UNIT 2

Kinematics

1 **Define motion; also describe the different types of motion.**

Ans. **Motion**

A body is said to be in motion, if it changes its position with respect to its surroundings.

Types of Motion

There are three types of motion

   (a)   Translatory motion (linear, random and circular)

   (b)   Rotatory motion

   (c)   Vibratory motion (to and fro motion)

(i) **Translatory Motion**

It a body moves along a line without any rotation. The line may be straight or curve. Then its motion is called translatory motion.

Example

A car moving in a straight line has translatory motion. Similarly, an aeroplane moving straight is in translational motion. Translatory motion can be divided into linear motion, circular motion and random motion.

(a) **Linear Motion**

Straight line motion of a body is known as its linear motion.

(b) **Circular Motion**

The motion of an object in a circular path is known as circular motion.

(c) **Random Motion**

The disordered or irregular motion of an object is called random motion.

(ii) **Rotatory Motion**

The spinning motion of a body about its axis is called rotatory motion.

Example

The motion of a wheel about its axis and that of a steering wheel are the examples of rotatory motion. The motion of earth about its geographic axis that causes day and night is also rotatory motion.

(ii) **Vibratory Motion**

To and fro motion of a body about its means position is known as vibratory motion.

Example

A baby in a cradle moving to and fro, to and fro motion of the hammer of a ringing electric bell and the motion of the string of a sitar are some of the examples of vibratory motion.

2 **Define translatory motion and describe its types.**

Ans. **Translatory Motion**

If a body moves along a line with out any rotation then its motion is called translatory motion.

Types

There are three types of translatory motion.

   (i)   Linear motion

   (ii)   Circular motion

   (iii)   Random motion

(i) **Linear Motion**

Straight line motion of a body is known as its linear motion.

Examples

Aeroplanes flying straight in air and objects falling vertically down are also the examples of linear motion

(ii) **Circular Motion**

The motion of an object in a circular path is known as circular motion.

Example

The motion of the earth around the sun and motion of the moon around the earth are also the examples of circular motions.

(iii) Random Motion

The disordered or irregular motion of an object is called random motion.

Examples

The motion of insects and birds is random motion. The motion of dust or smoke particles in the air is also random motion.

3 **What is meant by scalars and vectors? Give their examples.**

Ans. **Scalars**

A scalar quantity is described completely by its magnitude only.

Examples

Mass, length, time, speed, volume, work and energy etc.

Vectors

A vector quantity is described completely by magnitude and direction.

Example
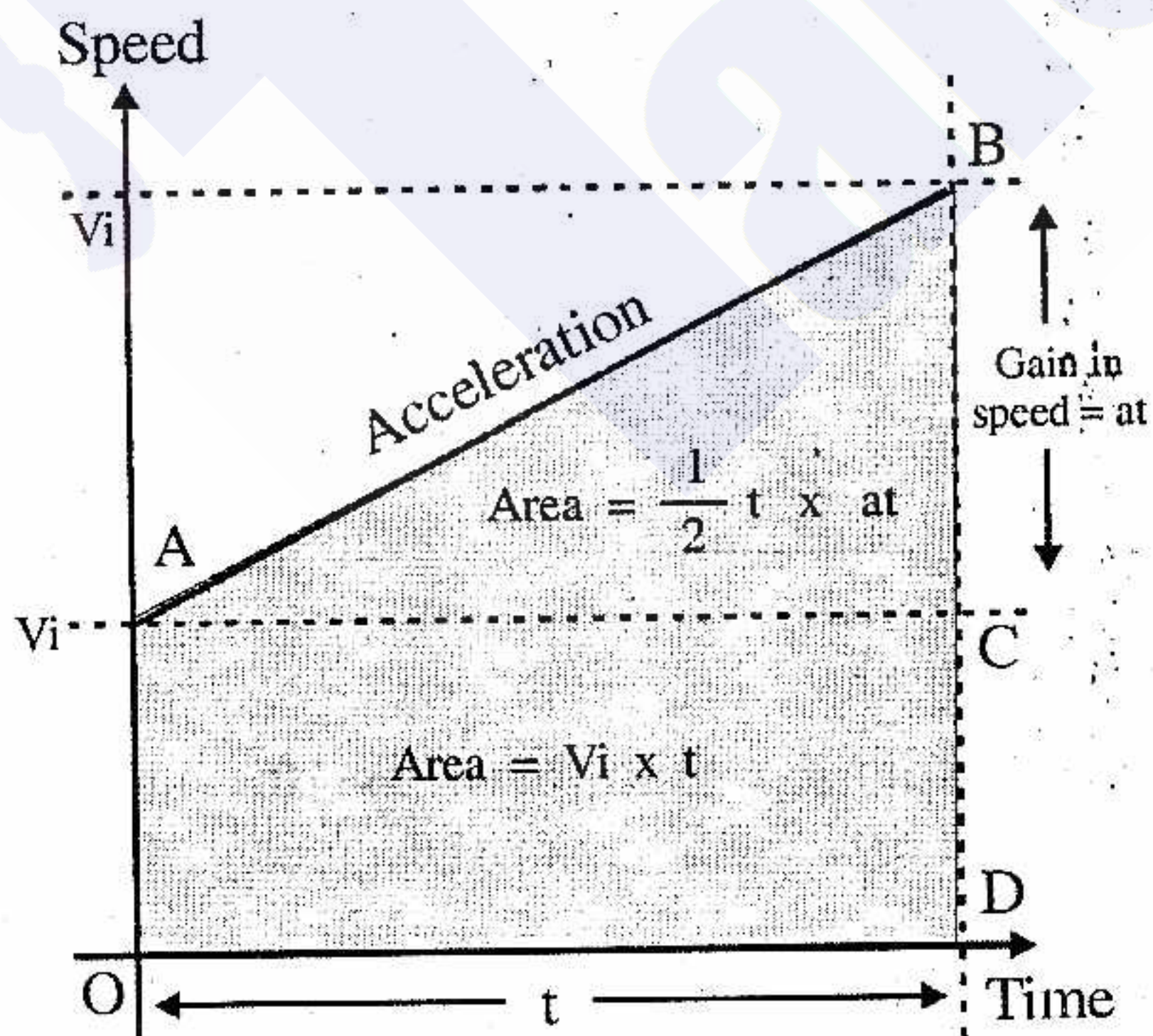
Velocity, displacement, force, momentum and torque etc.

4 **With the help of speed-time graph, derive the first equation of motion.**

OR

With the help of speed time graph prove that $V_f = V_i + at$

Ans. **First Equation of Motion**

Speed-time graph for the motion of a body is shown in figure. Slope of line AB gives the acceleration a of a body.

Slope of line AB $= a = \dfrac{BC}{AC} = \dfrac{BD - CD}{OD}$

as $\quad BD = v_1,\ CD = v_i\ $ and $\ OD = t$

Hence $\quad a = \dfrac{v_f - v_i}{t}$

or $\qquad v_f - v_i = at$

$\therefore \qquad v_f = v_i + at$

5 **With the help of speed – time graph derive the second equation of motion.**
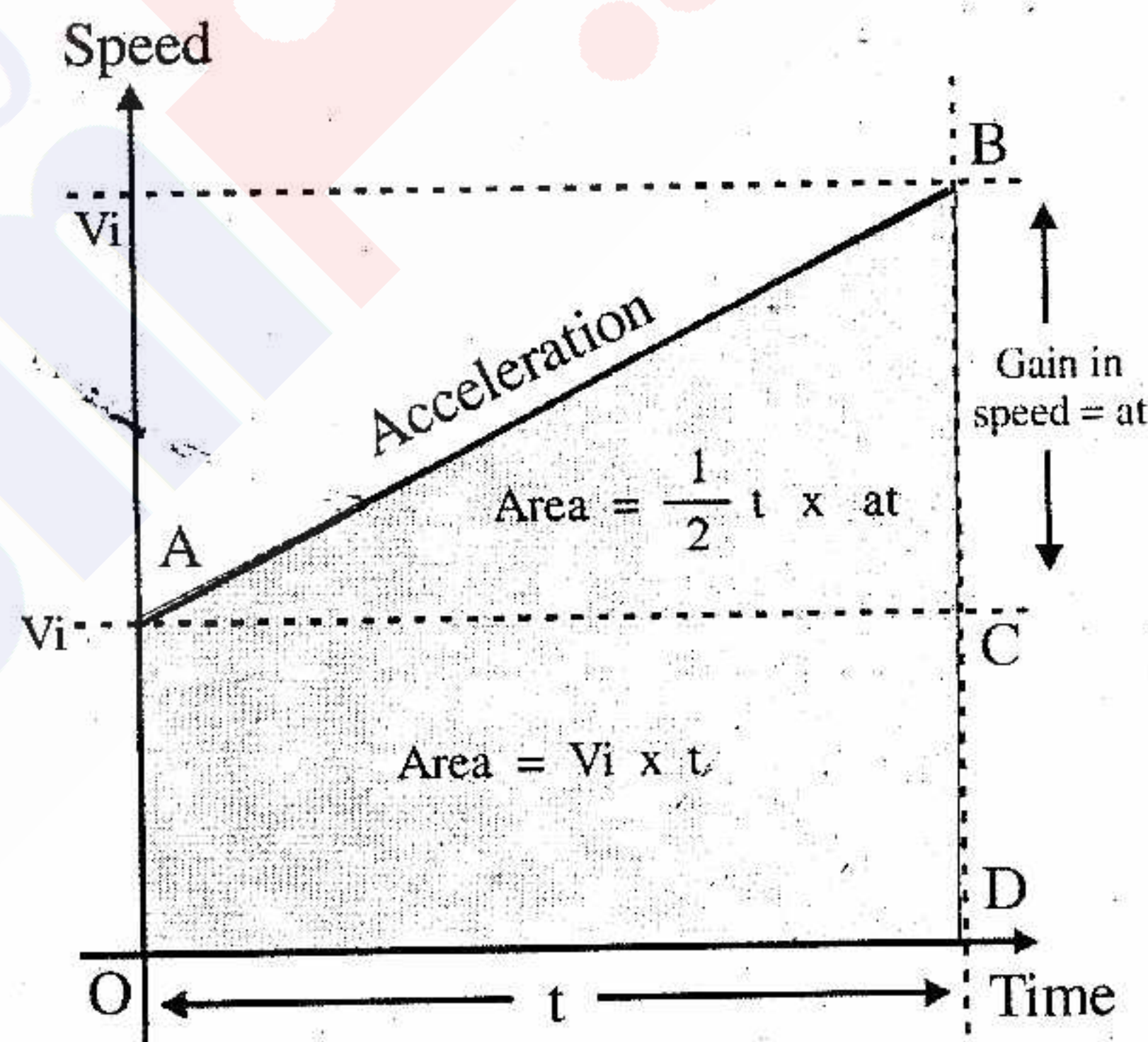
OR

With help of speed – time graph prove that $s = V_i t + \dfrac{1}{2} at^2$.

Ans. **Second Equation of Motion**

In speed-time graph shown in figure, the total distance 'S' travelled by the body is equal to the total area OABD under the graph. That is

Total distance S = area of

(rectangle OACD + area of $\triangle ABC$)

Area of

Rectangle OACD $= OA \times OD$

$= v_i \times t$

Area of the $\triangle ABC = \dfrac{1}{2}(AC \times BC)$

$= \dfrac{1}{2} t \times at$

Total area of OABD = area of rectangle OACD + area of triangle ABC

Putting values in the above equation, we get

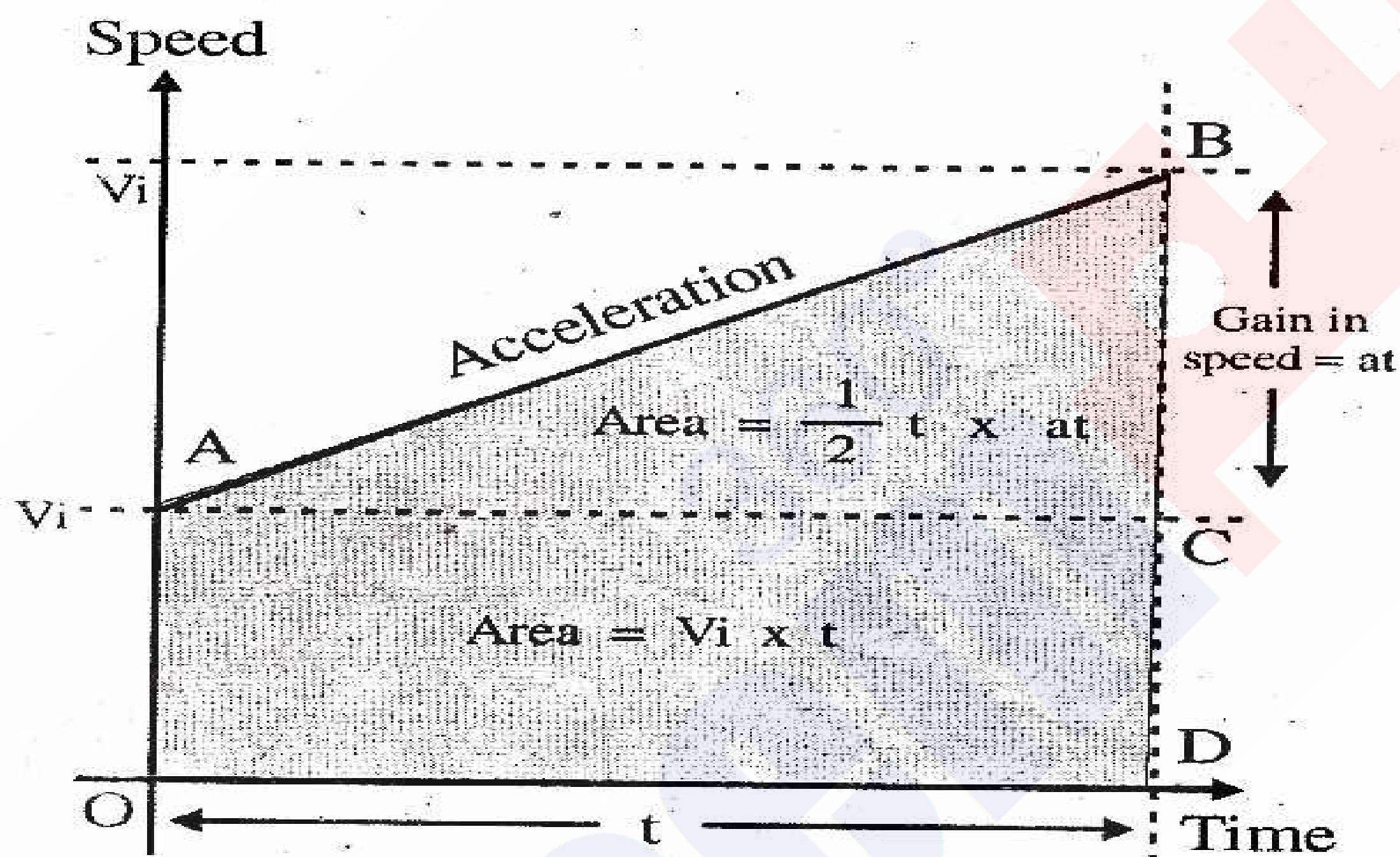$$S = V_i t + \frac{1}{2} t \times at$$

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

6 **With the help of speed-time graph derive the third equation of motion.**

OR

With the help of speed-time graph prove that $2as = Vf^2 - Vi^2$

Ans. **Third Equation of Motion**

In speed-time graph shown in figure the total distance S travelled by the body is given by the total area OABD under the graph.

Total area of OABD $= S = \dfrac{OA + BD}{2} \times OD$

Or $\qquad\qquad 2S = (OA + BD) \times OD$

Multiple both sides by $\dfrac{BC}{OD}$, we get

$$2S \times \frac{BC}{OD} = (OA + BD) \times OD \times \frac{BC}{OD}$$

$$2S \times \frac{BC}{OD} = (OA + BD) \times BC$$

Putting the values in the above equation, we get

$$2S \times a = (v_i + v_t) \times (v_t - v_i)$$

$$2aS = v_t^2 - v_i^2$$

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Define uniform acceleration.

If the velocity of a body increases by equal amount in equal intervals of time, its acceleration is said to be uniform.

When does the acceleration of a body positive?

Acceleration of a body is positive if its velocity increases with time.

When does the acceleration of a body negative?

Acceleration of a body is negative if its velocity is decreasing with time.

What is meant by deceleration or retardation?

The negative acceleration is called deceleration or retardation.

A body is moving with a uniform velocity. What will be its acceleration?

Acceleration is defined as the rate of change of velocity. When the body is moving with uniform velocity, the change in velocity will be zero and thus, the acceleration will also be zero.

Can a body moving with certain velocity in the direction of East have acceleration in the direction of West.

Yes. A body moving with some velocity in the direction of East will have an acceleration towards West. It is the case when velocity decreases.

If velocity-time graph is a straight line then what information we get from it?

If velocity-time graph is a straight line, then the acceleration will be uniform.

If velocity-time graph is parallel to x-axis, then what information we get from it?

If velocity-time graph is parallel to x-axis, it means the body is moving with constant velocity i.e. with no acceleration.

What is meant by slope or gradient of a graph?

Slope or gradient of a graph is defined as the ratio of distance covered along y-axis to the distance covered along x-axis.

i.e.   Slope or Gradient $= \dfrac{y_2 - y_1}{x_2 - x_1}$

Where y_2 and y_1 are final and initial values along y-axis and x_2 and x_1 are final and initial values along x-axis.

If in a velocity-time graph, gradient is negative, what does it mean.

It means the acceleration of the body is decreasing.

If the speed of a body is variable, then how this graph looks like?

If the speed of the body is variable, then the graph is not a straight line.

Define gravitation acceleration? What is its value on the surface of earth?

The acceleration of freely falling bodies is called gravitational acceleration. It is denoted by 'g' it value on the surface of earth is 10 ms^{-2}.

When 'g' is taken positive and when it is taken as negative?

For bodies falling down freely 'g' is positive while 'g' is negative for bodies moving up.

Write down three equation of motion.

1st equation: $V_f = V_i + at$

2nd equation: $S = V_i t + \dfrac{1}{2} at^2$

3rd equation: $2as = V_f^2 - V_i^2$

EXERCISE

2.1   Encircle the correct answer from the given choices:

(i)   A body has translatory motion if it moves along a

(a) straight line

(b) circle

(c) line without rotation

(d) curved path

(ii) The motion of a body about an axis is called:

(a) circular motion (b) rotatory motion
(c) vibratory motion (d) random motion

(iii) Which of the following is a vector quantity?

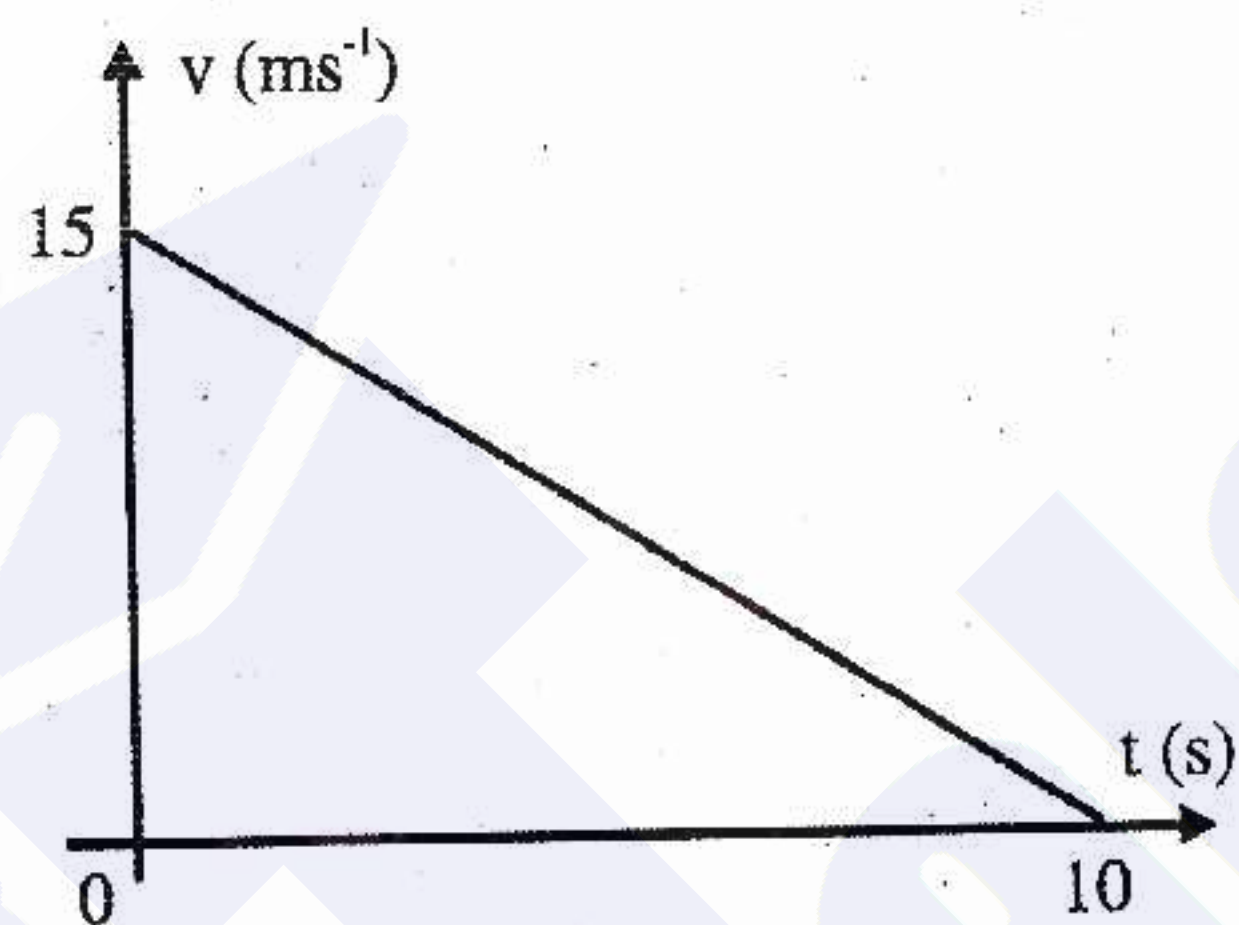(a) speed (b) distance
(c) displacement (d) power

(iv) If an object is moving with constant speed then its distance time graph will be a straight line.

(a) along time-axis
(b) along distance-axis
(c) parallel to time-axis
(d) inclined to time-axis

(v) A straight line parallel to time-axis on a distance-time graph tells that the object is:
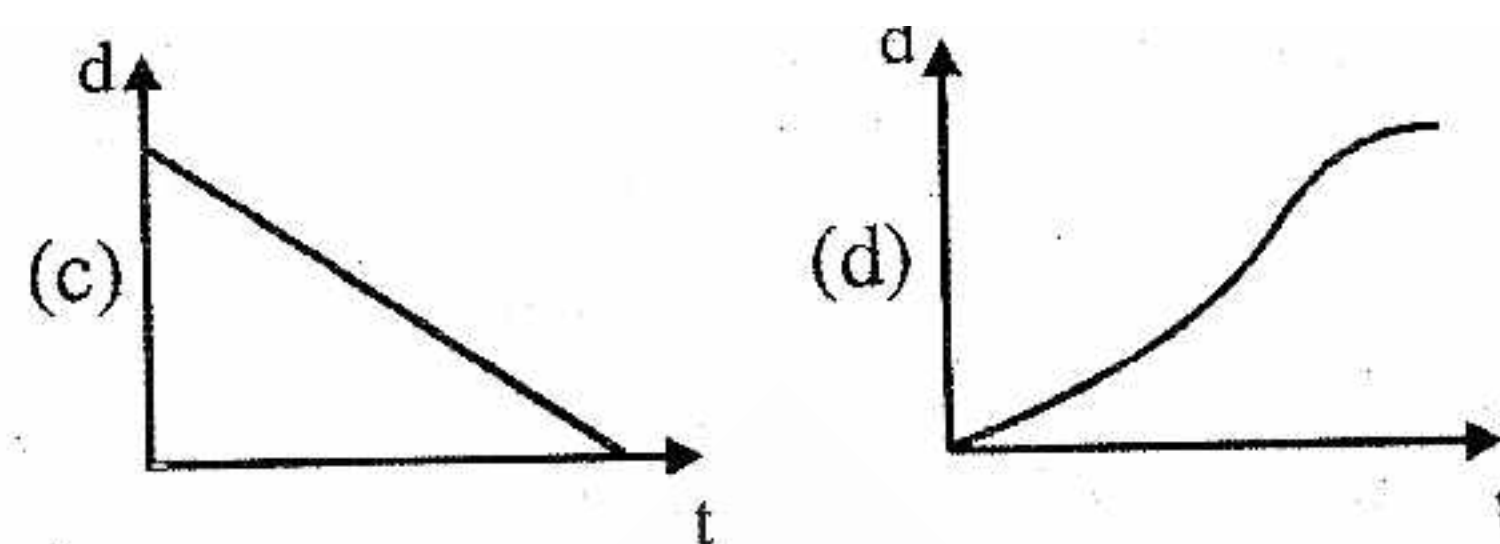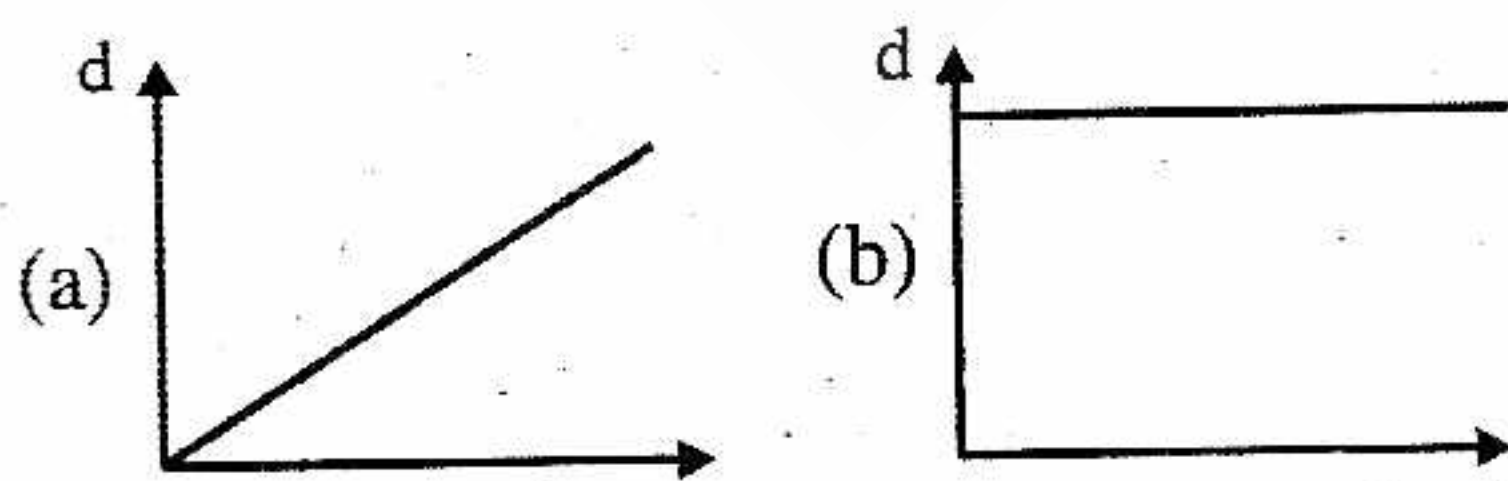
(a) moving with constant speed
(b) at rest
(c) moving with variable speed
(d) in motion

(vi) The speed-time graph of a car is shown in the figure, which of the following statement is true?

(a) car has an acceleration of 1.5 ms^{-2}
(b) car has constant speed of 7.5 ms^{-1}
(c) distance travelled by the car is 75 m
(d) average speed of the car is 15 ms^{-1}

(vii) Which one of the following graphs is representing uniform acceleration?

(viii) By dividing displacement of a moving body with time, we obtain:

(a) speed (b) acceleration
(c) velocity (d) deceleration

(ix) A ball is thrown vertically upward. Its velocity at the highest point is:

(a) -10ms^{-1} (b) zero
(c) 10 ms^{-2} (d) none of these

(x) A change in position is called:

(a) speed (b) velocity
(c) displacement (d) distance

(xi) A train is moving at a speed of 36 kmh^{-1}. Its speed expressed in ms^{-1} is:

(a) 10 ms^{-1} (b) 20 ms^{-1}
(c) 25 ms^{-1} (d) 30 ms^{-1}

(xii) A car starts from rest. It acquires a speed of 25 ms^{-1} after 20 s. The distance moved by the car during this time is:

(a) 31.25 m (b) 250 m
(c) 500 m (d) 5000 m

Answers

(i)	(a)	(ii)	(b)	(iii)	(c)	(iv)	(d)
(v)	(a)	(vi)	(c)	(vii)	(a)	(viii)	(b)
(ix)	(b)	(x)	(c)	(xi)	(a)	(xii)	(b)

2.2. Explain translatory motion and give examples of various types of translatory motion.

Ans. If a body moves along a line without any rotation then its motion is called translatory motion. e.g. aeroplane flying straight in air, motion of earth around the sun and motion of insects and birds etc. there are three types of translatory motion.

(i) **Linear Motion**

Straight line motion of a body is called linear motion .e.g. objects falling vertically down wards.

(ii)   Circular Motion

The motion of an object in a circular path is known as circular motion. e.g. toy train moving on a circular track.

(iii)   Random Motion

Irregular motion of an object is called random motion e.g. the motion of insects and birds.

2.3   Differentiate between the following:

    (i)   Rest and motion

    (ii)   Circular motion and rotatory motion

    (iii)   Distance and displacement

    (iv)   Speed and velocity

    (v)   Linear and random motion

    (vi)   Scalars and vectors

Ans.   (i)   Rest

If a body does not change its position with respect to its surround then it is said to be at rest.

Motion

If a body changes its position with respect to its surrounding then it is said to be in motion.

(ii)   Circular Motion

The motion of an object in a circular path is called circular motion.

Rotatory Motion

The spinning motion of a body about its axis is called rotatory motion.

(iii)   Distance

Length of a path between two points is called distance between those points. It is scalar quantity.

Displacement

The shortest distance between two points is called displacement. It is a vector quantity.

(iv)   Speed

The distance covered in unit time is called speed. It is a scalar quantity.

Velocity

Rate of displacement of a body is called velocity. It is a vector quantity.

(v)   Linear Motion

Straight line motion of a body is called linear motion.

Random Motion

The irregular motion of an object is called random motion.

(vi)   Scalars

Those quantities which are described completely by their magnitude are called scalars.

Vectors

Those quantities which are described completely by magnitude and direction are called vectors.

2.4.   Define the terms speed, velocity, and acceleration.

Ans.   Speed

The distance covered in unit time is called speed.

Velocity

The rate of displacement of a body is called velocity.

Acceleration

The rate of change of velocity is called acceleration.

2.5.   Can a body moving at a constant speed have acceleration?

Ans.   If a body is moving at constant speed and it is not changing its direction then it has no acceleration. If it is changing its direction then it has acceleration?

2.6.   How do riders in a Ferris wheel possess translatory motion but not rotatory motion?

Ans.   The riders in a Ferris wheel possess translatory motion because their motion is in a circle with out rotation. So they do not have rotatory motion.

2.7.   Sketch a distance-time graph for a body starting from rest. How will you determine the speed of a body from this graph?

Ans.   Its speed after 15s can be calculated as

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

$$= \frac{30}{15}$$

$$= 2 \text{ ms}^{-1}$$

2.8. **What would be the shape of a speed-time graph of a body moving with variable speed?**

Ans. If a body is moving with variable speed then its distance time graph will not a straight line.

2.9. **Which of the following can be obtained from speed-time graph of a body?**

    (i)   **Initial speed**

    (ii)   **Final speed**

    (iii)   **Distance covered in time t.**

    (iv)   **Acceleration of motion**

Ans. It means all of then can be obtained from speed-time graph.

2.10. **How can vector quantities be represented graphically?**

Ans. Graphically, a vector can be represented by a line segment with an arrow head. E.g. the line AB with arrow head at 'B' represent vector V. the length of the line AB gives the magnitude of the vector 'V' on a selected scale. While the direction of the line from A to 'B' gives the direction of the vector V.

2.11. **Why vector quantities cannot be added and subtracted like scalar quantities?**

Ans. Vector quantities cannot be added and subtracted like scalar quantities because vectors have a definite direction.

2.12. **How are vector quantities important to us in our daily life?**

Ans. Vector quantities are very important in our daily life. These quantities help us in different ways. e.g.

(i)   If more than one forces act on a body then we can easily find the resultant force of all these force.

(ii)   If resultant force is given then we can find the rectangular components of that force.

(iii)   With the help of a vector we can determine the position of a point or place.

(iv)   With the help of vector the pilots detect their destination.

1.13. **Derive equation of motion for uniformly ~~accelerated~~ rectilinear motion.**

Ans. ~~See long Questions Nos. 4, 5 and 6.~~

i.e. 1st equation Question No. 4

    2nd equation Question No. 5

    3rd equation Question No. 6

2.14. **Sketch a velocity-time graph for the motion of the body. From the graph explaining each step, calculate total distance covered by the body.**

Ans. Consider a body moving with initial velocity 'vi' in a straight line with uniform acceleration its velocity become V_f after time 't'. the motion of body is described by speed-time graph. The slop of line 'AB' is acceleration 'a' the total distance covered by the body is shown by the shaded area under the line AB.

So, the total distance 'S' travelled by the body is equal to the total area OABD under the graph. That is

Total distance = Area of rectangle OACD + Area of triangle ABC

$$\text{Area of rectangle (OACD)} \quad = OA \times OD$$

$$= Vi \times t$$

$$\text{Area of triangle ABC} = \frac{1}{2}(AC \times BC)$$

$$= \frac{1}{2} t \times at$$

$$= \frac{1}{2} at^2$$

Since

Total area = Area of rectangle OACD + Area of triangle ABC

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

PROBLEMS

2.1. **A train moves with a uniform velocity of 36 kmh^{-1} for 10 s. find the distance travelled by it.**

Ans.   V $= 36 \text{ km h}^{-1}$

$$= \frac{36 \times 1000}{3600} = 10 \text{ m/sec}$$

    t $= 10 \text{ s}$

$$S = ?$$

$$S = v \times t$$

$$= 10 \times 10$$

$$= 100 \text{ m}$$

2.2. **A train starts from rest. It moves through 1 km in 100s with uniform acceleration. What will be its speed at the end of 100 s.**

Ans. $Vi = 0 \text{ ms}^{-1}$

$s = 1 \text{ km} = 1000 \text{ m}$

$t = 100 \text{ sec}$

$Vf = ?$

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

$$1000 = 0 \times 100 + \frac{1}{2} \times a \times (100)^2$$

$$100 = 0 + \frac{1}{2} \times a \times 100 \times 100$$

$$1000 = a \times 5000$$

$$a = ?$$

$$a = \frac{1}{5} \text{ m sec}^{-2}$$

$$V_f = vi + at$$

$$V_f = 0 + \frac{1}{5} \times 100 = 20 \text{ ms}^{-1}$$

2.3. **A car has a velocity of 10 ms⁻¹. It accelerates at 0.2 ms⁻² for half minute. Find the distance travelled during this time and the final velocity or the car.**

Ans. $Vi = 10 \text{ ms}^{-1}$

$a = 0.2 \text{ ms}^{-2}$

$t = 30 \text{ s}$

$s = ?$

$V_f = ?$

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

$$s = 10 \times 30 + \frac{1}{2} \times 0.2 \times (30)^2$$

$$s = 300 + 90 = 390 \text{ m}$$

$$V_f = Vi + at$$

$$= 10 + 0.2 \times 30 = 10 + 6.0 = 16 \text{ ms}^{-1}$$

2.4. **A tennis ball is hit vertically upward with a velocity of 30 ms⁻¹. It taken 3 s to reach the highest point. Calculate the maximum height reach by the ball. How long it will take to return to ground?**

Ans. $Vi = 30 \text{ ms}^{-1}$

$t = 3 \text{ sec}$

$g = -10 \text{ ms}^{-2}$

$h = ?$

total time = ?

$$h = Vit + \frac{1}{2}gt^2$$

$$= 30 \times 3 + \frac{1}{2}(-10) \times 3 \times 3$$

$$= 90 + (-45)$$

$$h = 90 - 45 = 45 \text{ m}$$

(ii) The ball takes 3 sec to reach the highest point so, it will take same time to return the ground

So total time $= 3 + 3$

$$= 6 \text{ sec}$$

2.5. **A car moves with uniform velocity of 40 ms⁻¹ for 5s. It comes to rest in the next 10s with uniform deceleration. Find**

(i) **deceleration**

(ii) **Total distance travelled by the car.**

Ans. $Vi = 40 \text{ ms}^{-1}$

$t = 5 \text{ sec}, s = ?, a = ?, V_f = 0$

The distance covered in first 5 seconds

$S_1 = \bar{v} \times t$ (velocity is uniform)

$$= 40 \times 5 = 200 \text{ m}.$$

(ii) When breaks are applied then deceleration

$$a = \frac{V_f - V_i}{t}$$

$$= \frac{0 - 40}{10} = -4 \text{ ms}^{-2}$$

(iii) The distance covered after applying the breaks.

$$S_2 = Vit + \frac{1}{2}at^2$$

$$= 40 \times 1 + \frac{1}{2}(-4) \times 10 \times 10$$

$$= 400 - 200 = 200 \text{ m}$$

So, Total distance 's' = $s_1 + s_2$

$s = 200 + 200$

$s = 400$ m

2.6. **A train starts from rest with an acceleration of 0.5 ms^{-2}. Find its speed in kmh^{-1}. When it has moved through 100 m.**

Ans. $V_i = 0$ ms^{-1}

$a = 0.5$ ms^{-2}

$s = 100$ m

$V_f = ?$

$2as = V_f^2 - V_i^2$

$2(0.5) \times 100 = (V_f)^2 - (0)^2$

$100 = V_f^2$

$\sqrt{100} = V_f$

$V_f = 10$ ms^{-1}

In   kmh^{-1}

$V_f = \dfrac{10 \times 1000}{3600} = 36$ kmh^{-1}

2.7. **A train staring from rest accelerates uniformly and attains a velocity 48 kmh^{-1} in 2 minutes. It travels at this speed for 5 minutes. Finally, it moves with uniform retardation and is stopped after 3 minutes. Find the total distance travelled by the train.**

Ans. $V_i = 0$ ms^{-1}

$V_f = 48$ kmh^{-1} = $\dfrac{48 \times 1000}{3600}$

$t = 2$ min = $\dfrac{480}{36}$ ms^{-1}

$= 2 \times 60 = 120$ sec

(i) The distance covered in first 2 minutes

$s_1 = \bar{v} \times t$ $\left\{ \bar{v} = \dfrac{0 + 480}{2 \times 36} \right\}$

$= \left(\dfrac{0 + 480}{2 \times 36} \right) \times t = 800$ m

(ii) Distance covered in next 5 minutes.

$S_2 = \bar{v} \times t$ $\left\{ \text{so its } \bar{v} = \dfrac{480}{36} \text{ ms}^{-1} \right\}$

$= \dfrac{480 \times 300}{36}$

$= 4000$ m

(iii) When break are applied then

$V_f = 0$ ms^{-1}

So the distance covered in last 3 minutes.

$S_3 = \bar{v} \times t$ $\left\{ \bar{v} = \dfrac{480 + 0}{36 \times 2} \right\}$

$= \dfrac{480 \times 180}{36 \times 2}$

$S_3 = 1200$ m

Total distance $s = s_1 + s_2 + s_3$

$s = 800 + 4000 + 1200$

$= 6000$ m

2.8. **A cricket ball is hit vertically upwards and returns to ground 6 s later. Calculate (i) maximum height reached by the ball. (ii) initial velocity of the ball.**

Ans. $V_i = ?$

$T = 3$ sec

$g = -10$ ms^{-2}

$V_f = 0$ m/sec

$V_f = v_i + gt$

$0 = v_i + (-10) \times 3$

$0 = v_i - 30$

$v_i = 30$ ms^{-1}

(i) Maximum height 'h' = ?

$V_i = 30$ ms^{-1}

$g = -10$ ms^{-1}

$t = 3$ sec, h = ?

$h = v_i t + \dfrac{1}{2} gt^2$

$= 30 \times 3 + \dfrac{1}{2} (-10) \times 3 \times 3$

$= 90 - 45 = 45$ m

2.9. **When brakes are applied, the speed of a train decreases from 96 kmh^{-1} to 48 khm^{-1} in 800 m. how much further will the train move before coming to rest? (Assuming the retardation to be constant).**

Ans.

$V_i = 96 \text{ kmh}^{-1} \Rightarrow \dfrac{80}{3} \text{ ms}^{-1}$

$V_f = 48 \text{ kmh}^{-1}$

$\Rightarrow \quad \dfrac{48 \times 1000}{3600} = \dfrac{40}{3} \text{ ms}^{-1}$

$s = 800 \text{ m}$

$a = ?$

$2as = V_f^2 - V_i^2$

$2 \times a \times 800 = \left(\dfrac{40}{3}\right)^2 - \left(\dfrac{80}{3}\right)^2$

$1600 \times a = \dfrac{1600}{9} - \dfrac{6400}{9}$

$1600 \times a = -\dfrac{4800}{9}$

$a = \dfrac{4800}{9 \times 1600} = -\dfrac{1}{3} \text{ ms}^{-2}$

So the distance covered after applying the breaks $s = ?$

$V_i = \dfrac{40}{3} \text{ ms}^{-1}$

$V_f = 0 \text{ ms}^{-1}$

$a = -\dfrac{1}{3} \text{ ms}^{-2}$

$s = ?$

$2as = V_f^2 - V_i^2$

$2\left(-\dfrac{1}{3}\right) \times S = (0)^2 - \left(\dfrac{40}{3}\right)^2$

$-\dfrac{2}{3} \times s = 0 - \dfrac{1600}{9}$

$s = \dfrac{-1600}{9} \times \left(\dfrac{-3}{2}\right)$

$s = \dfrac{800}{3} = 266.66 \text{ m}$

2.10. In the above problem, find the time taken by the train to stop after the application of breaks.

Ans. $V_i = \dfrac{40}{3} \text{ ms}^{-1}$

$V_f = 0 \text{ ms}^{-1}$

$a = -\dfrac{1}{3} \text{ ms}^{-2}$

$V_f = v_i + at$

$0 = \dfrac{40}{3} + \left(-\dfrac{1}{3}\right) \times t$

$\dfrac{40}{3} = \dfrac{1}{3} \times t$

$t = 40 \text{ sec.}$