Chapter– 3

Motion in a Straight Line

1. What is meant by **Kinematics**?

Ans: It is the branch of Physics which describes the motion of objects without going in to the causes of motion.

2. What is meant by **frame of reference**?

Ans: A coordinate system used to specify position of an object along with a clock to measure time constitutes a frame of reference.

Eg: The Cartesian coordinate system along with a clock is a frame of reference.

3. Define motion in **1D**, **2D** and **3D**. Also give examples.

Ans:

One dimensional motion

It is the motion of an object along a **straight line**. It is also called **rectilinear motion** or linear motion.

To describe one dimensional motion only one coordinate (x or y or z) is needed.

Eg: (i) Motion of a train along a straight rail

(ii) Motion of a freely falling body.

Two Dimensional Motion

It is the motion of an object in a **plane**. To describe two dimensional motion, two coordinates (x,y or y,z or x,z) are needed.

Eg: (i) A car moving on a plane ground.

(ii) A boat sailing in a still lake.

(iii) Motion of planets around the sun.

(iv) Motion of a simple pendulum.

(v) Projectile Motion

(vi) Circular motion

Three dimensional motion

It is the motion of an object in **space**. To describe three dimensional motion, three co-ordinates (x, y and z) are needed.

Eg: (i) Motion of gas molecules

(ii) A kite flying on a windy day.

(iii) Motion of an aeroplane.

4. Distinguish between **Distance** and **Displacement.**

Ans:

Distance or Path length

It is the length of the path travelled by the object.

Displacement

It is the **straight line distance** between the initial and final positions of the object, measured in the direction from initial point to the final point.

Note: Both distance and displacement has the same dimension [L] and same unit (meter).

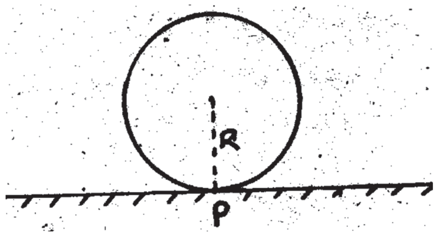
Differences between Distance and Dispalcement

a) Distance is a scalar quantity but displacement is a vector quantity.
b) For a moving particle, distance can never be zero or negative while displacement can be zero, positive or negative.
c) For a moving particle distance can never decrease with time while displacement can.

5P. A particle describes a circle of radius '**r**'. What are the displacement and distance travelled when the particle describes (a) 90^0 (b) 180^0 (c) 360^0

Ans:

6P. In figure, the point P on a wheel of radius R is in contact with the ground. What is the displacement of the point, when the wheel rolls a half revolution?



Ans:

7. Define **Uniform motion** along a straight line.

Ans: If an object moving on a straight line covers equal distances in equal intervals of time, it said to be in uniform motion along a straight line.

8. Distinguish between **average velocity** and **average speed**.

Ans:

$$\text{Average velocity} = \frac{\text{Displacement}}{\text{Total time interval}}$$

$$\bar{v} = \frac{x_2 - x_1}{t_2 - t_1} = \frac{\Delta x}{\Delta t}$$

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

Speed is a scalar quantity but velocity is a vector.

Note: Both speed and velocity have the same unit (m/s) and dimension [LT^{-1}].

9P. A body moving in a straight line travels with uniform velocity $\mathbf{v_1}$ for a time $\mathbf{t_1}$ and with another uniform velocity $\mathbf{v_2}$ for a time $\mathbf{t_2}$. What is the average velocity for the whole journey?

Ans:

10P. A car moves with a speed of **30km/hr** for **3 hours** and then moves with a speed of **40km/hr** for **2 hours**. What is the magnitude of average velocity of the car?

Ans:

11P. A body moving in a straight line travels with velocity $\mathbf{v_1}$ for the first **half time** and with velocity $\mathbf{v_2}$ for the second **half time**. What is the average velocity for the whole journey?

Ans:

12P. A body moving in a straight line travels the first **half distance** at $\mathbf{v_1}$ and the second **half distance** at $\mathbf{v_2}$. What is the average speed for the whole journey?

Ans:

13P. A car moves along a straight path. It covers the first half of the distance at the rate of 40km/hr and second half at the rate of 60km/hr, find the magnitude of average velocity?

Ans:

14P. A travels from A to B with a velocity **36km/hr** and returns to A with **72km/hr**. What are the average speed and the average velocity?

Ans:

15. Define **Instantaneous velocity** and **instantaneous speed.**

Ans:

Instantaneous velocity is the limit of the average velocity as the time interval Δt becomes infinitesimally small.

$$\vec{v} = \lim_{\Delta t \to 0} \frac{\overrightarrow{\Delta x}}{\Delta t} = \frac{\overrightarrow{dx}}{dt}$$

[Instantaneous velocity is simply called velocity]

Note: The velocity at a particular instant is equal to the slope of the tangent drawn on the position time graph at that instant.

Instantaneous speed at an instant is the magnitude of the instantaneous velocity.

Note: Speedometer of an automobile indicates instantaneous speed.

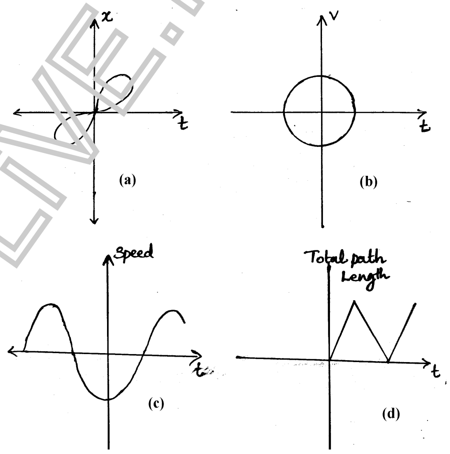
Some important features of **uniform motion along a straight line**

(i) Uniform motion is the motion along a straight line with uniform speed.

(ii) The magnitude of displacement is equal to the actual distance (path length) covered by the object.

(iii) In uniform motion, the instantaneous velocity is equal to the average velocity at all times.

16P. Look at the graphs (a) to (d) carefully and state, with reasons, which of these cannot possibly represent one-dimensional motion of the particle



Ans:

Acceleration

17. Define acceleration.

The rate of change of velocity of an object with time is called the acceleration.

$$\text{Acceleration} = \frac{\text{change in velocity}}{\text{time taken}}$$

$$a = \frac{v - u}{t}$$, u → initial velocity

v → final velocity

S.I unit of acceleration is $\mathbf{m/s^2}$

The dimensional formula of acceleration is $\mathbf{[M^0L^1T^{-2}]}$.

18. Define **uniform acceleration**. Give an example for uniformly accelerated motion.

Ans: An object is said to be moving with uniform acceleration, if its velocity changes by equal amounts in equal intervals of time.

Eg: Motion of a freely falling body. A freely falling body has a uniform acceleration of $\mathbf{9.8\ m/s^2}$

19. Define average acceleration.

Ans:

Average acceleration

$$= \frac{\text{Total change in velocity}}{\text{time taken}}$$

$$\bar{a} = \frac{v_2 - v_1}{t_2 - t_1} = \frac{\Delta v}{\Delta t}$$

20. Define instantaneous acceleration.

Ans: Instantaneous acceleration is defined as the limit of the average acceleration as the time interval Δt becomes infinitesimally small.

$$a = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} = \frac{dv}{dt}$$

Note: The acceleration of an object at a particular time is the slope of the velocity- time graph at that instant of time.

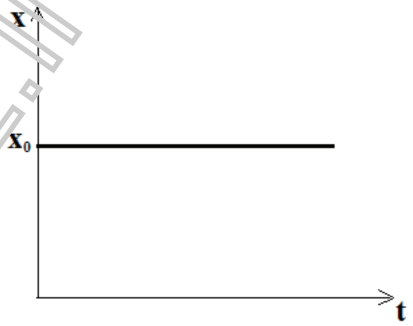
Position–Time Graphs

21. Draw the position-time graphs for **(i) rest** and **(ii) uniform motion.**

Ans:

i. For an object at rest

The graph is a straight line parallel to the time axis.

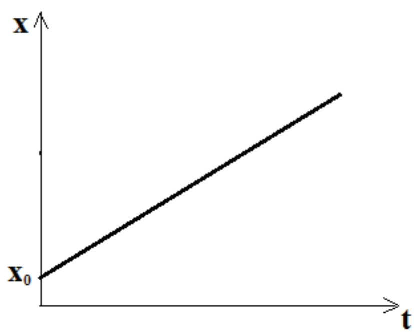


ii. For Uniform Motion

The graph is a straight line with positive or negative slope.

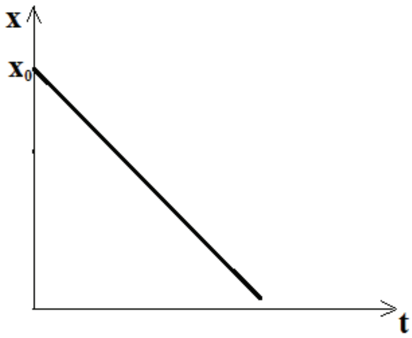
(a) Uniform Positive Velocity

[Positive velocity means that the object moves away from the observer.]



(b) Uniform Negative Velocity

[Negative velocity means that the object moves towards the observer.]



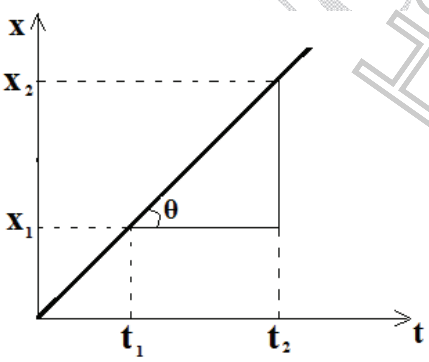
22. What are the uses of position-time graphs?

Ans: (i) From the position- time graph, we get the positions of the object at different instants of time.

(ii) The slope of the position-time graph gives the velocity.

23. Prove that the slope of the position-time graph gives acceleration.

Ans:



slope = $\tan\theta$

$= \frac{x_2 - x_1}{t_2 - t_1}$

$= \frac{\Delta x}{\Delta t}$

= v, the velocity

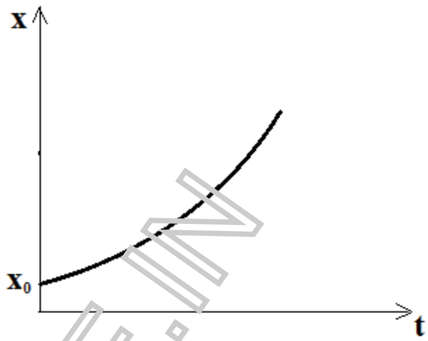
That is the slope of the x-t graph gives the velocity of the object.

24. Draw the position-time graphs for uniform acceleration.

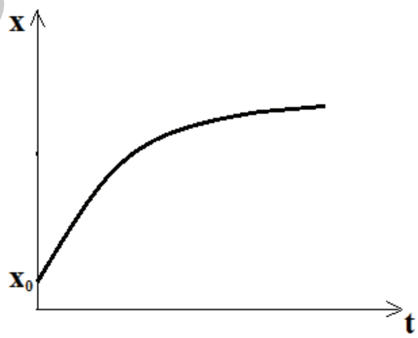
Ans:

(iii) **<u>Uniformly accelerated motion</u>**

(a) Uniform Positive acceleration



(b) Uniform Negative acceleration (Retardation)



25P. A drunkard walking on a narrow lane takes **3** steps forward **1** step backward, followed by **3** steps forward and **1** step backward, and so on. Each step is **1m** long and requires **1s**. Plot the **x-t** graph of his motion. Determine graphically that how long the drunkard takes to fall in a pit **7m** away from the start.

Ans:

Velocity-Time Graphs

26. Draw the velocity-time graphs for

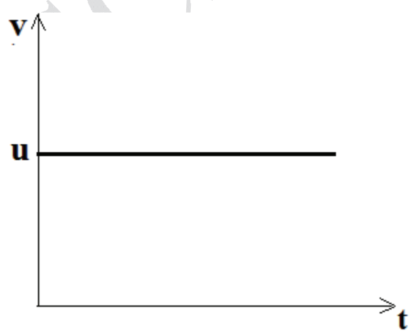
(i) Uniform motion

(ii) Uniform acceleration

Ans:

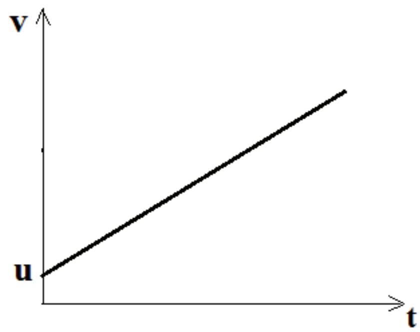
i.Uniform motion
(Uniform Velocity)

The graph is a straight line parallel to the time axis.

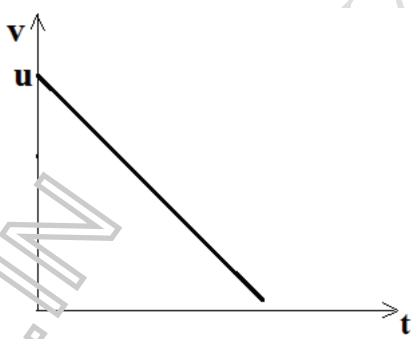


ii.Uniform Acceleration

(a) Uniformly Accelerated Motion



(b) Uniformly Retarded Motion



27. What are the uses of velocity-time graphs?

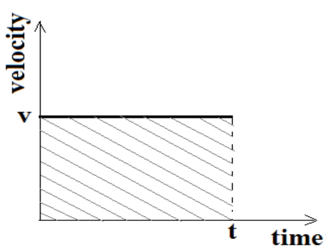
Ans: (i) Velocity-time graph gives the velocity of the object at different instants of time.

(ii) The area under v-t graph gives displacement.

(iii) The slope of v-t graph gives the acceleration of the object.

28. Prove that the area under v-t graph gives the displacement of the object.

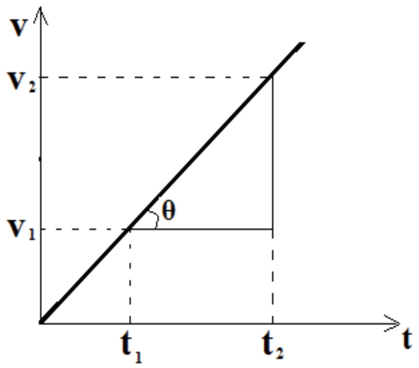
Ans:



Area under the graph= =
$v \times t = S$, the displacement.

29. Prove that the slope of the velocity-time graph gives acceleration.

Ans:



$$\text{slope} = \tan\theta$$

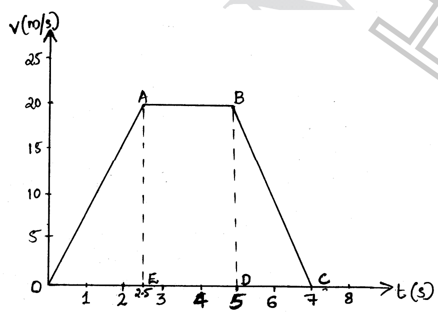
$$= \frac{v_2 - v_1}{t_2 - t_1}$$

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

$$= a, \text{ the acceleration}$$

Hence the slope of the velocity-time graph gives the acceleration of the object.

30P. The velocity-time graph of a vehicle is as shown.



(a) What is the type of motion

(i) along OA (ii) along AB

(iii) along BC

(b) Find the distance covered by the vehicle during (i) 2.5s (ii) 7s

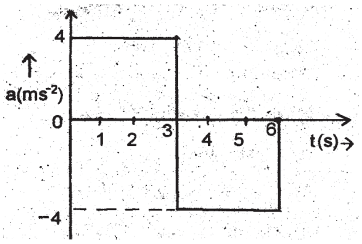
(c) Calculate the acceleration for

(i) OA (ii) AB and BC

(d) Draw the acceleration-time graph for the above motion.

Ans:

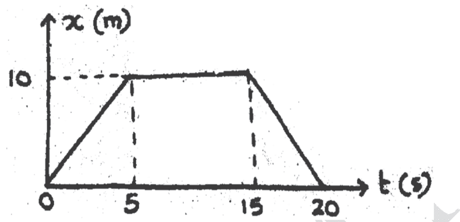
31P. Acceleration-time graph of a body starts from rest is as shown below:



a) What is the use of acceleration time graph?
b) Draw the velocity-time graph using the above graph.
c) Find the displacement in the given interval of time from 0 to 3 seconds.

Ans:

32P. The figure shows the x-t graph of a body moving along a straight line.



a) Draw the velocity- time graph of the body.
b) From the graph find the displacement in 20 seconds.

Ans:

33P. The table below shows the velocity of a car at different times.

Time(s)	Velocity(m/s)
0	11
1	16
2	21
3	26

4	31
5	36

a) Plot the a-t graph of this motion. What do you infer from this?
b) Find the distance travelled by the car in 6 sec.

Ans:

34. What is the equation of motion for uniform velocity?

Ans: $S = vt$

35. Give the kinematic equations for uniform acceleration.

Ans:

$$v = u + at$$

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

$$v^2 = u^2 + 2aS$$

36P. Derive the kinematic equations for uniform acceleration from **v-t** graph.

Ans: **v-t Graph**

(i) Velocity-Time Relation

(ii) Dispacement-Time Relation

(iii) Velocity-Displacement Relation

37P. A car moving on a straight highway with a speed of **72km/hr** is brought to a stop with in a distance of **100m**.

(a) What is the retardation of the car?

(b) How long will it take for the car to stop?

Ans:

38P.Show that for a car, starting from rest, moving with constant acceleration for a period of time, the distance travelled in the second half is three times of that in the first half.

Ans:

39P. A truck is moving forward at a constant speed of **20 m/s**. The driver sees a car in front of him at a distance of **110m** stopping suddenly. After a reaction time he applies the brakes which give the truck an acceleration of **-3m/s^2**. What will be the maximum allowable reaction time to avoid a collision and what distance the truck would have moved before the brakes take hold?

Ans:

40P. When brakes are applied on a moving vehicle, it stops after travelling a distance. This distance is called stopping distance.

a) Write an expression for the stopping distance in terms of initial velocity (**u**) and retardation (**a**).

b) If the initial speed is doubled, keeping the retardation same, by how much will the stopping distance change?

Ans:

Motion under Gravity

41. A ball is thrown vertically up, with an initial velocity u.

(a) What is the force acting on the ball after being projected?

(b) What is the acceleration of the ball?

(c) What is the velocity of the ball at the highest position?

(b) What is the acceleration of the ball at the highest position?

Ans: (a) F= -mg

(b) a = -g

(c) v = 0

(d) a= -g

42. Draw **(a)** x - t graph

(b) v – t graph

(c) a – t graph

for a ball thrown vertically up from the ground and returns to the ground.

Ans: (a) **x-t graph**

(b) **v-t graph**

(c) **a-t graph**

43P. A body is projected up with a velocity **u.**

(a) What is the time taken by it to reach the highest point?

(b) Show that, if air resistance is neglected, the **time of ascent is equal to the time of descent**.

Ans:

44P. A body is dropped from a height '**h**'. Calculate

(a) The time taken by it to reach the ground.

(b) The velocity on reaching the ground.

Ans:

$$(a)\ We\ have,\ S = ut + \frac{1}{2}at^2$$

$$\Rightarrow -h = 0 \times t + \frac{1}{2}(-g)t^2$$

$$\Rightarrow -h = -\frac{1}{2}gt^2$$

$$\Rightarrow \frac{1}{2}gt^2 = h$$

$$\Rightarrow t^2 = \frac{2h}{g} \Rightarrow t = \sqrt{\frac{2h}{g}}$$

$$(b)\ We\ have,\ v^2 = u^2 + 2aS$$

$$\Rightarrow v^2 = 0^2 + 2(-g)(-h)$$

$$\Rightarrow v^2 = 2gh$$

$$\Rightarrow v = \sqrt{2gh}$$

45P. A ball is thrown vertically upwards with a velocity of **20m/s** from the top of a multi-storeyed building. The height of the point from where the ball is thrown is **25m** from the ground.

(i) How high will the ball rise?

(ii) How long it will be before the ball hits the ground?

Ans:

46P. If 'v' is the velocity and 'a' is the acceleration, give an example of a physical situation for each of the following cases.

a) $v \neq 0, a = 0$
b) $v = 0, a \neq 0$
c) $v > 0, a < 0$

Ans:

a) A body moving with uniform velocity.
b) For a ball thrown vertically up, at the highest point of its path the velocity is zero but still it has an acceleration **–g.**
c) For a ball thrown vertically up, during its upward motion the velocity is positive and acceleration is negative.

47. Can a body have acceleration without velocity? Justify your answer with a physical situation

Ans: Yes. For a ball thrown vertically up, at the highest point of its path the velocity is zero but still it has an acceleration **–g**.

48. A ball is thrown vertically upwards from the top of a tower with velocity '**v**'. Another ball is thrown vertically downwards with the same velocity '**v**'. Which ball will hit the ground with greater velocity?

Ans:

Relative Velocity

49. Define relative velocity

Ans: It is the velocity of one object with respect to another object.

50. Give the expressions to find relative velocity.

Ans: <u>When the objects are moving along the same direction</u>,

The relative velocity of 'A' with respect to 'B' is $\mathbf{V_{AB} = V_A - V_B}$

The relative velocity of 'B' w. r. t 'A' is $\mathbf{V_{BA} = V_B - V_A}$

<u>When the objects are moving in the opposite direction</u>,

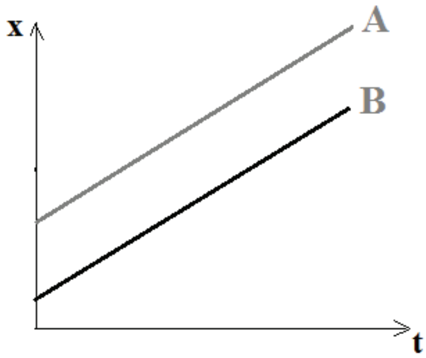
Relative velocity $= V_A - (-V_B)$

$= V_A + V_B$

51. Draw the position-time graphs for relative motion

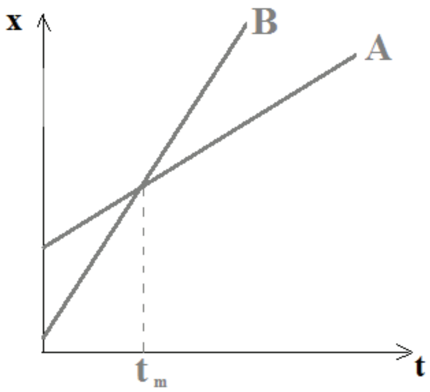
Ans:

(i) <u>When the relative velocity is zero (i.e., when $\mathbf{V_A = V_B}$)</u>



The bodies are always at the same separation.

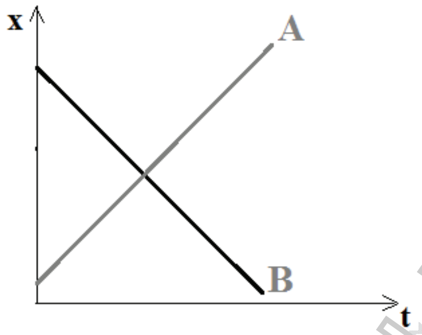
(ii) <u>When $\mathbf{V_B > V_A}$</u>



A and B meet together

t_m → time of meeting.

(iii) <u>When the objects are moving in the opposite direction.</u>



t_m → time of meeting

55P. A police van moving on a highway with a speed of **30km/hr** fires a bullet at a thief's car speeding away in the same direction with a speed of **192km/hr**. If the muzzle speed of the bullet is **150m/s**, with what speed does the bullet hit the thief's car?