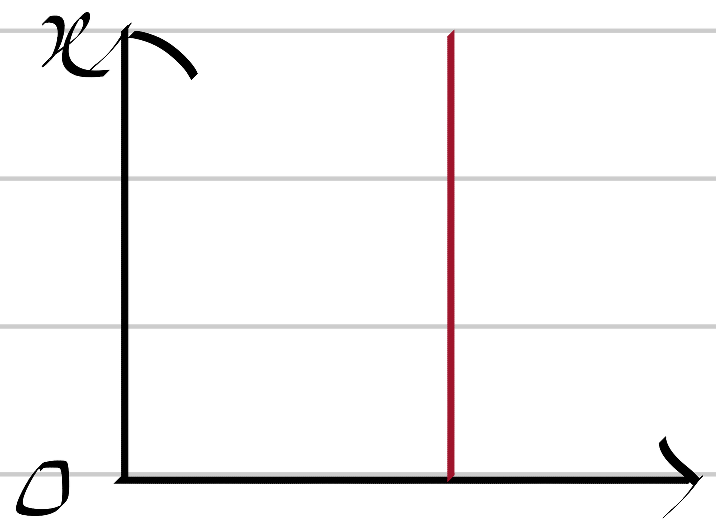
Object is at rest
(a)

uniform motion
(b)

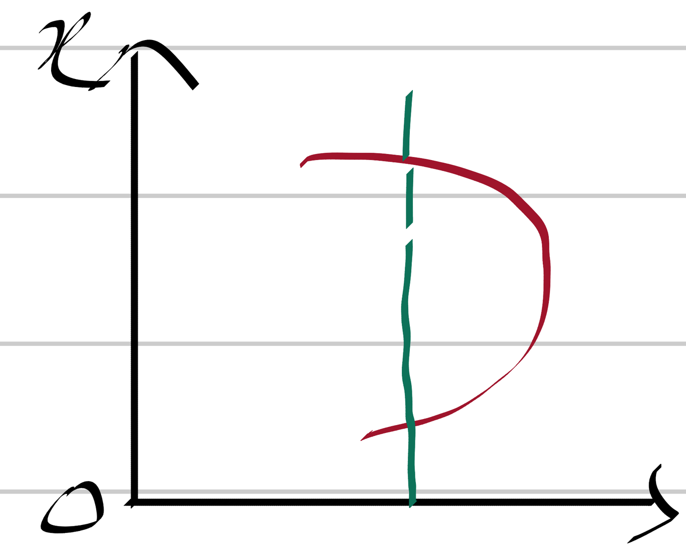
non-uniform motion
(c)



non-uniform motion
(d)

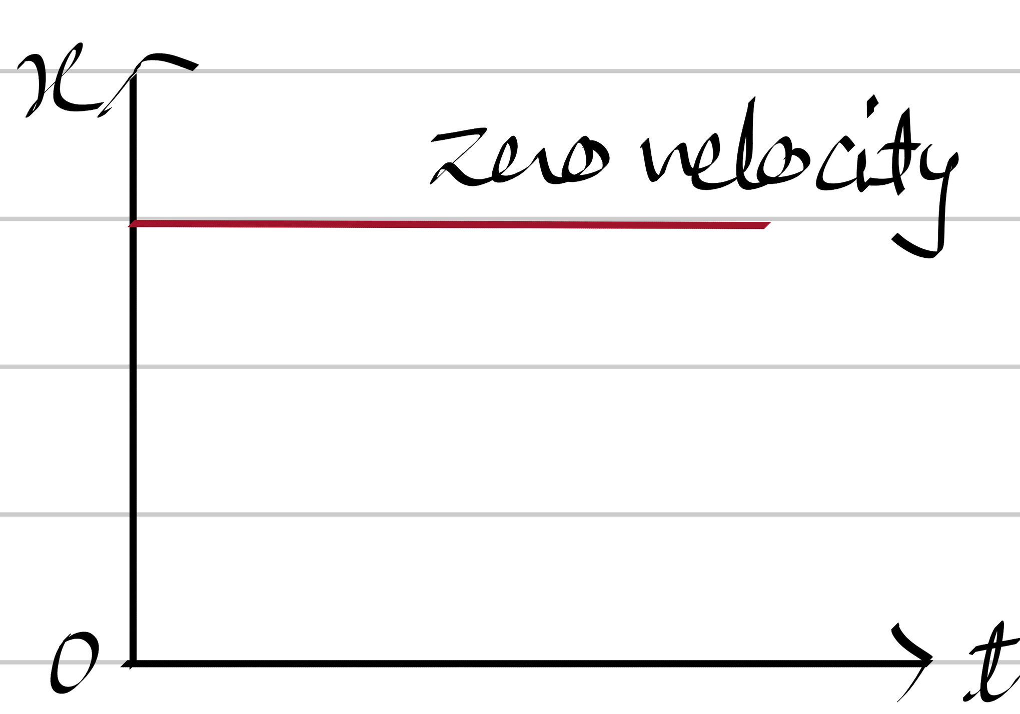


not possible
(position changing but time is constant)
(e)

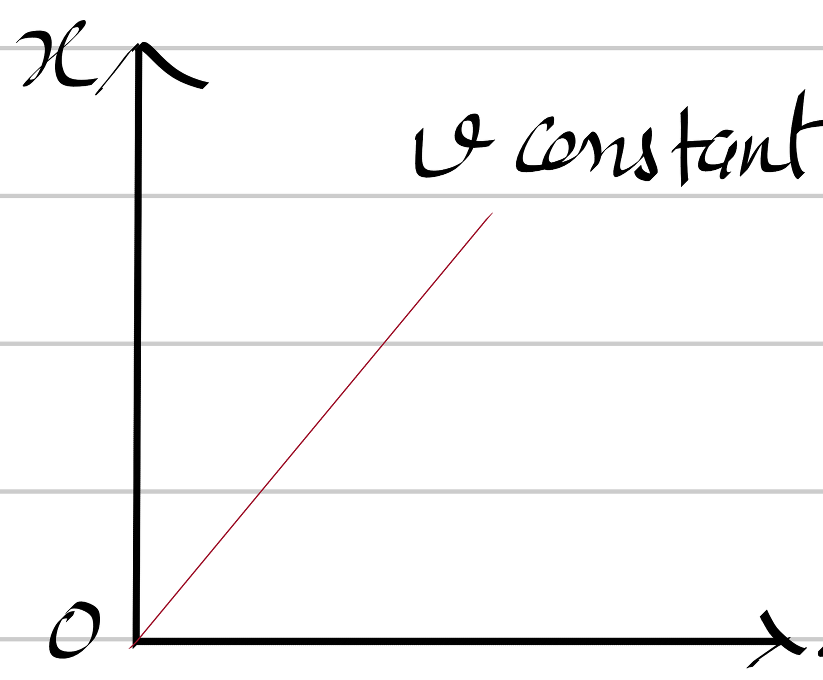


not possible
(two position at one time)
(f)

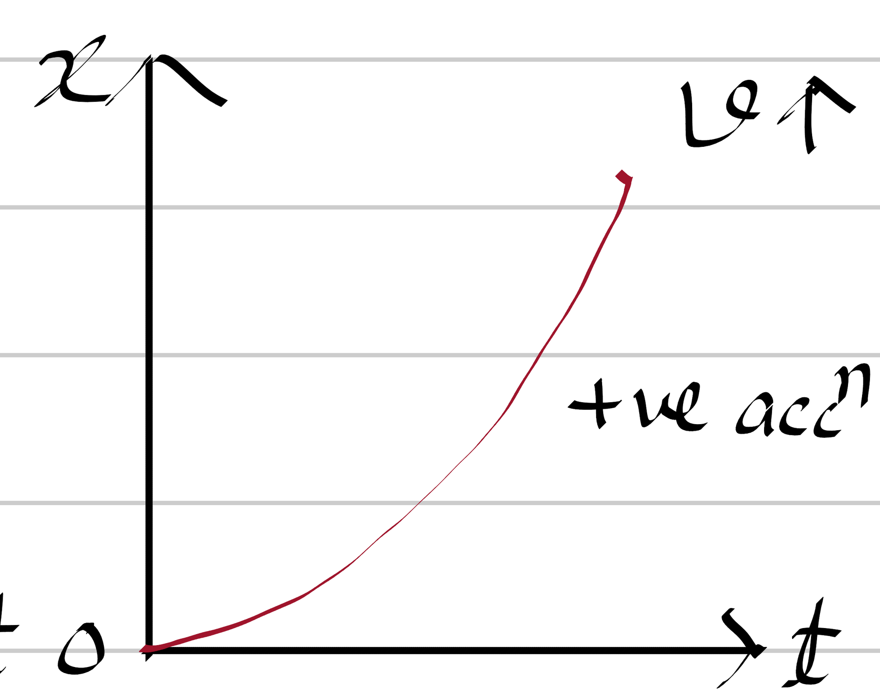
2. Displacement-time graphs



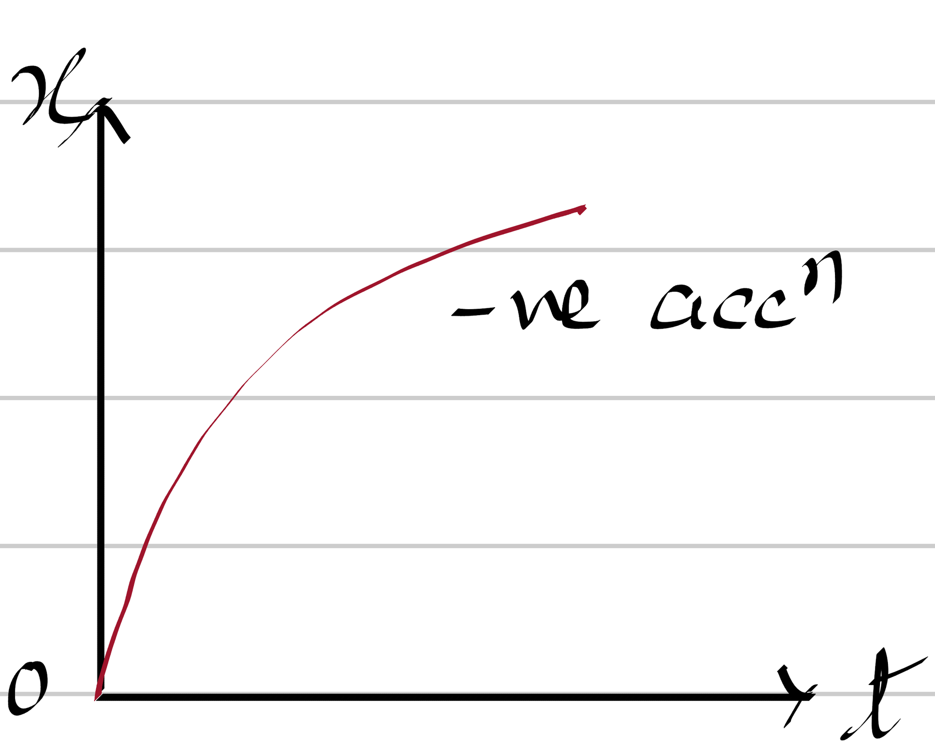
Stationary object
(a)



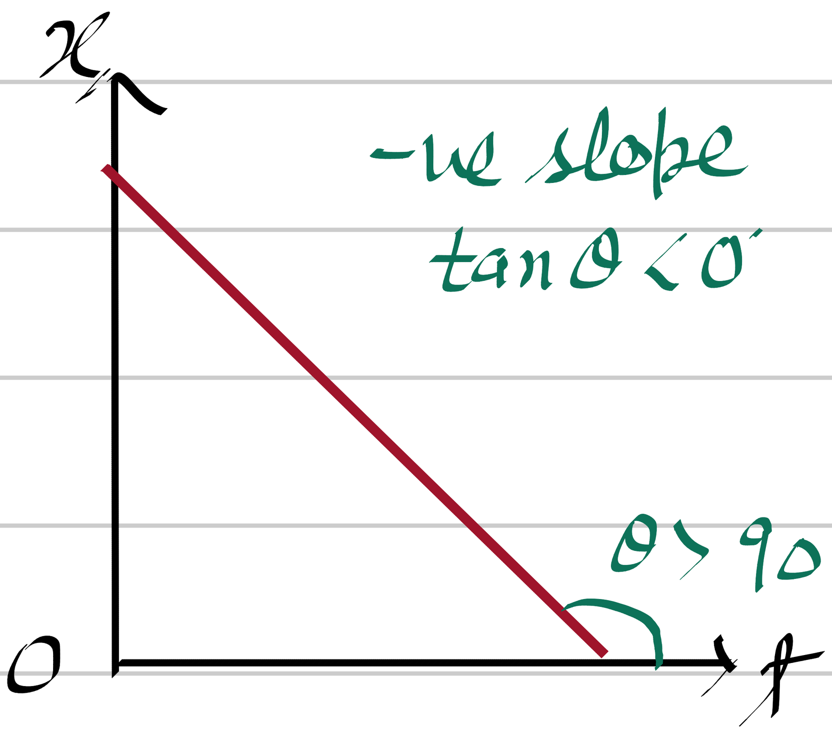
uniform motion
(b)



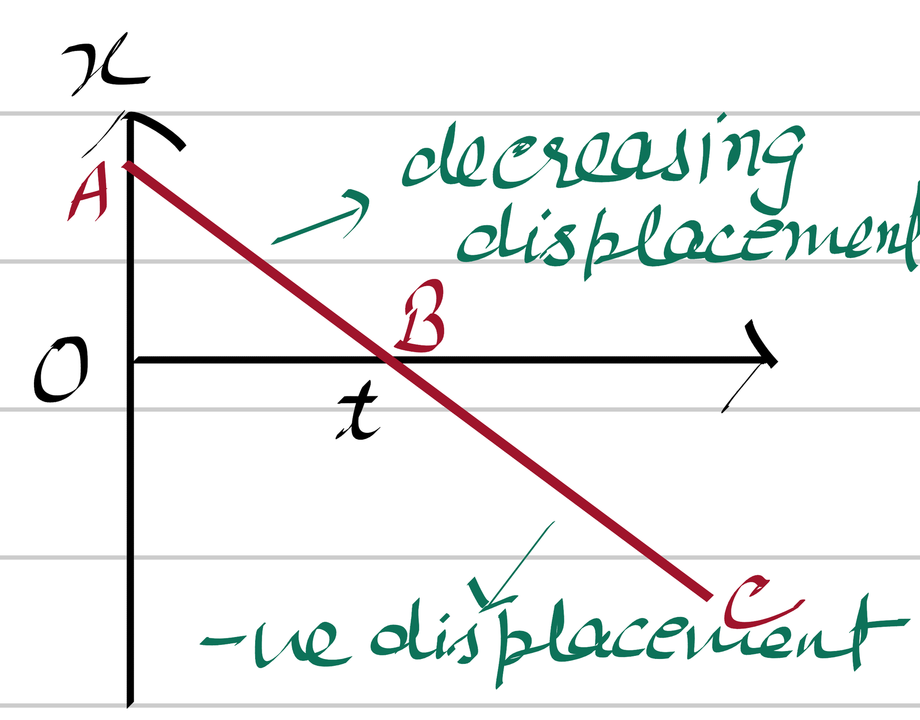
Increasing velocity
(c)



Decreasing velocity
(d)



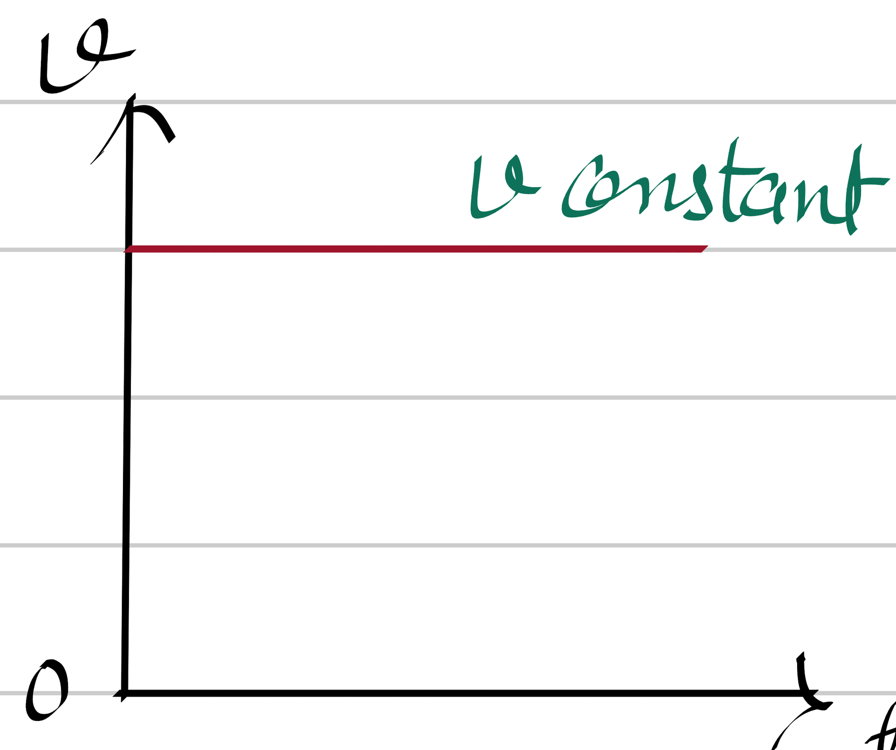
Uniform negative velocity
(e)



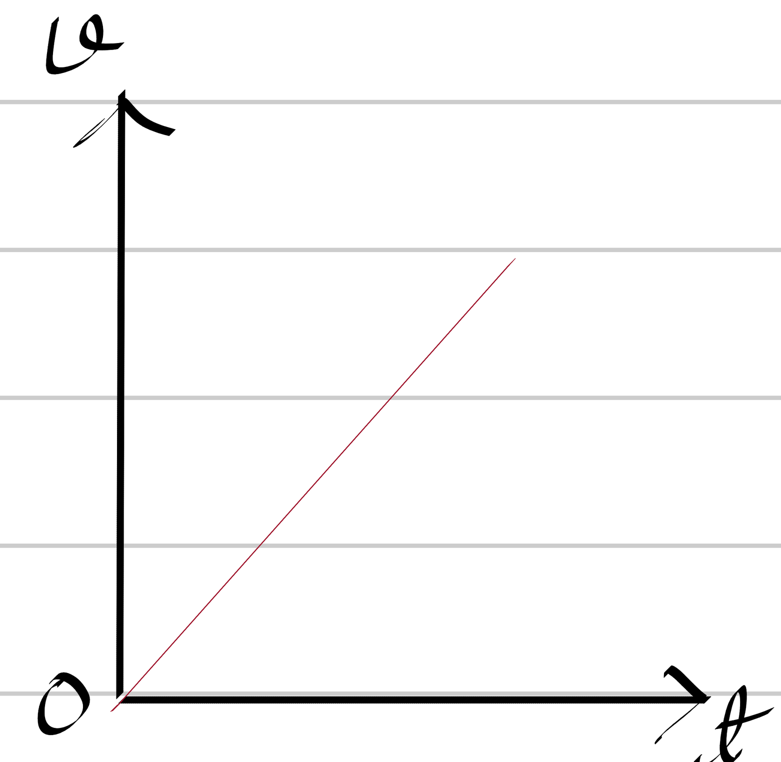
Uniform velocity in both dirⁿs
(f)

* For last graph (f): A to B → -ve slope, -ve velocity
B to C → -ve displacement, -ve slope, -ve velocity

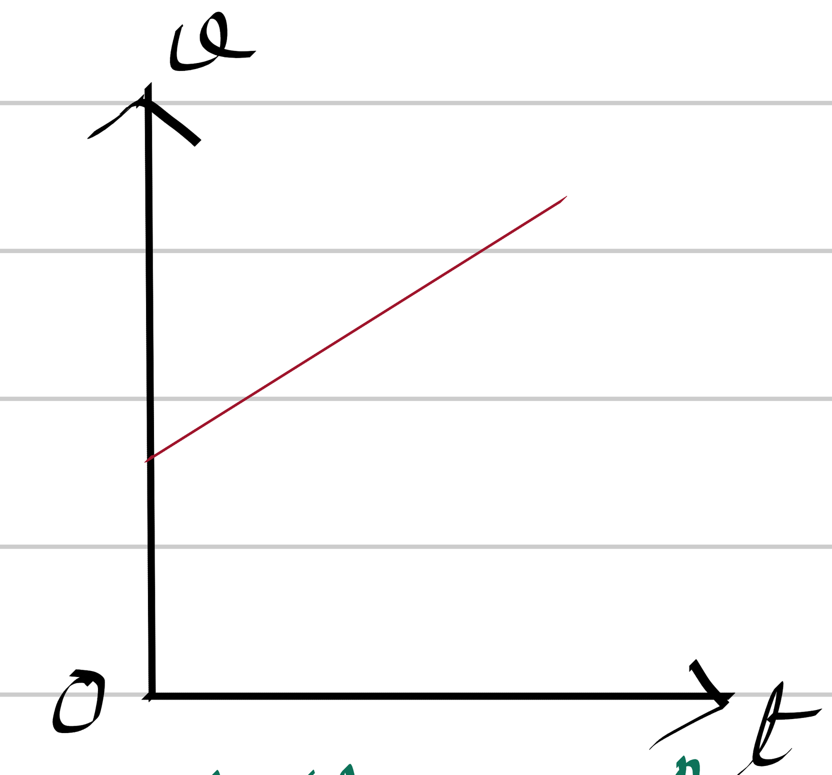
3. Velocity-time graphs



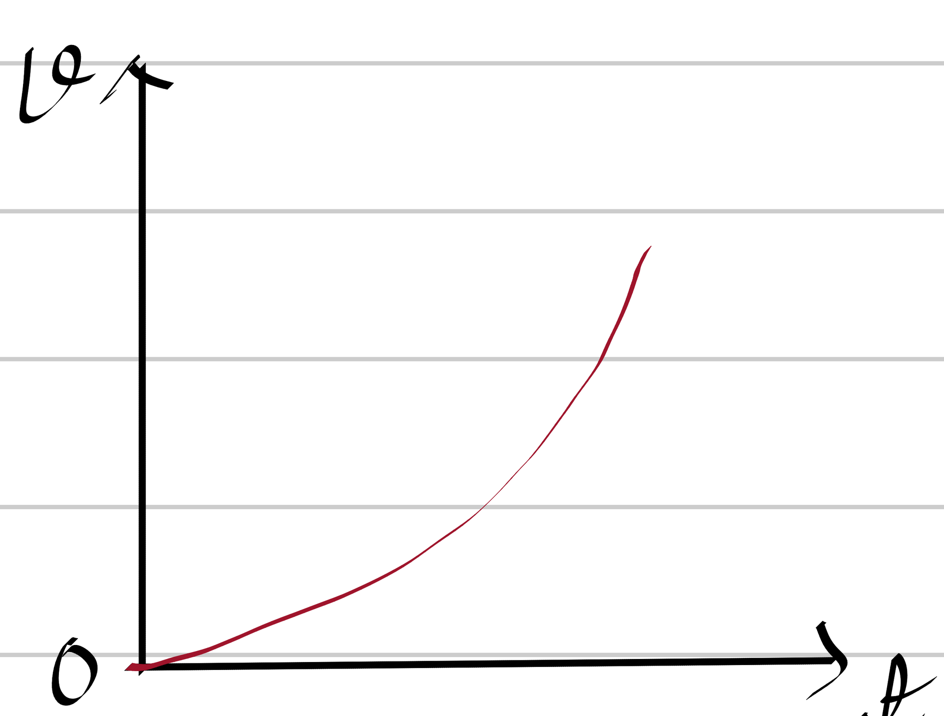
Zero acceleration



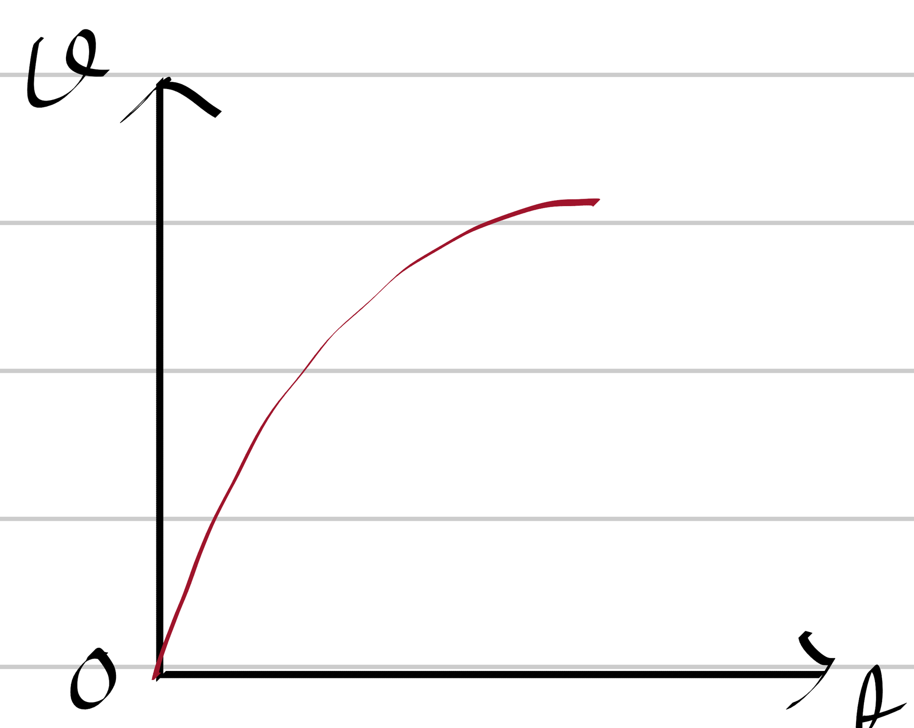
Uniform acceleration
u = 0 at t = 0



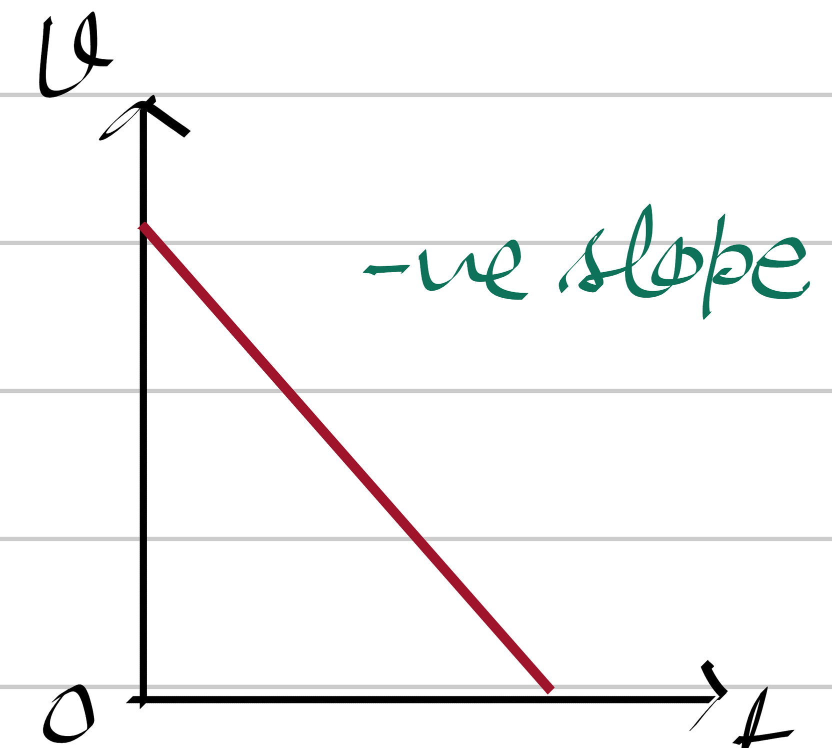
Uniform accⁿ
u ≠ 0 at t = 0



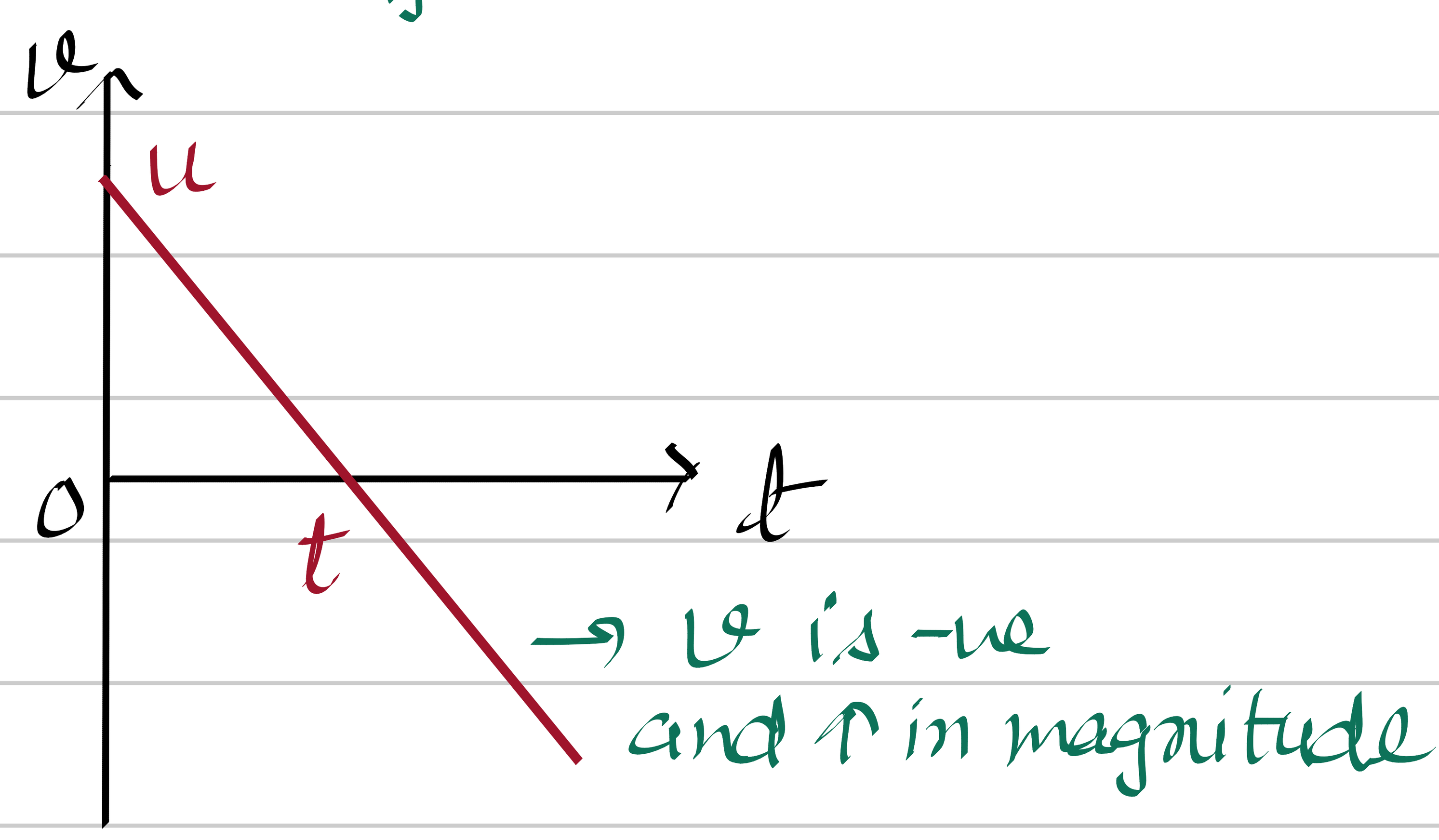
Increasing accⁿ
non uniform accⁿ



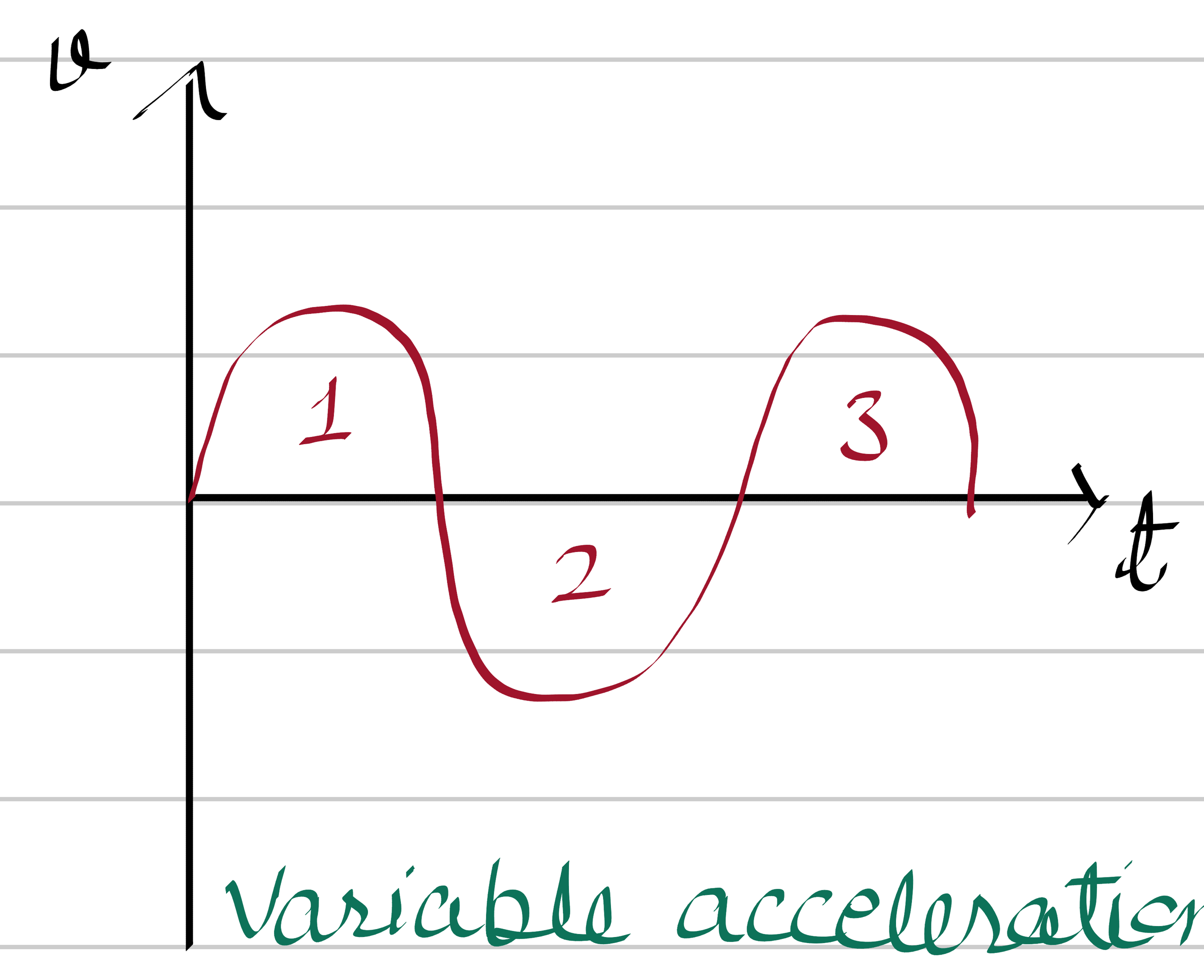
Decreasing accⁿ
non uniform accⁿ



Uniform -ve acceleration



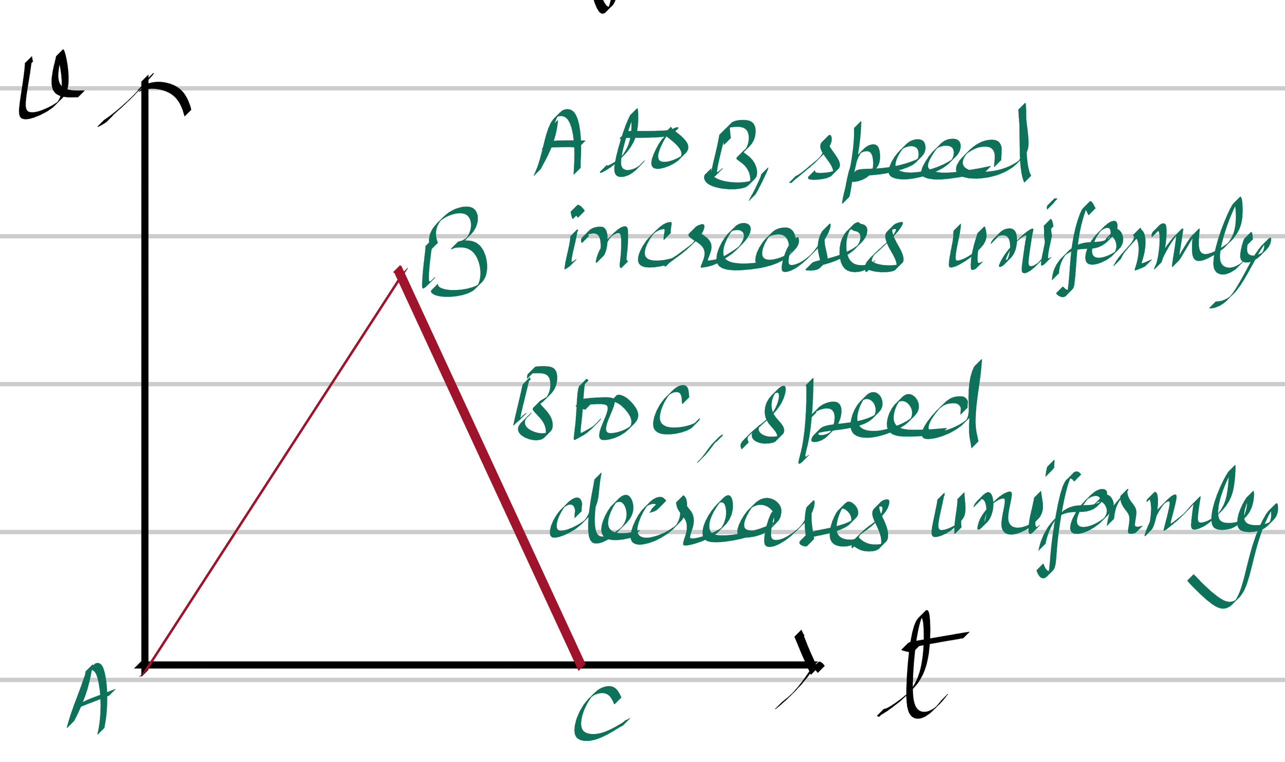
Velocity decreases
(-ve uniform accⁿ)

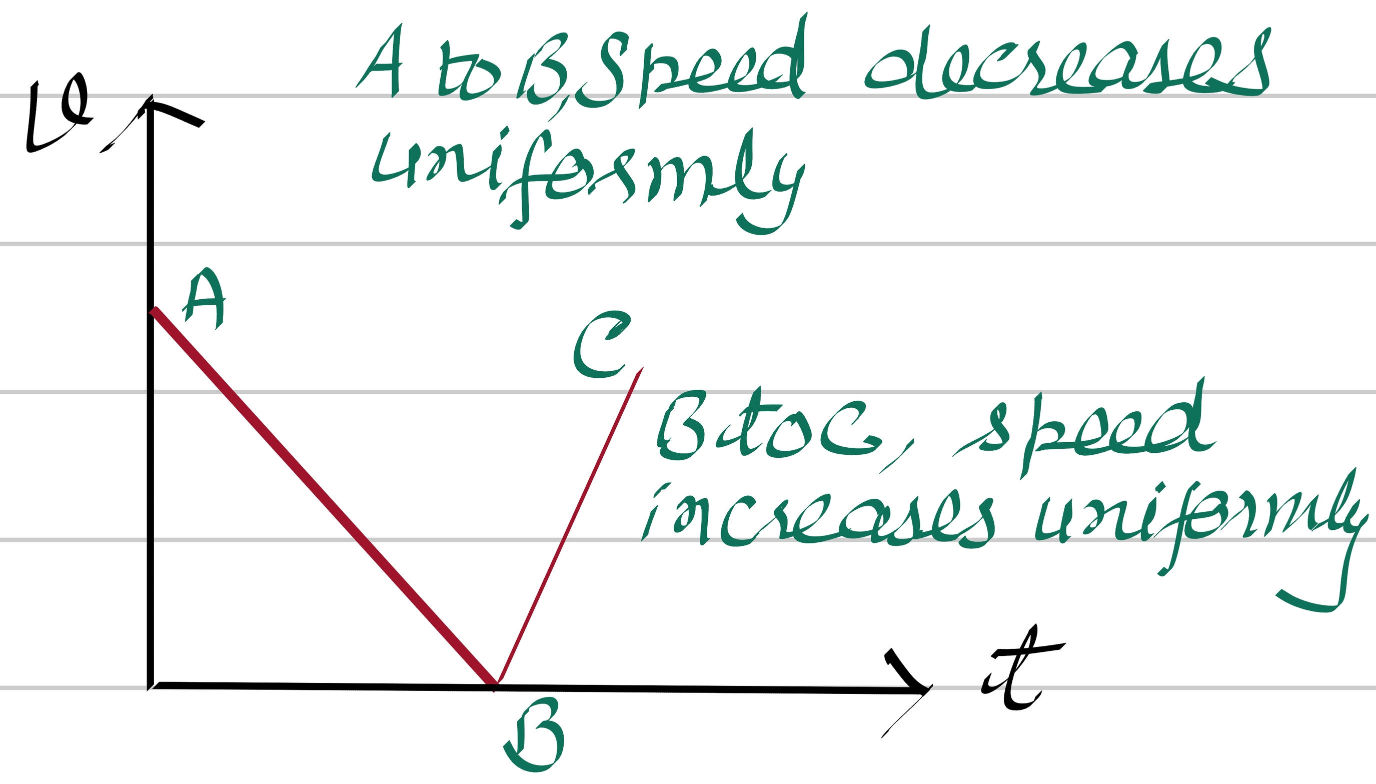


Variable acceleration
displacement = Area (1 + 3 - 2)

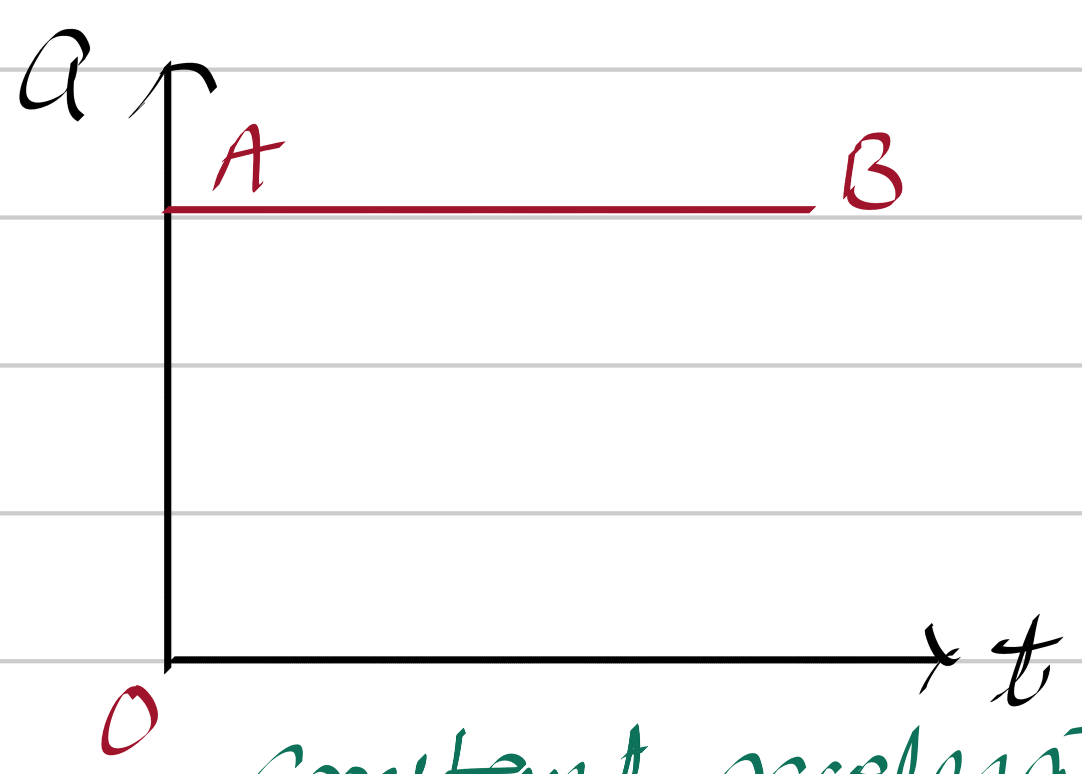
(For 1D motion speed-time graph and velocity-time graph are same)

Speed-time graph

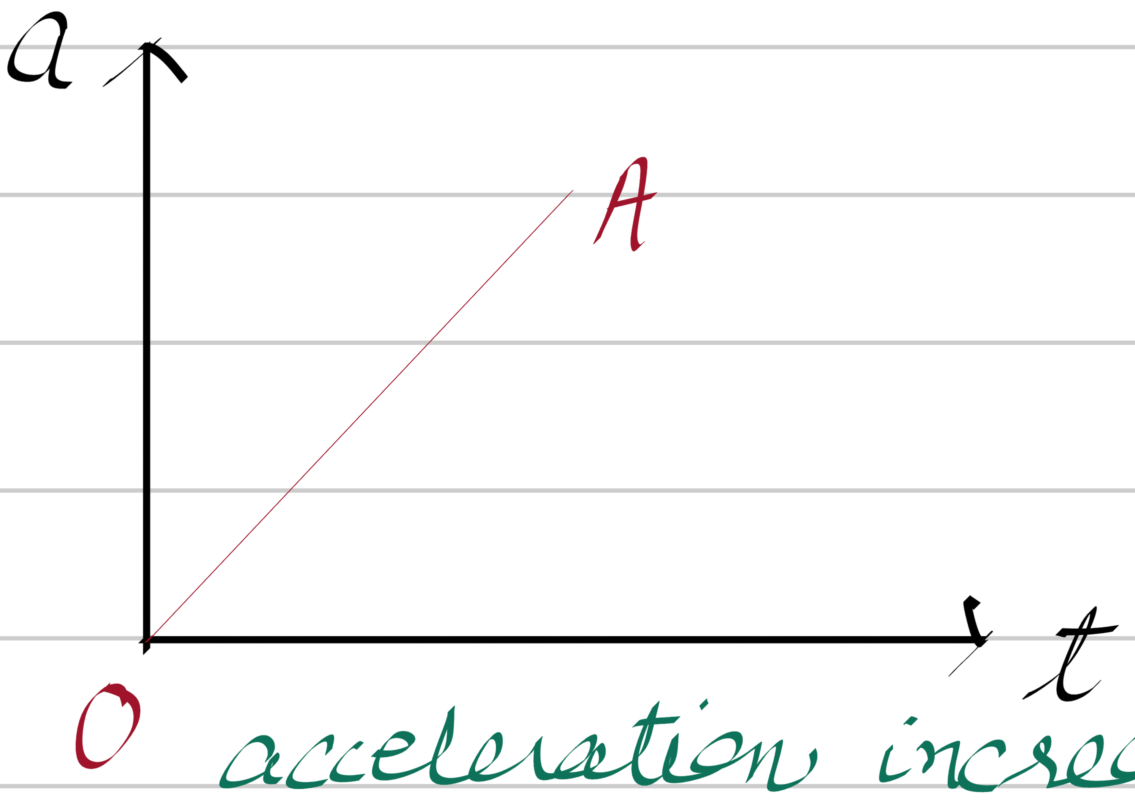




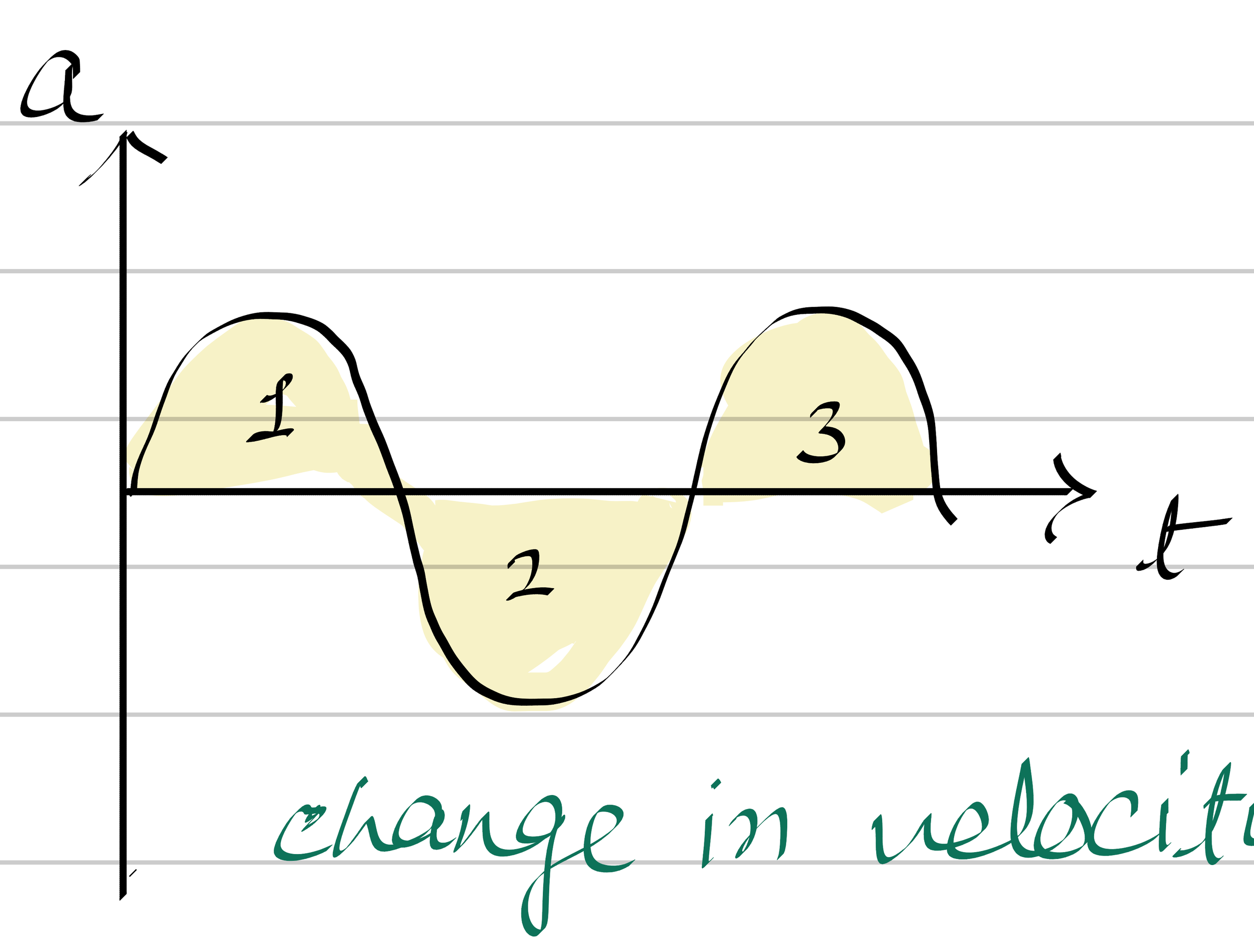
Acceleration-time graphs (a-t graph)



Constant acceleration

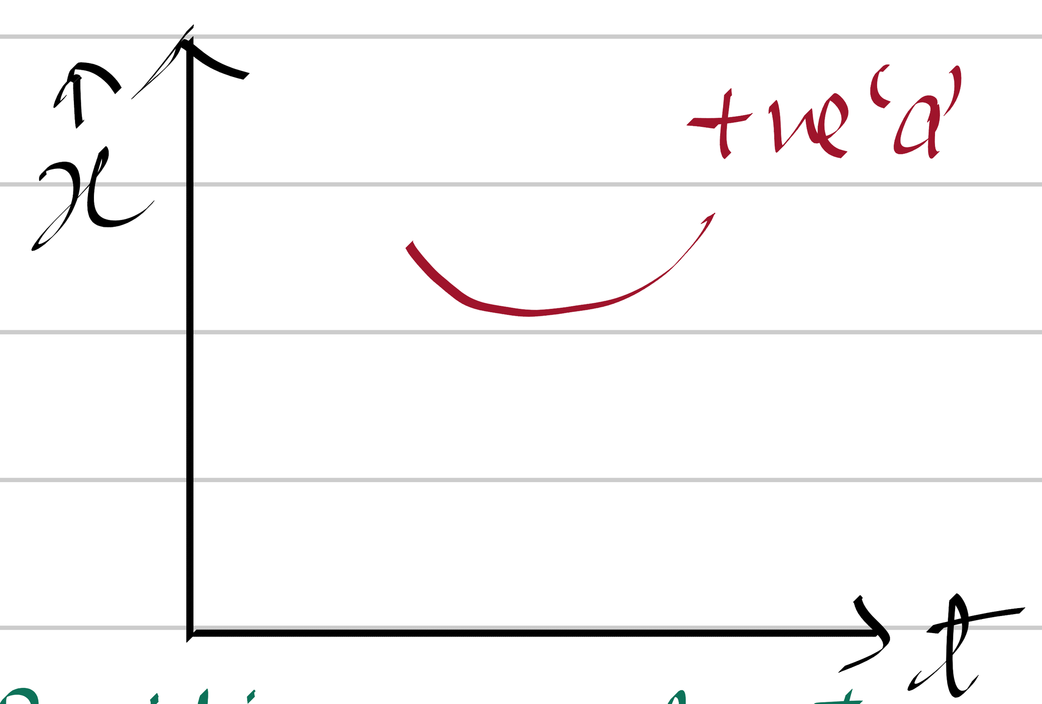


acceleration increases uniformly with time.



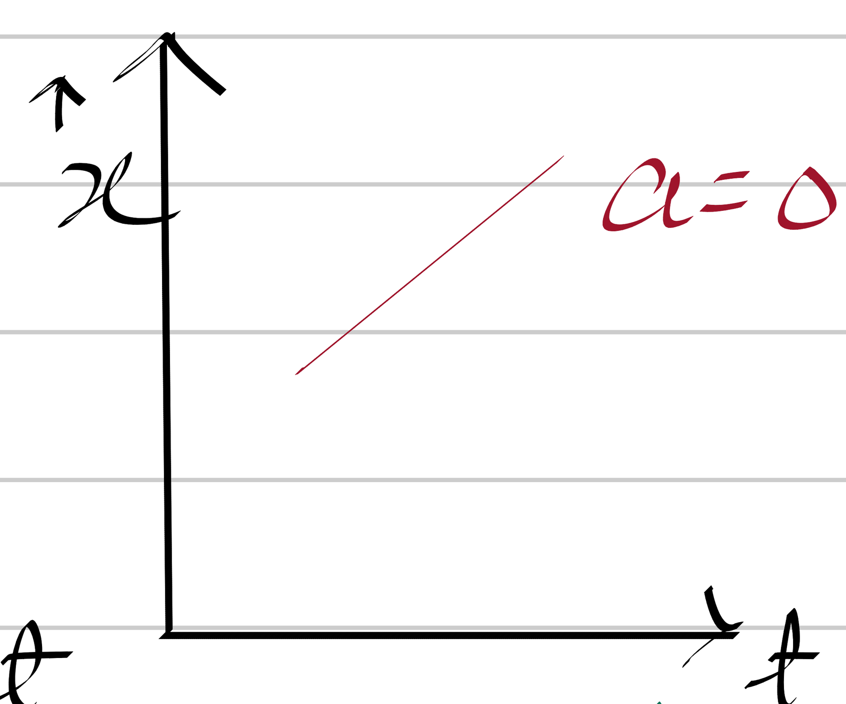
change in velocity = Area 1 − Area 2 + Area 3

Position-time graphs for acceleration



Positive acceleration

negative accⁿ



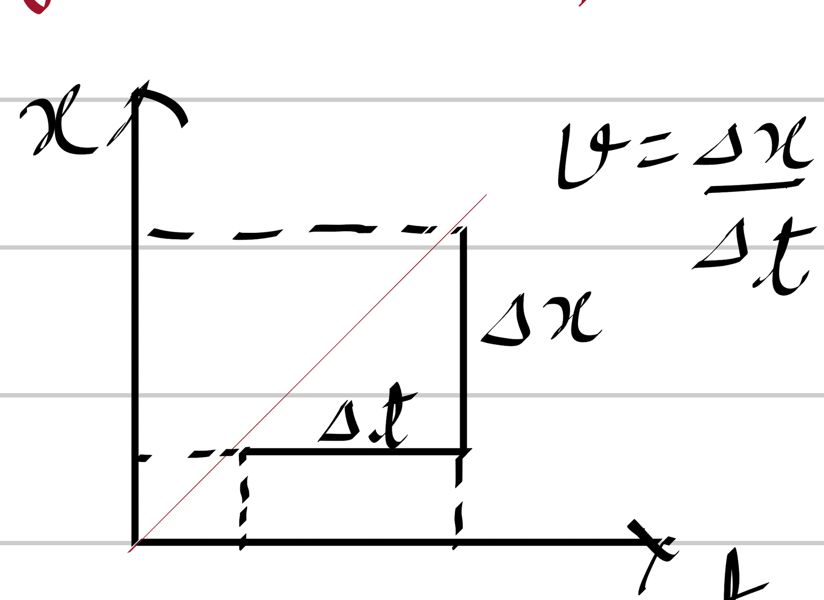
zero accⁿ

* (i) Slope of x-t graph gives velocity
* (ii) Slope of v-t graph gives acceleration

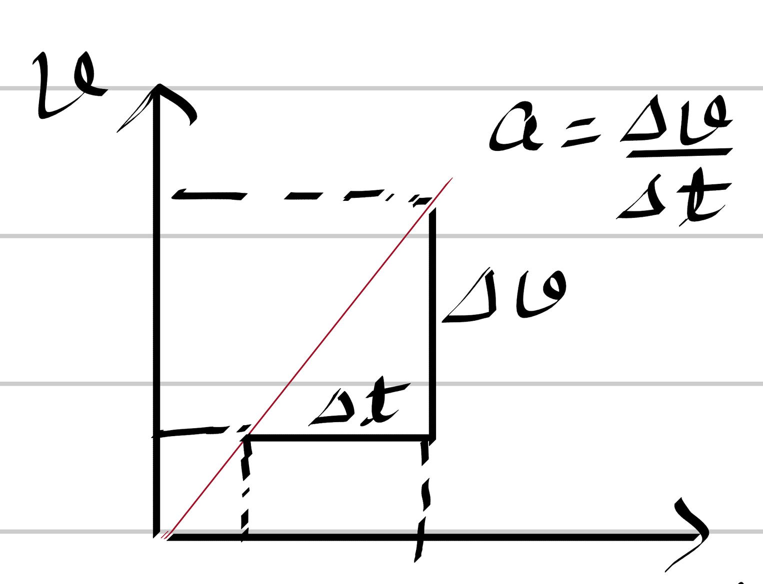
$$a = \frac{v_2 - v_1}{t_2 - t_1} = \frac{\Delta v}{\Delta t}$$

* (iii) For v-t graph, area under the graph gives displacement.

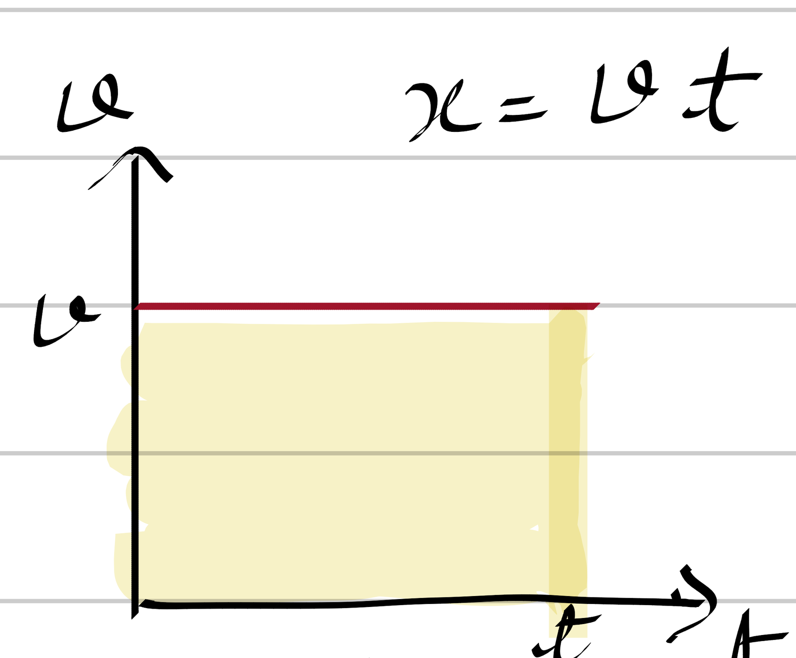
e.g.



(i)



(ii)



(iii)

Instantaneous Acceleration. It is defined as the rate of change of velocity with respect to time at a particular instant.

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

→ The acceleration at an instant is the slope of the tangent to the v-t graph at that instant.

Types of acceleration

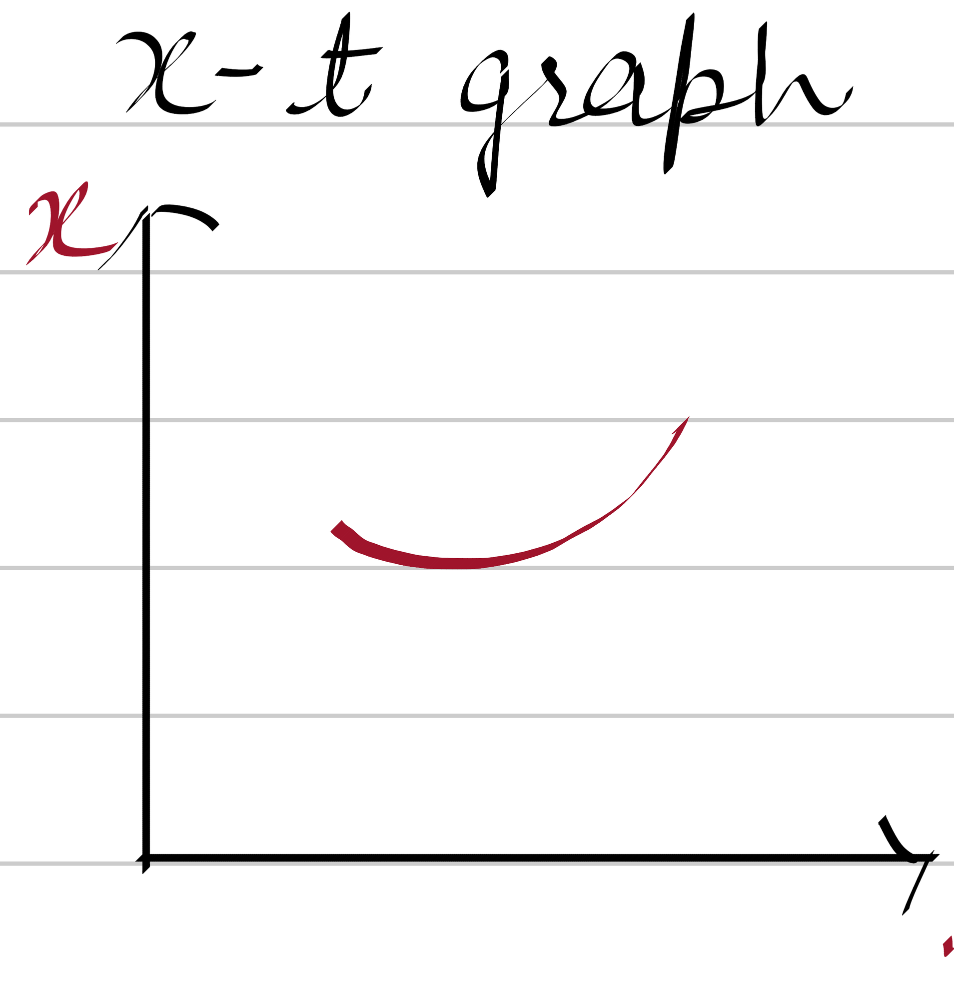
Since velocity is a vector quantity therefore acceleration can be –

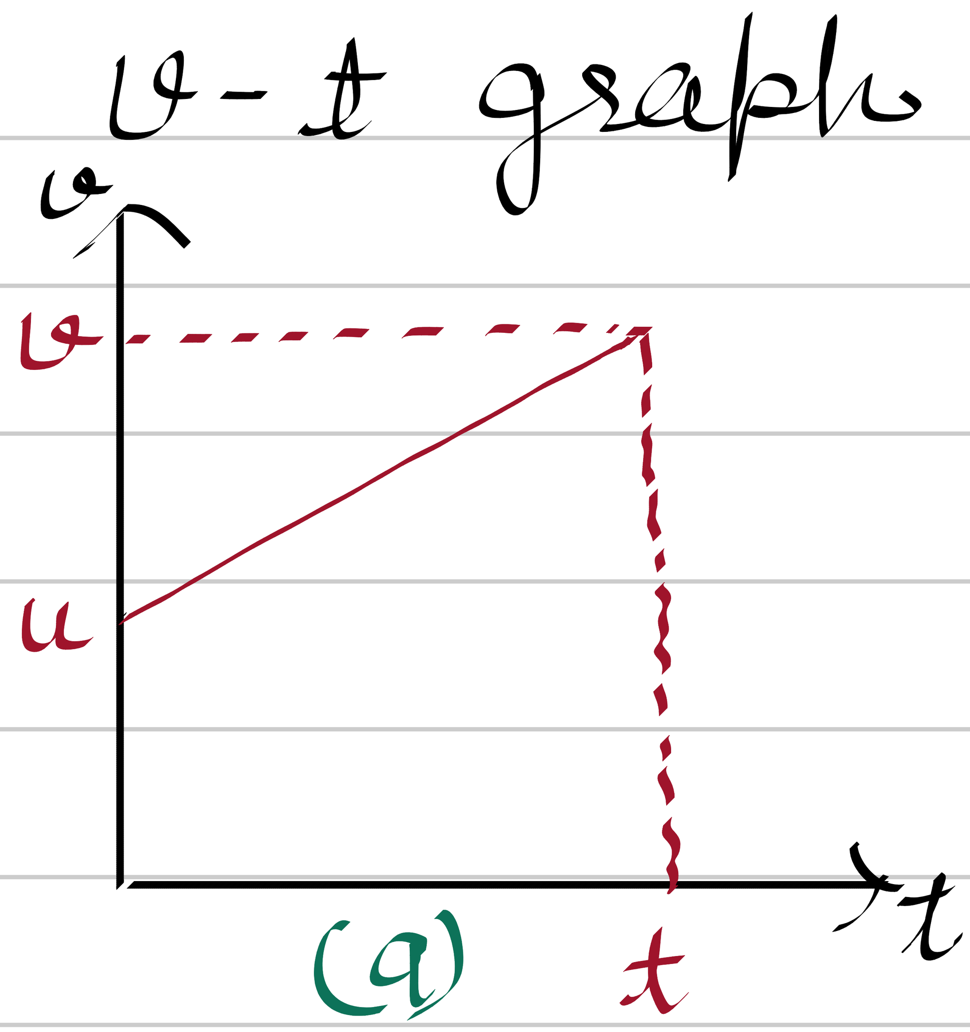
1. Positive acceleration

→ Velocity increases with time.

→ The slope of the velocity-time graph is +ve.

→ The position-time graph is curved and upward bending.



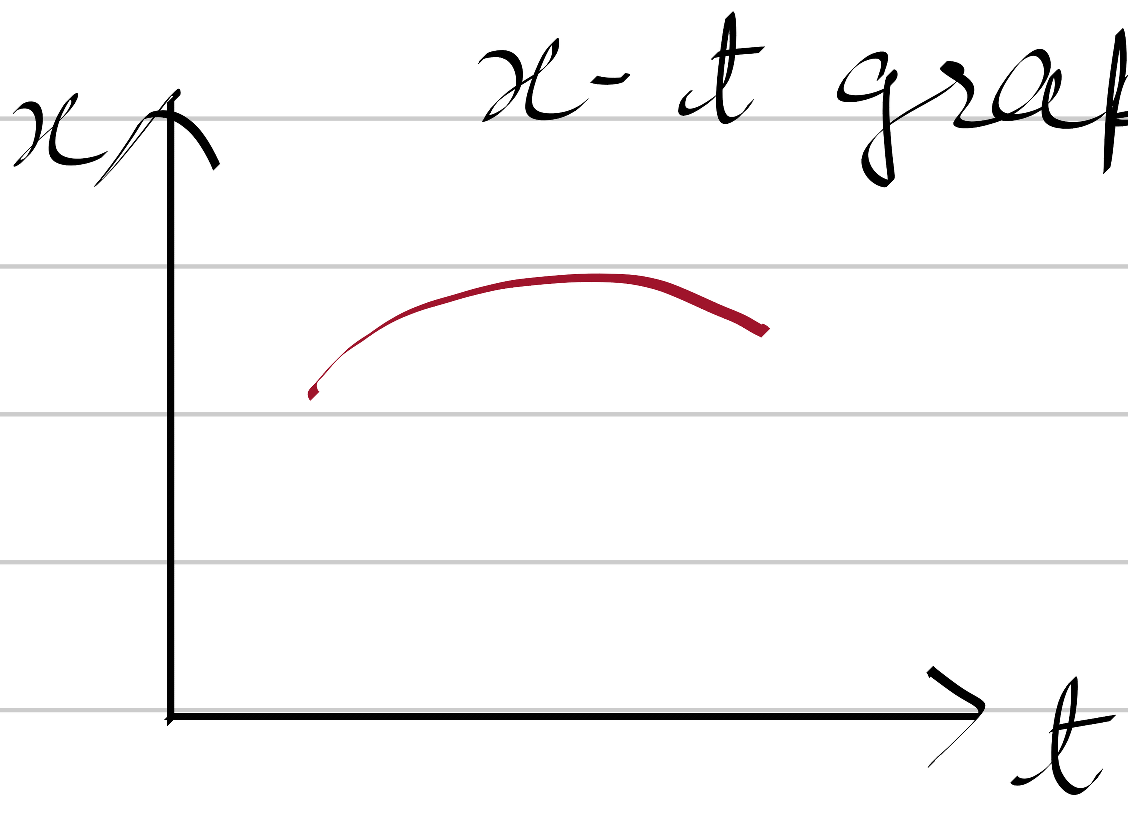


2. Negative acceleration

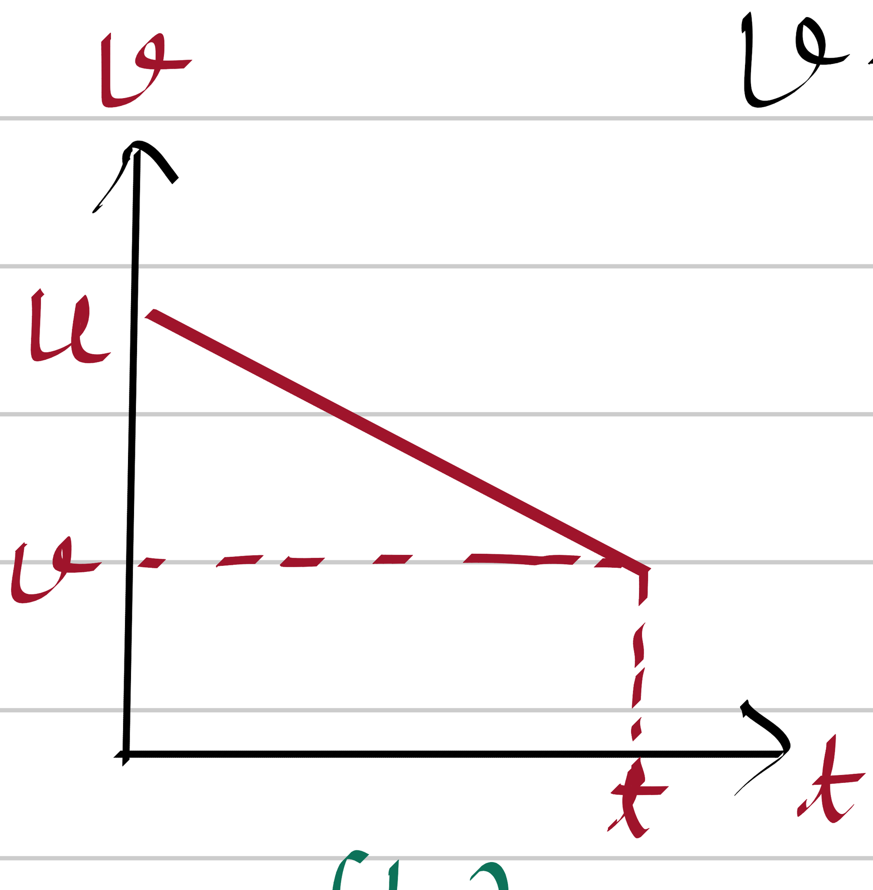
→ Velocity decrease with time.

→ The slope of velocity-time graph is –ve (downward sloping)

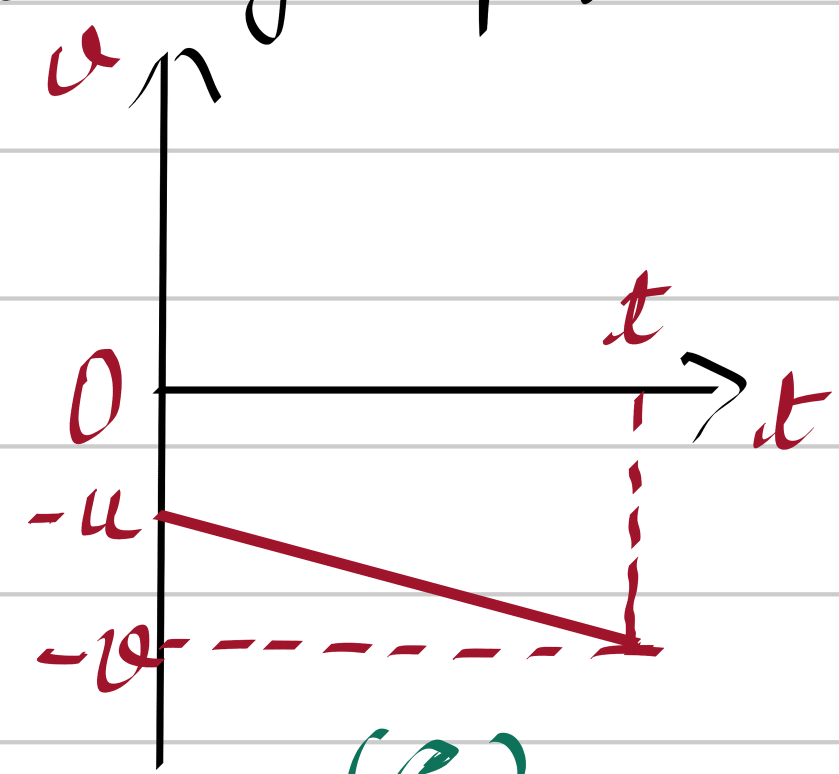
→ Position-time graph is curved and bending downward.



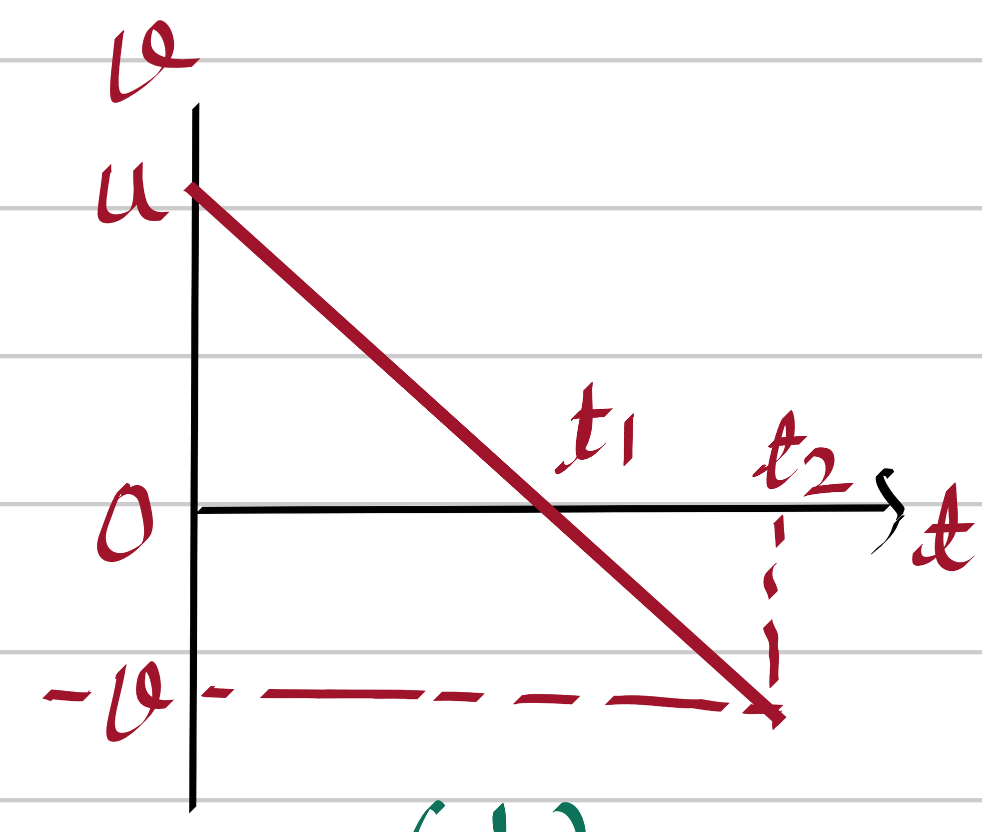
v-t graph



(b)



(c)

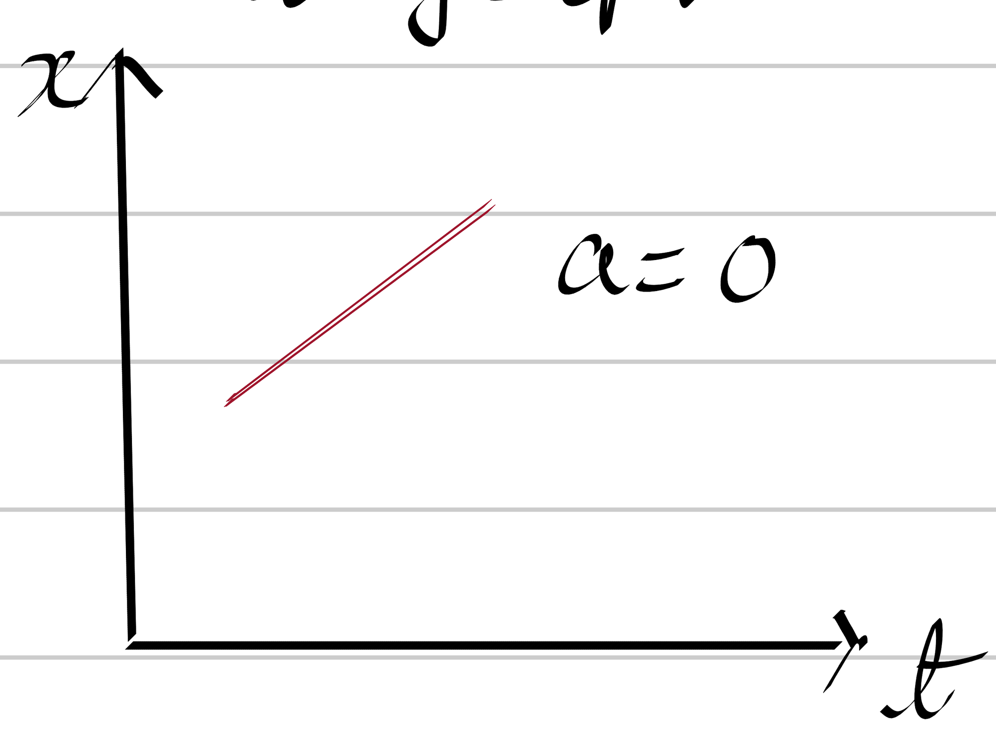


(d)

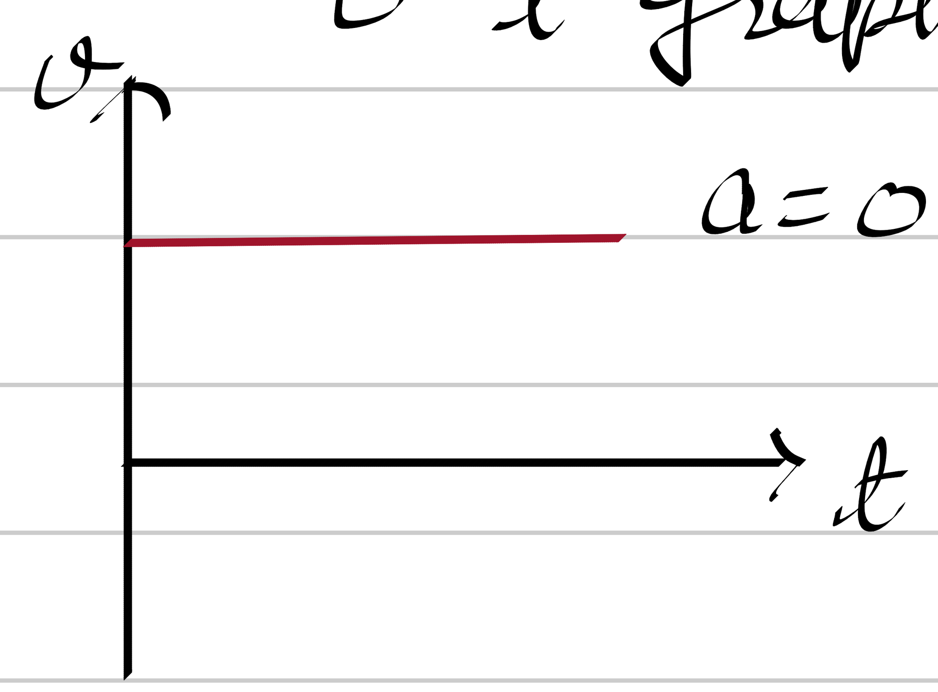
(b) An object is moving in +ve dir^n with a -ve acc^n
(c) An object is moving in -ve dir^n with a -ve acc^n
(d) An object is moving in +ve dir^n till t_1 and then turns back with the same -ve acc^n.

3. <u>Zero acceleration</u> → velocity remains constant

x-t graph



v-t graph

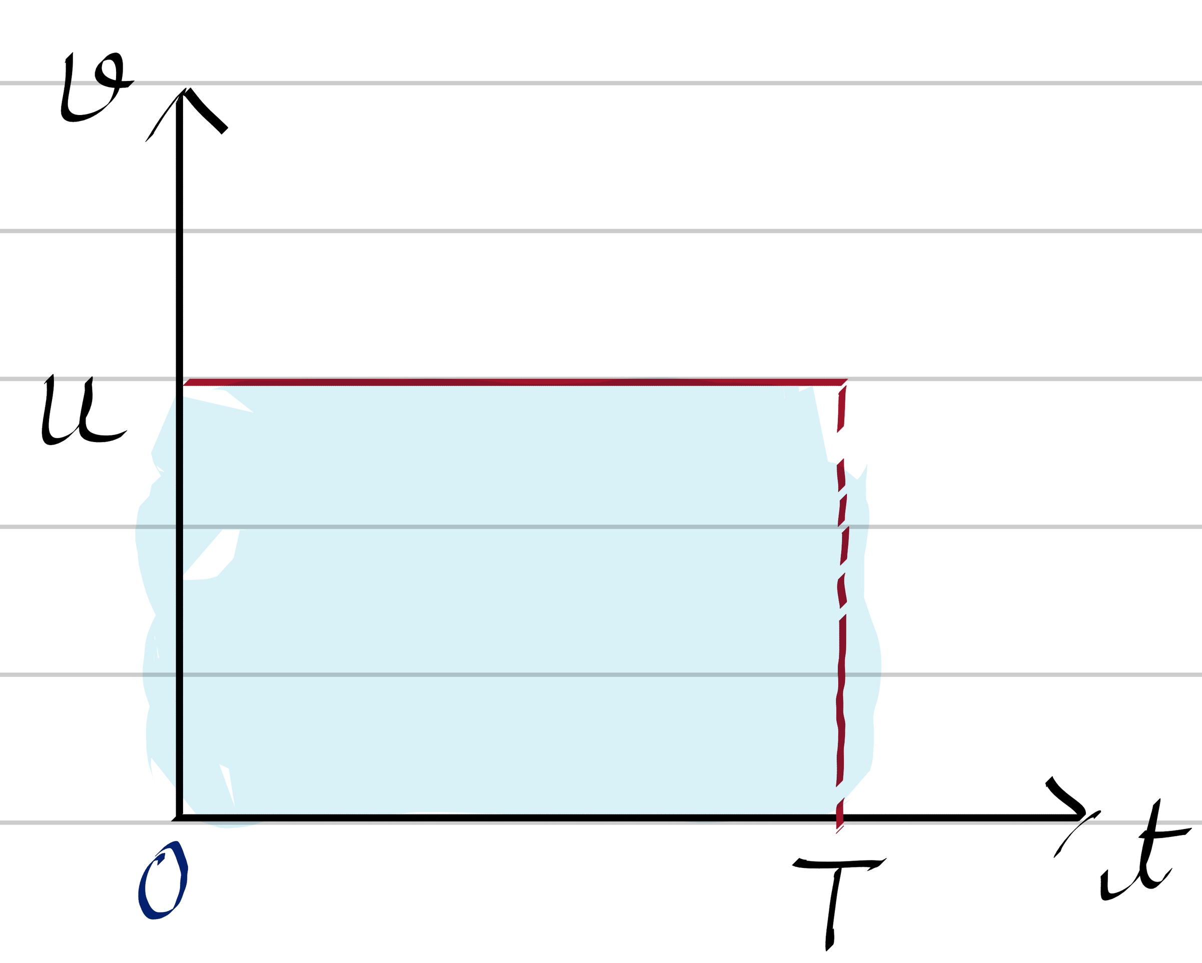


<u>Area under velocity-time graph</u>

→ <u>Area under v-t graph gives displacement.</u>

(I) <u>Constant velocity</u>

→ Area under v-t curve equals displacement,



S = Area of rectangle
= base x height
= $u \times T$

or $\boxed{S = uT}$

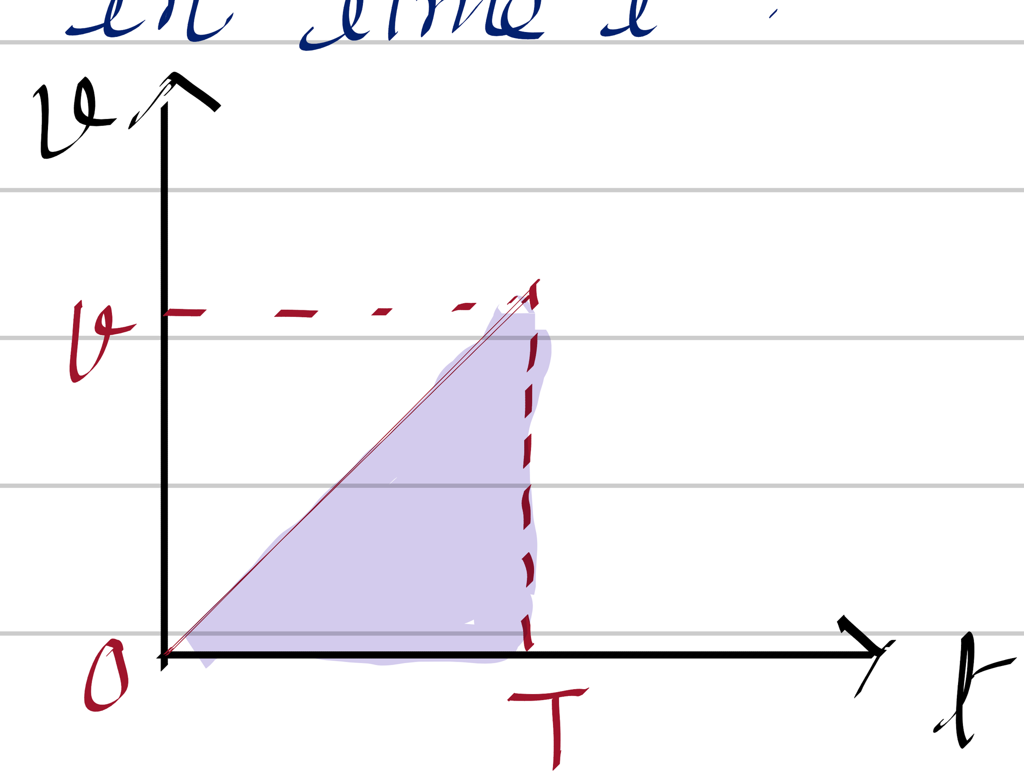
(II) <u>Uniform acceleration</u>

→ Velocity changes from 0 to v in time t.

→ Displacement S = Area of triangle

$S = \frac{1}{2}$ height x base

$S = \frac{1}{2} \times v \times T$



Acceleration due to gravity (g)

Acceleration produced due to the gravitational force of the Earth is called acceleration due to gravity.

$$g = 9.8\ m/s^2$$

It is a vector quantity, always directed towards the centre of the earth (downward)

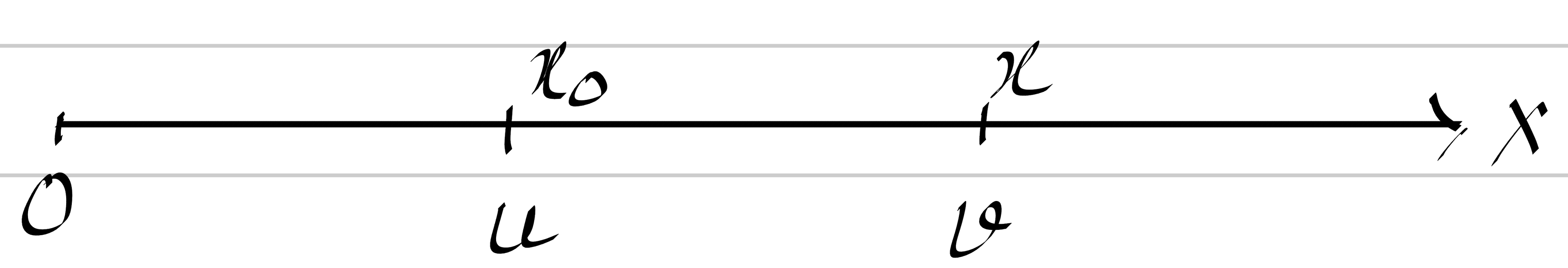
Kinematic equations for the uniformly accelerated motion:

(I) $v = u + at$

(II) $x = x_0 + ut + \frac{1}{2}at^2$ or $s = ut + \frac{1}{2}at^2$

(III) $v^2 = u^2 + 2a(x - x_0)$ or $v^2 = u^2 + 2as$

Extra* (IV) $S_{nth} = u + \frac{a}{2}(2n-1)$



uniformly accelerated motion.

x_0 = position of object at time, $t=0$

x = position of object at time t, $t=t$

u = velocity of object at $t=0$ (initial velocity)

v = velocity of object at time 't'. (final velocity)

a = uniform acceleration

s = $(x - x_0)$

Equations for uniformly accelerated motion

(I) Velocity after a certain time

By definition of acceleration

$$a = \frac{\text{change in velocity}}{\text{time taken}}$$

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

or $v - u = at \Rightarrow \boxed{v = u + at}$

This is the velocity-time relation

(ii) Distance covered in a certain time

Average velocity of the object b/w time 0 to t,

$$v_{av} = \frac{u+v}{2}$$

Displacement $x - x_0 = v_{av} \times t$

$$x - x_0 = \frac{u+v}{2} \times t$$

or

$$x - x_0 = \frac{u+(u+at)}{2} \times t \qquad [v = u+at]$$

or $$x - x_0 = \frac{(2u+at)}{2} \times t$$

or $$x - x_0 = \frac{2ut + at^2}{2} = \frac{2ut}{2} + \frac{at^2}{2}$$

or $$x - x_0 = ut + \frac{1}{2}at^2 \Rightarrow \boxed{x = x_0 + ut + \frac{1}{2}at^2}$$

also $x - x_0 = S$, then

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

This is the distance-time relation.

(iii) velocity at a certain position:

We have,

$$v = u + at$$

or $v - u = at \Rightarrow t = (v-u)/a$

also, displacement $= v_{av} \times t$

$$x - x_0 = \frac{u+v}{2} \times \frac{(v-u)}{a}$$

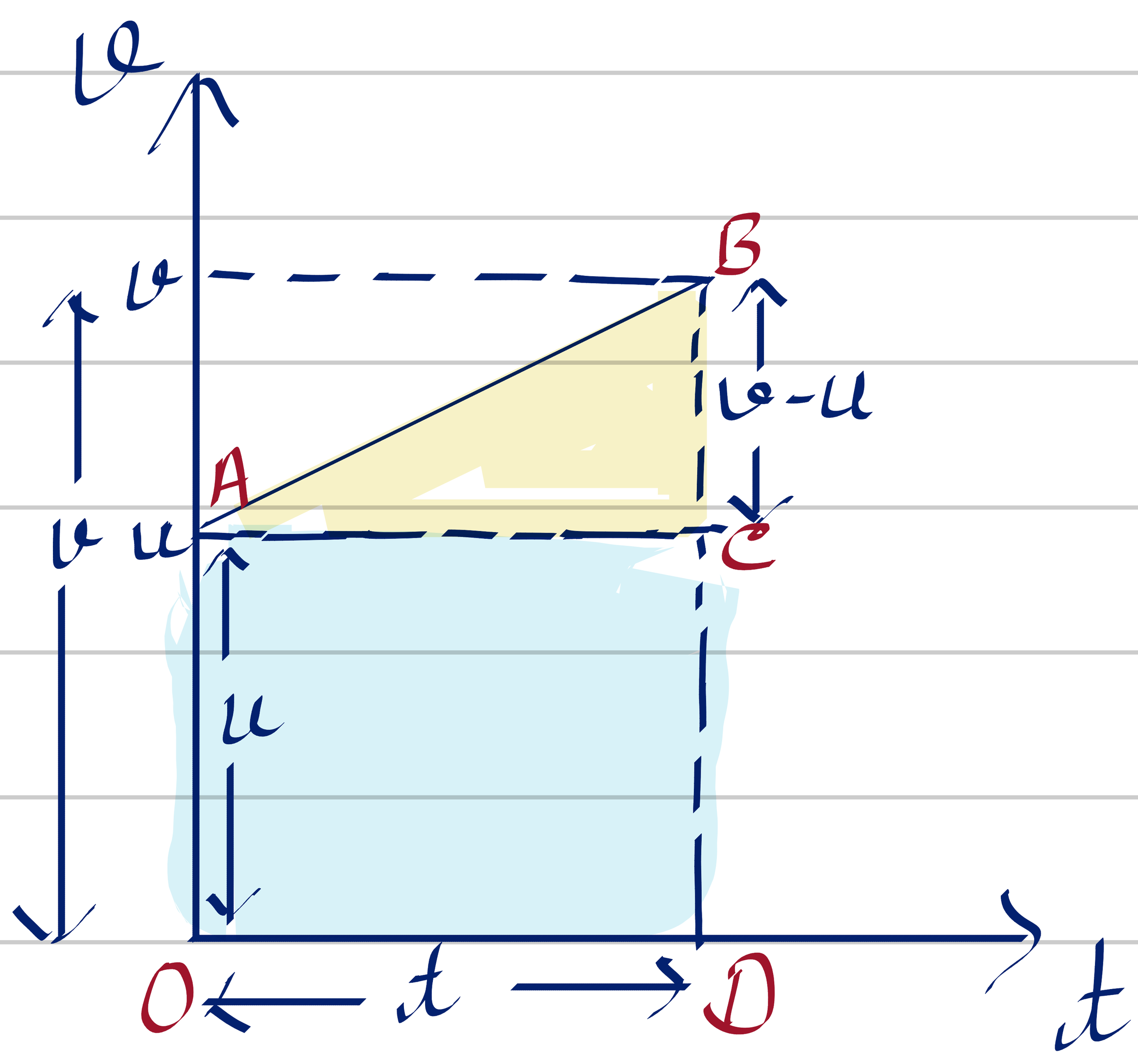
or $$x - x_0 = \frac{v^2 - u^2}{2a}$$

or $$v^2 - u^2 = 2a(x - x_0)$$

or $$\boxed{v^2 - u^2 = 2aS} \qquad [x - x_0 = S]$$

This is the velocity-displacement relation.

Derivation of Kinematic equations by Graphical method



$AC = OD = t$

$OA = u,\ BD = OE = v$

$BC = v - u$

(i) $v = u + at$

Proof:

Slope of v-t graph gives acceleration,

slope of graph $a = \frac{BC}{AC}$

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

or $\boxed{v - u = at}$

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

Proof:

Distance travelled (s) = Area of trapezium OABD

$$S = \frac{\text{Sum of } \parallel \text{ side}}{2} \times \text{distance b/w them}$$

$$S = \frac{OA + BD}{2} \times AC$$

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

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

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

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

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

OR (II method)

S = Area of ΔABC + area of $\square$ ACDO

$= \frac{1}{2} \times b \times h + l \times b$

$S = \frac{1}{2} \times AC \times BC + OA \times AC$

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

or $s = \frac{1}{2} \times t \times at + u \times t$ $[v-u = at]$

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

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

(iii) $v^2 = u^2 + 2as$

Proof:

s = Area of trapezium OABCD

= $\frac{\text{sum of } \parallel \text{ sides} \times \text{distance b/w them}}{2}$

$= \frac{OA + BD}{2} \times AC$

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

$= \frac{u+v}{2} \times \frac{v-u}{a}$ $[\because t = \frac{v-u}{a}]$

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

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

or $\boxed{v^2 = u^2 + 2as}$

Calculus Method: $u \rightarrow$ velocity at $t=0$, $v \rightarrow$ velocity at time 't'

(i) First Equation:

We have, $a = \frac{dv}{dt}$

$dv = a\,dt$

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

$[v]_u^v = a[t]_0^t$

$v - u = a(t-0)$

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

$\frac{d}{dx} x^n = nx^{n-1}$

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

$\int x^n dx = \frac{x^{n+1}}{n+1}$

$\int dx = x$, $\int dv = v$

$\int dt = t$, $\int t\,dt = \frac{t^2}{2}$

$\int_u^v v\,dv = \left[\frac{v^2}{2}\right]_u^v = \frac{v^2 - u^2}{2}$

(ii) Second Equation

We know, $v = \frac{dx}{dt}$

$$dx = v\,dt$$

$$dx = (u+at)\,dt$$

or $$dx = u\,dt + at\,dt$$

On integrating within the limits,

$$\int_{x_0}^{x} dx = \int_0^t u\,dt + \int_0^t at\,dt$$

or $$[x]_{x_0}^{x} = u[t]_0^t + a\left[\frac{t^2}{2}\right]_0^t$$

or $$x - x_0 = u(t-0) + a\left(\frac{t^2}{2} - 0\right)$$

put $x - x_0 = S$,

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

(iii) Third Equation

We know, $a = \frac{dv}{dt}$

$$= \frac{dv}{dt} \cdot \frac{dx}{dx}$$

$$= \frac{dv}{dx} \cdot \frac{dx}{dt}$$

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

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

or $$v\,dv = a\,dx$$

On integrating within the limit,

$$\int_u^v v\,dv = \int_{x_0}^{x} a\,dx$$

$$\left[\frac{v^2}{2}\right]_u^v = a[x]_{x_0}^{x}$$

or $\frac{v^2}{2} - \frac{u^2}{2} = a(x - x_0)$

put $x - x_0 = S$

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

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

Motion under gravity

Free Fall: Motion of an object under the effect of gravity only is called free fall, if air resistance is neglected. The acceleration with which a body falls is called acceleration due to gravity.

For earth $g = 9.8\ m/s^2$ (near the earth surface)

For freely falling body, the equations of motion are

(I) $v = u + gt$ (II) $h = ut + \frac{1}{2}gt^2$ (III) $v^2 = u^2 + 2gh$

* For a freely falling body, g is taken +ve
* For a body thrown vertically upward, g is taken −ve
* When a body is just dropped $u = 0$
* When a body is thrown vertically upward with initial velocity u.
  (I) At maximum height $v = 0$
  (II) Maximum height,

By $v^2 = u^2 + 2gh$

$v = 0$, $g \to -g$

$0 = u^2 - 2gh$

or $\boxed{h = \frac{u^2}{2g}}$

(III) Time of ascend = time of decend = $\frac{u}{g}$

(IV) Total time = $\frac{u}{g} + \frac{u}{g} = \frac{2u}{g}$

[by $v = u + gt$
$0 = u - gt$
$t = u/g$]

(V) Velocity attained when a body dropped from height h,

by $v^2 = u^2 + 2gh$

$u = 0$ in free fall so

$$v^2 = 2gh \Rightarrow \boxed{v = \sqrt{2gh}}$$

→ If we assume motion along y axis, in $-y$ axis (choose upward direction as +ve)

→ Acceleration due to gravity is always downward, it is in the −ve direction and we have

$$a = -g = -9.8\ m/s^2$$

→ The object is released from rest at $y = 0$. i.e $u = 0$. Then equations of motion becomes:

(i) $v = u - gt$

$\Rightarrow v = 0 - 9.8t$ $\quad [u = 0,\ g = -9.8\ m/s^2]$

or $\boxed{v = -9.8\,t}$

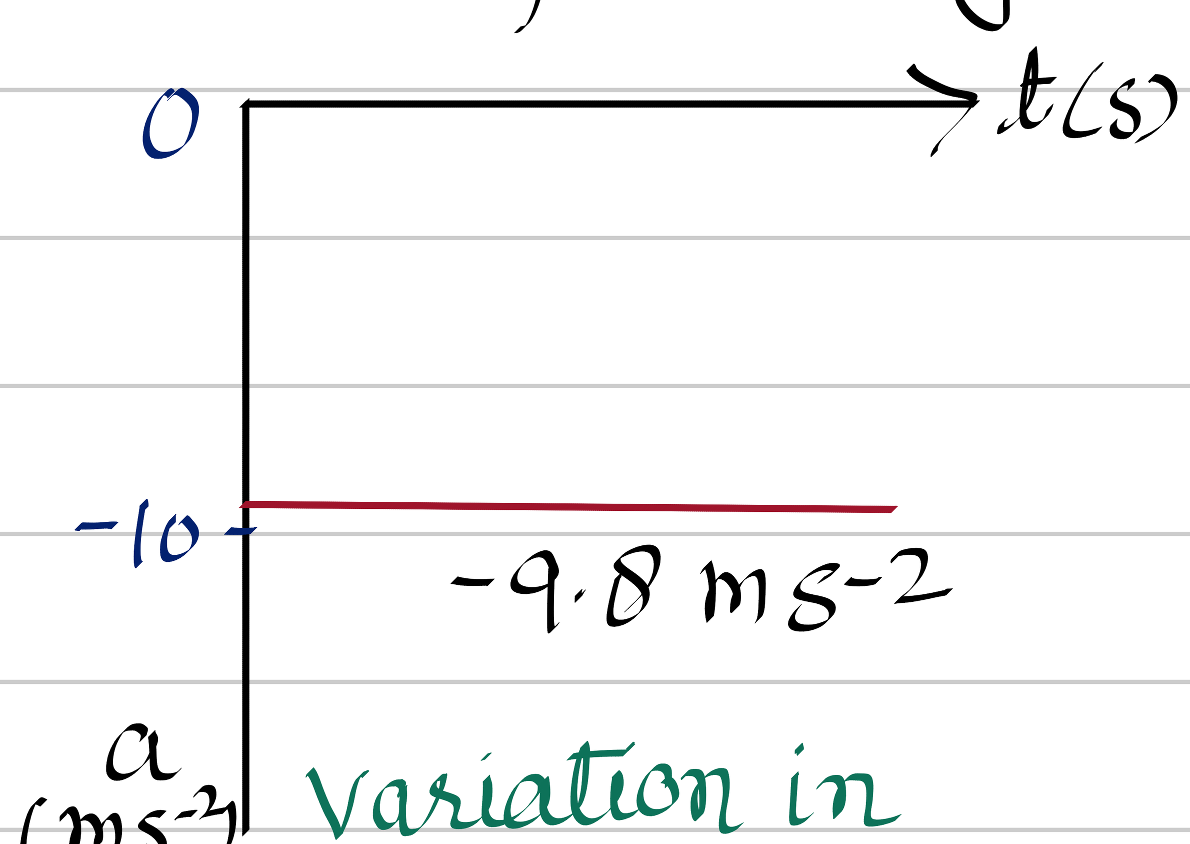
(ii) $y = ut - \frac{1}{2} g t^2$

or $\boxed{y = -4.9\,t^2}$

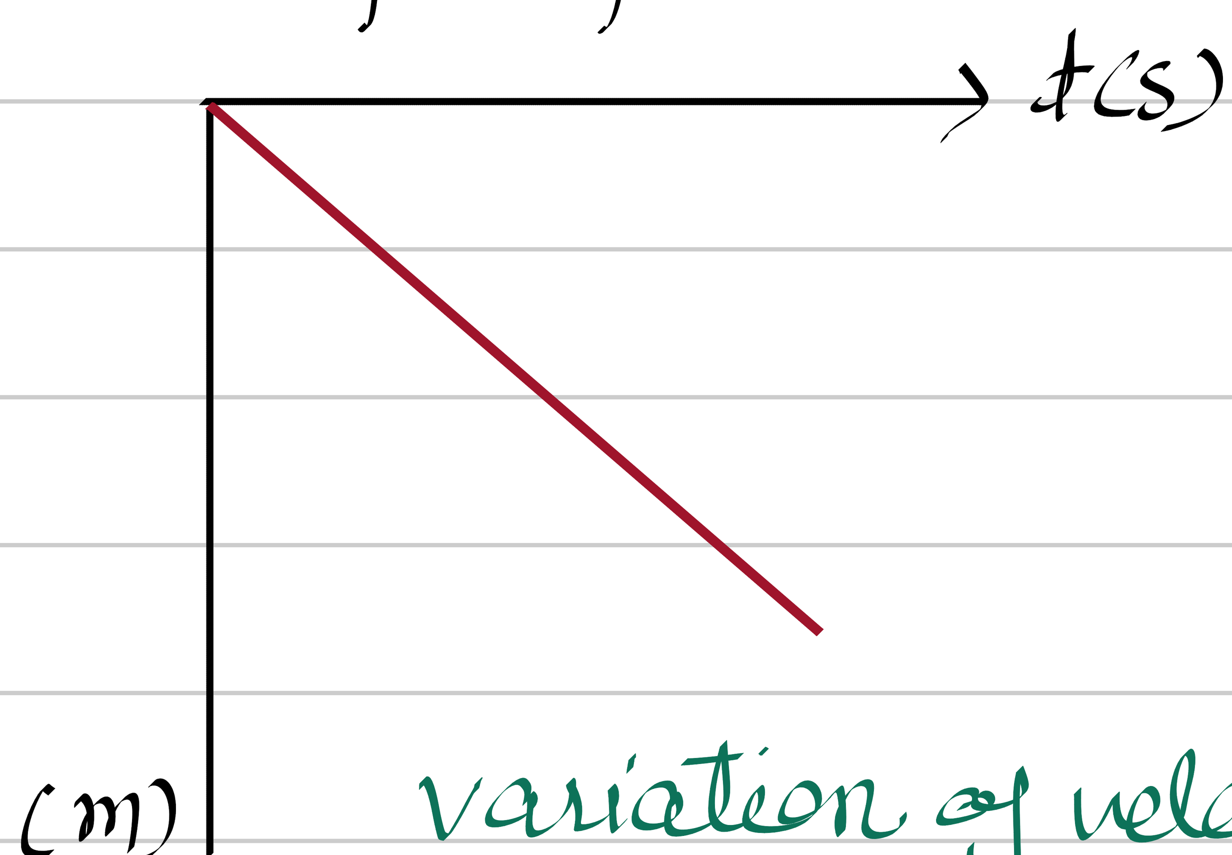
(iii) $v^2 = u^2 - 2gy$

$\boxed{v^2 = -19.6\,y}$

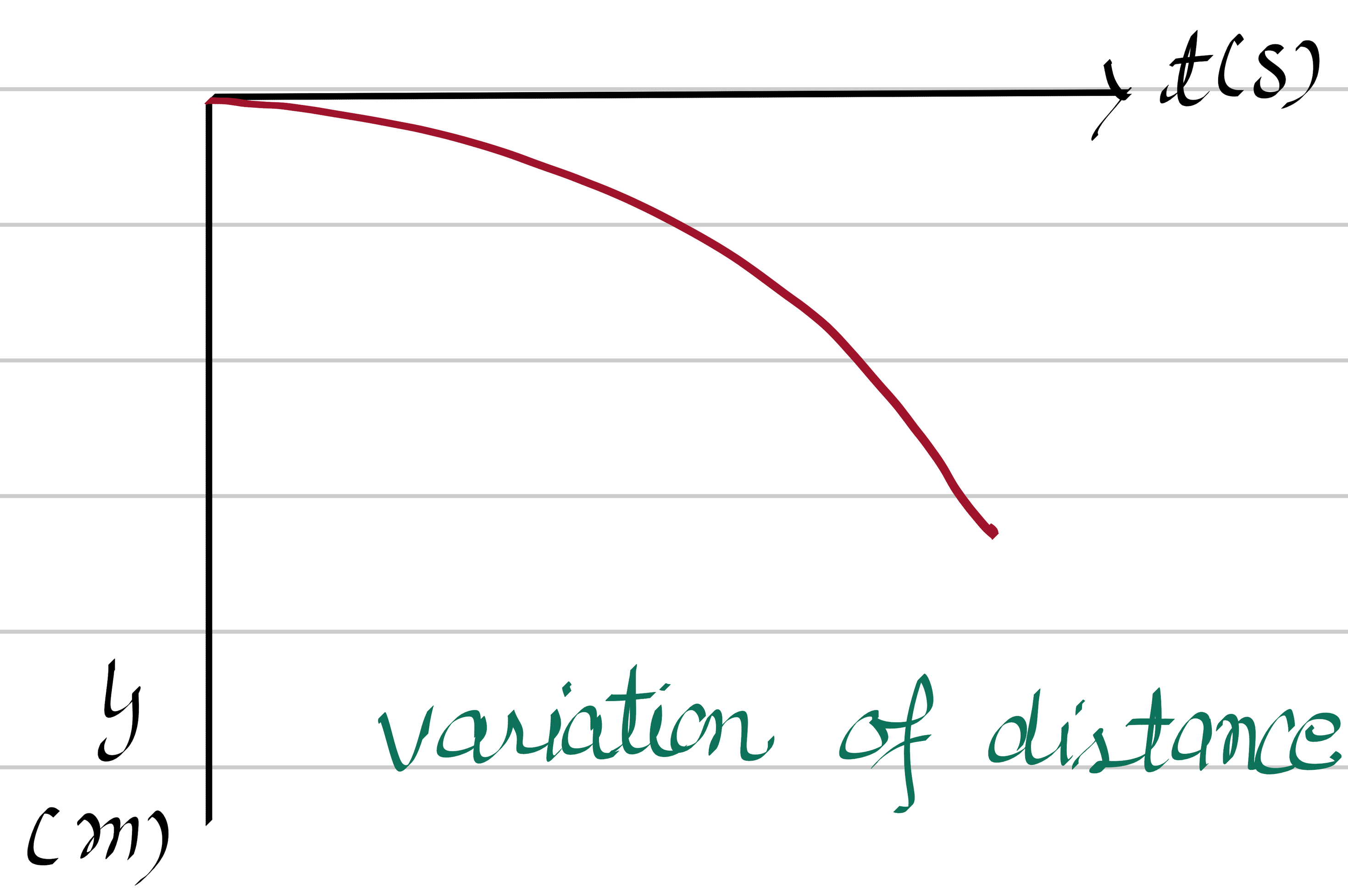
Motion of an object under free fall (Graphs)



Variation in acc^n with time



variation of velocity with time.



variation of distance with time