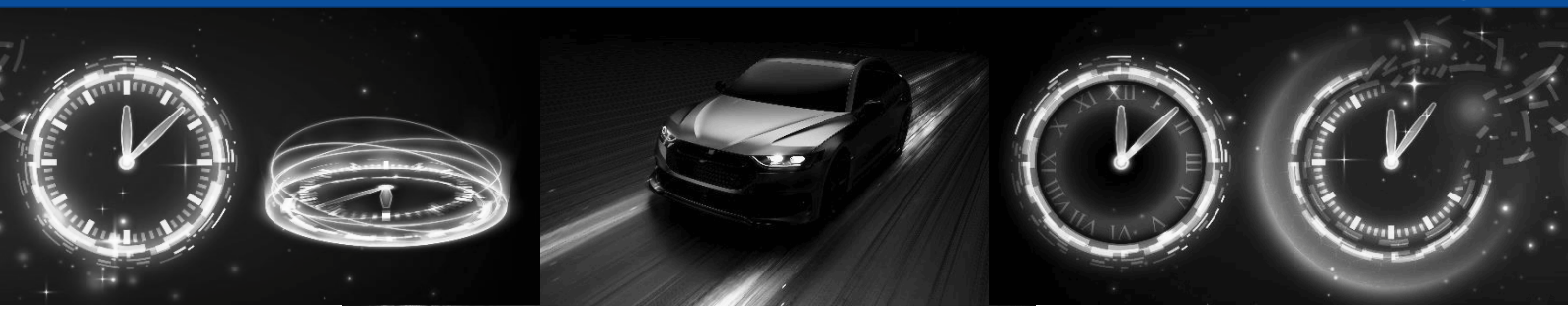


MOTION & TIME

Concepts Covered

- Physical Quantities
- Rest and Motion
- Types of Motion
- Distance and Displacement
- Speed and its types
- Velocity and its types
- Acceleration and its types
- Measurement of Time and Speed
- Distance-Time Graph

Rest and Motion

When we look around, we find some objects are in motion whereas, some other objects are at rest. Like when athletes run in a race then we can say that they are in motion, or the water in a river is said to be in motion, while a book lying on the table, a lamp post, a table, a chair, a blackboard etc., all are said to be at rest. When do we say that an object is in motion? When do we say that it is at rest?

An object in motion is the one that changes its position with respect to its surroundings whereas, an object which is at rest is the one that does not change its position with respect to its surroundings.

Rest and motion are relative terms. An object at rest with respect to one observer may not be at rest with respect to another observer. The same can be said about motion. For a person inside a bus, the fellow passengers are at rest but the same passengers are in motion with respect to a person standing on the ground.

If we closely observe the motion of different objects, we find them performing different kinds of motion. A car moving on a straight road, the rotation of blades of a table fan, and the motion of a swing which moves to and fro are all different kinds of motion.

Distance

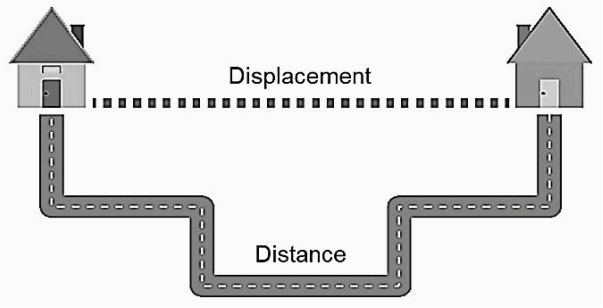
Distance travelled by a body can be defined as the length of the path covered by a body irrespective of the direction of motion.

- It is a scalar quantity.
- The SI unit of distance travelled is meter (m) while the CGS unit is centimeter (cm).

Displacement

Displacement of a body can be defined as the shortest distance travelled in a direction of motion from the initial to the final point.

It is a vector quantity.
The SI unit of displacement is meter (m) while the CGS unit is centimeter (cm).



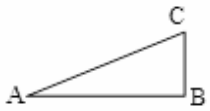
Note: If a body travels in such a way that it comes back to its starting point, then the displacement is zero. However, the distance travelled is never zero.

Difference between distance and displacement

S. No.	Distance	Displacement
1.	Distance is the length of the path actually travelled by a body in any direction.	Displacement of a body can be defined as the shortest distance travelled in a direction of motion from the initial to the final point.
2.	Distance between two given points depends upon the path chosen.	Displacement between two points is measured by the straight path between the initial and final points.
3.	Distance may be positive or zero.	Displacement may be positive as well as negative and even zero.
4.	Distance is a scalar quantity.	Displacement is a vector quantity.
5.	Distance will never decrease.	Displacement may decrease.

Examples:

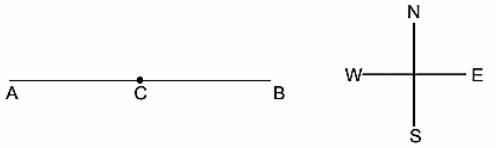
(1) Suresh walks from point A to C via B. Calculate distance and displacement.



Answer: Distance = length of AB + length of BC.
Displacement = length of AC.

(2) A train starts from station A and moves along a straight path towards station B which is 100 km from A. Reaching B it turns back and stops midway between A and B. Find the distance and displacement of the train. Neglect the length of the train.

Answer: Let's say the midpoint is C.
∴ Distance = AB + BC = 100 + 50 = 150 km
and Displacement = AC
= 50 km or 50 km along the east.



Check Your Concept - 1

(i) A person is moving along a rectangular path (ABCD), where the length of side AB is 12 m and of BC is 5 m. He starts from point A and goes to C via B. Calculate distance and displacement.

(ii) A person starting from point A travels a distance of 30 m west, then 20 m south and then 30 m east. His displacement will be_____.

Speed

The distance covered by a body in unit time is called speed.
Mathematically,

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

- The SI unit of speed is m/s while the CGS unit is cm/s.
- It can also be expressed in km/hr (1 km/hr = $\frac{5}{18}$ m/s).

Types of Speed

(i) Uniform speed
When a body covers equal distances in equal intervals of time, however small the time interval may be, then the speed of the body is said to be uniform. A car moving with a constant speed of 20 km/hr is an example of uniform speed.

(ii) Non-uniform speed
When a body covers unequal distances in equal intervals of time or when it covers equal distances in unequal intervals of time, then the speed of the body is said to be non-uniform. The motion of a bus after the application of brakes is an example of non-uniform speed.

(iii) Average Speed
It is the ratio of the total distance travelled by a body divided by the total time taken to cover that distance.

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

Examples:

(1) The distance between the two stations is 200 km. A train takes 4 hours to cover this distance. Calculate the speed of the train.

Solution: Distance = 200 km
Time taken = 4 hours

$$\text{Speed} = \frac{\text{Distance covered}}{\text{Time taken}} = \frac{200}{4}\ \text{km/hr}$$

Speed = 50 km/hr.

(2) A bus leaves station A at 7 PM and reaches station B at 9 PM. The speed of the bus is 20 km/h. What is the distance between stations A and B?

Solution: Distance = Speed × Time = 20 × (9 – 7) = 40 km.

(3) A car travels at 10 m/s. Express the same speed in km/h.

Solution: We know that, $1\ \text{m/s} = \frac{18}{5}\ \text{km/hr}$

$$\text{So,} \quad 10\ \text{m/s} = \frac{18}{5} \times 10$$
$$= 36\ \text{km/hr}.$$

Check Your Concept - 2

(i) A car moves with a speed of 20 km/h for 15 minutes and then with a speed of 60 km/h for the next 15 minutes. The total distance covered by the car is_____.

(ii) A car covers 1000 m in 10 sec and a cycle cover 50 m in 10 sec. Which one is faster?

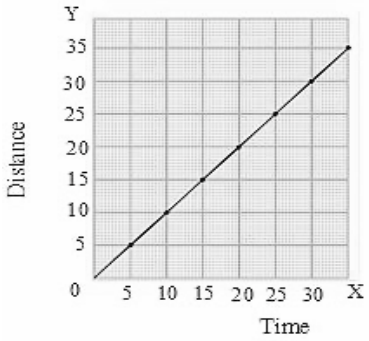
(iii) A car travels 30 km at a uniform speed of 40 km/h and the next 30 km at a uniform speed of 20 km/h. Find its average speed.

Distance-Time Graph

Consider an example: Rahul was travelling with his father in their car from Delhi to Kanpur. He kept himself busy by noting the distance travelled by the car every 5 minutes. This is what he noted in the first 30 minutes.

You do not need superpowers to go as fast as a sports car: Just go skydiving! In only three seconds, you pass 62 mph (100kph).

S. NO.	Time in minutes	Distance in km
1	0	0
2	5	5
3	10	10
4	15	15
5	20	20
6	25	25
7	30	30



You can make a graphical representation of his observations follow these simple steps.

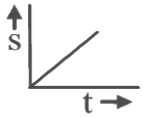
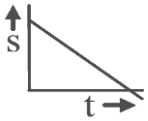
1. Taking axes and scale: Take a graph sheet and draw two lines perpendicular to each other. Mark the horizontal line as OX (x-axis) and the vertical line as OY (y-axis).
2. Time is taken on the X-axis and distance on the Y-axis.
3. Choose scales to represent distance and time.

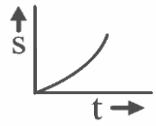
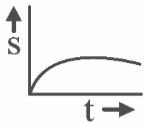
Note: The slope of the distance-time graph gives speed.

Example: The scales could be
X-axis: 1 cm = 5 minutes
Y-axis: 1 cm = 5 km

Plotting the graph: Mark the value on the axes for time and distance according to the scales you have chosen. According to the values noted, mark the points on the graph sheet. Join the points.

Displacement-Time Graph for various types of Motion

1.	The straight line inclined to the time axis at an angle less than 90° in the s-t graph represents constant velocity. 	2.	In the s-t graph, the straight line inclined to the time axis at an angle greater than 90° shows negative velocity. 

3.	Body with accelerated motion. 	4.	Body with decelerated motion. 

Note: Greater the speed, steeper will be the graph.

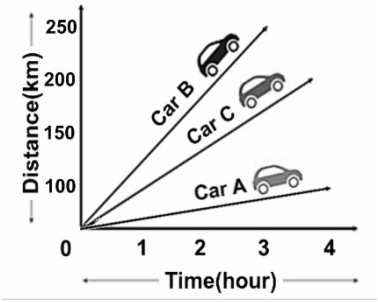
Examples:

(1) Three cars A, B and C travel from Delhi to Agra. The time taken and the distance covered are given in the table below.

S. NO.	Time taken in hours	Distance travelled in km		
		Car A	Car B	Car C
1	1	20	50	40
2	2	40	100	80
3	3	60	150	120
4	4	80	200	160
5	5	100	250	200

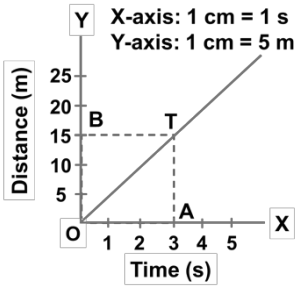
Plot the distance-time graph of the three cars in the same graph sheet.

Solution:



The spacecraft would have to attain a speed of at least 11.186 km per second to escape the Earth's gravitational pull.

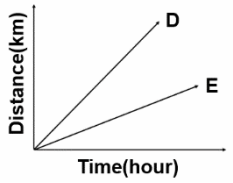
(2) The adjacent figure shows the graphical representation of the movement of a body. Find its speed after three seconds. What information do you get from the graph?



Answer: Draw a perpendicular on the X-axis from point A (i.e., three seconds on a time scale) which intersects the graph at point T. Now draw a line from T, parallel to X-axis which intersects the Y-axis at point B. You can now calculate the speed of the moving body after three seconds.

$$\text{Here,} \quad \text{speed} = \frac{\text{Distance}}{\text{time}} = \frac{15}{3}$$
$$= 5 \text{ m/s}.$$

(3) The adjacent figure shows the distance-time graph for the motion of two objects D and E. Which one of them is moving slower?



Answer: After studying the figure given alongside, E is moving slower as the slope of the distance-time graph of E is less than that of graph D

Level – 1

(1) A body travels 10 m in 2 s then the speed of the body in ms^{-1} is.

Solution: Speed $= \frac{\text{distance}}{\text{time}} = \frac{10}{2} = 5\ \text{m s}^{-1}$.

(2) A body moves with a speed of $2\pi\ ms^{-1}$ in a circular path of radius 1 m, then the time taken to complete one revolution is s.

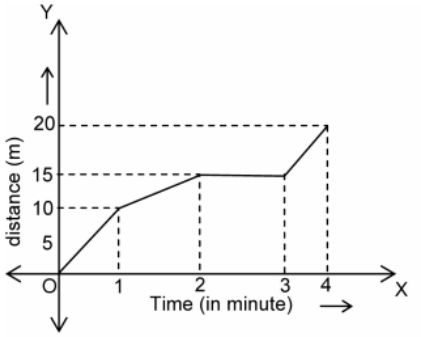
Solution: Speed $= \frac{\text{distance}}{\text{time}}$

$\therefore$ Time $= \frac{\text{distance}}{\text{speed}} = \frac{2\pi \times r}{2\pi} = \frac{2\pi \times 1}{2\pi} = 1\ \text{s}.$

(3) The odometer of a bus reads 6700 km when it starts from the station at 9 a.m., and when it comes back to the station at 10 p.m. the odometer reading is found to be 6960 km, then the average speed of the bus in the whole journey in kmh^{-1} is.

Solution: Average speed $= \frac{\text{total distance}}{\text{total time}} = \frac{6960 - 6700}{13} = 20\ \text{km h}^{-1}$.

(4) Distance versus time graph of an object is as shown in the adjacent figure. The average speed of the object is_____ ms^{-1}.



Solution: Average velocity $= \frac{\text{total displacement}}{\text{total time}}$

$= \frac{20}{4\times60} = 0.08\ \text{ms}^{-1}$.

(5) 20 m/s = _____km/h.

Solution: We know, $1\ \text{km/h} = \frac{5}{18}\text{m/s}$

$1\ \text{m/s} = \frac{18}{5}\ \text{km/h}$

$20\ \text{m/s} = 20 \times \frac{18}{5}\ \text{km/h} = 72\ \text{km/h}.$

(6) A girl participated in a marathon walk and completes the journey in 10 h. If she travels half of the distance with a speed of 10 km h^{-1} and rest of the distance with a speed of 15 km h^{-1}, then calculate the total distance of the marathon walk.

Solution: Let the total distance be x km.

$\text{Speed} = \frac{\text{distance}}{\text{time}}$

$\text{Time} = \frac{\text{distance}}{\text{speed}}$

$t_1 = \frac{x}{2 \times 10} = \frac{x}{20}$

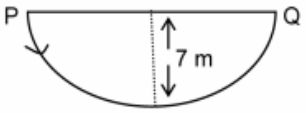
$t_2 = \frac{x}{2 \times 15} = \frac{x}{30}$

$t_1 + t_2 = 10$ hours

$\frac{x}{20} + \frac{x}{30} = 10 \Rightarrow 30x + 20x = 6000$

$50x = 6000 \Rightarrow x = 120$ km.

(7) A car is moving along a semi-circular track as shown in the adjacent figure in a duration of 2π second from P to Q, then choose the correct statement(s).



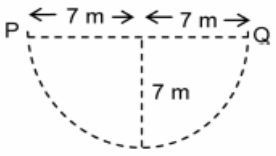
(A) The distance covered by the car is 14 m.

(B) The average velocity of the car is 2.23 m s^{-1}.

(C) The average speed of the car is 3.5 m s^{-1}.

(D) Both (B) and (C)

Solution: (D)



Time taken to travel $= 2\pi$

Total distance travelled $= \frac{2\pi r}{2} = \pi r = \pi(7) = 7\pi$ m

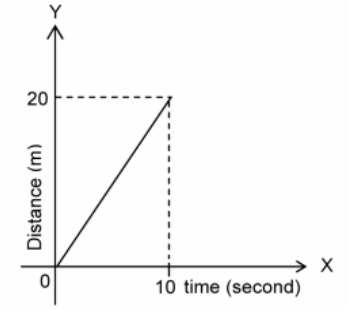
Average speed of the car $= \frac{7\pi}{2\pi} = 3.5\ \text{m s}^{-1}$

Average velocity $= \frac{\text{total displacement}}{\text{total time taken}} = \frac{(7+7)}{2\pi}$

$= \frac{14 \times 7}{2 \times 22} = \frac{49}{22}\ \text{m s}^{-1} = 2.23\ \text{m s}^{-1}.$

(8) The motion of a body is depicted graphically as shown in the given adjacent figure. Then

(A) The average speed of the body is $2\ \text{ms}^{-1}$.
(B) The average speed of the body is zero.
(C) The body changes its direction twice.
(D) All the above



Solution: (A)

From the figure:

The distance moved by the body $= 20$ m

Time taken to trace the path, $(t) = 10$ s

$$\text{average speed} = \frac{\text{total distance}}{\text{total time}} = \frac{20}{10} = 2\ \text{m/s}.$$

Graph is showing that body is moving in straight line.

(9) The odometer of car reads 57321.0 km when the clock shows the time 08 : 30 AM. What is the distance moved by the car, if at 08 : 50 AM, the odometer reading has changed to 57336.0 km? Calculate the speed of the car in km/min during this time. Express the speed in km/h also.

Solution: In this question, it is given that,

Initial reading of odometer = 57321.0 km
Final reading of odometer = 57336.0 km
Initial time = 08.30 AM
Final time = 08.50 AM
Now, total distance covered = Final reading of odometer – Initial reading of odometer
= 57336.0 km – 57321.0 km = 15.0 km
Total time taken = Final time – Initial time = 08.50AM – 08.30AM = 20 min

$$\text{We know that, speed} = \frac{\text{Total distance}}{\text{Total time taken}} = \frac{15}{20} = 0.75\ \text{km/min}$$

Speed in km/h = 0.75 × 60 (1 hr = 60 min) = 45 km/hr.

(10) A boy went to his college from his house on his car with a uniform speed of $60\ \text{kmh}^{-1}$ and returns to his house with a different speed. If the average speed of the car for whole journey is $50\ \text{kmh}^{-1}$, then find the speed of his car when it travelled from college to house.

Solution: Let the speed of the car from college to house be x kmh $^{-1}$.

$$\text{Average speed} = \frac{\text{total distance}}{\text{total time}}$$

Take the distance between house and college as d

Time taken from house and college is t_1

$$\therefore \text{ Time } (t_1) = \frac{\text{distance}}{\text{speed}} = \frac{d}{60}$$

Time taken from college to house is t_2

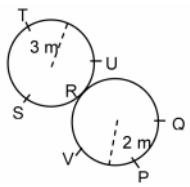
$$\therefore \text{ Time } (t_2) = \frac{\text{distance}}{\text{speed}} = \frac{d}{x}$$

$$\text{Average speed} = \frac{\text{total distance}}{\text{total time}} = \frac{d + d}{t_1 + t_2}$$

$$\frac{2d}{\frac{d}{60} + \frac{d}{x}} = 50 \Rightarrow 120x = 3000 + 50x$$

$70x = 3000 \quad x = 42.86\ \text{kmh}^{-1}$.

(11) An athlete moves along a path PQRSTUVP, in 44 seconds as shown in the figure, then the average speed of the athlete in ms^{-1} is



Solution: Total distance traced by the athlete = sum of perimeter of two circles

$$= 2\pi r_1 + 2\pi r_2 = 2\pi(r_1 + r_2)$$
$$= 2\pi(2 + 3) = 10\pi$$

Time taken to trace the path, $(t) = 44$ s

$$\text{Average speed} = \frac{\text{total distance}}{\text{total time taken}} = \frac{10\pi}{44} = \frac{10 \times 22}{7 \times 44} = \frac{5}{7}\ \text{m s}^{-1}.$$

(12) A train of length $200\ \text{m}$ is moving along a circular path as shown in the figure. If it completes one rotation with a speed of $54\ \text{kmh}^{-1}$, then the time taken by it to trace the path in seconds is

Solution: Length of the trains, $l = 200$ m

Number of rotations completed $= 1$

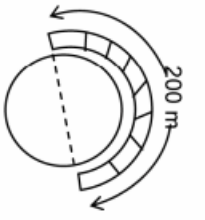
Speed with which it is moving along the circle path $= 54$ km/h

$$= 54 \times \frac{5}{18}\ \text{ms}^{-1} = 15\ \text{ms}^{-1}$$

As the train is completing 1 rotation,

the distance moved by the train $= 2 \times 200 = 400$ m

$$\text{Speed} = \frac{\text{distance}}{\text{time}} \Rightarrow \text{Time} = \frac{400}{15} = \frac{80}{3}\ \text{s} = 26.666\ \text{s} = 26.\bar{6}\ \text{s}.$$



Exercise

FILL IN THE BLANKS

(1) The distance moved by an object in a unit time is called its _____.
(2) Magnitude of displacement cannot be _____than distance.
(3) The motion of a simple pendulum is _____ and _____.
(4) If a body travels with a speed of 50 km/hr then the distance travelled by him in 5 hrs is _____km.

TRUE OR FALSE

(1) Displacement can't be zero.
(2) 1 km/hr = $\frac{18}{5}$ m/s.
(3) When a particle covers equal distance in unequal interval of time is uniform motion.

OBJECTIVE TYPE QUESTIONS

(1) A boy whose position with respect to surrounding does not change, is said to be in a state of
(A) Rest (B) Motion
(C) Vibration (D) Oscillation

(2) A distance is always
(A) Shortest length between two points (B) Path covered by an object between two points
(C) Product of length and time (D) None of these

(3) A particle is travelling with a constant speed. This means
(A) Its position remains constant as time passes (B) It covers equal distance in equal interval of time
(C) Its acceleration is zero (D) It does not change its direction of motion

(4) In 15 minutes, a car with speed of 60 kmh^{-1} travels a distance of
(A) 6 km (B) 15 km
(C) 10 km (D) 7km

(5) The device used to measure speed of a vehicle is
(A) Odometer (B) Speedometer
(C) Thermometer (D) Voltmeter

(6) Which of the following relations is correct?
(A) $\text{Speed} = \text{Distance} \times \text{Time}$ (B) $\text{Speed} = \frac{\text{Distance}}{\text{Time}}$
(C) $\text{Speed} = \frac{\text{Time}}{\text{Distance}}$ (D) $\text{Speed} = \frac{1}{\text{Distance} \times \text{Time}}$

(7) S.I. unit of speed is:
(A) m/s (B) ms
(C) m/s^2 (D) s/m

(8) In what time does a boy covers a distance of 160 m, if his speed is 20 m/s.
(A) 3200 s (B) 8 s
(C) 0.125 s (D) None of these

(9) Which of the physical quantity can be negative?
(A) Distance (B) Speed
(C) Displacement (D) None of these

(10) A car travels $40\ \text{km}$ at an average speed of $80\ \text{km/h}$ and then travels $40\ \text{km}$ at an average speed of $40\ \text{km/h}$. The average speed of the car for this $80\ \text{km}$ trip is **[SOF NSO 2018]**
(A) $40\ \text{km/h}$ (B) $45\ \text{km/h}$
(C) $48\ \text{km/h}$ (D) $53\ \text{km/h}$

(11) A person is running along a circular track of area $625\pi m^2 (\pi = 22/7)$ with a constant speed. Find the displacement in 15 seconds if he has to complete the race in 30 seconds. **[SOF NSO 2018]**
(A) $200\ \text{m}$ (B) $100\ \text{m}$
(C) $25\ \text{m}$ (D) $50\ \text{m}$

(12) A train moving on linear path travels a distance D at a constant speed of $30\ \text{km/h}$, then it travels the same distance in opposite direction and reaches initial position at a constant speed of $45\ \text{km/h}$. What is the average speed of the train? **[SOF NSO 2018]**
(A) $36\ \text{km/h}$ (B) $10\ \text{km/h}$
(C) 0 (D) $75\ \text{km/h}$

Answer Key

CHECK YOUR CONCEPT

(1) **(i)** Distance = 17m and Displacement = 13m

(ii) Displacement = 20 m south.

(2) **(i)** 20 km

(ii) Car moves faster than cycle.

(iii) $\frac{80}{3}$ km/h

FILL IN THE BLANKS

(1) Speed

(2) greater

(3) to, fro

(4) 250 km

TRUE OR FALSE

(1) False

(2) False

(3) False

OBJECTIVE TYPE QUESTIONS

(1) (A)

(2) (B)

(3) (B)

(4) (B)

(5) (B)

(6) (B)

(7) (A)

(8) (B)

(9) (C)

(10) (D)

(11) (D)

(12) (A)