9TH CBSE SCIENSE - MOTION

- 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.

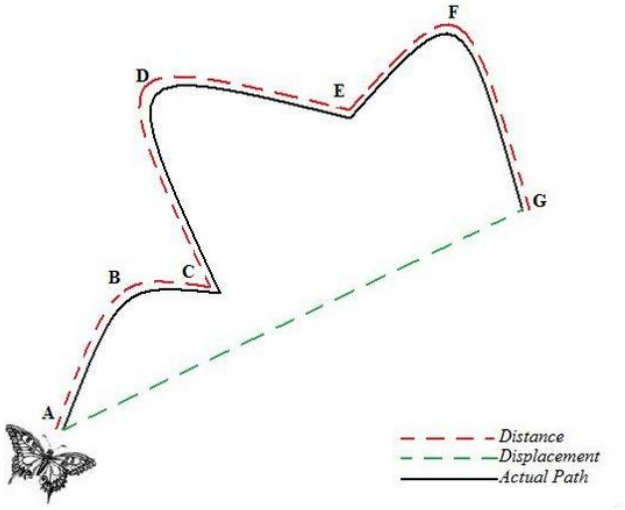
Rest and Motion

- If the position of an object does not change as time passes, then it is said to be at **rest**. If the position of an object changes as time passes, then it is said to be in**motion**.
- An object can be at rest with respect to one thing and in motion with respect to some other thing at the same time. So, the states of **rest and motion are relative**only.
- Tolocatethepositionofanobject,wehavetochoosesomesuitable**referencepoint**calledth e

  origin.

Distance and Displacement

- The **distance** travelled by an object is the length of the actual path traversed by the object during motion. It is a **scalar**quantity.
- The **displacement** of an object in motion is the shortest distance between the initial position and the final position of the object. It is a **vector**quantity.



- The distance travelled by an object in motion can never be zero ornegative.
- The displacement of an object can be positive, zero or negative. Never can the distance travelled be less than thedisplacement.
- Both distance and displacement have the sameunits.

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.

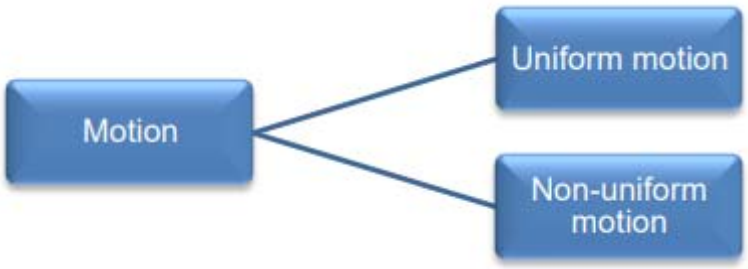
Time and speed

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

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

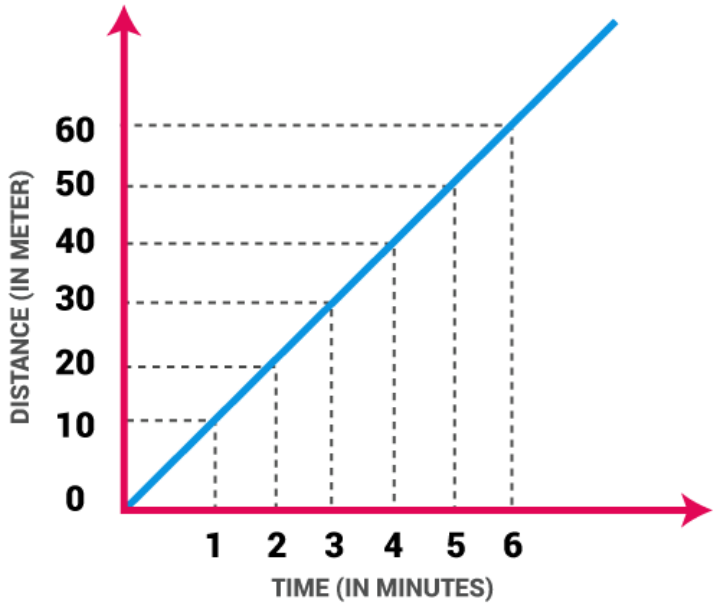
Uniform and Non-uniform Motion



- An object is said to be in **uniform motion** if it travels equal distances in equal intervals of time, howsoever small the intervals maybe.
- An object is said to have **non-uniform motion** if it travels unequal distances in equal intervals oftime.

Uniform Motion:

Definition: 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.



If a body is involved in rectilinear motion and the motion is consistent, then the acceleration of the body must be zero.

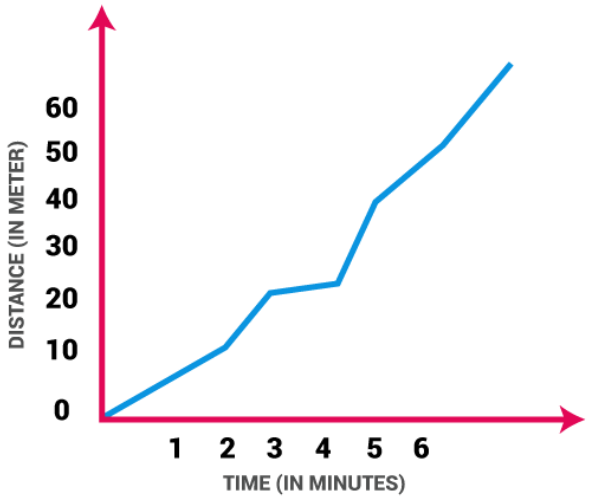
Example of Uniform Motion:

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:

Definition: 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.



Speed

Speedofabodyisdefinedasthedistancetravelledbythebodyinunittime.TheSIunitofspeedis

metre/second (m/s

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

- If ‘s’ is the distance travelled by a body in time ‘t’, then its speed ‘v’ ’ is given as v = s\t
- Speed of a body is a scalar quantity. It can be zero or positive but can never be negative.
- If a body covers equal distances in equal time intervals, howsoever small the intervals may be, then it is said to have uniform speed (or constant speed).
- If a body covers unequal distances in equal time intervals, however small the intervals may be, then it is said to have non-uniform speed (or variable speed).
- For bodies moving with non-uniform speed, we describe the rate of motion in terms of their average speed.

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

Velocity

- **Velocity** of a body is defined as the distance travelled by the body in unit time in a givendirection.
- The SI unit of velocity is the same as that of speed, i.e.metre/second(m/s).

$$\text{Velocity} = \frac{\text{Distance travelled in a given direction}}{\text{Time taken}}$$

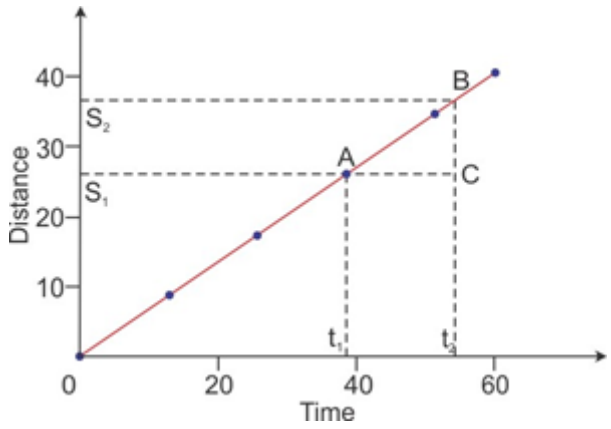
$$\text{or, Velocity} = \frac{\text{Displacement}}{\text{Time taken}}$$

$$\text{i.e. } \vec{v} = \frac{\vec{s}}{t}$$

where v is velocity and s is displacement of the body in time t.

- Velocity of a body is a **vector** quantity. It can be positive, negative orzero.
- A body is said to be moving with **uniform velocity** (or **constant velocity**) if it travels along a straight line, covering equal distances in equal intervals of time, howsoever small these intervals maybe.
- A body is said to be moving with **non-uniform velocity** (or **variable velocity**) if it covers unequal distances in a particular direction in equal intervals of time or if the direction of motion of the body changes.
- Whenthevelocityofabodyischangingatauniformrateoveraperiodoftime,the**average velocity**

  for that time period is given by the arithmetic mean of the initial and final velocity of the body.



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

or $$\vec{v}_{av} = \frac{u + v}{2}$$

where 'u' is initial velocity, 'v' is final velocity and $\vec{v}_{av}$ is average velocity.

Acceleration

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

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

where 'u' is initial velocity, 'v' is final velocity, 'a' is acceleration of the body and 't' is time taken for change in velocity.

- Acceleration is a **vector** quantity. It can be positive, negative or zero. The SI unit of acceleration is metre per second square(m/s^2).
- If the velocity of a body increases, then the acceleration is positive. If the velocity of a body decreases, then the acceleration is negative. **Negative acceleration** is called**retardation**.
- If acceleration occurs in the direction of velocity, then it is taken as positive and negative when it is opposite to the direction ofvelocity.
- A body is said to possess **uniform acceleration** if it travels in a straight line and its velocity increases or decreases by equal amounts in equal intervals oftime.
- A body is said to possess **non-uniform acceleration** if its velocity changes by unequal amounts in equal intervals oftime.

Distance–Time Graph

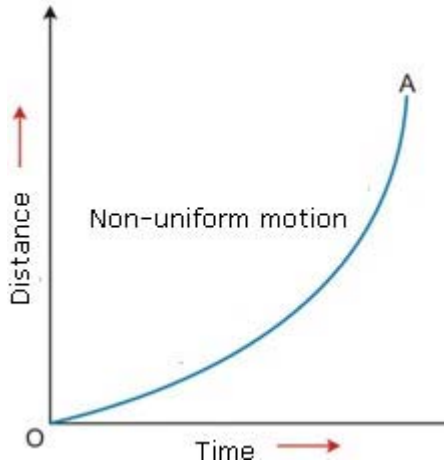
- Distance-Time graphs show the change in position of an object with respect to time.
- Linear variation = uniform motion and non-linear variations imply non- uniform motion
- The slope gives us speed
- The distance–time graph of a body moving with uniform speed is a straight line.
- Speed of a body can be obtained from the slope of the distance–time graph.
- Let s_1 and s_2 be the distance travelled by the object in time t_1 and t_2,

respectively. Here ($s_2 - s_1$) gives the distance travelled by the body in time interval ($t_2 - t_1$).

Speed

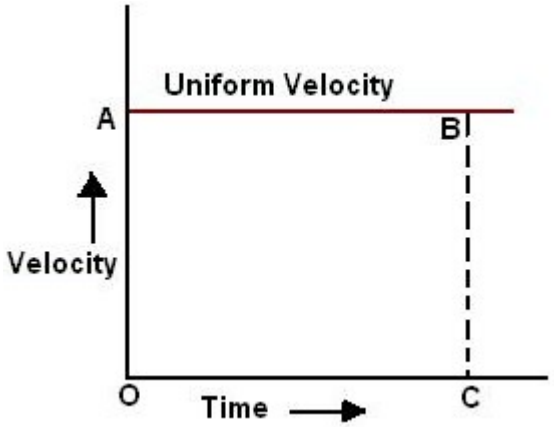
$$v = \frac{s_2 - s_1}{t_2 - t_1}$$

- The distance–time graph of a body moving with non-uniform speed is a curved line with a variable slope indicating variable speed.



Velocity–Time Graph

- The velocity–time graph of a body moving with uniform velocity is a straight line parallel to the time axis.



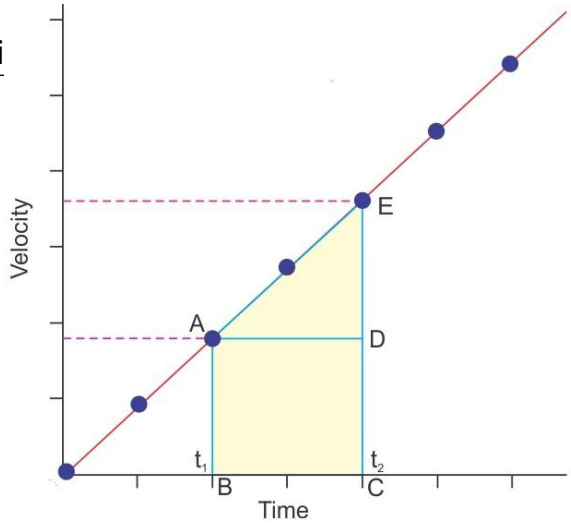
- The magnitude of displacement or distance travelled by the body is equal to the area enclosed by the velocity–time graph and time axis.

  Distance travelled = Speed × Time taken

  = OA × OC

  = Area of rectangle OABC

- The velocity–time graph of a body moving with uniform acceleration is a straight line inclined to the time axis.



- The slope of the velocity–time graph represents the acceleration of the body.

$$\text{Acceleration} = \frac{\text{Change in speed}}{\text{Time taken}} = \frac{ED}{AD}$$

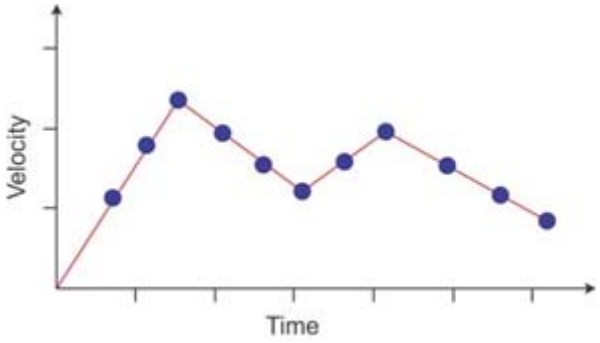
The area enclosed by the velocity–time graph and time axis gives the distance travelled by the body.

Distance travelled = Area of ABCDE

= Area of triangle ADE+ Area of rectangle ABCD

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

- The velocity–time graph of a body moving with non-uniform acceleration can have any shape, indicating variable speed.



Application Of Distance - Time Graph

What is a Distance-Time Graph

A distance-time graph shows how far an object has travelled in a given time. It is a simple line graph that denotes distance versus time findings on the graph.

Distance is plotted on the Y-axis.

Time is plotted on the X-axis.

Note: Curved lines on a distance-time graph indicate that the speed is changing.

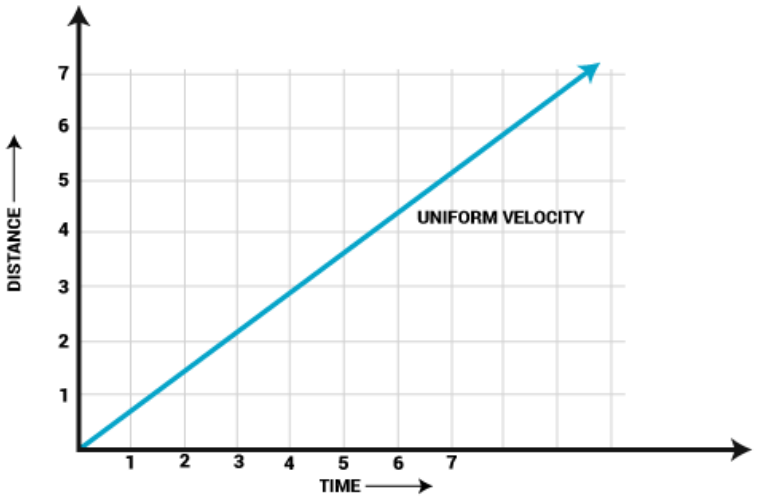
Importance of Distance-Time Graph

We deal with the distance-time graph while studying the motion of bodies. If we record distance and time for the motion of a body and plot the same data on a rectangular graph, we will obtain a distance-time graph corresponding to the motion of that body.

Example:

For better understanding, let us consider an example of uniform motion. A bus driver drives at a constant speed which is indicated by the speedometer and the driver measures the time taken by the bus for every kilometre. The driver notices that the bus travels 1 kilometre in every 2 minutes.

DISTANCE (IN KM)	1	2	3	4	5	6	7
TIME (IN MIN)	2	4	6	8	10	12	14

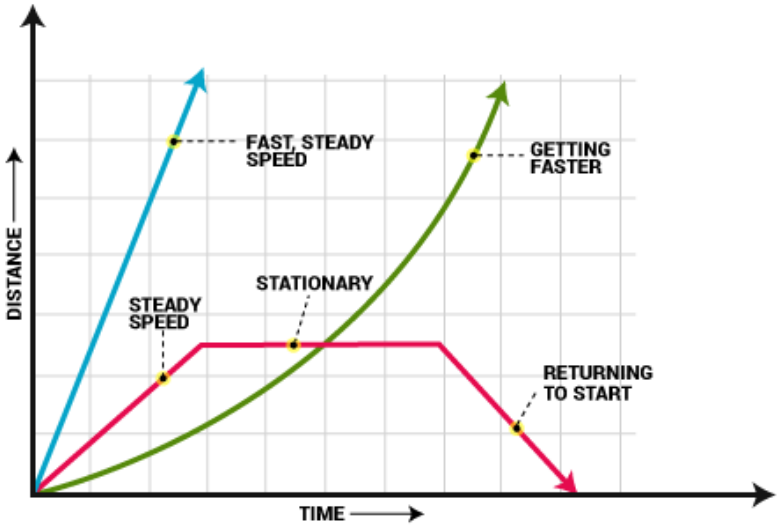


By this table, he had a clear idea about the speed which is: ½ × 60 = 30 km/hr.

The graph is a straight line and the motion of the bus is also uniform. Also, from the graph, we can find the speed of the bus at any instant of time. The initial and final position of the car can be found as the following:

Speed = (Final Position-Initial position)/Time

The slope of the line can be found by drawing a rectangle anywhere near the straight line which determines the speed of the bus. If an object is not moving, the distance-time graph results in a horizontal line which shows that the object is at rest.



The following things can be concluded now:

If the distance-time graph is a straight line then the motion is uniform.

If the distance-time graph of anybody is given, its speed can be calculated using the slope of the graph.

The slope of the straight-line graph is the same irrespective of the interval which is chosen. This implies that the speed of an object under uniform motion remains

constant.

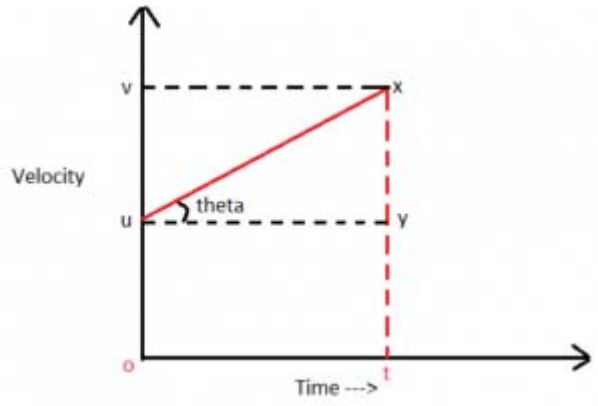
Equations of Motion

- The three equations of motion of a body moving along a straight line with uniform acceleration are

where ‘u’ is initial velocity of the body which moves with uniform acceleration ‘a’ for time t, ‘v’ is final velocity and ‘s’ is distance travelled by the body in time t.

Equation of motion

In this article, we will learn how we can relate quantities like velocity, time, acceleration and displacement provided the acceleration remains constant. These relations are collectively known as the equation of motion. There are three equations of motion. There are three ways to derive the equation of motion and here we are going to derive with the help of graph.



First Equation of Motion

First equation of motion relates velocity, time and acceleration. Now in Δuxy,

$\tan\theta = \frac{xy}{uy}$

$\tan\theta = \frac{v-u}{t}$

We also know that tanθ is nothing but the slope and slope of v – t graph represents acceleration.

⇒ v = u + at ———– (1)

This is the first equation of motion where,

v = final velocity

u = initial velocity

a = acceleration

t = time taken

Second Equation of Motion

Now coming to the second equation of motion, it relates displacement, velocity, acceleration and time. The area under v – t graph represents the displacement of the body.

In this case,

Displacement = Area of the trapezium (ouxt)

$S = \frac{1}{2}$

x sum of parallel sides x height

$S = \frac{1}{2}$

x (v + u) x t ———- (2)

We can substitute v in terms of others and get the final equation as:

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

Where symbols have their usual meaning.

Third Equation of Motion

The third equation of motion relates to velocity, displacement, and acceleration. Using the same equation (2),

$S = \frac{1}{2} x (v + u) x t$

Using equation (1) if we replace t we get,

$S = \frac{1}{2} \times (v + u) \times \frac{(v-u)}{a}$ $S = \frac{v^2-u^2}{2a}$ $u^2 = u^2 + 2as$

Uniform Circular Motion

- When a body moves along a circular path with a uniform speed, its motion is called uniform circular motion.
- Examples: Motion of the Moon around the Earth, a cyclist moving in a circular track at constant speed
- In uniform circular motion, although the speed remains constant, the direction of motion and velocity change continuously. Thus, uniform circular motion is an accelerated motion.
- The external force needed to make a body travel in a circular path is known as centripetal force.
- The circumference of a circle of radius 'r' is given by $2\pi r$. If a body takes 't' seconds to go once roundthe circular path of radius 'r', then its velocity 'v' is given by