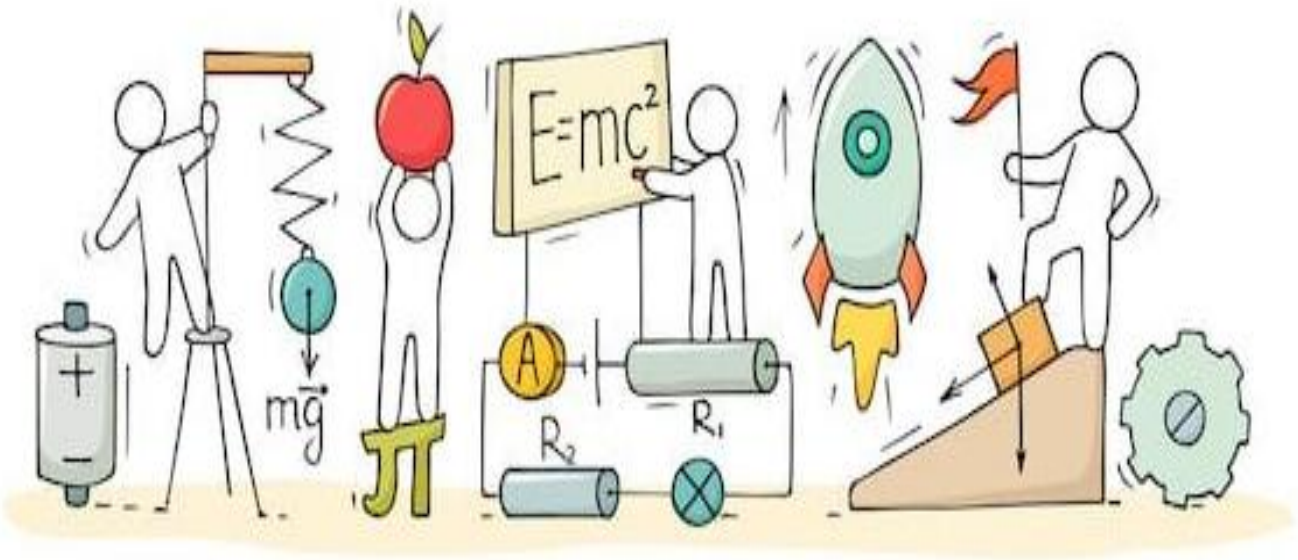
PHYSICS

Chapter 8: Motion



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 at the same time.
- 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.
- 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.
- To locate the position of an object, we have to choose some suitable **reference point** called the **origin**.
- Reference point or origin is a fixed point with respect to which a given body changes its position.

System of Units

System of Units	Length	Mass	Time
CGS	Centimetre	Gram	Seconds
FPS	Foot	Pound	Seconds
SI / MKS	Metre	Kilogram	Seconds

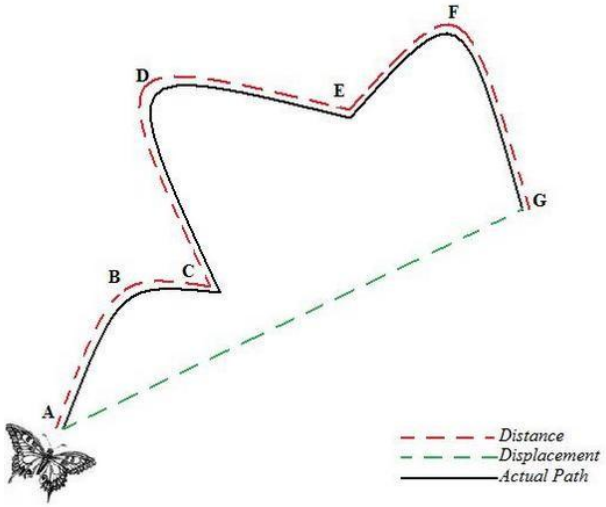
Physical Quantity

- A **physical quantity** is a quantity that can be measured.
- Magnitude is the size or extent of a physical quantity.
- A physical quantity can be scalar or vector.
- A **scalar quantity** is a quantity which is completely specified by magnitude only. For example: mass, distance, time etc.
- A **vector quantity** is a quantity which possesses both magnitude and direction. For example: displacement, velocity, force etc.

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 or negative.
- The displacement of an object can be positive, zero or negative. Never can the distance travelled be less than the displacement.
- The displacement of a body can be equal to distance only if the body travels in straight line otherwise is always smaller than distance.
- Distance of a moving body can never be zero whereas its displacement can be zero if it comes back to its starting position.
- Both distance and displacement have the same units.

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

- **Speed** of a body is defined as the distance travelled by the body in unit time. The SI unit of speed is **metre/second** (m/s

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

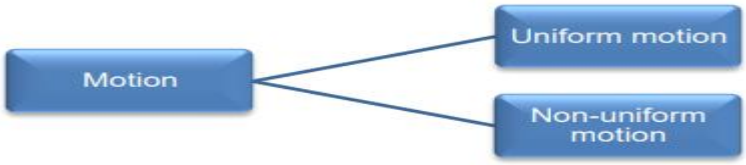
- If ‘s’ is the distance travelled by a body in time ‘t’, then its speed ‘v’ is given as v = s\t
- Speed of a body is a scalar quantity. It can be zero or positive but can never be negative.
- If a body covers equal distances in equal time intervals, howsoever small the intervals may be, then it is said 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).

- The speed of an object at any instant of time, during its motion is called instantaneous speed.
- The instantaneous speed of a vehicle is measured by a device on the dashboard of a car called speedometer.
- For bodies moving with non-uniform speed, we describe the rate of motion in terms of their average speed.

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

Uniform and Non-uniform Motion



- An object is said to be in **uniform motion** if it travels equal distances in equal intervals of time (constant speed) along a straight line (constant direction), howsoever small the intervals may be.
- An object is said to have **non-uniform motion** if it travels unequal distances in equal intervals of time.

Velocity

- **Velocity** of a body is defined as the distance travelled by the body in unit time in a given direction.
- 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 $\vec{v}$ is velocity & $\vec{s}$ is displacement of the body in time t.

- Velocity of a body is a **vector** quantity. It can be positive, negative or zero.
- 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.
- When the velocity of a body is changing at a uniform rate over a period of time, the **average velocity** for that time period is given by the arithmetic mean of the initial and final velocity of the body.

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

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

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

Acceleration

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

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

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).
- A body undergoing acceleration is having non uniform motion as velocity of the body changes.
- If the velocity of a body increases, then the acceleration is positive and the direction of acceleration is in the direction of motion of the body.
- If the velocity of a body decreases, then the acceleration is negative and the direction of acceleration is in the direction opposite to that of motion of the body. **Negative acceleration** is also called **retardation**.
- A body is said to possess **uniform acceleration** if its velocity increases or decreases by equal amounts in equal intervals of time.
- A body is said to possess **non-uniform acceleration** if its velocity changes by unequal amounts in equal intervals of time.

- Uniform retardation is a type of motion in which the velocity of an object decreases by an equal amount in every equal interval of time.

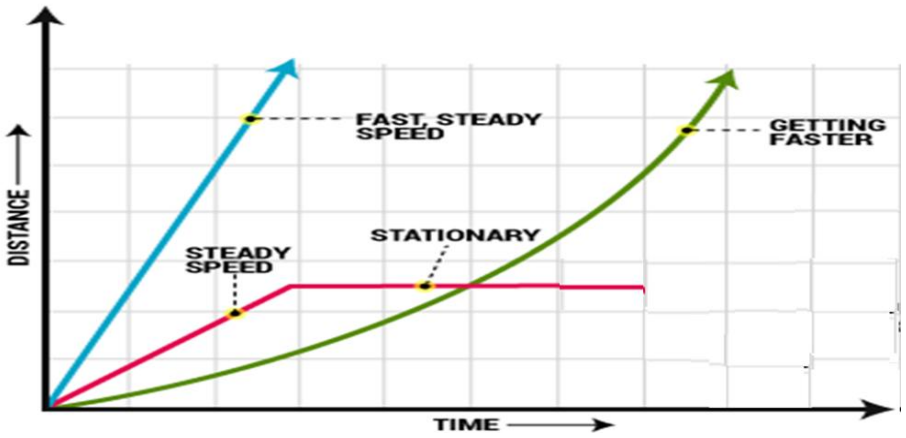
- Non uniform retardation is a type of motion in which the velocity of an object decreases by an unequal amount in every equal interval of time.

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. It shows the change in position of an object with respect to time.
- Distance is plotted on the Y-axis and Time is plotted on the X-axis.
- For a stationary body, the distance-time graph is a straight line parallel to time axis.
- 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.

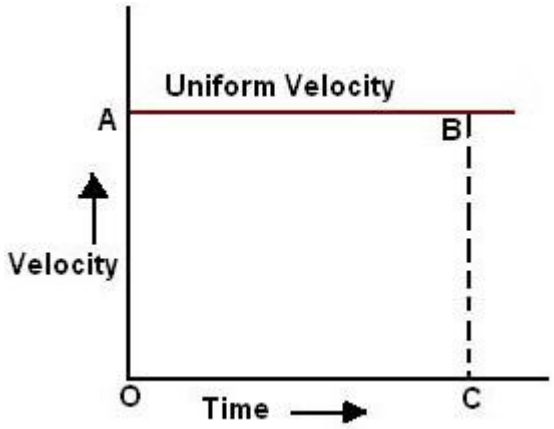
$$\text{Slope of a graph} = \frac{Change\ in\ Y\ axis}{Change\ in\ X\ axis}$$

- 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.

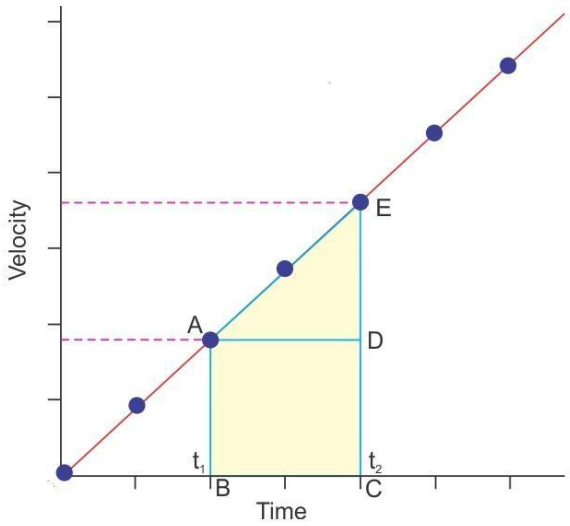
  Distance travelled = Speed × Time taken

  = OA × OC

  = Area of rectangle OABC

- The velocity–time graph of a body moving with uniform acceleration is a straight line making a constant angle with the time axis.

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



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

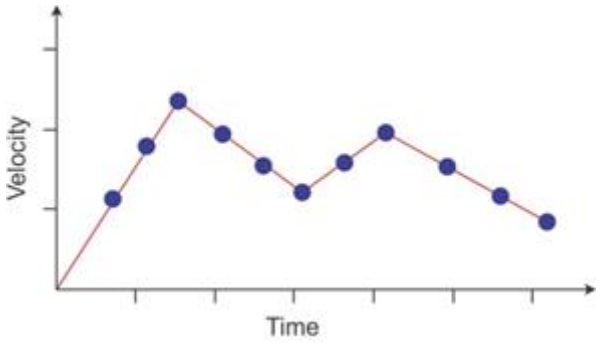
  Distance travelled = Area of ABCDE

  = Area of triangle ADE+ Area of rectangle ABCD

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

- For a body having non uniform acceleration, the graph is a curve having increasing or decreasing

slope or gradient.



The following things can be concluded now:

- The distance-time graph
  - i. For a stationary body, is a straight line parallel to the time-axis.
  - ii. For a body having uniform motion, is a straight line having a constant angle with the time axis or constant slope or gradient.
  - iii. For a body having non-uniform motion, is a curved line having an increasing or decreasing slope or gradient.
- The slope of a Distance-Time graph gives the speed of the body.
- The velocity-time graph
  - i. For a body having uniform velocity, is a straight line parallel to the time-axis.
  - ii. For a body having uniform acceleration, is a straight line having a constant angle with the time axis or constant slope or gradient.
  - iii. For a body having non-uniform acceleration, is a curve having increasing or decreasing slope or gradient.
- Area under Velocity-Time graph gives the magnitude of displacement travelled by the body.
- The slope of Velocity-Time graph gives the acceleration of the body.

Equations of Motion

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

$v = u + at$

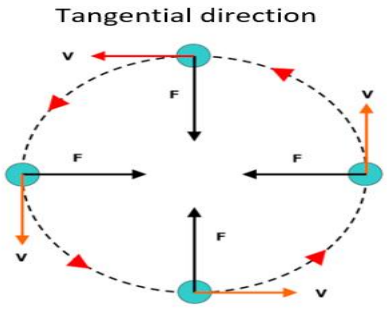
$s = ut + (1/2)\, at^2$

$v^2 - u^2 = 2as$

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

Uniform Circular Motion

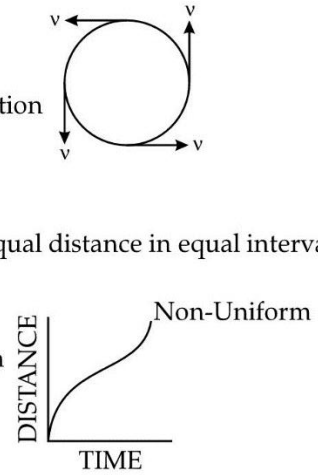
- When a body moves along a circular path with a uniform speed, its motion is called uniform circular motion.
- Examples: Motion of the Moon around the Earth, a cyclist moving in a circular track at constant speed
- In a uniform circular motion, although the speed remains constant, the direction of motion 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 direction of motion of a body moving in a circular path at any instant is along a tangent to the position of the body on the circular path at that instant of time. (**A tangent is a straight line touching a circle at a point**.)



- The circumference of a circle of radius 'r' is given by $2\pi r$. If a body takes 't' seconds to go once round the circular path of radius 'r', then its velocity 'v' is given by $\frac{2\pi r}{t}$.

Motion

- Types of Motion
  - Random Motion
  - Translation Motion
    - Rectilinear
    - Curvilinear
    - Circular
  - Rotational Motion
  - Oscillatory Motion
  - Uniform Circular Motion
    - Speed $= \frac{2\pi r}{T}$
  - Uniform Motion → Equal distance in equal intervals of time
  - Non-Uniform Motion



- Rate of Motion
  - Speed $= \frac{\text{Distance}}{\text{Time}}$
  - Velocity $= \frac{\text{Displacement}}{\text{Time}}$
  - Acceleration $= \frac{\text{Change in Velocity}}{\text{Time Taken}}$
- Equations of Motion
  - $v^2 - u^2 = 2as$
  - $s = ut + \frac{1}{2}at^2$
  - $v = u + at$

Important Questions

➢ Multiple Choice Questions:

1. A particle is moving in a circular path of radius r. The displacement after half a circle would be:

(a) Zero

(b) πr

(c) 2r

(d) 2πr

2. A body is thrown vertically upward with velocity u, the greatest height h to which it will rise is,

(a) u/g

(b) $u^2/2g$

(c) u^2/g

(d) u/2g

3. The numerical ratio of displacement to distance for a moving object is

(a) always less than 1

(b) always equal to 1

(c) always more than 1

(d) equal or less than 1

4. If the displacement of an object is proportional to the square of time, then the object moves with

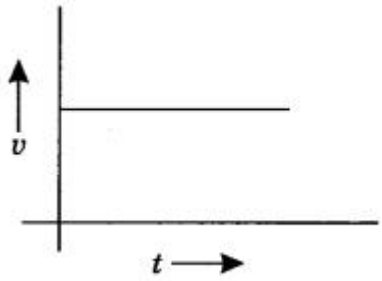
(a) uniform velocity

(b) uniform acceleration

(c) increasing acceleration

(d) decreasing acceleration

5. From the given υ – t graph, it can be inferred that the object is



(a) in uniform motion

(b) at rest

(c) in non-uniform motion

(d) moving with uniform acceleration

6. Suppose a boy is enjoying a ride on a merry-go-round which is moving with a constant speed of 10 ms^{-1} It implies that the boy is

(a) at rest

(b) moving with no acceleration

(c) in accelerated motion

(d) moving with uniform velocity

7. Area under a υ -t graph represents a physical quantity which has the unit

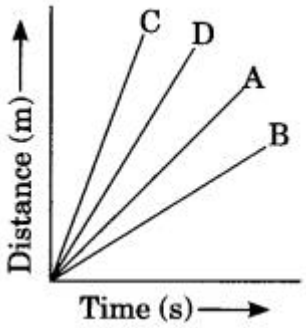
(a) m^2

(b) m

(c) m3

(d) ms^{-1}

8. Four cars A, B, C and D are moving on a levelled road. Their distance versus time graphs are shown in the adjacent figure. Choose the correct statement.



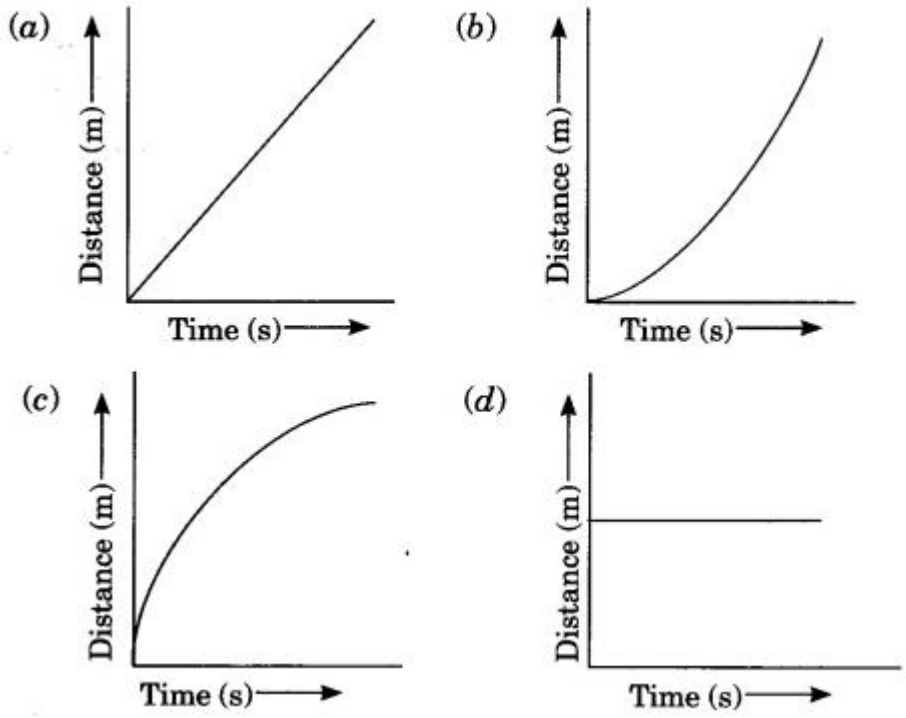
(a) Car A is faster than car D.

(b) Car B is the slowest.

(c) Car D is faster than car C.

(d) Car C is the slowest.

9. Which of the following figures correctly represents uniform motion of a moving object?



10. The slope of a velocity-time graph gives

(a) the distance

(b) the displacement

(c) the acceleration

(d) the speed

11. In which of the following cases of motions, the distance moved and the magnitude of displacement are equal?

(a) If the car is moving on a straight road

(b) If the car is moving in a Circular path

(c) The pendulum is moving to and from

(d) The earth is revolving around the sun.

12. A boy goes from A to B with a velocity of 20 m/min and comes back from B to A with a velocity of 30 m/min. The average velocity of the boy during the whole journey is

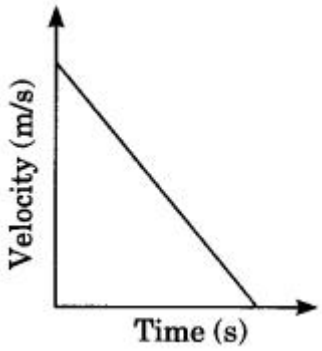
(a) 24 m/min

(b) 25 m/s

(c) Zero

(d) 20 m/min

13. Velocity-time graph of an object is given below. The object has



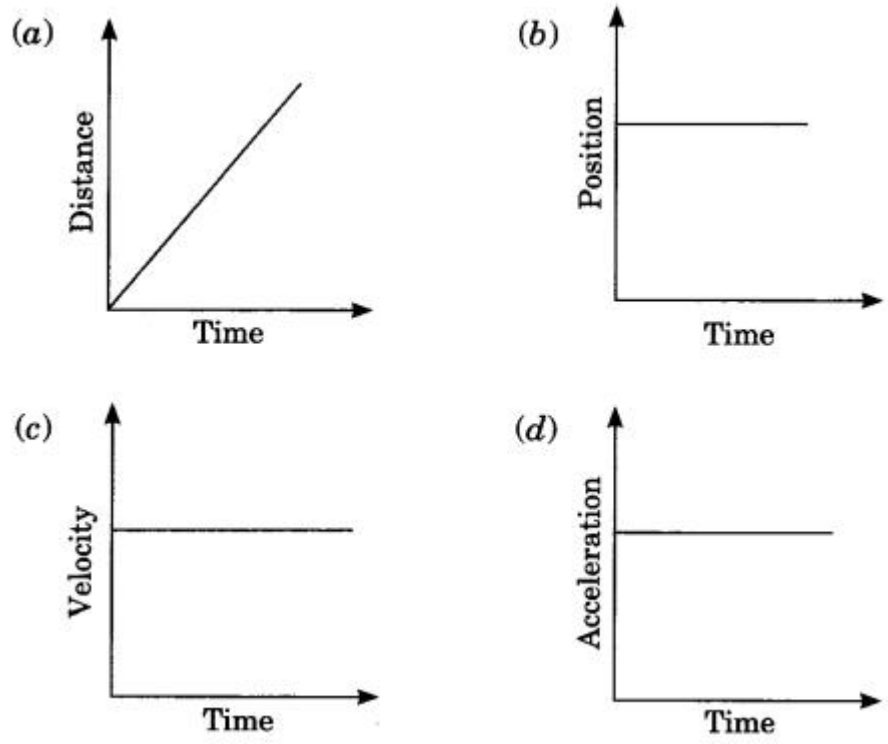
(a) Uniform velocity

(b) Uniform speed

(c) Uniform retardation

(d) Variable acceleration

14. Which one of the following graphs shows the object to be stationary?



15. A body is projected vertically upward from the ground. Taking vertical upward direction as positive and point of projection as origin, the sign of displacement of the body from the origin when it is at height h during upward and downward journey will be

(a) Positive, positive

(b) Positive, negative

(c) Negative, negative

(d) Negative, positive

➢ Very Short Question:

1. An object has moved through a distance. Can it have zero displacement? If yes, support your answer with an example.
2. What do you mean by a body at rest?
3. Are motion and rest absolute or relative? Explain with an example.
4. What is meant by scalar and vector quantity?
5. A farmer moves along the boundary of a square field of side 10 m in 40 s. What will be the magnitude of displacement of the farmer at the end of 2 minutes 20 seconds?
6. Which of the following is true for displacement?

   (a) It cannot be zero.

   (b) Its magnitude is greater than the distance travelled by the object.
7. What does the odometer of an automobile measure?
8. Distinguish between speed and velocity.
9. Under what condition(s) is the magnitude of average velocity of an object equal to its average speed?
10. What does the path of an object look like when it is in uniform motion?

➢ Short Questions:

1. Distinguish between distance and displacement.
2. Write down the SI unit of the following quantities:

   (a) Displacement

   (b) Speed

   (c) Velocity

   (d) Acceleration
3. Distinguish between uniform motion and non-uniform motion.
4. Distinguish speed at any instant and average speed.
5. What is uniform circular motion? How is uniform circular motion regarded as an acceleration motion? Explain.
6. A person travels a distance of 4.0 m towards the east, then turns left and travels 3.0 m towards the north. Calculate its displacement and distance travelled.
7. A person travels on a semi-circular track of radius 50 m during a morning walk. If he starts from one end of the track and reaches the other end, calculate the distance travelled and displacement of the person.

➢ Assertion Reason Questions:

1. For two statements are given- one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below:

   a. Both Assertion and Reason are correct, and reason is the correct explanation for assertion.

   b. Both Assertion and Reason are correct, and Reason is not the correct explanation for Assertion.

   c. Assertion is true but Reason is false.

   d. Both Assertion and Reason are false.

   Assertion: An object may acquire acceleration even if it is moving at a constant speed.

   Reason: With change in the direction of motion, an object can acquire acceleration.

2. For two statements are given- one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below:

   a. Both Assertion and Reason are correct, and reason is the correct explanation for assertion.

   b. Both Assertion and Reason are correct, and Reason is not the correct explanation for Assertion.

   c. Assertion is true but Reason is false.

   d. Both Assertion and Reason are false.

   Assertion: Displacement of an object may be zero even if the distance covered by it is not zero.

   Reason: Displacement is the shortest distance between the initial and final position.

➢ Case Study Based Question:

1. Read the following and answer any four questions from (i) to (v)

   One day Rahul decided to go his office by his car. He is enjoying the driving along with listening the old songs. His car is moving along a straight road at a steady speed. On a particular moment, he notices that the car travels 150 m in 5 seconds.

(i) What is its average speed?

(a) 20 m/s

(b) 30 m/s

(c) 10 m/s

(d) 40 m/s

(ii) How far does it travel in 1 second?

(a) 20 m

(b) 30 m

(c) 10 m

(d) 40 m

(iii) How far does it travel in 6 seconds?

(a) 120 m

(b) 130 m

(c) 180 m

(d) 140 m

(iv) How long does it take to travel 240 m?

(a) 2s

(b) 4s

(c) 6s

(d) 8s

(v) Which of the following statement is correct regarding velocity and speed of a moving body?

(a) velocity of a moving body is always higher than its speed

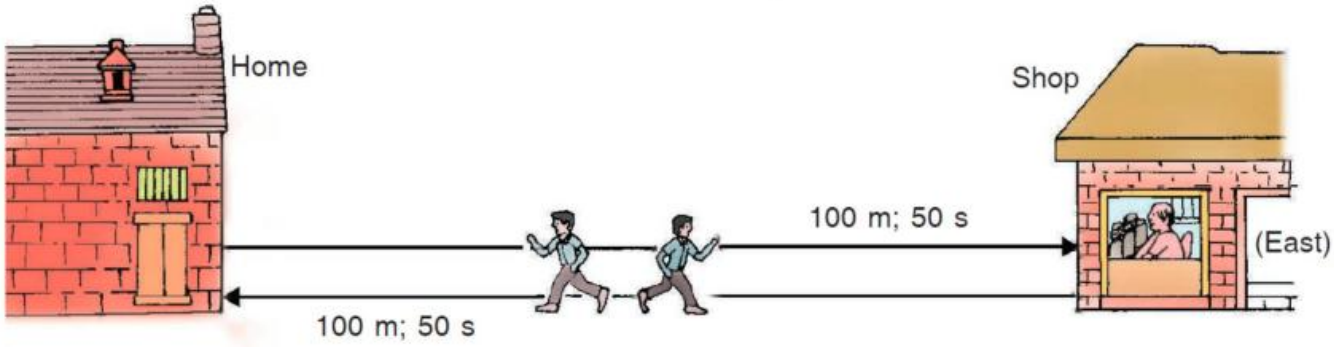
(b) speed of a moving body is always higher than its velocity

(c) speed of a moving body is its velocity in a given direction

(d) velocity of a moving body is its speed in a given direction

2. Read the following and answer any four questions from (i) to (v)

Suppose the boy first runs a distance of 100 metres in 50 seconds in going from his home to the shop in the East direction, and then runs a distance of 100 metres again in 50 seconds in the reverse direction from the shop to reach back home from where he started (see Figure 21).



(i) Find the speed of the boy.

(a) 1 m/s

(b) 2 m/s

(c) 3 m/s

(d) none of these

(ii) Find the Velocity of the boy.

(a) 1 m/s

(b) 2 m/s

(c) 3 m/s

(d) 0 m/s

(iii) A boy is sitting on a merry-go-round which is moving with a constant speed of 10m/s. This means that the boy is:

(a) at rest

(b) moving with no acceleration

(c) in accelerated motion

(d) moving with uniform velocity

(iv) In which of the following cases of motion, the distance moved and the magnitude of displacement are equal?

(a) if the car is moving on straight road

(b) if the car is moving on circular road

(c) if the pendulum is moving to and from

(d) if a planet is moving around the sun

(v) A particle is moving in a circular path of radius r. The displacement after half a circle would be:

(a) 0

(b) πr

(c) 2r

(d) 2πr

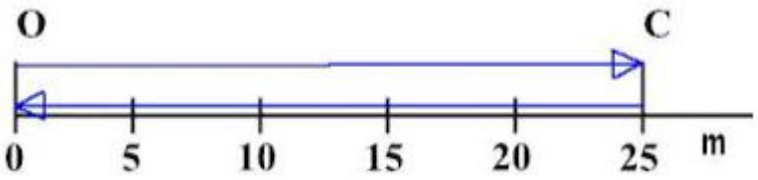
✓ Answer Key-

➢ Multiple Choice Answers:

1. (c) 2r
2. (b) $u^2/2g$
3. (d) equal or less than 1
4. (b) uniform acceleration
5. (a) in uniform motion
6. (c) in accelerated motion
7. (b) m
8. (b) Car B is the slowest.
9. (a)
10. (c) the acceleration
11. (a) If the car is moving on a straight road
12. (a) 24 m/min
13. (c) Uniform retardation
14. (b)
15. (b) Positive, negative

➢ Very Short Answers:

1. Answer: Yes an object can have zero displacement even though it has moved through a distance. It happens when the object moves back to its original position i.e. final position coincides with the starting position.



Example: Suppose an object travels from O to C and then comes back to original position O.

Total distance traveled = actual path covered = OC + CO = 25 + 25 = 50m

Total displacement = shortest distance between final position and initial position = 0m

2. Answer: A body is said to be at rest, if it does not change its position with respect to a fixed point in its surroundings.

3. Answer: No these terms rest and motion are relative. For example, a person inside a car, carrying a ball in his hand will see the ball is at rest. While for another person, outside the car will see the ball is also moving.

4. Answer:

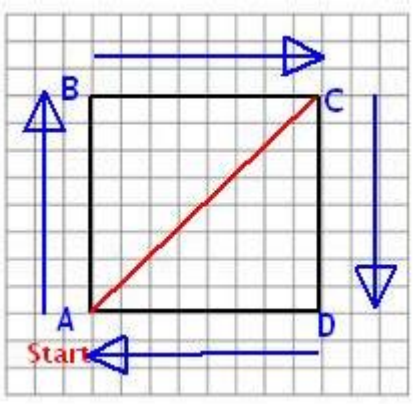
   Scalar Quantities: Quantities that require magnitudes only to specify them are called scalar quantities or scalars. Mass, length, time, temperature, angle, area, speed, distance, volume and density are examples of scalar quantities.

   Vector Quantities: Quantities that require both magnitudes and direction to specify them are called vector quantities or vectors. Displacement, velocity, force, momentum, weight etc. are the examples of vectors.

5. Answer: As shown in figure, let us assume, the farmer starts from A.

   Given, length of each side = 10m

   Distance covered in 1 lap = Perimeter of ABCD = 4 x 10 = 40m



   Time taken by farmer to cover 1 lap = 40s

   Speed of farmer = Distance ÷ Time Taken for one lap = 40/40s = 1m/s

   Distance covered by farmer in 2min 20 secs = Speed x Time = 1 x 140s = 140m

   Number of laps covered = 140 ÷ 40 = 3.5 laps.

   ⇒ After 140s, the farmer will be at position C (i.e. 3 and ½ laps).

   Displacement = AC = (AB2 + BC2)½

   (applying Pythagoras theorem)

   = (100+100)½ = 10√2 = 10 x 1.414 = 14.14m

   Note: Displacement is a vector quantity that measures the shortest distance (straight line) between the starting point and ending point, not taking the actual path traveled into account.

6. Answer:

   (a) False. Displacement can be zero.

(b) False. Displacement is less than or equal to the distance travelled by the object.

7. Answer: Odometer is used to measure the distance covered by the automobile. It also tells the instant speed of the vehicle. It can be mechanical or electronic or electro-mechanical.

8. Answer:

Speed	Velocity
It is distance traveled by an object per unit time.	It is the displacement covered by an object per unit of time.
Speed cannot be zero for a moving body.	Velocity can be zero for a moving body.
It is a scalar quantity i.e. it has magnitude only.	It is a vector quantity i.e. has both magnitude and direction.

9. Answer: When a body is in rectilinear motion i.e. moves in straight line in a particular direction, the magnitude of average velocity of an object is equal to its average speed.

10. Answer: Straight line.

➢ Short Answers:

1. Answer:

Distance:

- It is the actual length of the path covered by a moving body.
- It is always positive.
- It is a scalar quantity.

Displacement:

- It is the shortest distance measured between the initial and final positions.
- It may be positive, negative, or zero.
- it is a vector quantity.

2. Answer:

(a) m

(b) m/s

(c) m/s

(d) m/s^2

3. Answer:

Uniform motion: A body moving in a straight line has a uniform motion if it travels equal distances in equal intervals of time.

Non-uniform motion: A body has a non-uniform motion if it travels an unequal distance in equal intervals of time

4. Answer:

1. Instantaneous speed:

The speed at any particular instant is known as instantaneous speed.

2. Average speed:

Average speed is the ratio of the total distance traveled by a body and the time taken to travel that distance.

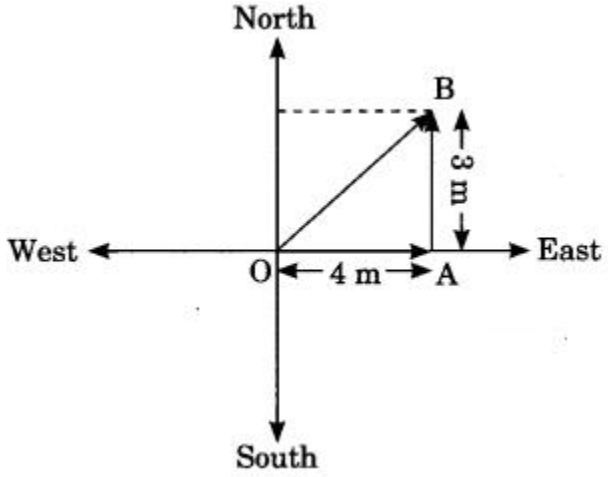
5. Answer: When an object is moving in a circular path with a constant speed, the motion of an object is said to be uniform circular motion. When a body has a uniform circular motion, its velocity changes due to the continuous change in the direction of its motion. Hence, the motion of the body is accelerated motion.

6. Answer:

1. Total distance = OA + AB

= 4m + 3m

Total distance = 7m



2. Total displacement = OB = $\sqrt{(OA)^2 + (AB)^2}$

$= \sqrt{(4)^2 + (3)^2} = \sqrt{25} = 5$

Displacement = 5 m

7. Answer:

Let the person start moving from A and reach B via O.

The distance travelled by the person

= Length of track = πr

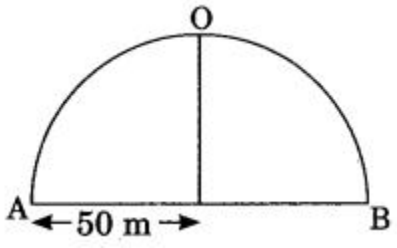
= 227 x 50 m = 157.14m

Distance = 157.14 m

The displacement is equal to the diameter of the semi-circular track joining A to B via O.

= 2r = 2 x 50 m = 100m

∴ Displacement = 100 m



➢ Assertion Reason Answer:

1. (a) Both Assertion and Reason are correct, and reason is the correct explanation for assertion.
2. (a) Both Assertion and Reason are correct, and reason is the correct explanation for assertion.

➢ Case Study Answer:

1. Answer:

(i) (b) 30 m/s

Solution:

Average speed = total distance travelled/total time taken

= 150/5

= 30 m/s

(ii) (b) 30 m

Solution:

Time = 1 s

Distance = (average speed)(time)

= 30 m/s x 1s

= 30 m

(iii) (c) 180 m

Solution:

Time = 6 s

Distance = (average speed)(time)

= 30 m/s x 6s

= 180m

(iv) (d) 8s

Solution:

Distance = 240m

Time = Distance/average speed

= 240/30

= 8s

(v) (d) velocity of a moving body is its speed in a given direction.

2. Answer:

(i) (b) 2 m/s

Solution:

Total distance travelled is 100 m + 100 m = 200 m and

the total time taken is 50 s + 50 s = 100 s.

$$\text{Speed of boy} = \frac{\text{Distance travelled}}{\text{Time taken}} = \frac{200\ \text{m}}{100\ \text{s}} = 2\ \text{m/s}$$

(ii) (d) 0 m/s

Solution:

The boy runs 100 m towards East and then 100 m towards West and reaches at the starting point, his home. So, the displacement will be 100 m – 100 m = 0 m.

The total time taken is 50 s + 50 s = 100 s.

$$\text{Velocity of boy} = \frac{\text{Displacement}}{\text{Time taken}} = \frac{0\ \text{m}}{100\ \text{s}} = 0\ \text{m/s}$$

(iii) (c) in accelerated motion

(iv) (a) if the car is moving on straight road

(v) (c) 2r