#### CLASS: 9<sup>th</sup>

#### 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. For example, if a chair is placed in the middle of a room, then the walls of the room are its surroundings. If the position of the chair (i.e. its distances from the walls) does not change with respect to the walls as well as time, then the chair is at rest.

**Motion:** When the position of a body continuously changes with respect to time and its surroundings, the body is said to be in motion.

In other words, when the position of a body continuously changes with respect to the reference point and time (any stationary object around the body), the body is said to be in a state of motion.

#### Motion is a relative term:

When we say that a body or an object is in motion, then it is essential to see whether the body or object changes its position with respect to other bodies or objects around it or with respect to any fixed point known as reference point. For example, when a bus moves on a road, then the bus as well as the passengers sitting in it change their positions with respect to a person standing on the road side. However, the passengers sitting in the bus do not change their positions with respect to each other. It means, the passengers sitting in a moving bus are not in motion with respect to each other. We find that an object is in motion only if it changes its position (or mover) with respect to a fixed point or a fixed body. Therefore, a body air an object is in motion with respect to one thing but the same body or an object may not be in motion with respect to another thing. Thus, motion is a relative term.

- **Distance:** It is the actual length of the path traveled by a moving body irrespective of the direction in which the body moves.
- **Units of distance:** In S.I. system, unit of the distance is metre (m). However, for distance more than 1000m, we use a bigger unit called kilometer (km).
- **Displacement:** The shortest distance of a moving body from the point of reference (*initial position of body*), in a specified direction is called the displacement.

Units of displacement: It has the same units as the distance except that the direction is also specified.

# DIFFERENCES BETWEEN DISTANCE & DISPLACEMENT

	Distance		Displacement
1.	It is the actual length of the path traveled by a moving object.	1.	It is the shortest distance between the initial position (point of origin) and the final position of the object.
2.	The direction need not be specified.	2.	The direction has to be specified with respect to the reference line.
3.	<i>The distance covered in different directions can be added by simple arithmetic.</i>	3.	The displacements in different directions can not be added by simple arithmetic.
4.	<i>The distance covered by a moving object cannot be zero.</i>	4.	<i>The displacement of a moving object can be zero.</i>

#### **Scalar Quantities**

The physical quantities which are completely described by the magnitude only are called scalar quantities.

*Examples of scalar quantities:* Physical quantities such as mass, length, area, volume, distance, speed, work, energy, power, temperature, pressure, electric charge, electric potential etc. scalar quantities.

#### Characteristics of scalar quantities:

- (i). They can be completely described by magnitude alone.
- (ii). They can be added by simple arithmetic. For example, the total mass of 5 kg of sugar and 5 kg of salt is 10 kg.

#### CLASS: 9<sup>th</sup>

## MOTION

(iii). They cannot be plotted on a graph it is because they are not represented by any direction. Thus, we do not know whether they should be taken on X-axis or Y-axis.

#### **Vector Quantities**

The physical quantities which are completely described only if their magnitudes and directions are specified are called vector quantities.

*Examples of vector quantities:* Physical quantities such as displacement, velocity, acceleration, retardation momentum, force, moment of a force weight, electric intensity, magnetic intensity etc., are vector quantities.

#### Characteristics of vector quantities:

- (i). They can be completely described only by specifying the magnitude as well as direction.
- (ii). They cannot be added by simple arithmetic. For example, a displacement vector of 3 m towards east and 4 m towards north cannot be 7 m towards north of east. Instead it is 5 m at an angle of 53°, north of east.
- (iii). They can be represented on graph as their direction is specified.

#### **Graphical Representation of Vectors**

The representation of vectors by line diagram is called graphic Tail of vector representation of vectors.

A vector quantity is completely represented by a straight line with an arrow head, such that the length of the line represents the magnitude of the vector and the arrow head represents the direction of the vector.

The tip of the arrow head of the victor, represented by a straight line is called the head of the vector. The end point of the straight line representing of the vector, is called the tail of the vector.

# **UNIFORM MOTION**

When a body covers equal distances in equal intervals of time, however small may be time intervals, the body is said to describe uniform motion.

#### **Characteristics of uniform motion**

- (i) The moving body covers equal distances in equal intervals of time, however small the time intervals may be.
- (ii) The graph between the distance covered and the time, is a straight line.
- (iii) The motion is non-accelerated in nature.

# **NON – UNIFORM MOTION**

When a body covers unequal distances in equal intervals of time, it is said to be moving with a non-uniform motion.

#### Characteristics of non-uniform motion

- (i) The body does not cover equal distances in equal intervals of time.
- (ii) The graph line between distance and the time is always a curve.
- (iii) The motion is accelerated in nature.





#### CLASS: 9<sup>th</sup>

#### MADIIADN

Speed of an object is defined as the distance travelled by it per unit time.

#### Mathematical expression for speed:

If a body travels a distance S in time t, then

In time t, the distance traveled = S

In time 1 second, the distance traveled =  $\frac{S}{r}$ *.*•.

the distance traveled in unit time =  $\frac{S}{4}$ or,

But the distance traveled in unit time is called the speed.

Speed =  $\frac{S}{t}$  =  $\frac{\text{Distance covered by the body}}{\text{Time taken}}$ *.*..

#### Units of speed

In S.I system, the unit of speed is metre per second (m/s). For measuring larger speeds, the unit is kilometer per hour (*km/hr*). Speed is a scalar quantity. It is because it has the magnitude, but no direction.

#### **UNIFORM SPEED**

When a body covers equal distances in equal intervals of time, however small the intervals may be, the body is said to be moving with uniform speed.

#### VARIABLE SPEED OR NON-UNIFORM SPEED

When a body covers unequal distances in equal intervals of time, the body is said to be moving with variable speed or non-uniform Speed.

#### **AVERAGE SPEED**

The average distance covered by a moving body per unit time, when the body is moving with a variable speed, is called average speed.

#### Or

The quotient of the total distance traveled by a body divided by the total time taken by the body to cover the distance is called its average speed.

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

#### **VELOCITY**

The distance covered by a body per unit time in a specified direction is called the velocity.

#### Or

*The speed of a body in a specified direction is called the velocity. Thus, mathematically:* 

 $Velocity = \frac{Distance travelled in a specified direction}{Time taken to travel the distance}$ 

If 'v' is the velocity, 'S' the distance in a specified direction and 't' the time required to travel the distance, then

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

Units of Velocity

The units of velocity are the same as speed. Thus, in S.I. system its unit is m/s. However, a larger unit such as *km/hr* is also used.

## KINDS OF VELOCITY

#### (A) UNIFORM VELOCITY

When a body covers equal distances in equal intervals of time (however small the time intervals maybe) in a specified direction, the body is said to be moving with uniform velocity.

#### Conditions for uniform velocity

- The body must cover equal distances in equal intervals of time. (i).
- The direction of motion of the body should not change. (ii).

## (B) VARIABLE VELOCITY OR NON UNIFORM VELOCITY

When a body covers unequal distances in equal intervals of time in a specified directions or when a body covers equal distances in equal intervals of time, but its direction changes, then the body is said to be moving with variable velocity.

#### Differences between speed and velocity

_	Speed		Velocity
1.	The distance covered per unit time is called	1.	The distance covered per unit time in a
	speed.		specified direction is called velocity.
2.	It is a scalar quantity.	2.	It is a vector quantity.
3.	Average speed of a moving object cannot be zero.	3.	Average velocity of a moving object can be zero.
4.	Speed tells how fast an object moves.	4.	Velocity tells how fast an object moves and in
			which direction it moves.
5.	Speed is a scalar quantity.	5.	Velocity is a vector quantity.

## ACCELERATION

The rate of change of velocity of a moving body is called acceleration.

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

Acceleration is a vector quantity.

## **Expression for acceleration**

*Let the velocity of an object at time* 
$$(t = 0) = u$$
 (known as initial velocity)

And the velocity of an object at time (=t) = v (known as final velocity)

Then change in velocity of the object = v - u

*Time taken for this change in velocity* = t - 0 = t

Now, acceleration of the object =  $\frac{\text{Change in velocity}}{\text{Time}}$ 

Acceleration, a =

v - u

t

= Final velocity –Initial velocity Time taken

Therefore,

The rate of change of velocity of a moving body, when the velocity is INCREASING is called positive acceleration only and is denoted by 'a'.

## **Negative acceleration (Retardation)**

The rate of change of velocity of a moving body, when the velocity is DECREASING is called negative acceleration and is denoted by -a.

Negative acceleration is commonly referred to as retardation or de-acceleration or deceleration.

#### Units of acceleration

The unit of acceleration must have the unit of *length* and *square of time*. In S. I system, the unit of acceleration in  $m/s^2$ .

# **UNIFORM ACCELERATION**

When a body undergoes equal changes in velocity in equal intervals of time (however small the time intervals may be), the body is said to be moving with uniform acceleration.

Example:- i) The motion of an object falling freely form the top of a building.

ii) The motion of a ball rolling down a smooth inclined plane.

# NON-UNIFORM ACCELERATION OR VARIABLE ACCELERATION

When a body describes unequal changes in velocity in equal intervals of time, the body is said to be moving with non-uniform acceleration.

A body moving with a variable velocity has non-uniform acceleration. For example, a car moving on a busy road has a non-uniform acceleration.

Example:- i) The motion of a bus leaving or entering the bus stop.

ii) The motion of a train leaving or entering the platform.

## **DISTANCE-TIME GRAPHS**

Distance-time graph shows how the distance of a body from a fixed point changes with time. To draw distancetime graph, distance travelled by the body is plotted along Y-0axis and the time taken by the body to travel this distance is plotted along X-axis.

# DISTANCE-TIME GRAPHS FOR A STATIONARY BODY

The distance of a stationary body from a fixed point does not change with the passage of time. It means, if the distance of a stationary body from a fixed point (say O) is 4 m at time t = 0, then the distance of this body will remain 4 m for all times.

Distance-time graph for a stationary body is a straight line (AB) parallel to time-axis.

## DISTANCE-TIME GRAPHS FOR UNIFORM MOTION

If a body travels equal distances in equal intervals of time, then the motion of the body is known as uniform motion.



Distance-time graph for (index) uniform motion of a body is a straight line having max (motion angle with the time-axis or constant gradient or slope.

#### CALCULATION OF THE SPEED OF A BODY

The speed of a body having uniform motion is constant throughout the motion.

We know, Speed =  $\frac{\text{Distance travelled}}{\text{Time taken to travel this distance}}$ 

To calculate the speed of the body from a distance-time graph, choose any two points say A and B on the straight line. From points A and B, draw perpendiculars AE and BC respectively on time axis. Now draw a perpendicular AD on BC.

The distance travelled by the body in going from point A to B

$$= \Delta \mathbf{x} = \mathbf{B}\mathbf{C} - \mathbf{C}\mathbf{D}$$
$$= \mathbf{S}_2 - \mathbf{S}_1$$

Time taken by the body to cover this distance =  $\Delta t$ 

Therefore, Speed =  $t_2 - t_1$ 

Hence = Slope of distance-time graph.

Therefore speed of a body = Slope of distance-time graph.

# DISTANCE-TIME GRAPHS FOR NON-UNIFORM MOTION

If a body travels unequal distances in equal intervals of time, then the motion of the body is known as nonuniform motion.

Non-uniform motion of a body is of two types:

1. When the speed of the body increases with passage of time: For example, when a train leaves the platform, its speed increases with passage of time. That is, the train covers more and more distance in unit time.

Distance-time graph for the non-uniform motion of a body is a curve having increasing slope of gradient.

2. When the speed of the body decreases with passage of time: For example, when a train approaches the platform, its speed decreases with the passage of time. That is, the train covers less and less distance in unit time.

Distance-time graph for the decreasing non-uniform motion of a body is a curve having decreasing slope. That is, the speed of the body decreases with passage of time.



## **VELOCITY-TIME GRAPHS**

In these graphs, the velocity is plotted on Y-axis and time on X-axis. The slope of the velocity-time graph gives acceleration. It is because:

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

Time

The acceleration will be positive if the slope of the graph is positive and negative if the slope of the graph is negative.

The area enclosed under the velocity-time curve, gives displacement of the body. It is because:

Area enclosed under the graph = Velocity × Time = Displacement

(a) When velocity-time graph is parallel to the time axis.

*Velocity – time graph parallel to time axis.* 

Velocity - time graph is a straight line, not parallel to any axis.

As the graph is a straight line, therefore its *Slope is zero*. Hence, its *acceleration is zero*. The distance covered by the body in a specified direction, i.e., displacement can be calculated by calculating the area of rectangle PQRS.

Thus,

Displacement = Area of rectangle PQRS =  $PS \times SR$ 

#### (b) When velocity-time graph is a straight line, but not parallel to any axis.

The velocity-time graph CA for a body, such that starting from rest, its velocity increasing at a uniform rate. The acceleration of the body can be calculated by finding the slope of the graph line CA. The acceleration of the body can be calculated by calculating the slope of the graph line CA.

#### (c) When velocity-time graph is a curve.

The velocity in this graph is variable and so is acceleration.

The acceleration at any point can be calculated from the slope of the curve at that point.

The distance covered (displacement) can be calculated by finding the area under the velocity-time curve.

# Conclusions which can be drawn from the velocity – time graphs

*Velocity – time graph is a curve.* 

- 1. When the velocity-time graph line is parallel to the time axis.
  - (a) The body is moving with a uniform velocity.
  - (b) The acceleration of the body is zero.
  - (c) The displacement can be calculated from the area under the graph line.
- 2. When the velocity-time graph is a straight line, but not parallel to any axis.
  - (a) The body is moving with a variable velocity.
  - (b) The body has a uniform acceleration. The acceleration can be calculated from the slope of the graph.
  - (c) The displacement can be calculated from the area under the graph line.
  - (d) If the slope of the graph is positive, then the body has a positive acceleration. However, if the slope is negative, then a body has a negative acceleration or retardation.
- 3. When the velocity-time graph is a curve.
  - (a) The body has a variable velocity and a variable acceleration.
  - (b) The area under the curve represents the displacement.
  - (c) The acceleration at any instant can be calculated by finding the slope of the curve at that point.

## **TO PROVE GRAPHICALLY**

(i)

- (i) v = u + at
- (*ii*)  $S = ut + \frac{1}{2}at^2$
- $(iii) \qquad V^2 u^2 = 2as$

To prove

*Fig.* (*j*) Represents a velocity-time graph BC, in which AB represents the initial velocity u, CE represents the final velocity v, such that the change in velocity is represented by CD, which takes place in time t, represented by AE.

We know, Acceleration = Slope of the graph line BC  $=\frac{CD}{BD}=\frac{CE-DE}{BD}$  $a = \frac{v - u}{t} \begin{bmatrix} \therefore DE = AB = u \\ \because BD = AE = t \end{bmatrix}$ or v - u = atorv = u + ator**To prove**  $S = ut + \frac{1}{2}at^2$ (ii) Distance traveled = Area of trapezium ABCE  $S = \frac{1}{2}(AB + CE)xAE$  $S = \frac{1}{2}(AB + CE)xAE$  $S = \frac{1}{2}(u+u+at)xt$  $\{:: v = u + at\}$  $S = \frac{1}{2}(2u + at)xt$ 

v = u + at

Figure (j)

 $S = \left(u + \frac{at}{2}\right)xt$ 

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

To prove  $V^2 - u^2 = 2as$ 

#### **CIRCULAR MOTION**

(iii)

The motion of a body around a circular path with a uniform speed is called circular motion.

The direction of motion keeps changing in uniform circular motion.

If the radius of the circular path is r, then in one round the distance travellved by a body is equal to the circumference of the circle. It't' is the time taken for completing one round and if 'v' is the constant speed with which the body is moving, then

V =

## **Examples of circular motion**

1. A stone tied to a thread and whirled in a circular path.

- 2. Wheels of various vehicles rotating about their axles.
- 3. A satellite moving around the Earth in a circular path, at constant speed.
- 4. The Moon revolving around the Earth in a circular path at constant speed.

\*\*\*