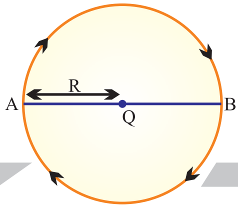


Chapter - 7

Motion

CONCEPT MAPPING

Physical State

- **Rest** (No change in position)
- **Motion** (change in position)
  - **Uniform Motion** → Equal distance travelled in equal time intervals.
  - **Non-uniform Motion** → Unequal distance travelled in equal time intervals.
    - **Accelerated Motion** → Increase in motion with time
      - Uniformly Accelerated Motion
      - Non Uniformly Accelerated Motion
    - **Deaccelerated Motion** → Decrease in motion with time
      - Uniformly Deaccelerated Motion
      - Non Uniformly Deaccelerated Motion
  - **Linear** → Straight line path
    - **Distance** → Actual path travelled by a body
      - **Speed** → Distance travelled in a unit time. Unit m/s It is **Scalar** (only Magnitude) quantity
    - **Displacement** → Shortest distance between Initial and final position
      - **Velocity** → Displacement traveled in a unit time. Unit - m/s It is **vector** (both magnitude and direction) quantity.
  - **Circulatory Motion** → Circulatory path
  - **Oscillatory Motion** (To and fro motion)

Equations of Motion

- $v = u + at$ → First Equation
- $S = ut + \frac{1}{2}at^2$ → Second Equation
- $v^2 = u^2 + 2as$ → Third Equation

Where :
v = Final velocity
u = Initial velocity
a = Acceleration
t = Time taken
s = Distance covered

Rest : A body is said to be in a state of rest when its position does not change with respect to a reference point.

Motion : A body is said to be in a state of motion when its position changes continuously with respect to a reference point.

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

(i) Circulatory motion/Circular motion – In a circular path.
(ii) Linear motion – In a straight line path.
(iii) Oscillatory/Vibratory motion – To and fro path with respect to origin.

Physical quantity:– There are seven basic physical quantity. Every quantity is written in two parts : first write the magnitude of the physical quantity and then write the unit of the quantity, i.e., magnitude per Unit

Physical Quantities :

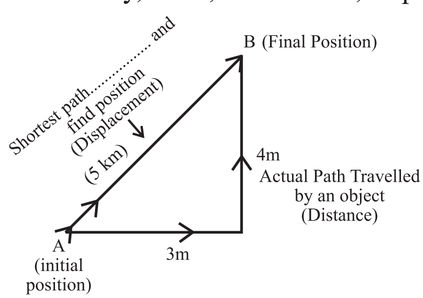
Quantity Name	SI Unit	
	Name	Symbol
Length	Metre	m
Time	Second	s
Mass	Kilogram	Kg
Absolute Temperature	Kelvin	K
Amount of Substance	Mole	mol
Electric Current	Ampere	A
Luminous Intensity	Candela	cd

Physical Quantities can be grouped into two :

i) Scalar quantities ii) Vector quantities

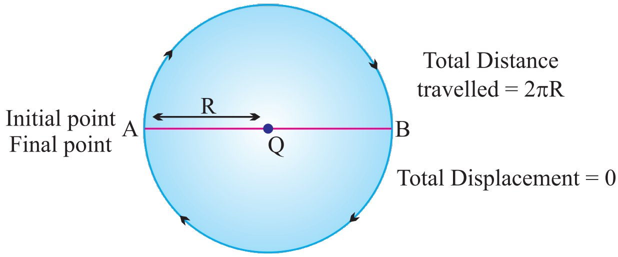
i) **Scalar quantities :** Those Physical quantities that has only magnitude but no direction. i.e. speed, distance, mass, volume, time, temperature, work, electric current.

ii) **Vector quantities :** Those physical quantities that has both magnitude as well as direction. i.e. velocity, force, momentum, displacement, acceleration etc.



- The actual path or length travelled by an object during its journey from its initial position to its final position is called the distance. It is denoted by 'd'
- Distance is a scalar quantity which requires only magnitude but no direction to explain it.
  Example, Ramesh travelled 65 km. (Distance is measured by odometer in vehicles.)
- The actual distance (covered by an object) in between its initial and final position is called displacement. It is denoted by S.
- Displacement is a vector quantity requiring both magnitude and direction for its explanation.
  Example, Ramesh travelled 65 km south-west from Clock Tower.

- Displacement can be zero (when initial point and final point of motion are same) ***Example,*** circular motion.



- Distance and displacement are denoted by 'S'.

Difference between Distance and Displacement

Distance	Displacement
1. Length of actual path travelled by an object.	1. Shortest length between initial point and far point of a distance travelled by an object.
2. It is scalar quantity. - It includes only magnitude	2. It is vector quantity. - It includes both magnitude and direction.
3. It remains positive, can't be '0' or negative.	3. It can be positive (+ve), negative (-ve) or zero.
4. Distance can be equal to displacement (in linear path).	4. Displacement can be equal to distance in linear path or it is lesser than distance.

Example 1. *A body travels in a semicircular path of radius 10 m starting its motion from point 'A' to point 'B'. Calculate the distance and displacement.*

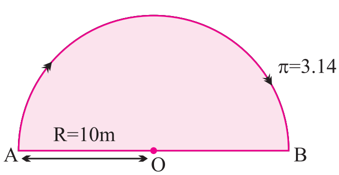
Solution : Total distance travelled by body, S = ?

Given, $\pi = 3.14, R = 10\text{ m}$

$S = \pi R$

$S = 3.14 \times 10\text{m}$

$= 31.4\text{m}$



Total displacement of body, S = ?

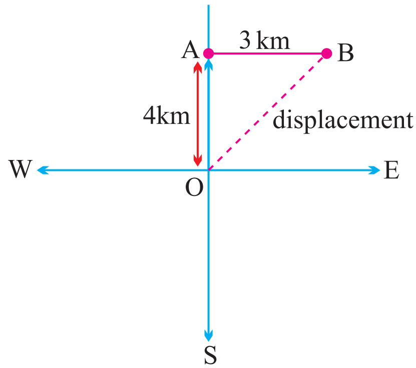
Given, $R = 10\text{ m}$

$S = 2 \times R$

$= 2 \times 10\text{ m} = 20\text{ m}$

Example 2. *A body travels 4 km towards North. There it turn to its right and travels another 3 km before coming to rest. Calculate (i) total distance travelled, (ii) total displacement.*

Solution :



Total distance travelled $= OA + AB$

$= 4\text{ km} + 3\text{ km}$

$= 7\text{ km}$ **Ans.**

Total displacement $= OB$

$$OB = \sqrt{OA^2 + AB^2}$$

$$= \sqrt{(4)^2 + (3)^2}$$

$$= \sqrt{16 + 9}$$

$$= \sqrt{25}$$

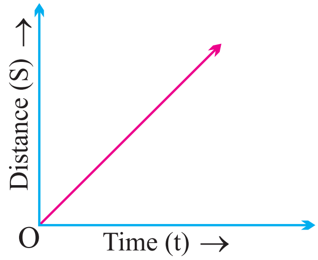
$= 5\text{ km}$ **Ans**

Uniform and Non-uniform Motions :

- ***Uniform Motion :***

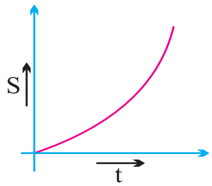
  When a body travels equal distance in equal interval of time, then the motion is said to be uniform motion.

eg. movements of hands of a clock, rotation and revolution of the earth.

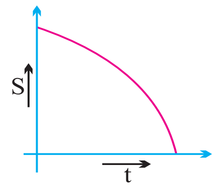


- **Non-uniform Motion :**

In this type of motion, the body will travel unequal distances in equal intervals of time. eg. motion of a car on a busy road.



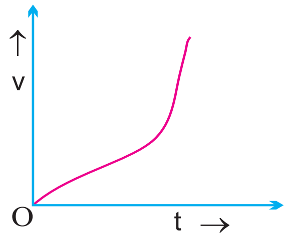
Continuous increase in slope of curve indicates accelerated non-uniform motion.



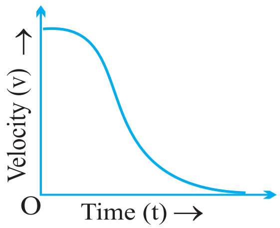
Continuous decrease in slope of curve indicates decelerate non-uniform motion.

Non-uniform motion is of two types :

(i) ***Accelerated Motion :*** When motion of a body increases with unequal *interval of time.*



(ii) ***De-accelerated Motion or Non uniform Retardation :*** When motion of a body decreases with unequal interval of time.



Continuous decrease in slope of curve indicates deaccelerated non-uniform motion.

Speed : The measurement of distance travelled by a body per unit time is called speed. It is denoted by v.

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

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

- SI unit = m/s (meter/second)
- If a body is travelling with uniform motion, then there will be a constant speed throughout the motion.
- Average speed will describe one single value of speed throughout the motion of the body.

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

- If a body is travelling with non-uniform motion, then the speed will not be constant and have different values throughout the motion.
- It is necessary to write the unit of every quantity in the answer of numerical questions :

Example : *What will be the speed of body in m/s and km/hr if it travels 40 kms in 5 hrs ?*

Solution : Distance (s) = 40 km

Time (t) = 5 hrs.

$$\text{Speed (in km / hr)} = \frac{\text{Total distance}}{\text{Total time}}$$

$$= \frac{40\text{ km}}{5\text{ hrs}}$$

= 8 km/hr **Ans.**

Speed (in m/s) = ?

40 km = 40 × 1000 m = 40,000 m

5 hrs = 5 × 60 × 60 sec.

$$= \frac{40 \times 1000\text{ m}}{5 \times 60 \times 60\text{ s}}$$

$$= \frac{80\text{ m}}{36\text{ s}}$$

= 2.22 m/s **Ans.**

Velocity : It is the speed of a body in given direction.

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

- Velocity is a vector quantity. Its value changes when either its magnitude or direction changes. It is also denoted by v
- For a non-uniform motion in a given line, average velocity will be calculated in the same way as done in average speed.

$$\text{Average velocity} = \frac{\text{Total displacement}}{\text{Total time}}$$

- For uniformly changing velocity, the average velocity can be calculated as follows :

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

$$V_{(avg)} = \frac{u+v}{2}$$

where, u = initial velocity, v = final velocity

SI unit of velocity = ms^{-1}

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

$\because$

- It can be positive (+ve), negative (-ve) or zero.

Example 1 : *During first half of a journey by a body it travel with a speed of 40 km/hr and in the next half it travels with a speed of 20 km/hr. Calculate the average speed of the whole journey.*

Solution : Speed during first half (v_1) = 40 km/hr

Speed during second half (v_2) = 20 km/hr

$$\text{Average speed} = \frac{v_1 + v_2}{2}$$

$$= \frac{40+20}{2} = \frac{60}{2}$$

$$= 30 \text{ km/hr}$$

Average speed by an object (body) = 30 km/hr. **Ans.**

Example 2 : *A car travels 20 km in first hour, 40 km in second hour and 30 km in third hour. Calculate the average speed of the train.*

Solution : Speed in Ist hour = 20 km/hr, *Distance travelled during 1st hr = 1×20= 20 km*

Speed in IInd hour = 40 km/hr, *Distance travelled during 2nd hr = 1×40= 40 km*

Speed in IIIrd hour = 30 km/hr, *Distance travelled during 3rd hr = 1×30= 30 km*

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

$$= \frac{20+40+30}{1+1+1} = \frac{90}{3}$$

$$= 30 \text{ km/hr}$$ **Ans.**

Acceleration : Acceleration is seen in uniform motion and it can be defined as the rate of change of velocity with time.

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

$$\Rightarrow \text{Acceleration} = \frac{\text{Final Velocity} - \text{Initial Velocity}}{\text{Time}} \qquad a = \frac{v-u}{t}$$

where, v = final velocity, u = initial velocity

If $v > u$, then 'a' will be positive (+ve).

Retardation/Deacceleration : Deacceleration is seen in uniform motion during decrease in velocity with time. It has same definition as acceleration.

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

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

Here $v < u$, 'a' = negative (-ve).

Unit of Acceleration and deacceleration is m/s^2 or ms^{-2}

Example 1 : *A car speed increases from 40 km/hr to 60 km/hr in 5 sec. Calculate the acceleration of car.*

Solution : $$u = \frac{40\text{ km}}{\text{hr}} = \frac{40 \times 1000}{60 \times 60} = \frac{40 \times 5}{18} = \frac{200}{18} = 11.11\text{ms}^{-1}$$

$$v = \frac{60\text{ km}}{\text{hr}} = \frac{60 \times 5}{18} = \frac{150}{9} = 16.66\text{ ms}^{-1}$$

$a = ?$ $t = 5$ sec.

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

$$= \frac{16.66 - 11.11}{5}$$

$$= \frac{5.55}{5}$$

$= 1.11\text{ ms}^{-2}$ **Ans.**

Example 2. *A car travelling with a speed of 20 km/hr comes to rest in 0.5 hrs. What will be the value of its retardation ?*

Solution : $v = 0$ km/hr

$u = 20$ km/hr

$t = 0.5$ hrs

Retardation, $a' = ?$

$$a' = \frac{v-u}{t}$$

$$= \frac{0-20}{0.5}$$

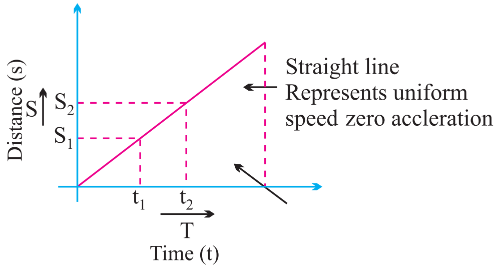
$$= -\frac{200}{5}$$

$= -40$ km/hr **Ans.**

Graphical Representation of Equation :–

(i) Distance-Time Graph : (s-t graph)

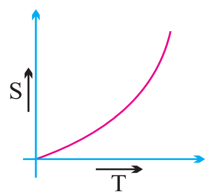
(a) *s-t* graph for uniform motion :



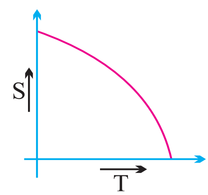
The slope of a distance - time graph represent speed of an object speed of an object moving with uniform speed can be determined by :

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

(b) *s-t* graph for non-uniform motion :

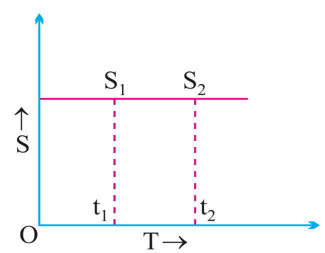


Continuous increase in slope of curve indicates accelerated non-uniform motion.



Continuous decrease in slope of curve indicates decelerated non-uniform motion.

(c) *s-t* graph for a body at rest :



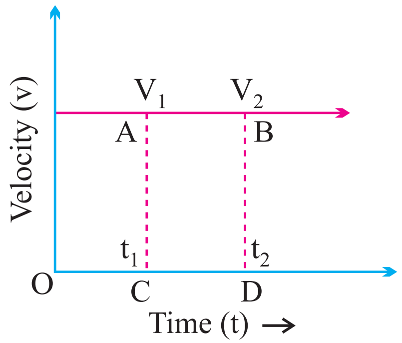
$$v = \frac{s_2 - s_1}{t_2 - t_1}$$

But, $s_2 = s_1$

$\therefore$ $v = \dfrac{0}{t_2 - t_1}$ Or $v = 0$

(ii) Velocity-Time Graph : (v-t graph)

(a) v-t graph for uniform motion :



$$a = \frac{v_2 - v_1}{t_2 - t_1}$$

But, $v_2 = v_1$

$$\therefore \quad a = \frac{0}{t_2 - t_1} \quad \text{Or} \quad a = 0$$

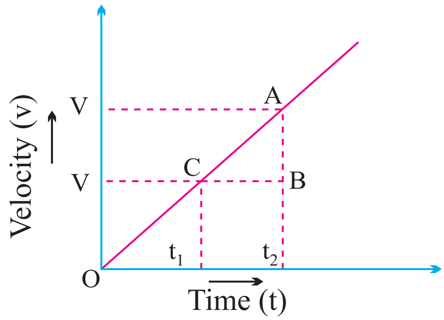
Distance covered by the object in time t_1 or t_2 is :-

distance (s) = AC x CD

= area of rectangle

ABCD

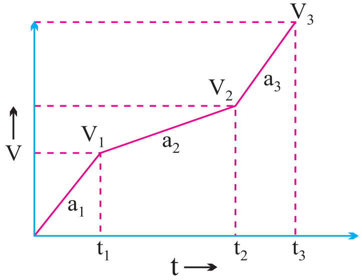
(A) v-t graph for accelerated (uniform) motion :



$$a - \frac{\text{change in velocity}}{\text{time taken}} \Rightarrow a = \frac{v - u}{t_2 - t_1} \quad \frac{\text{Final velocity (v) - Initial Velocity (u)}}{t_2 - t_1}$$

In uniformly accelerated motion, there will be equal increase in velocity in equal interval of time throughout the motion of body.

(B) *v-t* graph for accelerated (non-uniform) motion :



Here if, $t_2 - t_1 = t_2 - t_3$

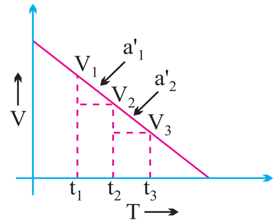
Then, $v_2 - v_1 \neq v_3 - v_2$

$$\frac{v_2 - v_1}{t_2 - t_1} \neq \frac{v_3 - v_2}{t_3 - t_2}$$

Or

Or $a_2 \neq a_3$

(C) *v-t* graph for deaccelerated (uniform) motion :



Here, $v_2 - v_1 = v_3 - v_2$

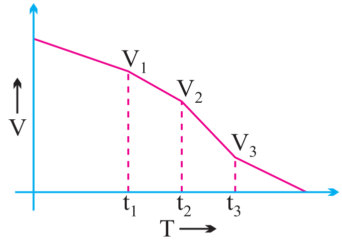
If $t_2 - t_1 = t_3 - t_2$

$$\frac{v_2 - v_1}{t_2 - t_1} = \frac{v_3 - v_2}{t_3 - t_2}$$

Then,

Or $a'_1 = a'_2$

(D) *v-t* graph for deaccelerated (non-uniform) motion :



Here, $v_2 - v_1 \neq v_3 - v_2$

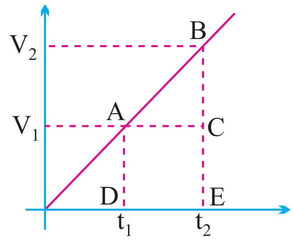
If $$t_2 - t_1 = t_3 - t_2$$

$$\frac{v_2 - v_1}{t_2 - t_1} \neq \frac{v_3 - v_2}{t_3 - t_2}$$

Then,

Or $$a'_1 \neq a'_2$$

Note : *The area enclosed between any two time intervals is '$t_2 - t_1$' in v/t graph will represent the total displacement by that body.*



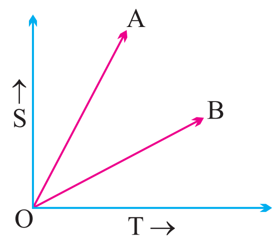
Total distance covered/travelled by body between t_2 and t_1, time intervals

= ½ × (CE-BE) x (OE-OD) + AD X (DE)

= Area of ΔABC + Area of rectangle ACED

$= \frac{1}{2} \times (v_2 - v_1) \times (t_2 - t_1) + v_1 \times (t_2 - t_1)$

Example : *From the information given in s/t graph, which of the following body 'A' or 'B' will be more faster ?*



Solution : $V_A > V_B$ **(Steeper The slope of line in distance-Time graph the greater the speed)**

- **Equation of Motion (For Uniformly Accelerated Motion) By graphical method:**

(Not in syllabus)

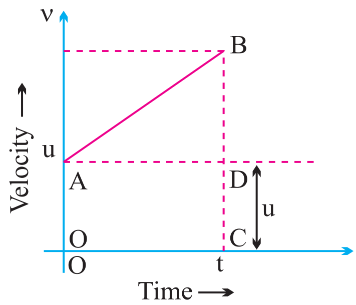
(i) First Equation of motion:

$$\boxed{v = u + at}$$

Or Final velocity = Initial velocity + Acceleration × Time

Graphical Derivation :

Suppose a body has initial velocity 'u' (*i.e.,* velocity at time $t = 0$ sec.) at point 'A' and this velocity changes to 'v' at point 'B' in 't' *i.e.,* final velocity will be 'v'.



For such a body there will be an acceleration.

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

$$a = \frac{\text{OB} - \text{OA}}{\text{OC} - 0} = \frac{v-u}{t-0}$$

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

Or

Or $$v = u + at$$

(ii) Second Equation of motion :-

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

Distance travelled by The object = Area of OABC (trapezium)

= Area of OADC (rectangle) + Area of ΔABD

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

$= u \times t + \frac{1}{2} \times t \times (v - u)$

$\left(\because \frac{v-u}{t} = a\right)$ so [v-u = at]

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

(iii) Third Equation of motion :-

$$\boxed{v^2 = u^2 + 2as}$$

s = Area of trapezium OABC

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

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

Or $$s = \left(\frac{u+v}{2}\right)\times\left(\frac{v-u}{a}\right) \qquad \left(\because \frac{v-u}{t} = a\right)$$

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

$\therefore$

Or $$v^2 = u^2 + 2as$$

Example 1. *A car starting from rest moves with uniform acceleration of 0.1 ms^{-2} for 4 mins. Find the speed and distance travelled.*

Solution : $u = 0$ ms^{-1} $\quad\because$ car is at rest.

$a = 0.1$ ms^{-2}

$t = 4 \times 60 = 240$ sec.

$v = ?$

From, $v = u + at$

$v = 0 + 0.1 \times 240$

Or $v = 24$ ms^{-1} **Ans.**

Distance travelled

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

$= 0 \times 240 + \frac{1}{2} \times 0.1 \times (240)^2$

$= 2880$ m or

$s = 2.88$km

Example 2. *The brakes applied to a car produces deceleration of 6 ms^{-2} in opposite direction to the motion. If car requires 2 sec. to stop after application of brakes, calculate distance travelled by the car during this time.*

Solution : Deceleration, $a = -6$ ms^{-2}

Time, $t = 2$ sec.

Distance, $s = ?$

Final velocity, $v = 0$ ms^{-1} $\quad\because$ car comes to rest.

Now, $v = u + at$

Or $u = v - at$

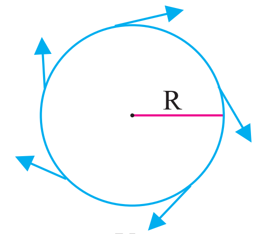
Or $u = 0 - (-6) \times 2 = 12$ ms^{-1}

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

$= 12 \times 2 + \frac{1}{2} \times (-6) \times (2)^2$

$= 24 - 12 = 12$ m **Ans.**

Uniform Circular Motion



Direction of velocity
(Tangential)

If a body is moving in a circular path with uniform speed, It is motion is called uniform circular motion.

In such a motion the speed may be same throughout the motion but its velocity (which is tangential) is different at each and every point of its motion due to continuous change in direction. Thus, uniform circular motion is an accelerated motion.

so, velocity of an object in a circular motion is :

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

QUESTIONS

VERY SHORT ANSWER TYPE QUESTIONS

1. Change the speed 6 m/s into km/hr.
2. Why are speedometer and odometer provided in a motor vehicle ?
3. What is the other name of negative acceleration ?
4. What does the slope of distance-time graph indicate ?
5. What can you say about the motion of a body if its speed-time graph is a) straight line parallel to the time axis b) straight line
6. Define Motion and speed
7. Is distance a scalar or vector quantity? Why?
8. Is displacement a scalar quantity? Why?
9. Define average speed. How do we calculate it ?
10. What is difference between speed and velocity?