MOTION

CLASS 9TH CHAPTER-8TH

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Describing Motion
Reference point and reference frame

- To describe the position of an object we need a reference point or origin. An object may seem to be moving to one observer and stationary to another.

- Example: A passenger inside a bus sees the other passengers to be at rest, whereas an observer outside the bus sees the passengers to be in motion.

- In order to make observations easy, a convention or a common reference point or frame is needed. All objects must be in the same reference frame.

Distance and Displacement

- The magnitude of the length covered by a moving object is called distance. It has no direction.

- Displacement is the shortest distance between two points or the distance between the starting and final positions with respect to time. It has magnitude as well direction.
  great size

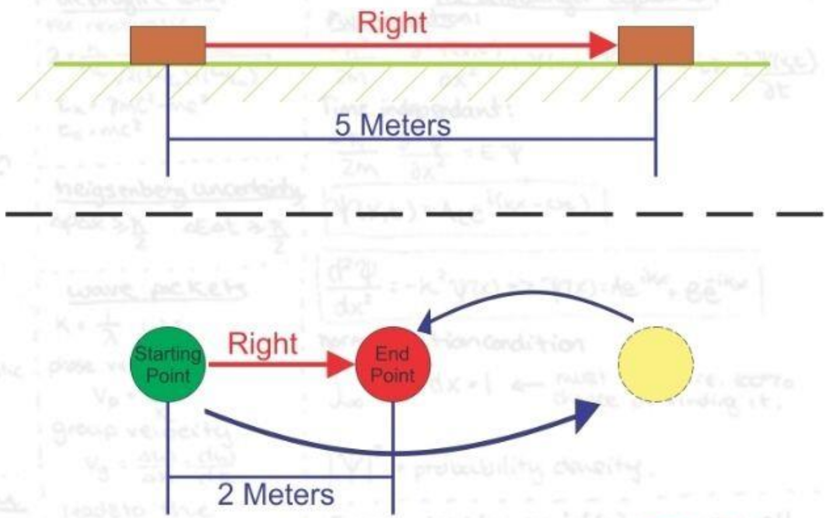
- Displacement can be zero, but distance cannot.

Displacement Vs. Distance

Displacement: The shortest length between an object's start and endpoint as well as the direction of the motion.

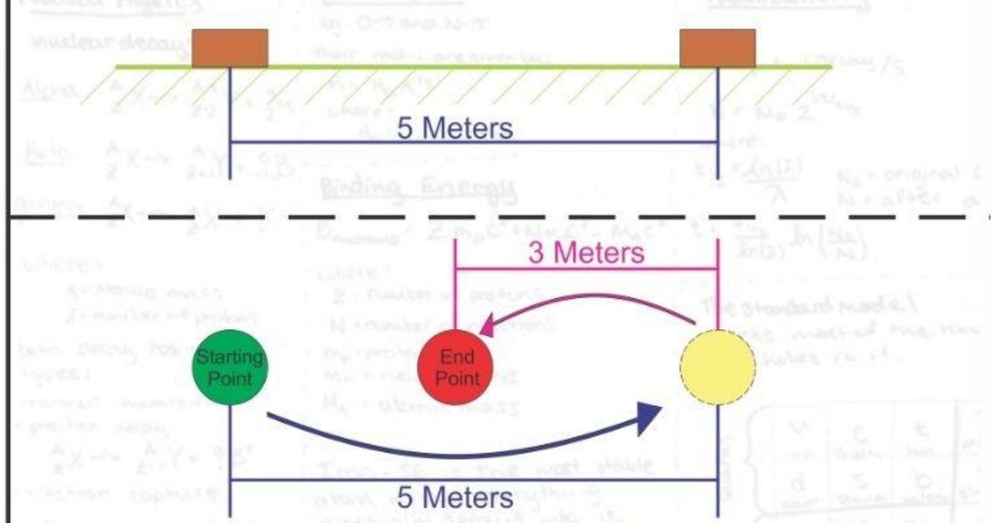
Distance: The total length of the path that the object travels.

Example:



Displacement = 2 meters to the Right

Example:



Distance = 8m = 5m+3m

What is Distance?
Distance is the total movement of an object without any regard to direction.

We can define distance as to how much ground an object has covered despite its starting or ending point.

Distance Formula
$\Delta d = d1 + d2$

How is Displacement defined?
Displacement is defined as the change in position of an object.

It is a vector quantity and has a direction and magnitude. It is represented as an arrow that points from the starting position to the final position.

For example- If an object moves from A position to B, then the object’s position changes.

This change in position of an object is known as Displacement.
Displacement = $\Delta x = x_f - x_0$

x_f = Final Position

x_0 = Initial Position

Δx = Displacement

Magnitude

- Magnitude is the size or extent of a physical quantity. In physics, we have scalar and vector quantities.

- Scalar quantities are only expressed as magnitude. E.g: time, distance, mass, temperature, area, volume

- Vector quantities are expressed in magnitude as well as the direction of the object. E.g: Velocity, displacement, weight, momentum, force, acceleration, etc.

Time and speed

- Time is the duration of an event that is expressed in seconds. Most physical phenomena occur with respect to time. It is a scalar quantity.

- Speed is the rate of change of distance. If a body covers a certain distance in a certain amount of time, its speed is given by

Speed=Distance/Time
Average speed = Total distance travelled / Total time taken

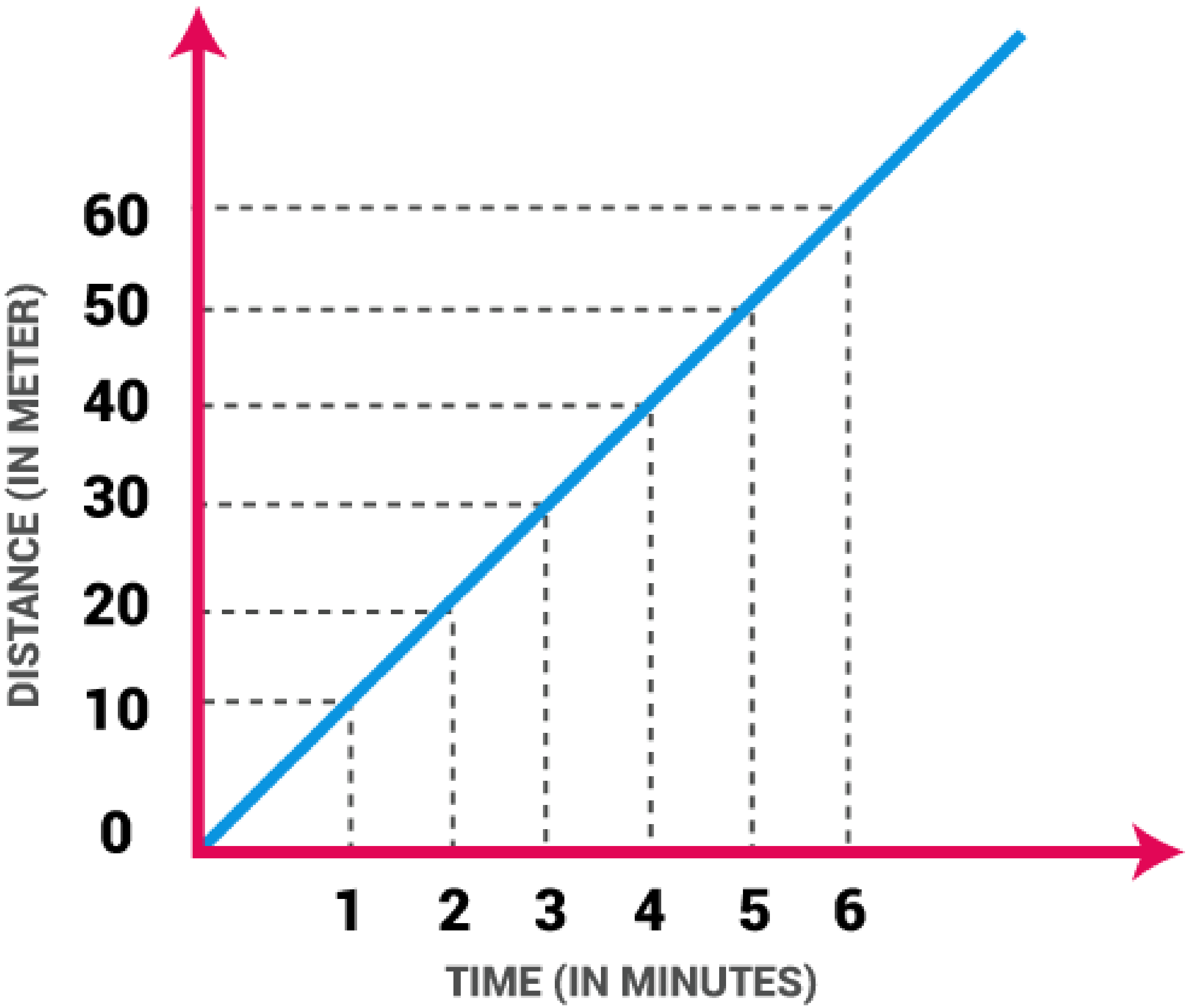
Uniform motion and non-uniform motion

- When an object covers equal distances in equal intervals of time it is in uniform motion.

- When an object covers unequal distances in equal intervals of time it is said to be in non-uniform motion.

- This type of motion is defined as the motion of an object in which the object travels in a straight line and its velocity remains constant along that line as it covers equal distances in equal intervals of time, irrespective of the duration of the time.

UNIFORM MOTION GRAPH



Example of Uniform Motion:

- If the speed of a car is 10 m/s, it means that the car covers 10 meters in one second. The speed is constant in every second.

- Movement of blades of a ceiling fan.

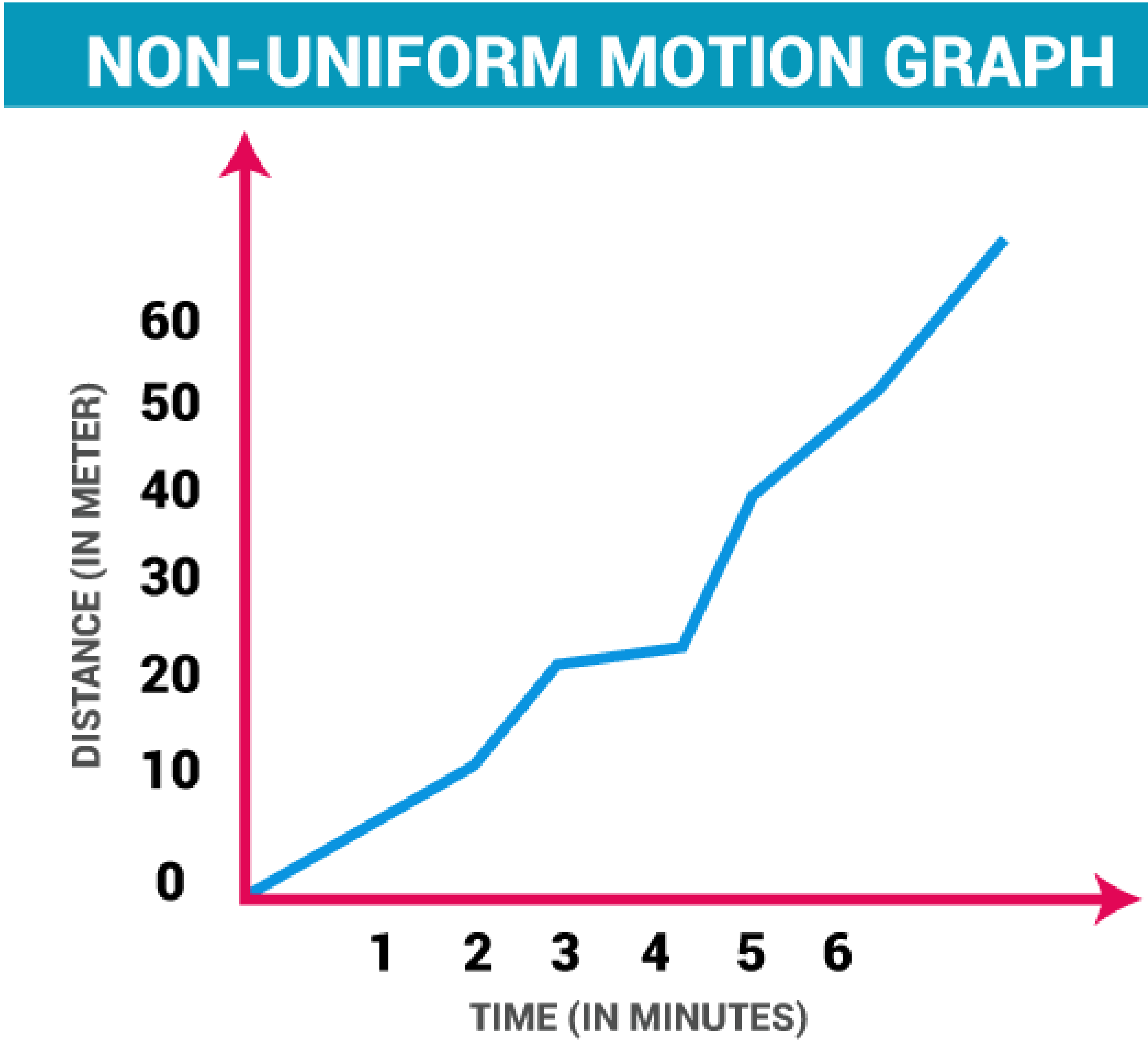
Non Uniform Motion:

This type of motion is defined as the motion of an object in which the object travels with varied speed and it does not cover same distance in equal time intervals, irrespective of the time interval duration.

Example of Non Uniform Motion:

- If a car covers 10 meters in first two seconds, and 15 meters in next two seconds.

- The motion of a train.


NON-UNIFORM MOTION GRAPH
DISTANCE (IN METER)
60
50
40
30
20
10
0
1
2
3
4
5
6
TIME (IN MINUTES)

Velocity

- The Rate of change of displacement is velocity.

- It is a vector quantity. The direction of motion is specified.

Velocity=Displacement/Time

- Average velocity = (Initial Velocity + Final velocity)/2 = u+v2.

Acceleration

- The rate of change of velocity is called acceleration.

- It is a vector quantity. In non-uniform motion, velocity varies with time, i.e., change in velocity is not 0.

- It is denoted by “a”. Acceleration is a vector quantity as it has both magnitude and direction.

- It is also the second derivative of position with respect to time or it is the first derivative of velocity with respect to time.

Acceleration = Change in Velocity / Time

(OR)

$a=v-ut$

Where, t (time taken), v (final velocity) and u (initial velocity).

Types of Acceleration

Uniform and Non-uniform acceleration

- It is possible in circular motion where speed remains constant but since the direction is changing hence the velocity changes, and the body is said to be accelerated.

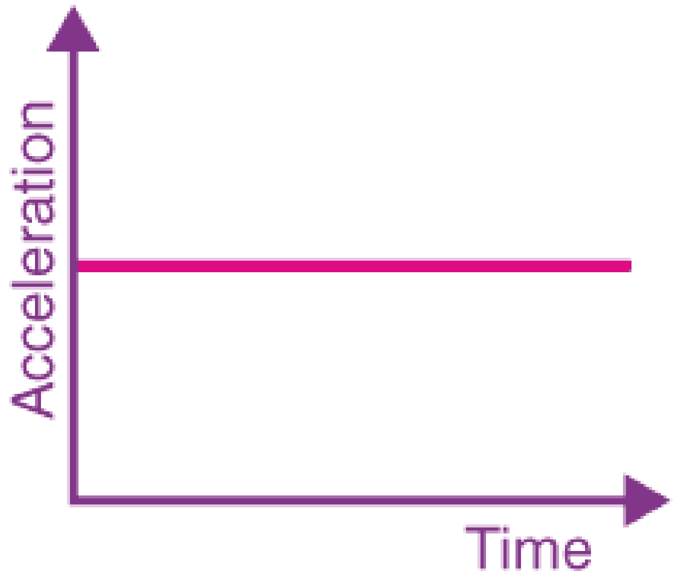
Average acceleration

- The average acceleration over a period of time is defined as the total change in velocity in the given interval divided by the total time taken for the change.

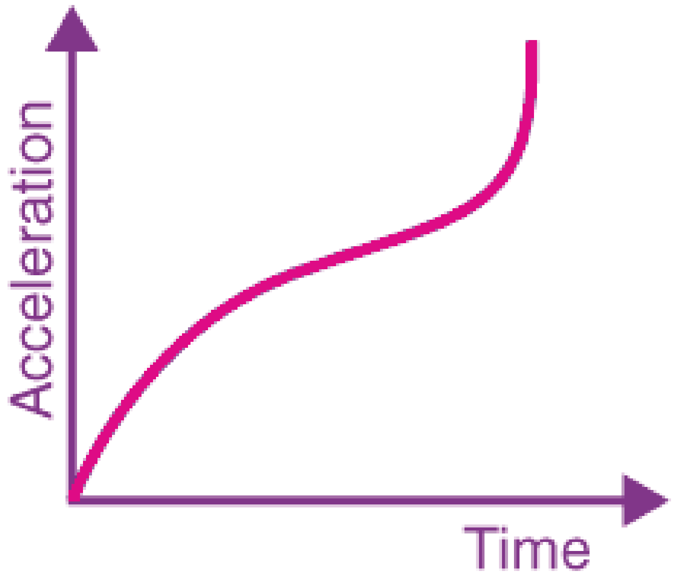
- For a given interval of time, it is denoted as $\bar{a}$.

- Mathematically,

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



Uniform Acceleration



Non-uniform Acceleration

When an object is travelling in a straight line with an increase in velocity at equal intervals of time, then the object is said to be in uniform acceleration. Free falling of an object is an example of uniform acceleration.

Non-uniform acceleration refers to the situation where an object’s velocity changes by unequal amounts in equal intervals of time.

Motion Visualised

- Distance-Time graphs show the change in position of an object with respect to time.

not straight line

- Linear variation = uniform motion and non-linear variations imply non- uniform motion

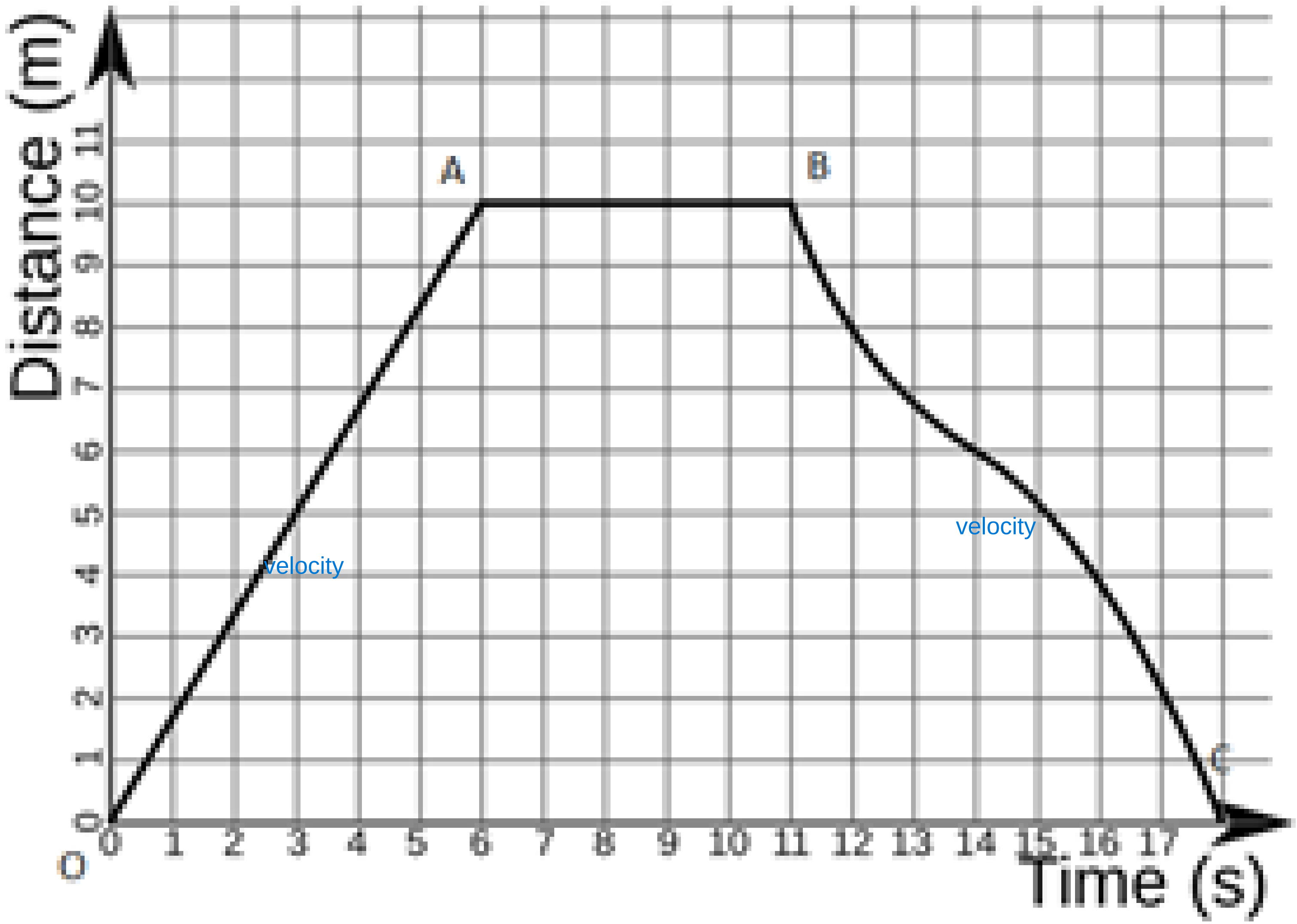
- The slope gives us speed

Distance – Time Graph

- OA implies uniform motion with constant speed as the slope is constant.

- AB implies the body is at rest as the slope is zero

- B to C is non-uniform motion


Distance (m)
Time (s)
A
B
C
O
velocity
velocity
0 1 2 3 4 5 6 7 8 9 10 11
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

Velocity-Time Graph

- Velocity-Time graphs show the change in velocity with respect to time.

- Slope gives acceleration

- The area under the curve gives displacement

- Line parallel to x-axis implies constant velocity-

Velocity – Time Graph

OA = constant acceleration, AB = constant velocity, BC = constant retardation

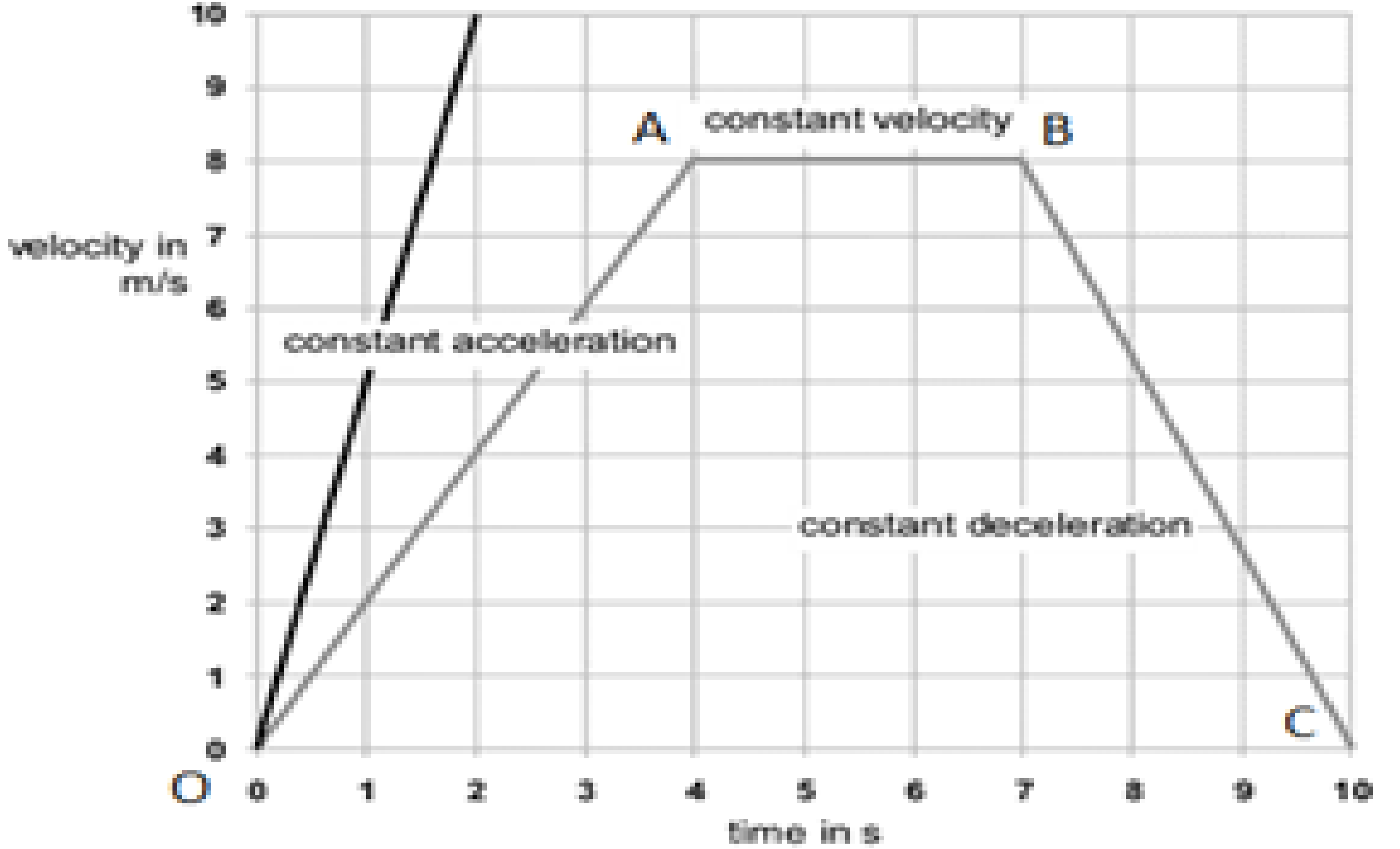
Equations of Motion

The motion of an object moving at uniform acceleration can be described with the help of three equations, namely

(i) $v = u + at$

(ii) $v2 - u2 = 2as$

(iii) $s = ut + (1/2)at2$



velocity in m/s
time in s
constant acceleration
constant velocity
constant deceleration
A
B
C
O
0
1
2
3
4
5
6
7
8
9
10

Derivation of velocity-time relation by graphical method

Velocity – Time Graph

A body starts with some initial non-zero velocity at A and goes to B with constant acceleration a.

From the graph $BD = v$ (final velocity) – $DC = u$ (initial velocity)…………..(eq 1).

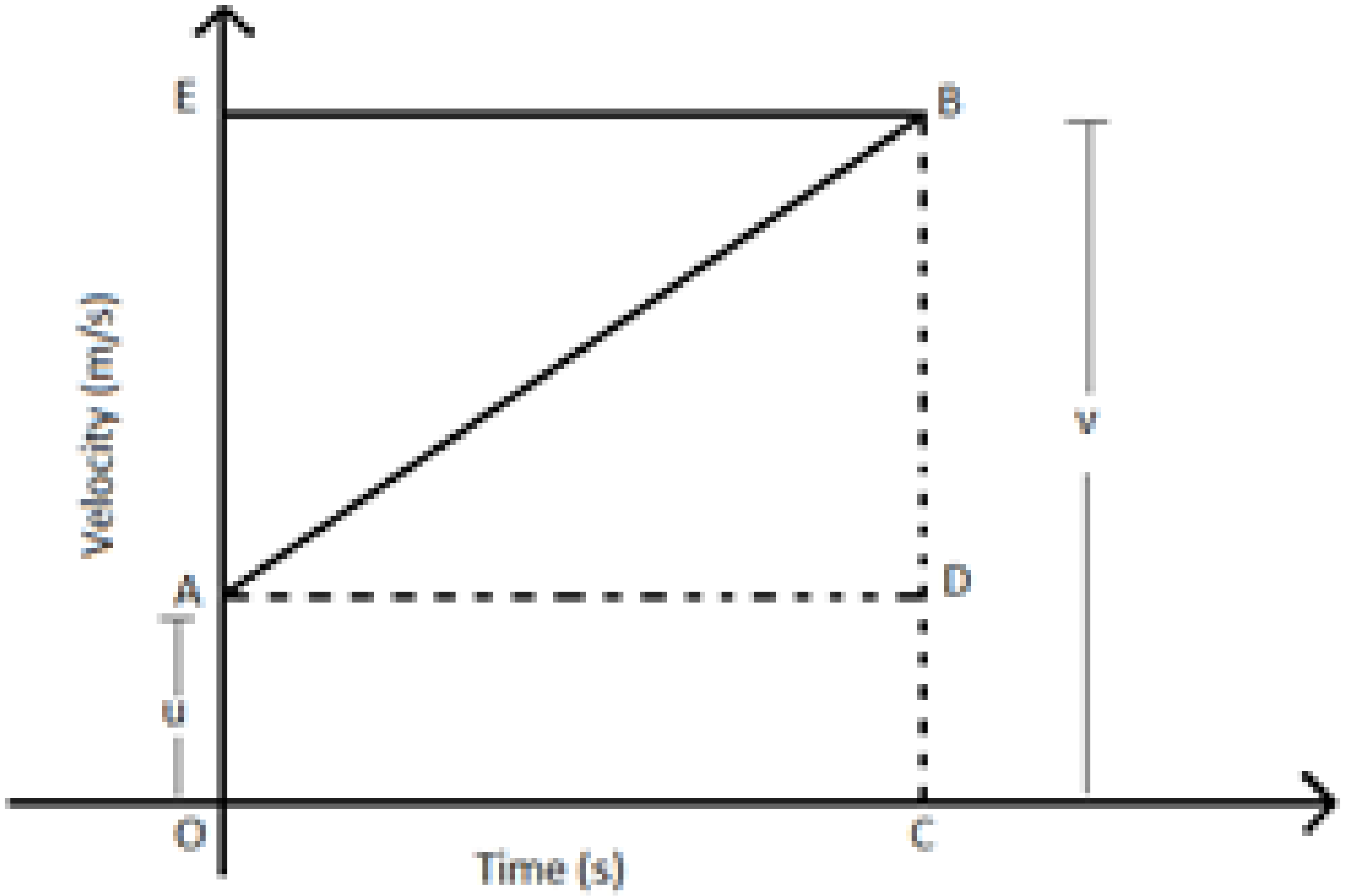
$BD = BC – DC$……………..(eq 2).

We know acceleration a = slope = BDAD or $AD = OC = t$ (time taken to reach point B).

Therefore $BD = at$…………………..(eq 3).

Substitute everything we get : $at = v – u$.

Rearrange to get $v = u + at$.


E
B
Velocity (m/s)
v
A
D
u
O
C
Time (s)

Derivation of position-time relation by graphical method

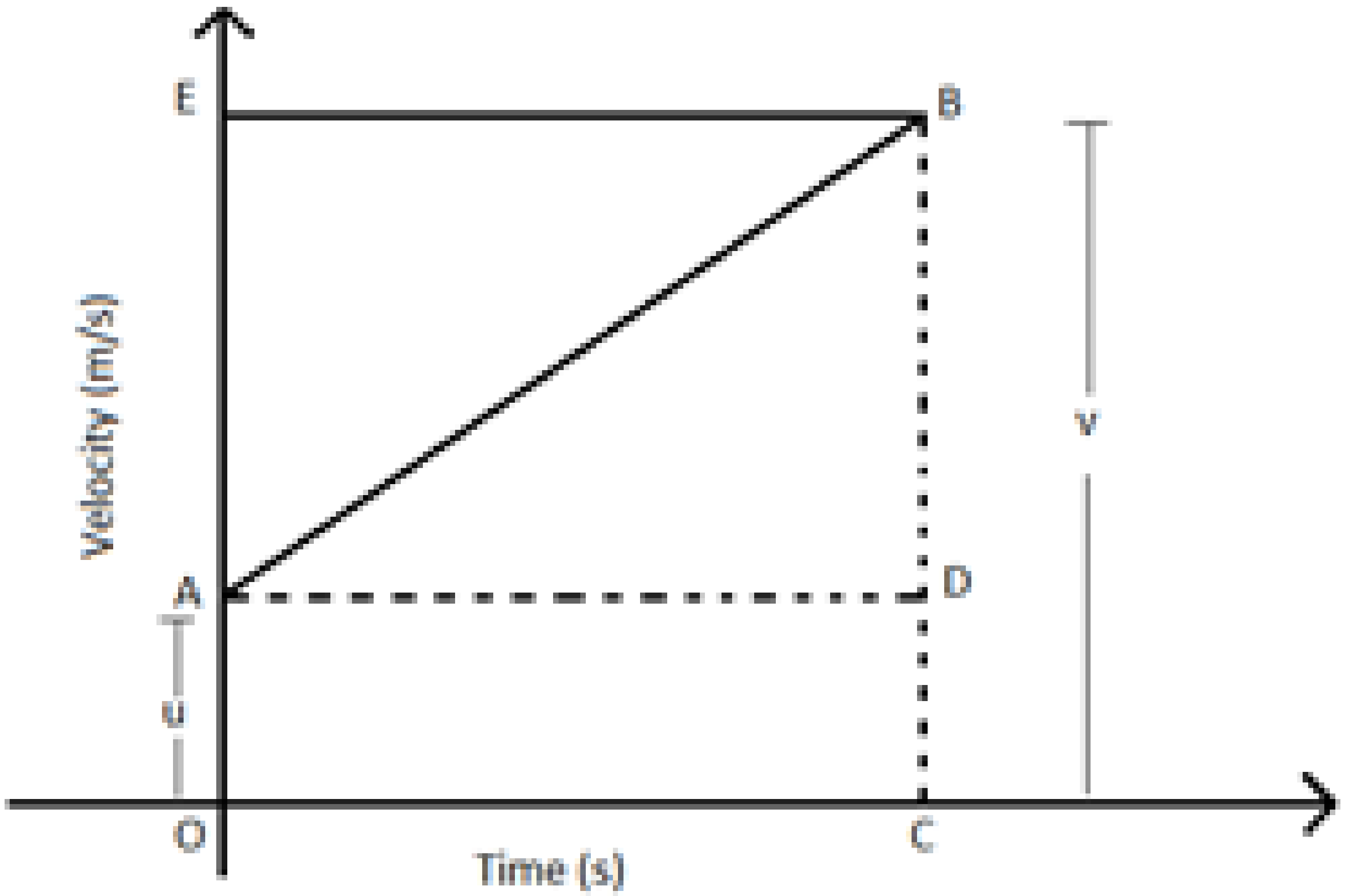
Velocity – Time Graph

A body starts with some initial non-zero velocity at A and goes to B with constant acceleration a

Area under the graph gives Displacement =A(ΔABD)+A(□OADC)=(12AD×BD)+OA×OC ……………(eq 1)

OA = u , OC = t and BD = at

Substituting in (eq 1) we get s= ut+12at2


E
B
Velocity (m/s)
v
A
D
u
O
C
Time (s)

Derivation of position-velocity relation by graphical method

Velocity – Time Graph
A body starts with some initial non-zero velocity at A and goes to B with constant acceleration a

Displacement covered will be the area under the curve which is the trapezium OABC.

We know the area of trapezium is s= (OA+BC)2∗OC

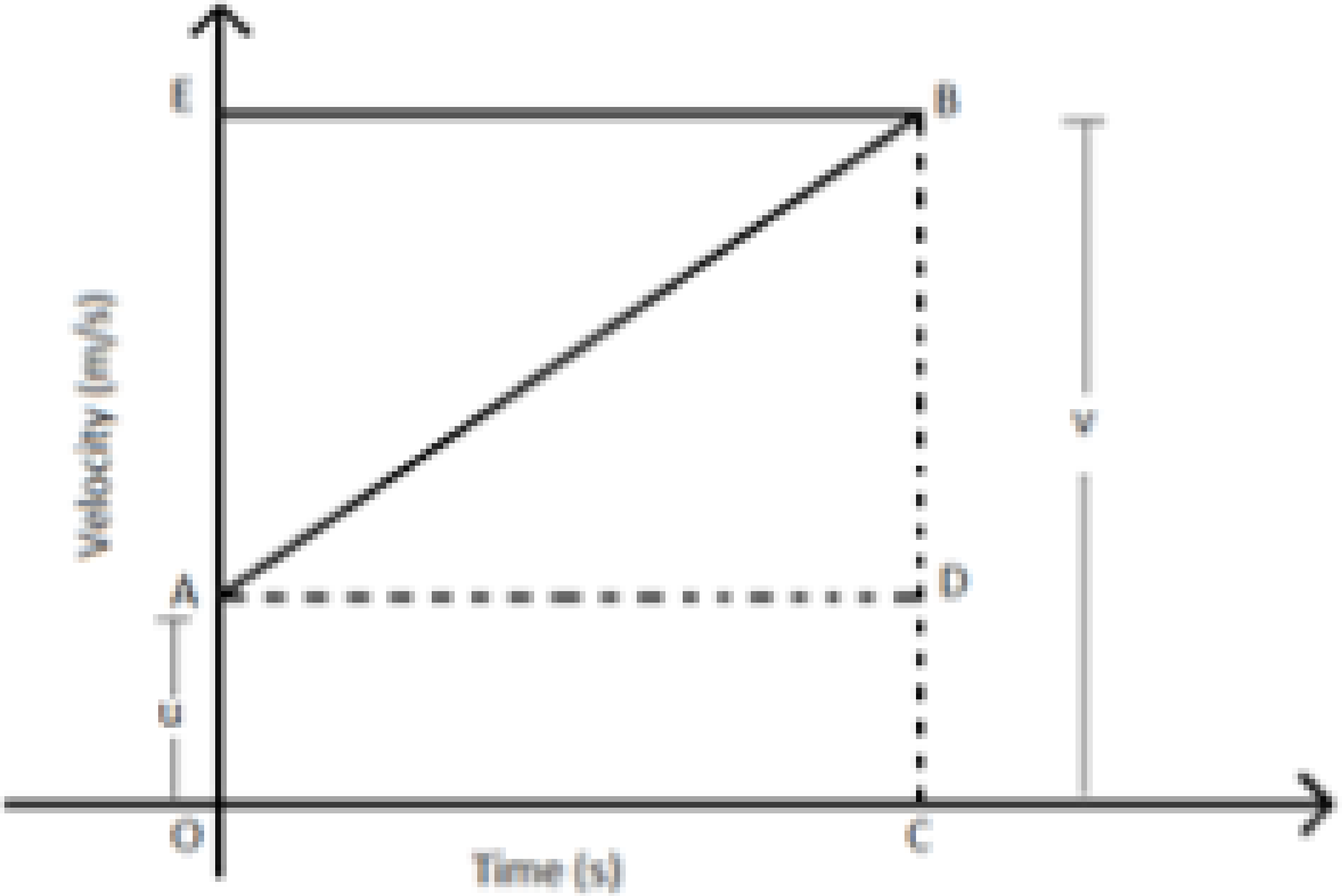
OA = u and BC = v and OC = t

Therefor, $s= (v+u)2*t$ ……………(eq 1)

We also know that $t =(v-u)a$ ……………..(eq 2)

Substitute (eq 2) in (eq 1) and arrange to get

$v2-u2=2as$



E
B
A
D
O
C
u
v
Velocity (m/s)
Time (s)

Uniform circular motion

- If an object moves in a circular path with uniform speed, its motion is called uniform circular motion.

- Velocity is changing as direction keeps changing.

- Acceleration is constant

What is Uniform Circular Motion?

- The movement of a body following a circular path is called a circular motion.

- The motion of a body moving with constant speed along a circular path is called Uniform Circular Motion.

- Here, the speed is constant but the velocity changes.

- If a particle is moving in a circle, it must have some acceleration acting towards the centre which is making it move around the centre.

- Since this acceleration is perpendicular to the velocity of a particle at every instant, it is only changing the direction of velocity and not magnitude and that’s why the motion is uniform circular motion.

- Call this acceleration centripetal acceleration (or radial acceleration), and the force acting towards the centre is called centripetal force.

- If the mass of the particle is m, we can say from the second law of motion that:

$F = ma$

$mv2r= m\omega 2r$

- This is not a special force, actually force like tension or friction may be a cause of origination of centripetal force.

- When the vehicles turn on the roads, it is the frictional force between tyres and ground that provides the required centripetal force for turning.

So if a particle is moving in a uniform circular motion:

1) Its speed is constant

2) Velocity is changing at every instant

3) There is no tangential acceleration

4) Radial (centripetal) acceleration = $\omega 2r$

5) $v=\omega r$

Uniform Circular Motion

- In the case of uniform circular motion, the acceleration is:

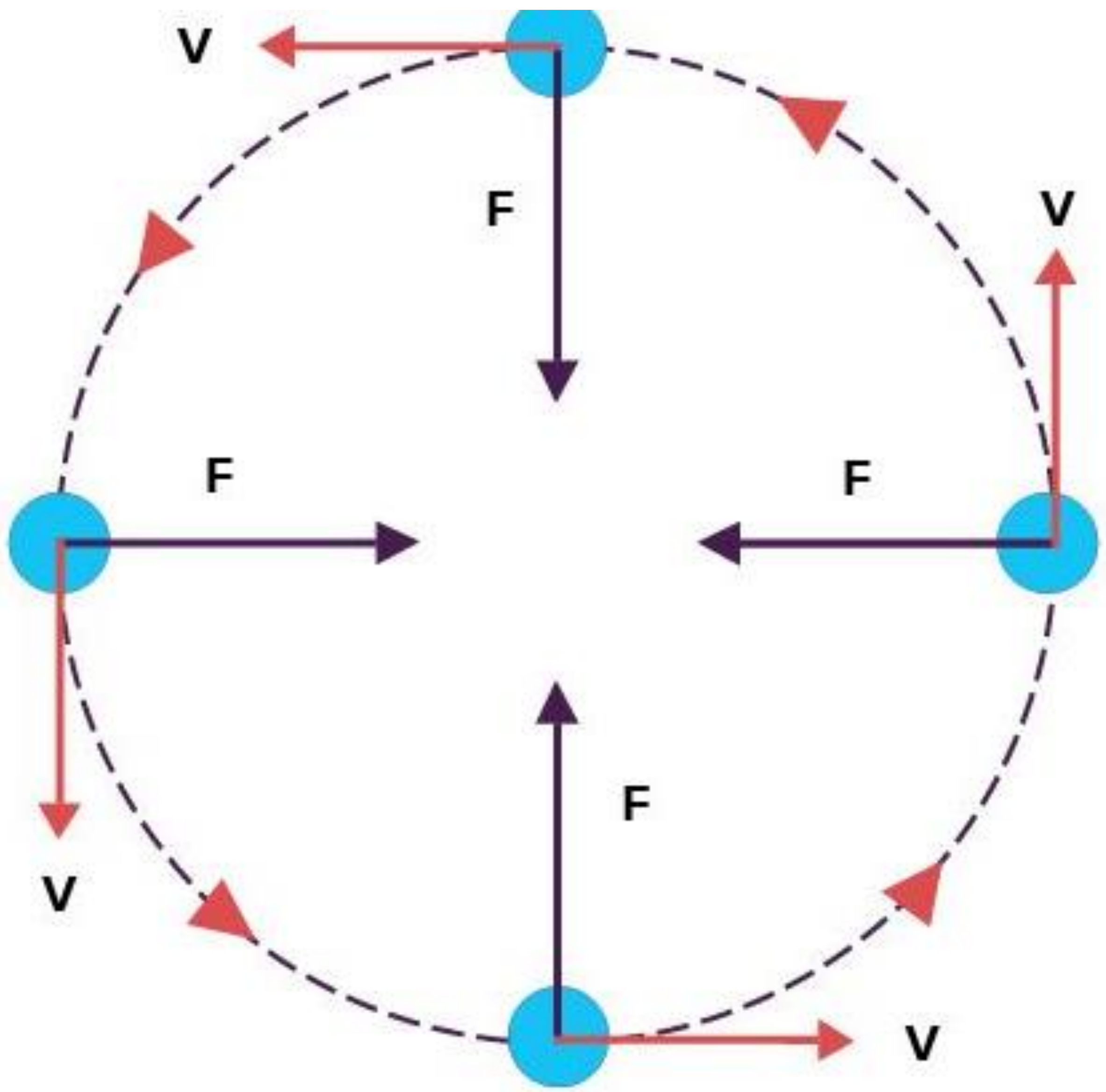
$ar = v2r = \omega 2r$

- In case of non-uniform circular motion, there is some tangential acceleration due to which the speed of the particle increases or decreases.
- The resultant acceleration is the vector sum of radial acceleration and tangential acceleration.

Motion Examples

Following are the examples of uniform circular motion:

- Motion of artificial satellites around the earth is an example of uniform circular motion.
- The gravitational force from the earth makes the satellites stay in the circular orbit around the earth.
- The motion of electrons around its nucleus.
- The motion of blades of the windmills.
- The tip of second’s hand of a watch with circular dial shows uniform circular motion.


V
F
V
F
F
V
F
V

THANKYOU….