Shri. A V Dhammanagi Vision Foundation ®

KALPAVRUKSHA MODEL SCHOOL

SUBJECT : SCIENCE

TOPIC : MOTION (PHYSICS)

CLASS : IX

PART 1

Online resources

VIDEO CODE : KMSENGX01

Alankar Nagar, Murgod Road, Bailhongal - 591102

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We will Learn

- Rest
- Motion
- Uniform and non-uniform motion
- Scalar and vector quantities
- Distance and displacement
- Speed and average speed
- Velocity and acceleration
- Equations of motion
- Graphical representation of motion
- Uniform circular motion

1) Describing motion :-

Rest : When a body does not change its position with respect to time and its surroundings, the body is said to be at rest.

Motion :- is the change in position of a body with time.

Motion can be described in terms of the distance moved or the displacement.

Distance :- is the actual length of the path travelled by a body.

Displacement :- is the length of the shortest path travelled by a body from its initial position to its final position.

- **Positive displacement:**
- **Negative displacement:**
- **zero displacement:**

2) Uniform motion and Non uniform motion :-

i) Uniform motion :- If a body travels equal distances in equal intervals of time, it is said to be in uniform motion.

ii) Non uniform motion :- If a body travels unequal distances in equal intervals of time, it is said to be in non uniform motion.

iii) Speed :- of a body is the distance travelled by the body in unit time.

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

If a body travels a distance s in time t then its speed v is

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

The SI unit of speed is metre per second m/s or ms^{-1}

Since speed has only magnitude it is a scalar quantity.

iv) Average speed :- is the ratio of the total distance travelled to the total time taken.

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

Scalar and Vector quantities

i) <u>Scalar quantity</u>:- A physical quantity which can completely expressed in magnitude (size or amount) is called scalar quantity.

Example: length, area, volume, mass, density, time, distance, speed, energy, pressure, work, temperature etc.

ii) <u>Vector quantity</u>:- A physical quantity which can completely expressed ONLY if its magnitude and directions are known is called vector quantity.

Example: displacement, velocity, acceleration, momentum, force and weight

3) Speed with direction :-

The rate of motion of a body is more meaningful if we specify its direction of motion along with speed. The quantity which specifies both the direction of motion and speed is velocity.

i) Velocity :- of a body is the displacement of the body per unit time.

$$\text{Velocity} = \frac{\text{Displacement}}{\text{Time taken}}$$

Since velocity has both magnitude and direction, it is a vector quantity.

ii) Average velocity :- is the ratio of the total displacement to the total time taken.

$$\text{Average velocity} = \frac{\text{Total displacement}}{\text{Total time taken}}$$

Average velocity is also the mean of the initial velocity u and final velocity v.

$$\text{Average velocity} = \frac{\text{Initial velocity} + \text{Final velocity}}{2} \qquad v_{av} = \frac{u + v}{2}$$

Speed and velocity have the same units m/s or ms^{-1}

Numericals

1. A cyclist covers a distance of 50m in 10s. Calculate the speed of the cyclist in m/s and km/s

Soln: In order to find the speed in metre per second, the distance should be in metres and time in seconds

Given : distance d = 50m
time t = 10s
speed = d/t
= 50/10 ➔ 5 m/s

In order to find the speed in kilometer per second, the distance should be in kilometers and time in hours

➔ 5 x 18/5 ➔ 18 km/h

1000 meter = 1 kilometer
3600 second = 1 hour
1000 meter / 3600 second = 1 kilometer / 1 hour
5 meter / 18 second = 1 kilometer / 1 hour

Numericals

1. A train starts from rest and covers a distance of 450m in 2 min. Calculate the speed of the train in m/s and km/h

Ans: i) 3.75 m/s ii) 13.5 km/h

2. An airplane starts from rest and covers a distance of 5km in 8 min. Calculate the speed of the airplane in m/s and km/h

Ans: i) 10.41m/s ii)37.5 km/h

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Acceleration

Acceleration of a body is defined as the rate of change of its velocity with time .

Acceleration = change in velocity / time taken for change

Acceleration = final velocity - initial velocity / time taken

a = (v-u) / t

Where, a = acceleration of the body

v = final velocity of the body

u= initial velocity of the body

And t = time taken for the change in velocity

- ***The SI unit of acceleration is meters per second square .***

When a body is moving with uniform velocity, its acceleration will be zero.

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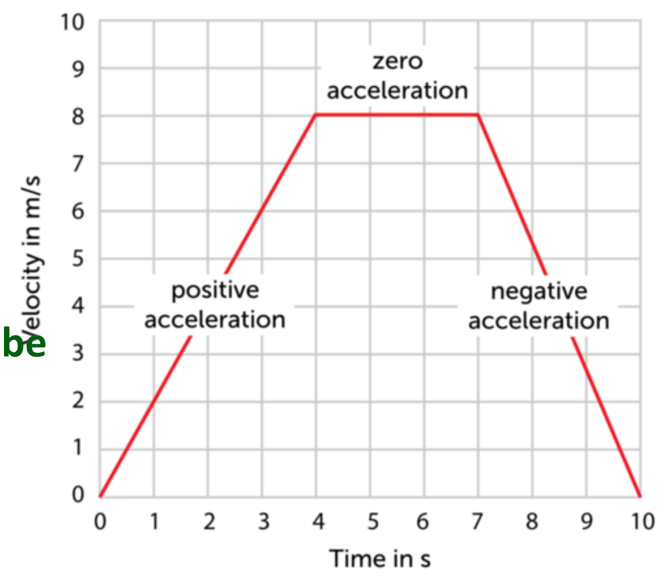


4) Rate of change of velocity :-

During uniform motion of a body in a straight line the velocity remains constant with time. In this case the change in velocity at any time interval is zero (no change in velocity).

During non uniform motion the velocity changes with time. In this case the change in velocity at any time interval is not zero. It may be positive (+ ve) or negative (- ve).

The quantity which specifies changes in velocity is acceleration.

Acceleration :- is the change in velocity of a body per unit time.(or the rate of change of velocity.)

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

If the velocity of a body changes from initial value u to final value v in time t, then acceleration a is

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

The SI unit of acceleration is ms^{-2}

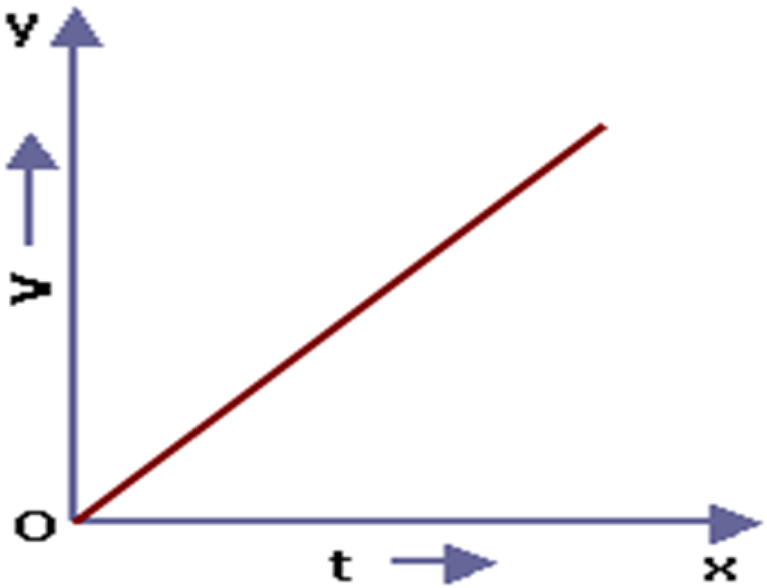
Uniform acceleration :- If the change in velocity is equal in equal intervals of time it is uniform acceleration.

Non uniform acceleration :- If the change in velocity is unequal in equal intervals of time it is non uniform acceleration.

Uniform Acceleration

velocity increases by equal amounts in equal intervals of time.

The velocity -time graph of a body having uniformly accelerated motion is a straight line.

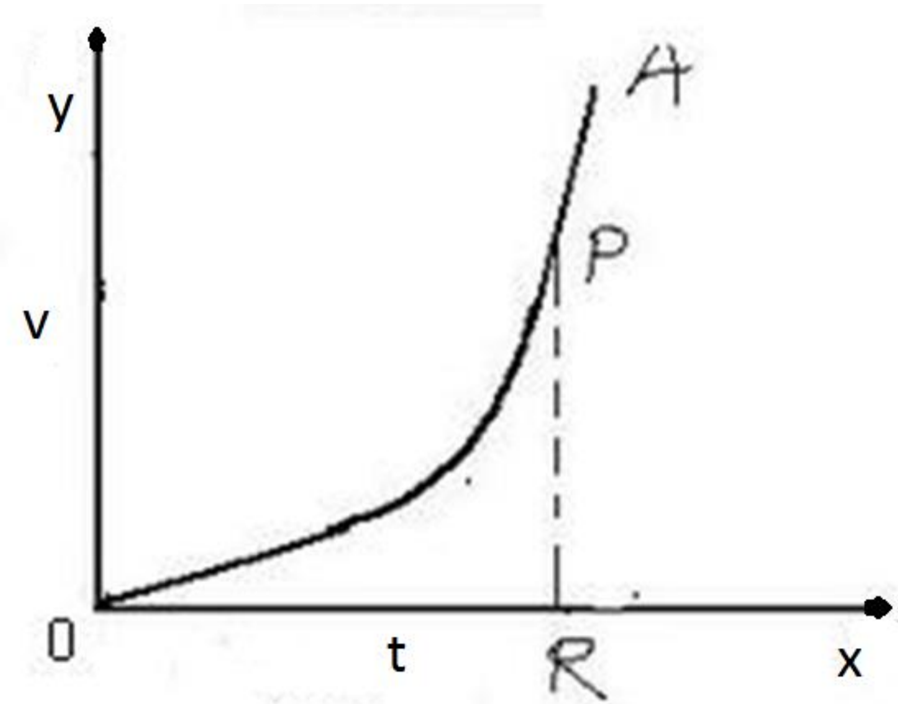


See the change in velocity

Non- Uniform Acceleration

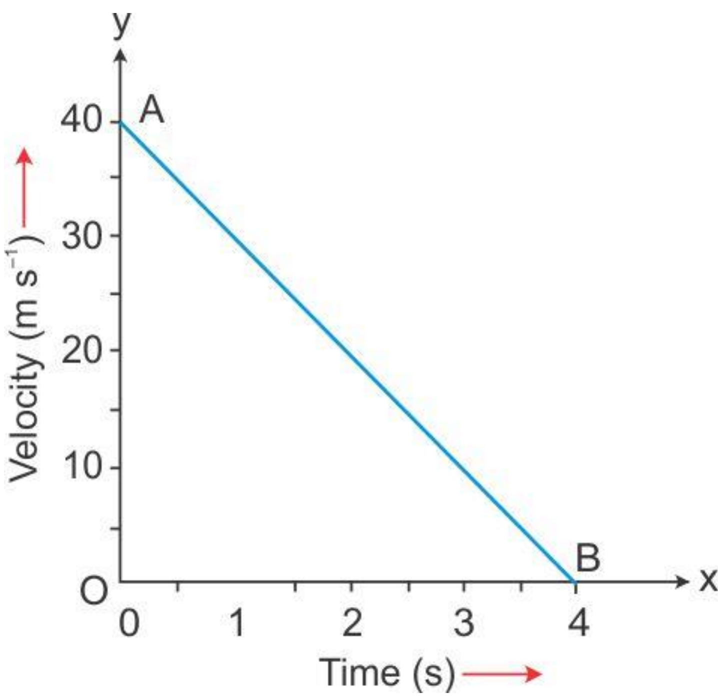
velocity increase by unequal amounts in equal intervals of time.

- The velocity -time graph for a body having non-uniform acceleration is a curved line.



Retardation (Deceleration or Negative Acceleration)

If the velocity of a body increases, the acceleration is positive, and if the velocity of the body decreases, the acceleration is negative. Retardation is measured in the same way as acceleration. Retardation is actually acceleration with the negative sign .



Average Velocity

Average velocity =(Initial velocity + Final velocity) / 2

v_{av} =(u + v)/ 2

When a bar on the v denotes the average velocity, u is the initial velocity and v is the final velocity .

Equations of Uniformly accelerated motion

1. To prove: v = u + at

Consider a body, having an initial velocity ‘u’, acted upon by a uniform acceleration ‘a’ for time ‘t’, such that final velocity of the body is ‘v’.

Now change acceleration = change in velocity / time

OR acceleration = Final velocity – Initial velocity / time

So, a = (v-u) / t

- ➔ **v-u = at**
- ➔ **v = u + at**

Equations of Uniformly accelerated motion

1. To prove: $s=ut+1/2\ at^2$

Consider a body, having an initial velocity 'u', acted upon by a uniform acceleration 'a' for time 't', such that final velocity of the body is 'v' and the distance covered is 's'.

Now average velocity = (Final velocity + Initial velocity) / 2

Also the distance covered = average velocity x time

➔ $s = \frac{(v+u)}{2} \times t$

But $v = u+at$

Thus, $s = \left(\frac{u+at+u}{2}\right) \times t$

OR $s = \left(\frac{2u}{2} + \frac{at}{2}\right) \times t$

$s=ut+1/2\ at^2$

Equations of Uniformly accelerated motion

1. To prove: $v^2 - u^2 = 2as$

Consider a body, having an initial velocity ‘u’, acted upon by a uniform acceleration ‘a’ for time ‘t’, such that final velocity of the body is ‘v’ and the distance covered is ‘s’.

We know that : $s = ut + 1/2\, at^2$ ------(1)

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

Squaring on both the sides we have $v^2 = (u + at)^2$

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

$v2 - u2 = 2a\,(ut + \frac{1}{2}\, at^2)$

Substituting the values of 1 and 2 we get,

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

Example: A car starts form rest and picks up a velocity of 54km/h in 10 seconds. Calculate the acceleration of the car.

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5) Graphical representation of motion :-

a) Distance – Time graphs :-

The change in the position of a body with time can be represented on the distance time graph. In this graph distance is taken on the y – axis and time is taken on the x – axis.

i) The distance time graph for uniform speed is a straight line (linear). This is because in uniform speed a body travels equal distances in equal intervals of time.

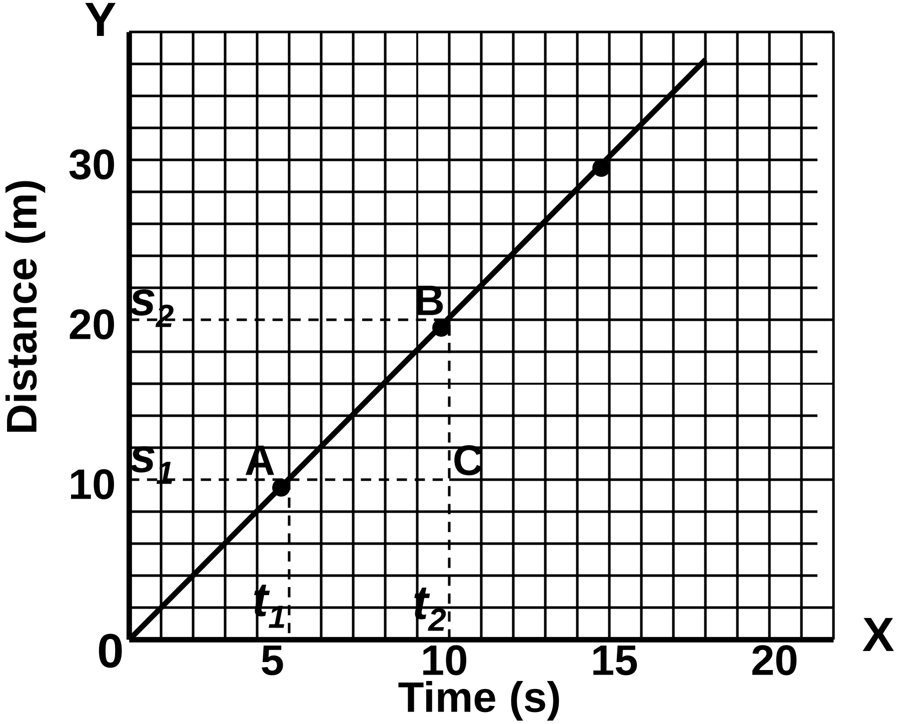
We can determine the speed of the body from the distance – time graph.

For the speed of the body between the points A and B, distance is $(s_2 - s_1)$ and time is $(t_2 - t_1)$.

$$v = \frac{s}{t} \qquad v = \frac{(s_2 - s_1)}{(t_2 - t_1)}$$

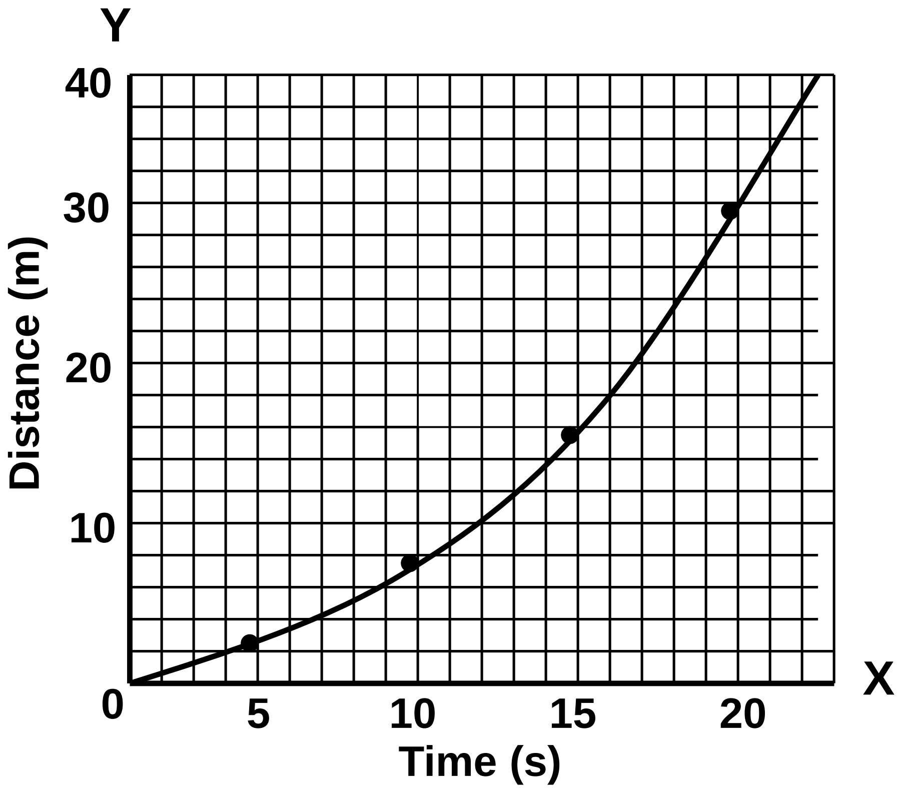
$$= \frac{20 - 10}{10 - 5} = \frac{10}{5}$$

$$= 2\ ms^{-1}$$

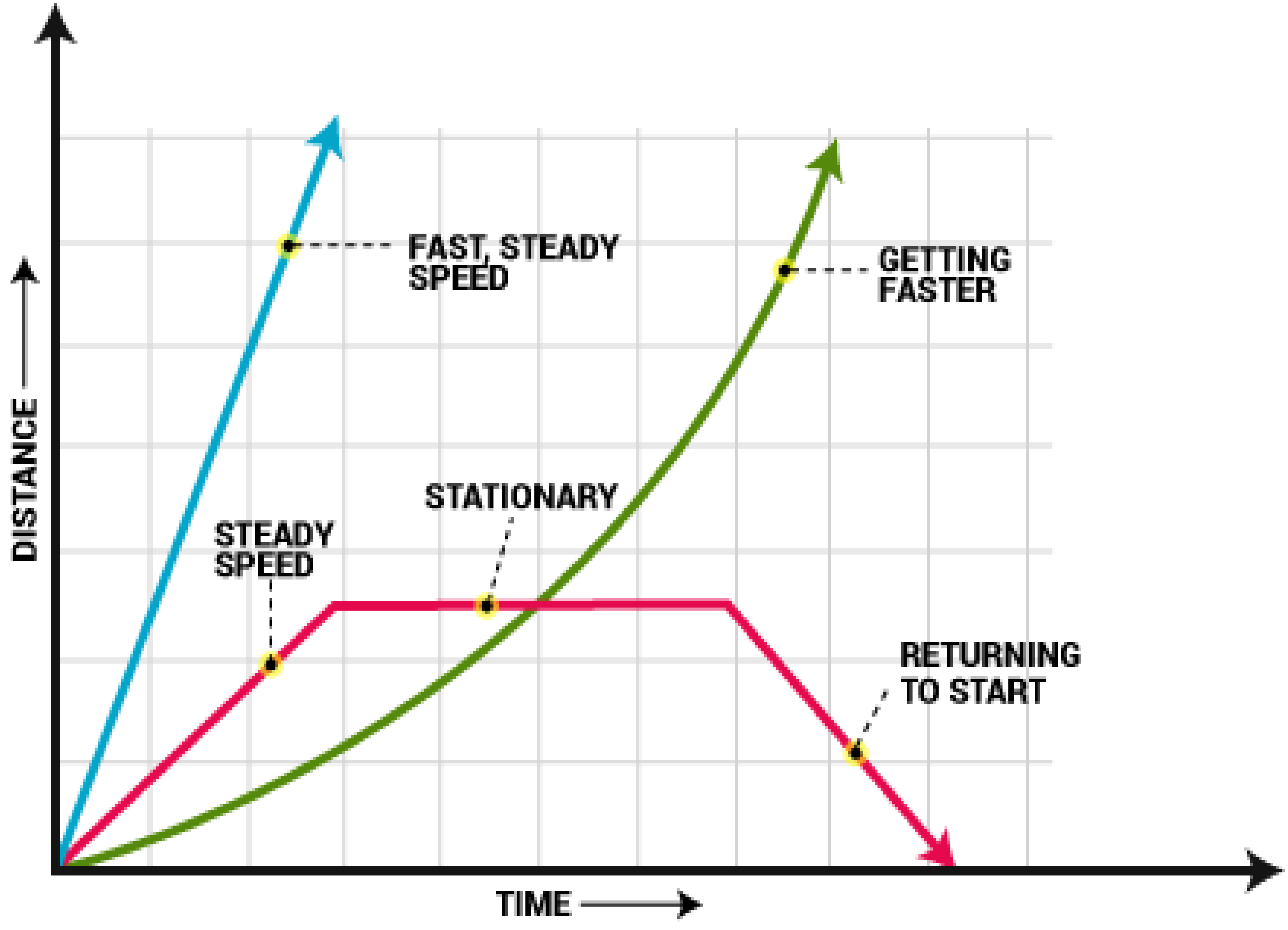


Distance – time graph for a body moving with uniform speed

ii) The distance – time graph for non uniform motion is non linear. This is because in non uniform speed a body travels unequal distances in equal intervals of time.



Distance – time graph for a body moving with non uniform speed


FAST, STEADY SPEED
GETTING FASTER
STATIONARY
STEADY SPEED
RETURNING TO START
DISTANCE
TIME

Conclusions from Distance – time Graph

- **If the graph is parallel to the time axis, then the body is stationary.**
- **If the graph is a straight line, but not parallel to the time axis, then the body is moving with a uniform speed. The speed can be calculated by calculating the slope of the graph.**
- **If the graph is curve, it means that the body is moving with a variable speed. Such body can have accelerated / retarded motion.**
- **The graph line can never be parallel to the distance axis, as it means that the distance increases indefinitely without any increase in time. Which is impossible.**

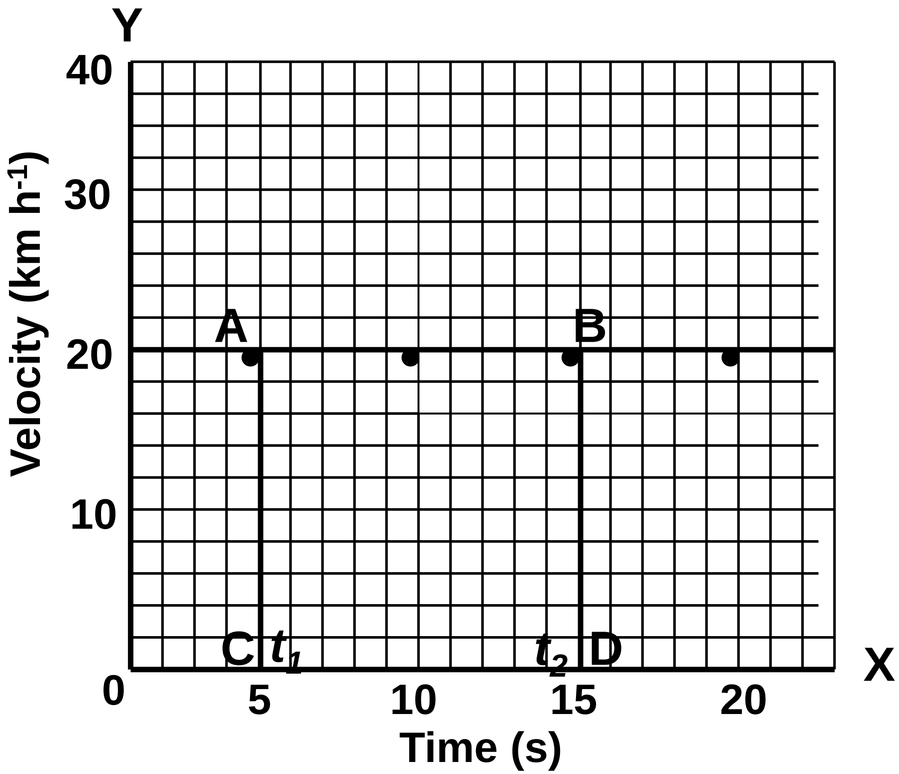
b) Velocity – time graphs :-

The change in the velocity of a body with time can be represented on the velocity time graph. In this graph velocity is taken on the y – axis and time is taken on the x – axis.

i) If a body moves with uniform velocity, the graph will be a straight line parallel to the x – axis . This is because the velocity does not change with time.

To determine the distance travelled by the body between the points A and B with velocity 20 km h^{-1}

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



Velocity – time graph for a body moving with uniform velocity

ii) If a body whose velocity is increasing with time, the graph is a straight line having an increasing slope. This is because the velocity increases by equal amounts with equal intervals of time.

The area under the velocity – time graph is the distance (magnitude of displacement) of the body.

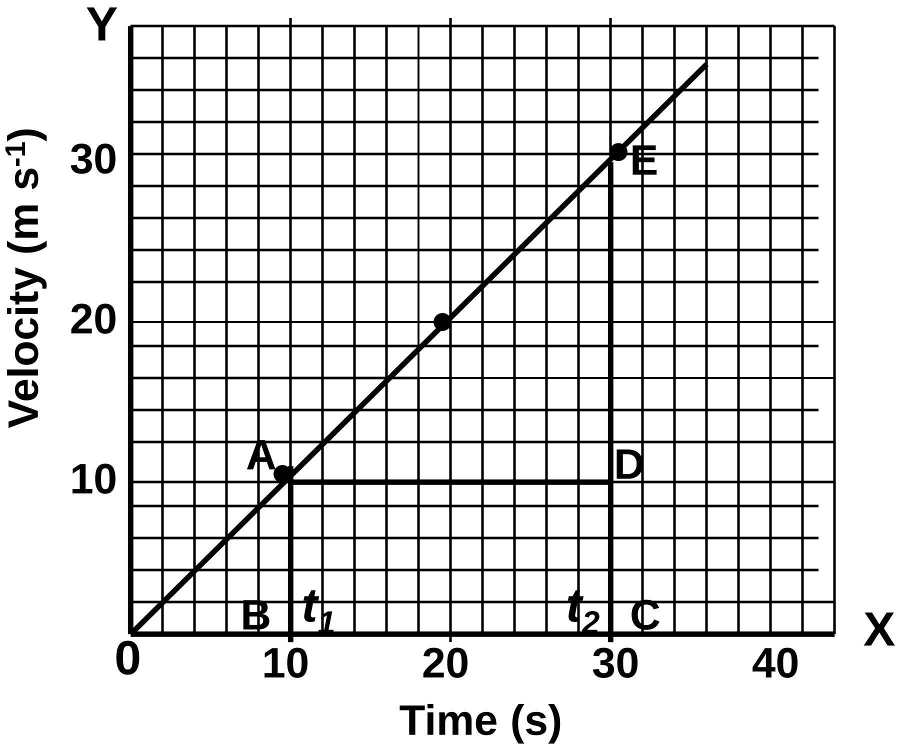
The distance travelled by a body between the points A and E is the area ABCDE under the velocity – time graph.

s = area ABCDE

= area of rectangle ABCD

+ area of triangle ADE

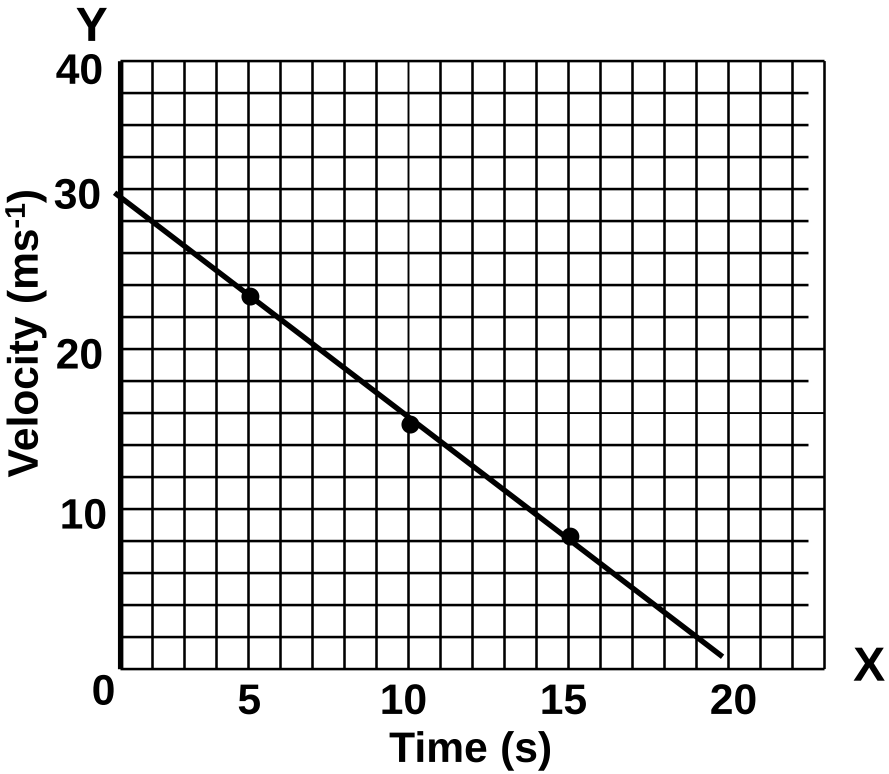
$$s = AB \times BC + \frac{1}{2}(AD \times DE)$$



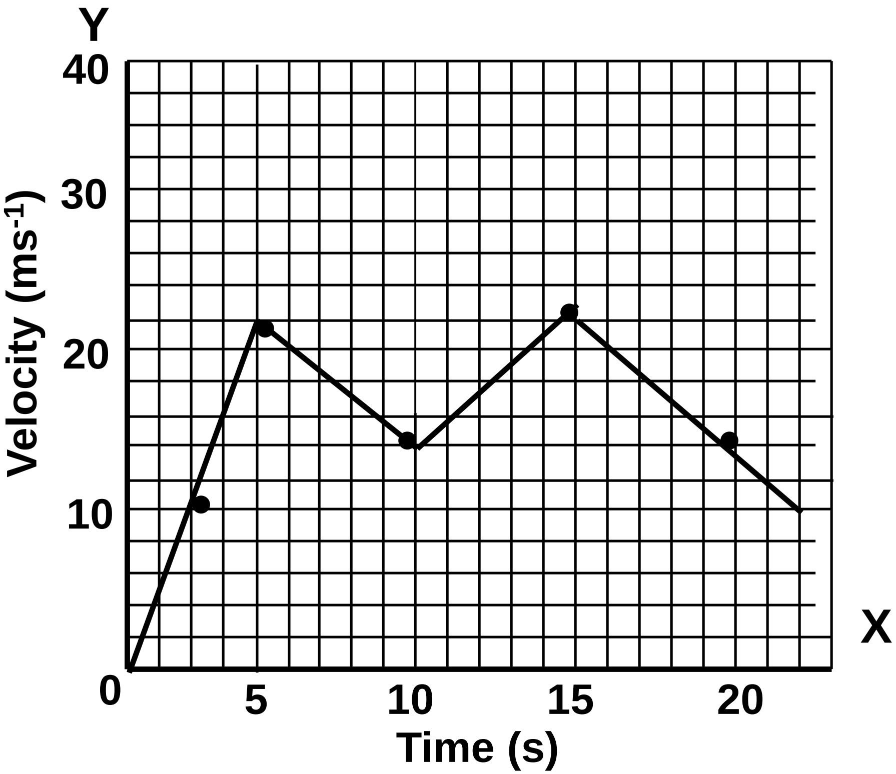
Velocity – time graph for a body moving with uniform acceleration

iii) If a body whose velocity is decreasing with time, the graph is a straight line having an decreasing slope. This is because the velocity decreases by equal amounts with equal intervals of time.

iv) If a body whose velocity is non uniform, the graph shows different variations. This is because the velocity changes by unequal amounts in equal intervals of time.



Velocity – time graph for a uniformly decelerated motion



Velocity – time graph for non uniform acceleration

6) Equations of motions by graphical method :-

The motion of a body moving with uniform acceleration can be described with the help of three equations called equations of motion.

The equations of motion are :-

i) $v = u + at$

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

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

where u - is the initial velocity

v - is the final velocity

a - is acceleration

t - is the time

s - is the distance traveled

a) Equation for velocity – time relation ($v = u + at$) :-

Consider a velocity – time graph for a body moving with uniform acceleration 'a'. The initial velocity is u at A and final velocity is v at B in time t.

Perpendicular lines BC and BE are drawn from point B to the time and velocity axes so that the initial velocity is OA and final velocity is BC and time interval is OC. Draw AD parallel to OC.

We observe that

BC = BD + DC = BD + OA

Substituting BC = v and OA = u

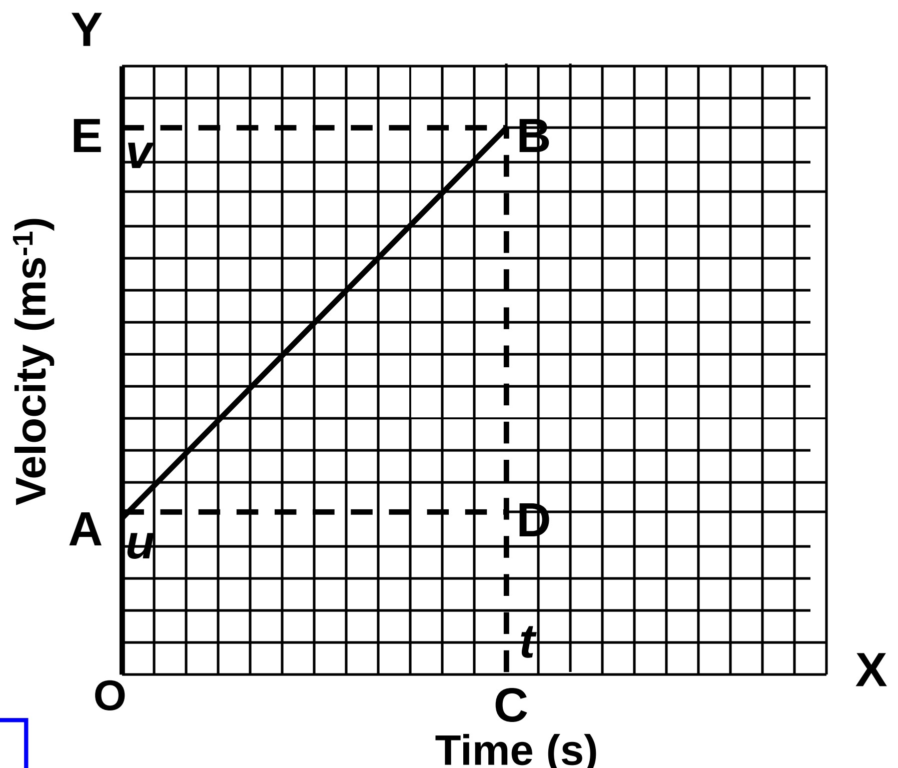
We get $v = BD + u$

or $BD = v - u$

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

$$a = \frac{BD}{AD} = \frac{BD}{OC} \quad \text{or} \quad a = \frac{v - u}{t}$$

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



Velocity – time graph for a uniformly accelerated motion

b) Equation for position – time relation ($s = ut + \frac{1}{2} at^2$) :-

Consider a velocity – time graph for a body moving with uniform acceleration 'a' travelled a distance s in time t.

The distance traveled by the body between the points A and B is the area OABC.

s = area OABC (which is a trapezium)

= area of rectangle OABC + area of triangle ABD

$$= OA \times OC + \frac{1}{2} (AD \times BD)$$

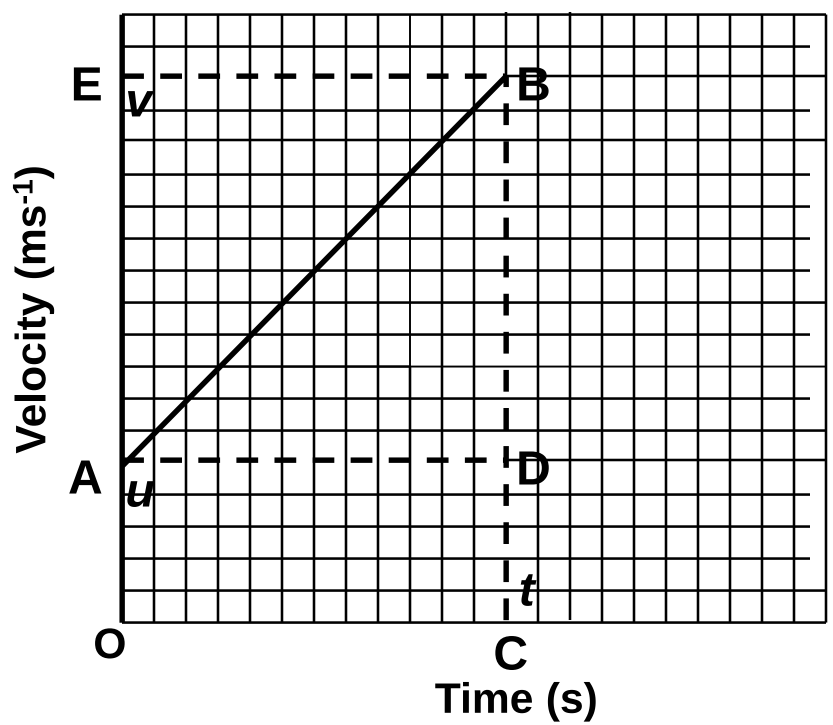
Substituting OA = u, OC = AD = t,

BD = v – u = at

We get

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

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



Velocity – time graph for a uniformly accelerated motion

c) Equation for position – velocity relation ($2as = v^2 - u^2$) :-

Consider a velocity – time graph for a body moving with uniform acceleration ‘a’ travelled a distance s in time t.

The distance travelled by the body between the points A and B is the area OABC.

s = area of trapezium OABC

$$s = \frac{(OA + BC) \times OC}{2}$$

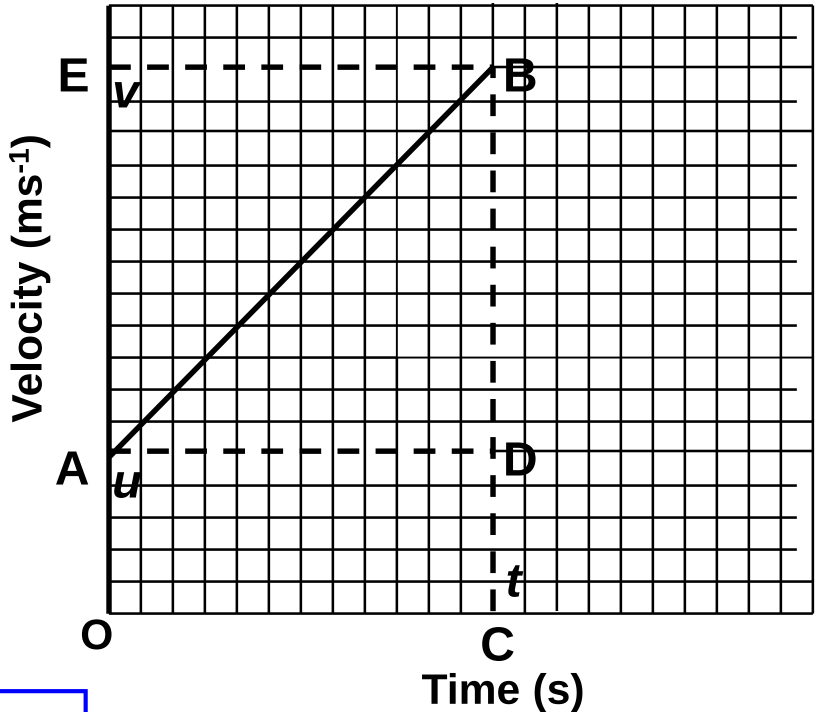
Substituting OA = u, BC = v and OC = t

We get $$s = \frac{(u + v) \times t}{2}$$

From velocity – time relation

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

$$s = \frac{(v + u) \times (v - u)}{2a}$$ or $$2as = v^2 - u^2$$



Velocity – time graph for a uniformly accelerated motion

7) Circular motion :-

The motion of a body in a circular path is called circular motion.

Uniform circular motion :- If a body moves in a circular path with uniform speed, its motion is called uniform circular motion.

Uniform circular motion is accelerated motion because in a circular motion a body continuously changes its direction.

The circumference of a circle of radius r is given by $2\pi r$. If a body takes time t to go once around the circular path, then the velocity v is given by

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