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Chapter – 7th

Motion

Describing Motion

A body is said to be in motion (or moving) when its position changes continuously with respect to a stationary object taken as reference point .

Example

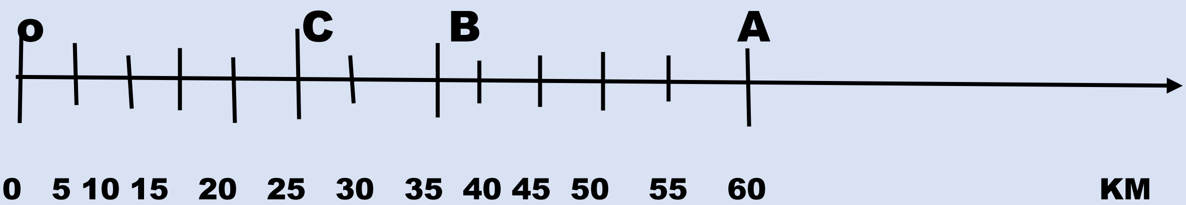
when the position of a car changes continuously with respect to stationary objects like houses and trees , etc. , we say that the car is moving or that the car is in motion

MOTION ALONG A STRAIGHT LINE

Consider the motion of an object moving along a straight path. The object starts its journey from O.

Let A, B and C represent the position of the object at different instants.

the object moves through C and B and reaches A. Then it moves back along the same path and reaches C through B.



The total path length covered by the object is

OA + AC

60 km + 35 km = 95 km.

Magnitude

The numerical value of a physical quantity is its magnitude

Displacement

The shortest distance measured from the initial to the final position of an object is known as the displacement.

Is magnitude of the displacement be equal to the distance travelled by an object?

For motion of the object from O to A, the distance covered is 60 km and the magnitude of displacement is also 60 km. During its motion from O to A and back to B, the distance covered = 60 km + 25 km = 85 km

while the magnitude of displacement = 35 km. Thus, the magnitude of displacement (35 km) is not equal to the path length (85 km).

UNIFORM MOTION AND NON-UNIFORM MOTION

The object covers equal distances in equal intervals of time, it is said to be in uniform motion.

The time interval in this motion should be small

Motions where objects cover unequal distances in equal intervals of time, is said to be non-uniform motion.

Measuring the Rate of Motion

One of the ways of measuring the rate of motion of an object is to find out the distance travelled by the object in unit time. This quantity is referred to as speed.

The SI unit of speed is metre per second. This is represented by the symbol $ms^{-}1$ or m/s.

To specify the speed of an object, we require only its magnitude. The speed of an object need not be constant.

In most cases, objects will be in non-uniform motion. Therefore, the rate of motion of such objects in terms of their average speed.

The average speed of an object is obtained by dividing the total distance travelled by the total time taken

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

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

$$V = \frac{S}{t}$$

SPEED WITH DIRECTION

The rate of motion of an object can be more comprehensive if we specify its direction of motion along with its speed.

The quantity that specifies both these aspects is called velocity.

Velocity is the speed of an object moving in a definite direction.

The velocity of an object can be uniform or variable. It can be changed by changing the object's speed, direction of motion or both.

When an object is moving along a straight line at a variable speed, we can express the magnitude of its rate of motion in terms of average velocity.

velocity of the object is changing at a uniform rate, then average velocity is given by the arithmetic mean of initial velocity and final velocity for a given period of time

average velocity $= \dfrac{\text{initialvelocity} + \text{final velocity}}{2}$

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

v_{av} **is the average velocity, u is the initial velocity and v is the final velocity of the object.**

Speed and velocity have the same units, that is,

m/s.

Acceleration

It is a measure of the change in the velocity of an object per unit time.

acceleration $= \dfrac{\text{change in velocity}}{\text{time taken}}$

If the velocity of an object changes from an initial value u to the final value v in time t, the acceleration a is α

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

This kind of motion is known as accelerated motion.

The acceleration is taken to be positive if it is in the direction of velocity and negative when it is opposite to the direction of velocity.

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

If an object travels in a straight line and its velocity increases or decreases by equal amounts in equal intervals of time, then the acceleration of the object is said to be uniform.

an object can travel with non-uniform acceleration if its velocity changes at a non-uniform rate.

Graphical Representation of Motion

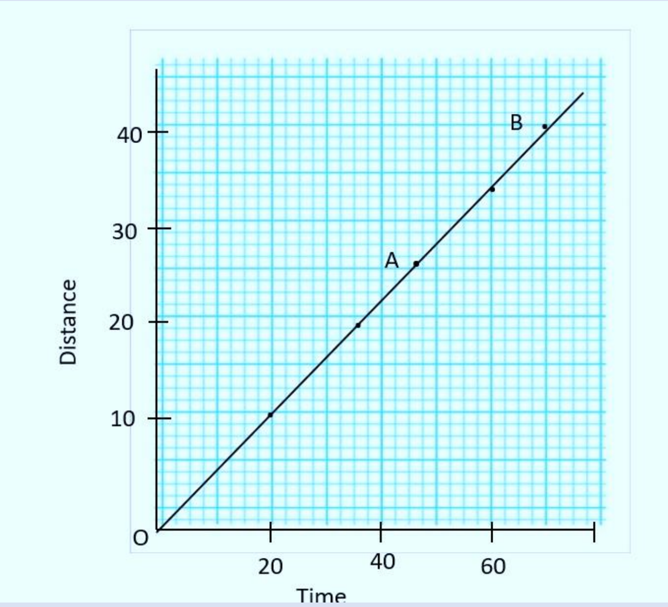
DISTANCE–TIME GRAPHS

The change in the position of an object with time can be represented on the distance-time.

In this graph, time is taken along the x–axis and distance is taken along the y-axis.

when an object travels equal distances in equal intervals of time, it moves with uniform speed. the distance travelled by the object is directly proportional to time taken. Thus, for uniform speed, a graph of distance travelled against time is a straight line.

We can also use the term uniform velocity in place of uniform speed if we take the magnitude of displacement equal to the distance travelled by the object along the y-axis



the distance-time graph to determine the speed of an object.

consider a small part AB of the distance-time graph .

Draw a line parallel to the x-axis from point A and another line parallel to the y-axis from point B. These two lines meet each other at point C to form a triangle ABC.

Now, on the graph, AC denotes the time interval

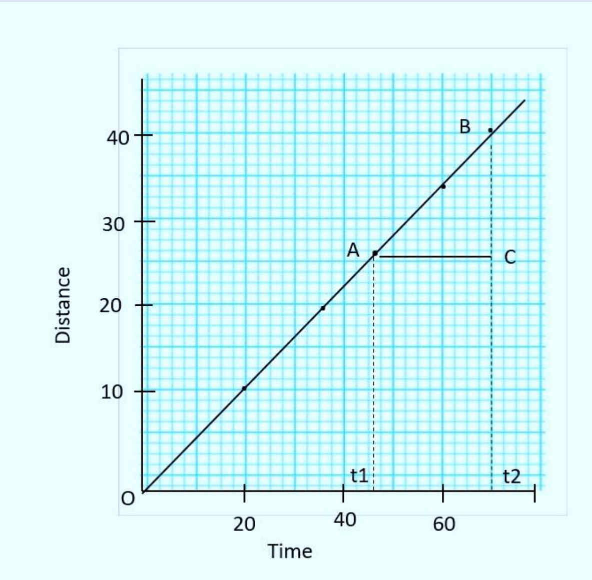
(t2 – t1) while BC corresponds to the distance

(s2 – s1).

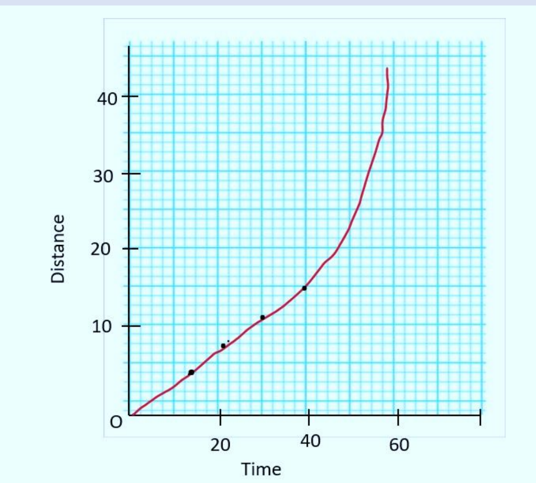
the graph that as the object moves from the point A to B,

it covers a distance (s2 – s1) in time (t2 – t1). The speed, v of the object, therefore can be represented as

$$v = \frac{s2 - s1}{t2 - t1}$$



Speed of the body is non uniform motion then the distance time graph is a curved line

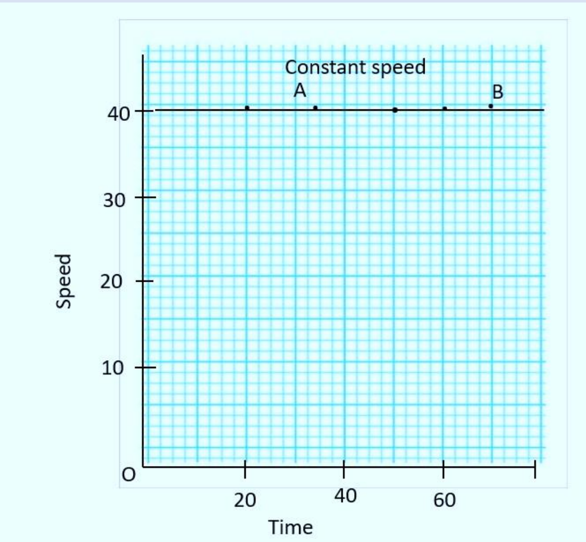


VELOCITY-TIME GRAPHS

The variation in velocity with time for an object moving in a straight line can be represented by a velocity-time graph.

In this graph, time is represented along the x-axis. and the velocity is represented along the y-axis.

If the object moves at uniform velocity, the height of its velocity-time graph will not change with time . It will be a straight line parallel to the x-axis.



If a speed time graph of a body is a straight line parallel to time axis then the speed of the body is constant.

Determine the distance moved by the body from its velocity-time graph. The area under the velocity-time graph gives the distance (magnitude of

displacement) moved by the body in a given interval of time.

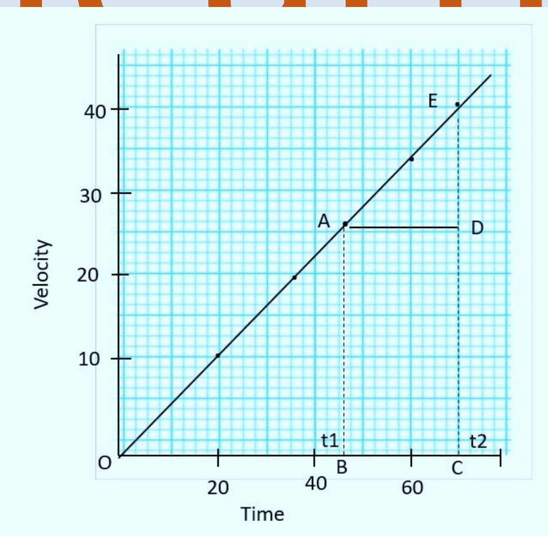
If the body would have been moving with uniform velocity, the distance travelled by it would be represented by the area ABCD under the graph .

Since the magnitude of the velocity of the body is changing due to acceleration, the distance s travelled by the body will be given by the area ABCDE under the velocity-time graph

s = area ABCDE

= area of the rectangle ABCD + area of the triangle ADE

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



In the case of non-uniformly accelerated motion, velocity-time graphs can have any shape.

Equations of Motion by Graphical Method

When an object moves along a straight line with uniform acceleration, it is possible to relate its velocity, acceleration during motion and the distance covered by it in a certain time interval by a set of equations known as the equations of motion

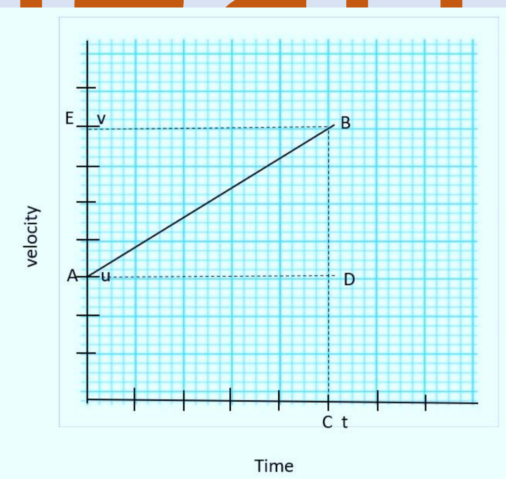
These are:

$v = u + at$

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

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

EQ UATION FOR VELOCITY-TIME RELATION



From this graph that initial velocity of the object is u (at point A) and then it increases to v (at point B) in time t.

The velocity changes at a uniform rate a.

the perpendicular lines BC and BE are drawn from point B on the time and the velocity axes

so that the initial velocity is represented by OA, the final velocity is represented by BC and the time interval t is represented by OC.

BD = BC – CD,

represents the change in velocity in time interval t.

draw AD parallel to OC.

BC = BD + DC = BD + OA

Substituting BC = v and OA = u,

we get v = BD + u

or BD = v – u 1

the acceleration of the object is given by

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

$$= \frac{BD}{AD} = \frac{BD}{OC}$$

Substituting OC = t,

$$\alpha = \frac{BD}{t}$$

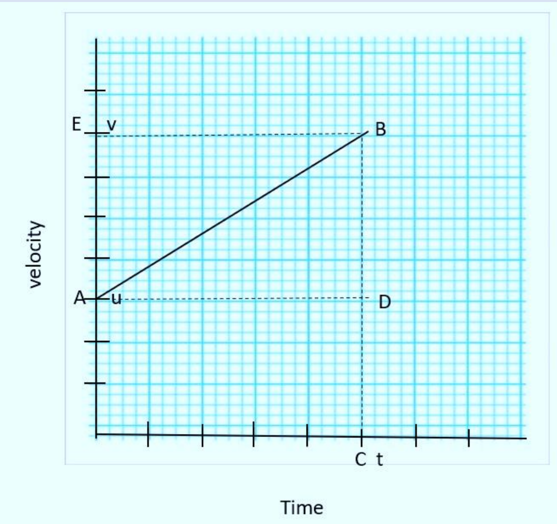
or BD =at 2

by eqs 1 & 2

v = u + αt

EQUATION FOR POSITION-TIME RELATION

consider that the object has travelled a distance s in time t under uniform acceleration a.



the distance travelled by the object is obtained by the area enclosed within OABC under the velocity-time graph AB.

the distance s travelled by the object is given by

s = area OABC (which is a trapezium)

= area of the rectangle OADC + area of the triangle ABD

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

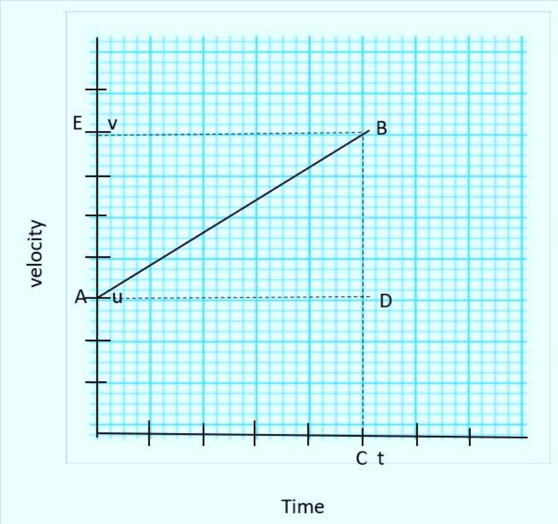
Substituting OA = u

OC = AD = t and BD = αt, we get

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

$\text{or } s = u\,t + \frac{1}{2}at^2$

<u>EQUATION FOR POSITION–VELOCITY RELATION</u>



the distance s travelled by the object in time t, moving under uniform acceleration a is given by the area enclosed within the trapezium OABC under the graph.

s = area of the trapezium OABC

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

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

$$S = \frac{u+vt}{2} \quad ....1$$

the velocity-time relation we get

$$t = \frac{v-u}{a} \quad ....2$$

frm eqs 1 & 2

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

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

Uniform Circular Motion

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

We know that the circumference of a circle of radius r is given by 2 r . If the body takes t seconds to go once around the circular path of radius r, the velocity v is given by

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