St. Andrews Scots Sr. Sec. School

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Session: 2026-27

Subject: Physics

Class: IX **Motion**

REFERENCE POINT

A **reference point** is a place or object used for comparison to determine if something is in motion or at rest.

REST

An object is said to be at **rest** if it is not changing its position w.r.t a reference point with the passage of time.

Example – A book lying on the table.

MOTION

An object is said to be in **motion** if it is changing its position w.r.t a reference point with the passage of time.

Example – A train moving on rails.

Motion can be of different types depending upon the type of path by which the object is going through :

(a) Circular Motion – In a circular path. E.g. Motion of the tip of the second hand of a clock.

(b) Linear Motion – In a straight line path. E.g. An athlete running on a 100 m track.

(c) Oscillatory Motion – To and fro motion. E.g. Motion of a pendulum.

SCALAR QUANTITY

The physical quantity which have only magnitude and no direction is called **scalar quantity** or **scalar**. A scalar quantity can be specified by a single number, along with the proper unit.
Example – Mass (50kg), Volume (21 m^3), Density (997kg/m^3 is the density of water), etc.

VECTOR QUANTITY

The physical quantity which have magnitude as well as direction both is called **vector quantity**.

DISTANCE

(1) The **distance** travelled by a body is the actual length of the path covered by a moving body irrespective of the direction in which the body travels.

(2) S.I. unit of distance is metre(m).

(3) For Example – The actual length of the path covered by the man is 5km + 3km = 8km, so the **distance** travelled by the man is 8km.

(4) It is a **scalar quantity (because it has magnitude only, it has no specified direction)**.

Imp. Note:-

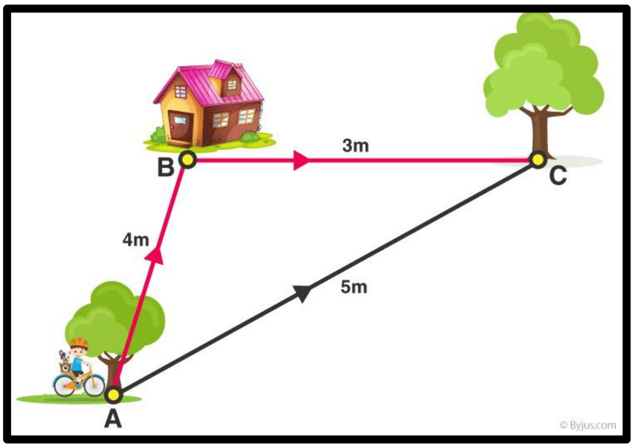
The distance travelled by a moving body cannot be zero.

DISPLACEMENT

(1) When a body moves from one position to another, the shortest (straight line) distance between the initial position and final position of the body, along with direction, is known as its **displacement**.

(2) S.I. unit of displacement is metre(m).

(3) For Example – The shortest distance between the initial position 'A' and final position 'C' is 5m, so the **displacement** is 5m in the east direction.



(4) It is a **vector quantity (because it has magnitude as well as a direction)**.

Imp. Note:-

Displacement can be **positive, negative or zero**.

UNIFORM MOTION

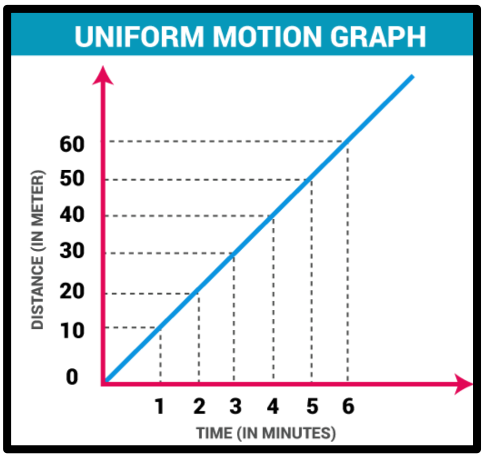
(1) A body has **uniform motion** if it travels equal distances in equal intervals of time.

(2) For Example -

a.) 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.

b.) Movement of blades of a ceiling fan.

(3) The distance-time graph for uniform motion is a **straight line**.



NON-UNIFORM MOTION

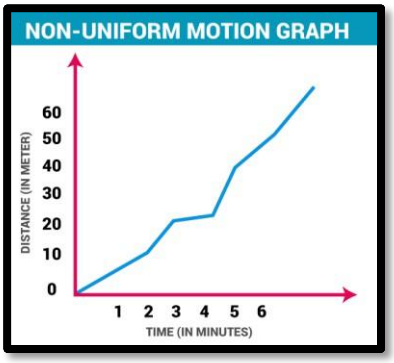
(1) A body has **non-uniform motion** if it travels unequal distances in equal intervals of time.

(2) For Example-

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

b.) The motion of a train.

(3) The distance-time graph for non-uniform motion is a **curved line**.



(4) Non-uniform motion is also known as **accelerated motion**.

SPEED

(1) **Speed** of a body is the distance travelled by it per unit time or the rate of change of position of a body with time in any direction is called its **speed**.

$$Speed = \frac{Distance\ travelled}{Time\ taken}$$

If a body travels a distance ‘s’ in time ‘t’, then its speed ‘v’ is given by:

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

Where, v = speed

s = distance travelled

t = time taken

(2) It is a **scalar quantity**.

(3) S.I. unit of speed is **m/s or ms^{-1}**.

(4) The speed of a running car at any instant of time is shown by an instrument called **speedometer** which is fixed in the car. The speedometer gives the speed in km/h.

The distance travelled by a car is measured by another instrument called **odometer** which is also installed in the car. It measures the distance in km.

AVERAGE SPEED

For a body moving with variable speed, the **average speed** is the total distance travelled by a body divided by the total time taken.

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

UNIFORM SPEED

A body has a **uniform speed** if it travels equal distances in equal intervals of time, no matter how small these time intervals may be.

For Example – A car is said to have uniform speed of 60km/h, if it is covering 60km in every hour.

VELOCITY

(1) **Velocity** of a body is the distance travelled by it per unit time in a given direction or the rate of change of position of a body with time in a given direction is called its **velocity**.

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

If a body travels a distance 's' in time 't' in a given direction, then its velocity 'v' is given by:

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

Where, v = velocity of body

s = displacement of the body

t = time taken

(2) It is a **vector quantity**.

(3) S.I. unit of velocity is **m/s or ms^{-1}**.

AVERAGE VELOCITY

For an object moving with variable velocity, **average velocity** is the total displacement divided by the total time taken in which that displacement occurs.

$$Average\ Velocity = \frac{Total\ displacement}{Total\ time\ taken}$$

Or,

If the velocity of a body is always changing, but changing at a uniform rate, then the average velocity is given by "arithmetic mean" of the initial velocity 'u' and final velocity 'v' for a given period of time, that is:

$$Average\ Velocity = \frac{Initial\ velocity + Final\ velocity}{2}$$

UNIFORM VELOCITY

A body is said to be moving with uniform velocity if it travels in a specified direction in a straight line and moves over equal distances in equal intervals of time.

The velocity of a body can be changed in two ways:

a) **by changing the speed of the body,** b) **by keeping the speed constant but by by changing the direction.**

So, if any one thing changes than the velocity is said to be **non-uniform velocity**.

For Example – Suppose a car is moving on a circular road with constant speed. Now, though the speed of the car is constant, its velocity is not constant because the direction of car is changing continuously. **(Non-uniform Velocity)**

ACCELERATION

(1) The rate of change of velocity of a body with time is called its **acceleration**.

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

Since, change in velocity = Final velocity – Initial velocity,

$$Acceleration = \frac{Final\ velocity - Initial\ velocity}{Time\ taken}$$

Suppose the initial velocity of a body is 'u' and it changes to a final velocity 'v' in time 't', then,

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

Where, a = acceleration of the body

v = final velocity of body

u = initial velocity of body

t = time taken for the change in velocity

(2) It is a **vector quantity**.

(3) S.I. unit of acceleration is **m/s^2 or ms^{-2}**.

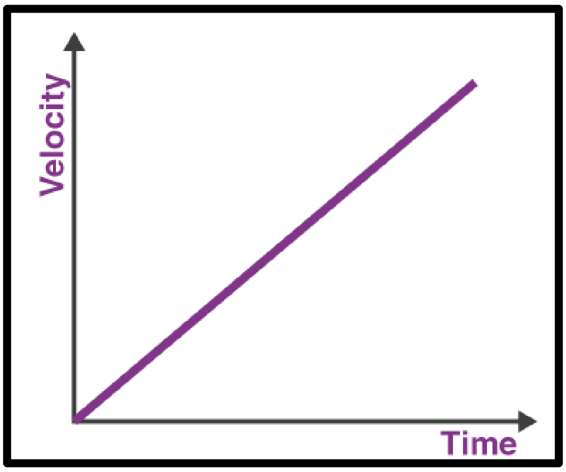
(4) When a body is moving with **uniform velocity**, its **acceleration** will be **zero**.

UNIFORM ACCELERATION

(1) The acceleration of a body is said to be in **uniform acceleration** if its velocity changes by equal amounts in equal intervals of time.

For Example – The motion of a ball rolling down an inclined plane is an example of uniformly accelerated motion.

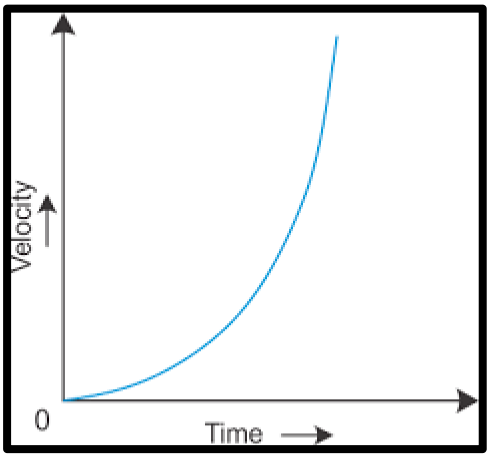
(2) The velocity-time graph of a body having uniformly accelerated motion is a **straight line**.



NON-UNIFORM ACCELERATION

(1) A body has a non-uniform acceleration if its velocity changes by an unequal amounts in equal intervals of time.

(2) The velocity-time graph of a body having non-uniform acceleration is a **curved line**.



RETARDATION

If the velocity of a body decreases with time , its acceleration is negative. Negative acceleration is also called **retardation or deceleration**.

For Example – Initial velocity = 10m/s

Final velocity = 0m/s

Time taken = 5m/s

So, $a = \frac{(0-10)}{5}$

a = -2m/s^2. Thus, the acceleration is -2m/s^2.

1.11. DERIVATION OF EQUATIONS OF MOTION BY GRAPHICAL METHOD

When a body is moving along a straight line with uniform acceleration, we can establish relation between velocity of the body, acceleration of the body and the distance travelled by the body in a particular time by a set of equations. These equations are called **equations of motion.** In all, there are three equations of motion represented as :

1. $v = u + at$ ...(1)
2. $s = ut + \frac{1}{2}at^2$ ...(2)
3. $v^2 - u^2 = 2\,as$ ...(3)

where u is initial velocity of the body (at $t = 0$) ; a is uniform acceleration of the body ; v is final velocity of the body after t second and s is the distance travelled in this time.

Equation (1) represents velocity-time relation, Equation (2) represents position-time relation, and Equation (3) represents position-velocity relation.

We can derive these three equations of motion by graphical method as detailed below :

1.12. EQUATION FOR VELOCITY-TIME RELATION

Suppose a body is moving along a straight line with a uniform acceleration a. Let u be the initial velocity of the body (at $t = 0$). The velocity-time graph of such a body is represented by a straight line AB, shown in Fig. 1.22. At $t = 0$, velocity $= OA = u =$ initial velocity. In going from A to B, the velocity of the body goes on increasing at a constant rate, a (= acceleration). At $t = OC$, velocity of body $= CB = v$.

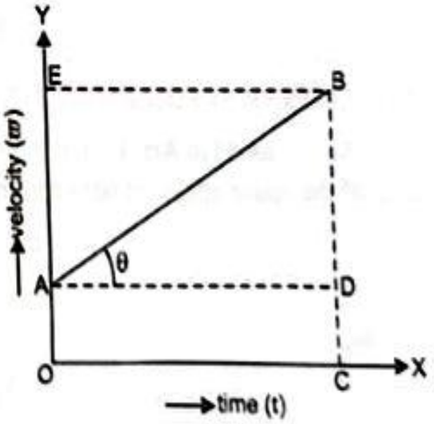


Fig. 1.22

Draw $AD \perp BC$ and $BE \perp OY$. Let $\angle BAD = \theta$

It is known that acceleration of the body = slope of velocity-time graph

i.e., $$a = \tan\theta = \frac{BD}{AD} \quad ...(4)$$

But $BD = BC - CD = BC - OA$ $(\because CD = OA)$

$= v - u$ = change in velocity

and $AD = OC = t$, the time

From eqn. (4), $a = \frac{v-u}{t}$ or $v - u = at$ or $v = u + at$

which is the required velocity-time relation.

1.13. EQUATION FOR POSITION-TIME RELATION

Suppose a body is moving along a straight line with a uniform acceleration a. Let u be the initial velocity of the body at $t = 0$. The velocity-time graph of such a body is represented by a straight line AB, shown in Fig. 1.22. Let s be the distance travelled by the body in time t, in going from A to B. As is known, the distance travelled in such a case is given by the area of the space enclosed between the velocity-time graph and the time axis, *i.e.*,

distance, s = area of figure $OABC$

= area of rectangle $OADC$ + area of ΔABD

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

$$= u \times t + \frac{1}{2}(BC - CD) \times OC$$

$$s = u \times t + \frac{1}{2}(BC - OA) \times OC$$

$$= ut + \frac{1}{2}(v-u)t \qquad ...(5)$$

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

Putting in eqn. (5), we get

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

$$s = ut + \frac{1}{2}at^2$$, which is the required position-time relation.

1.14. EQUATION FOR POSITION-VELOCITY RELATION

As discussed in Art. 1.13, the distance travelled by a uniformly accelerated body in time t is given by the area of the space enclosed between the velocity-time graph and the time axis. Therefore, from Fig. 1.22,

distance travelled, s = area of trapezium $OABC$

$$= \frac{\text{sum of parallel sides}}{2} \times \text{distance between parallel sides}$$

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

$$s = \frac{(u+v)}{2}t \qquad ...(6)$$

From $v = u + at$

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

Putting in eqn. (6), we get $s = \frac{(v+u)}{2}\frac{(v-u)}{a}$

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

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

which is the required equation for position-velocity relation.

Uniform Circular Motion (UCM) is a type of motion where an object moves in a **circle at a constant speed**. Even though the speed stays the same, the **velocity keeps changing** because its direction is always changing.

Distance

Distance is the **total path covered** by the object.

For one complete revolution:

$$Distance = 2\pi r$$

- r= radius of the circle

This is the circumference of the circle.

Displacement

Displacement is the **shortest straight-line distance** between initial and final positions.

After one complete revolution:

The object returns to the starting point.

$$Displacement = 0$$