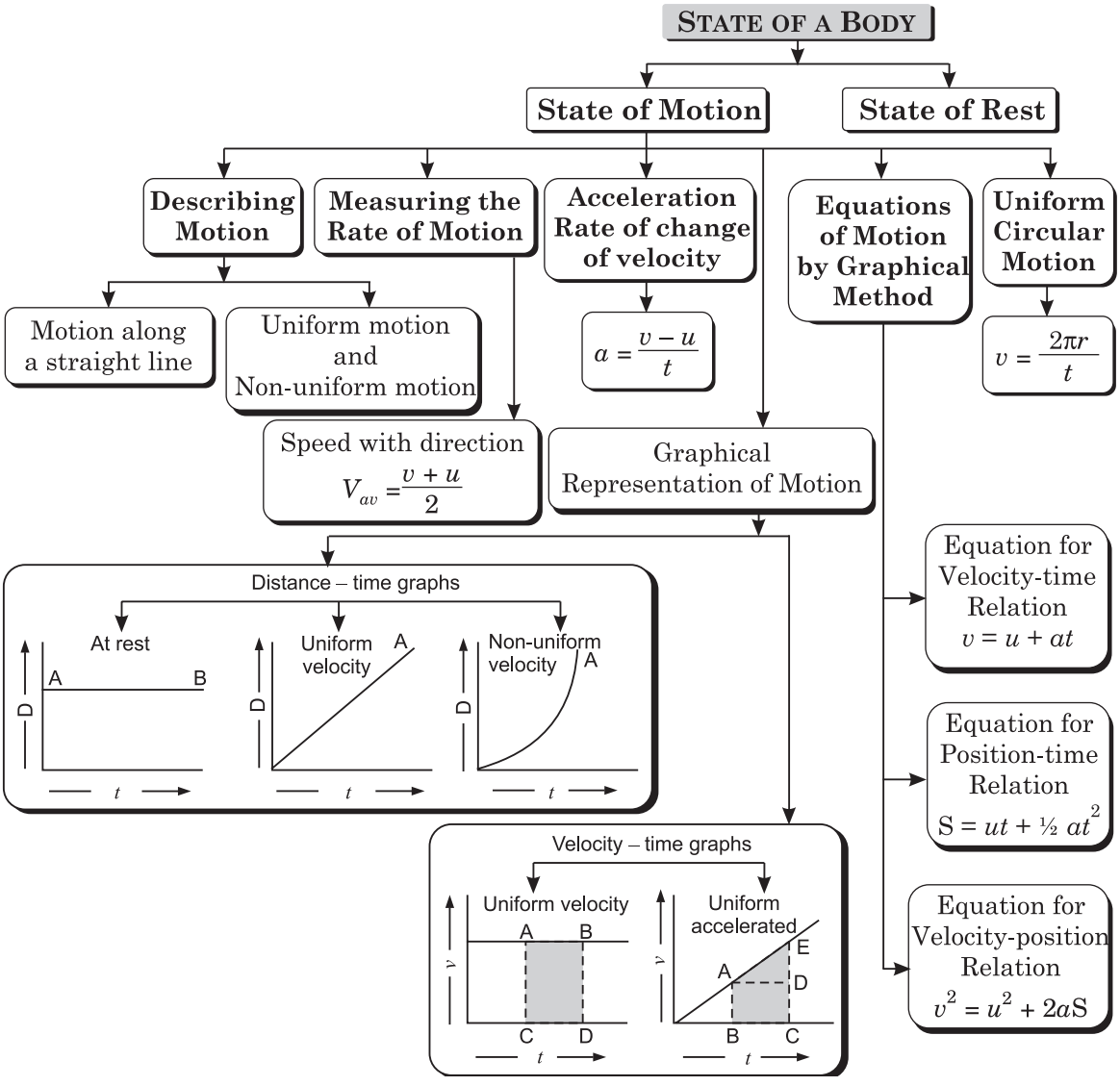
8 Motion

Topics Covered

8.1 Describing Motion, Uniform and Non-Uniform Motion, Speed with Direction
8.2 Rate of Change of Velocity, Graphical Representation of Motion
8.3 Equations of Motion by Graphical Method and Uniform Circular Motion

CHAPTER MAP



Quick Revision Notes

- A body is said to be in motion if its position changes continuously with the passage of time w.r.t. is surroundings.
- If a body is moving in a straight line, its motion is called linear motion, if moving in a circular path, its motion is called circular motion.
- If it is moving to and fro with respect to its origin, it is called a vibratory motion.
- Distance and speed have magnitude but no direction, are called scalar quantities.
- Displacement and velocity have both magnitude as well as direction therefore, these are vector called quantities.
- Motion is a change in position of a body w.r.t. to its surrounding with the passage of time. It can be described in terms of the distance moved or the displacement.
- The motion of an object can be uniform or non-uniform depending upon its velocity whether constant or changing.
- Speed is the distance travelled per unit time whereas velocity is a measure of displacement of a body per unit time.
- Acceleration is the change in velocity per unit time.
- We can represent uniform and non uniform motions with the help of graphs.
- Average speed is the ratio of the total distance travelled by an object to the total time taken. Its unit is metre per second (ms^{-1}).
- The motion of an object moving at a uniform acceleration can be described with the help of three equations.

  $v = u + at$,

  where 'v' is final velocity, 'u' is initial velocity, ($v - t$ relation)
  'a' is acceleration, 't' is time taken.

  $$s = ut + \frac{1}{2}at^2 \qquad (s - t \text{ relation})$$

  where 's' is distance covered, 'u' is initial velocity, 'a' is acceleration, 't' is time.

  $v^2 - u^2 = 2as$ ($v - s$ relation)
- If an object is moving in a circular path with a uniform speed it is called uniform circular motion.
- In circular motion, its distance covered will be equal to the circumference of the circular path are in revolution but displacement will be zero after one complete revolution.

  $$\text{Revolution period} = \frac{\text{Total distance covered in one revolution}}{\text{Constant – Speed}}$$

  $$\boxed{T = \frac{2\pi r}{V}}$$
- When a body travels equal distance in equal interval of time, then it is called uniform motion. When a body travels equal distance in unequal interval of time or unequal distances in equal interval of time is called non uniform motion.
- If a velocity of a body changes with time it is called accelerated motion, if motion of a body decreases with time it is said to be de-accelerated or retardated motion.
- If we plot a graph between distance and time, it is called distance time graph. It can be plotted for uniform as well as for non-uniform motion.
- Circular motion is an accelerated motion because if its speed remains same even though its direction changes continuously.

1. Describing Motion, Uniform and Non-Uniform Motion, Speed with Direction

Rest: A body is said to be at rest if its position does not change w.r.t. its surrounding with time.

Motion: A body is said to be in motion if it changes its position continuously with time.

The sunrise, sunset and change of seasons are due to the motion of the earth around the sun and along its own axis.

- **Controlled motion:** The motion which takes place at a particular speed in a particular direction is called controlled motion, e.g. generation of electricity by rotation of turbine with the help of falling water.
- **Uncontrolled motion:** If the motion is erratic, zig-zag or of high speed is termed as uncontrolled motion. It can be dangerous, e.g. flooded river, a hurricane or tsunami.

An object may appear to be moving for one person and stationary to the other, e.g. person sitting in a bus observes the tree on road moving backwards.

A person standing on the road observes that the bus is moving along with passengers. The persons sitting in the bus are at rest with respect to other persons travelling in a bus.

Scalar quantities are those quantities which has magnitude only, e.g. speed, distance.

Vector quantities are those quantities which has both magnitude as well as direction, e.g. velocity, displacement. Scalar quantities require only magnitude for their complete description whereas vector quantities require magnitude as well as direction both for their complete description.

Origin: A reference point from where distance is to be measured is called origin.

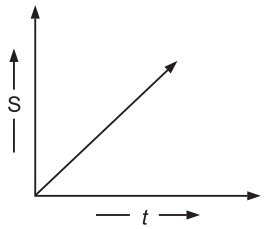
Distance: The actual length of the path travelled by an object is called distance. Its S.I. unit is metre. It is a scalar quantity.

Odometer: A device in a car or vehicle which shows the distance travelled is called odometer.

Displacement: It is the shortest distance between initial and final position of an object. It is a vector quantity. It may be positive, negative or zero.

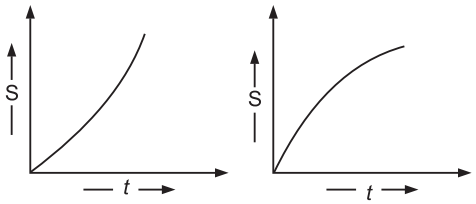
- Distance and displacements are used to describe the overall motion of an object and locate the object with reference to the initial position at a given time.

Linear motion: When motion takes place along a straight line, it is called linear motion. In linear motion, distance may be equal to displacement. If the starting and final point are same, distance covered by the body is not zero but its displacement is equal to zero.



Uniform motion: When a body covers equal distance in equal interval of time, its motion is said to be uniform motion, e.g. if a person covers 50 km in first hour and 50 km more in another second hour, then person is moving with a uniform motion.

Non uniform motion: When the object covers unequal distances in equal intervals of time, or equal distances in unequal interval of time it is called non-uniform motion, e.g. car moving in crowded street, person jogging in park.



Speed: It is defined as a distance covered per unit time. It is a scalar quantity. Its SI unit is m/s or ms^{-1} (metre per second). Its unit can be km/hour or cm/second. It can only have positive value.

Average speed: It is the ratio of total distance covered by an object to the total time taken.

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

$$\boxed{v = \frac{S}{t}}$$ where 'v' is speed, 'S' is total distance, 't' is total time.

Velocity: It is a distance covered per unit time in a particular direction. It is a vector quantity i.e. it has magnitude as well as direction. It can be positive or negative or zero.

Average velocity: It is defined as the total displacement travelled per unit time.

$$\boxed{v = \frac{S}{t}}$$

If velocity of an object is changing at a **uniform rate**, then average velocity is taken as arithmetic mean of initial and final velocity for a given period of time.

$$V_{av} = \frac{u + v}{2}$$. Its SI unit is ms^{-1}

'u' is initial velocity, 'v' is final velocity.

Exercise 8.1

I. Very Short Answer Type Questions (1 Mark)

1. An object has moved through a distance. Can it have zero displacement? If yes, support your answer with an example. [*NCERT*]
2. 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. [*NCERT*]
3. An object travels 16 m in 4 s and then another 16 m in 2 s. What is the average speed of the object? [*NCERT*]
4. What does the odometer of an automobile measures? [*NCERT*] [*CBSE* 2010, 2011]
5. What does the path of an object look like when it is in uniform motion? [*NCERT*] [*CBSE* 2012]
6. What does speedometer used for?
7. Change speed of 6 m/s into km/hr. **[HOTS]**
8. A tortoise moves a distance of 100 m in 15 minute. What is the average speed in km per hour?
9. A bus covers equal distance in equal interval of time. What type of motion does bus exhibits? [*DOE*]
10. A car travels a distance of 360 km in 5 hours. What is speed in ms^{-1}? [*CBSE* 2016]
11. A particle is moving in a circular path of radius 'r'. What is the displacement of half a circle? **[HOTS]** [*NCERT Exemplar Problems*]
12. What will be the numerical ratio of displacement to distance for a moving object? [*NCERT Exemplar Problem*]
13. A cricket ball covers 60 m in 2 seconds. Calculates the speed of the ball in km per hour.

II. Short Answer Type Questions–I (2 Marks)

14. 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? [*NCERT*] **[HOTS]** [*CBSE* 2012]

15. Distinguish between speed and velocity. [*NCERT*] [*CBSE* 2012]

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

17. During first half of a journey a body travels with a speed of 40 km/hour and in the next half it travels with a speed of 20 km/hr. Calculate the average speed of the whole journey. [*CBSE* 2011]

18. Usha swims in a 90 m long pool. She covers 180 m in one minute by swimming from one end to the other and back along the same straight path. Find the average speed and average velocity of Usha. [*NCERT*]

19. Under what condition(s) is the magnitude of average velocity of an object equal to its average speed? [*NCERT*] [*CBSE* 2012]

20. During an experiment, a signal from a spaceship reached the ground station in five minutes. What was the distance of the spaceship from the ground station? The signal travels at the speed of light, i.e. 3×10^8 m s^{-1}. [*NCERT*]

21. Give four differences between distance and displacement.

22. The displacement of a moving object in a given interval of time is zero. Would the distance travelled by an object is also zero? Justify your answer. **[HOTS]** [*NCERT Exemplar*]

III. Short Answer Type Questions–II (3 Marks)

23. A boy travels 5 km towards north, then he turns to right and travels another 5 km before coming to rest. Calculate, (*i*) total distance travelled (*ii*) total displacement. **[HOTS]**

24. What will be the speed of body in m/s if it travels 40 km in 5 hrs?

25. The odometer of a car reads 2000 km at the start of a trip and 2400 km at the end of the trip. If the trip takes 8 hr, calculate the average speed of the car in kmh^{-1} and ms^{-1}. [*NCERT*]

26. An athlete completes one round of a circular track of diameter 200 m in 40 s. What will be the distance covered and the displacement at the end of 2 minutes 20 s? [*NCERT*] **[HOTS]** [*CBSE* 2010]

27. Joseph jogs from one end A to the other end B of a straight 300 m road in 2 minutes 50 seconds and then turns around and jogs 100 m back to point C in another 1 minute. What is Joseph's average speed and velocity in jogging from (a) A to B and (b) A to C? [*NCERT*] **[HOTS]** [*CBSE* 2010]

28. The minutes hand is 7 cm long. Calculate the distance covered and the displacement of minute hand of the clock from 9 AM to 9.30 AM. **[HOTS]**

29. The sun light reaches the earth in 8.5 min. Calculate the distance between the sun and the Earth if velocity of light is 3×10^8 ms^1.**[HOTS]**

Answers 8.1

1. Yes, if its initial and final position is the same, then displacement will be equal to zero.

2. Both are not true because displacement can be zero if initial and final position are same.
   Its magnitude may be less or equal to the distance travelled but not more than distance travelled.

3. Total distance travelled = $16m + 16m = 32m$
   Total time taken= $4s + 2s = 6s$
   $$\text{Average speed} = \frac{\text{Total distance travelled}}{\text{Total time taken}} = \frac{32\text{m}}{6\text{s}} = 5.33 \text{ ms}^{-1}$$

4. It measures the distance covered.
5. It will be a straight line.
6. It is used to measure speed.
7. $1\text{ m} = 10^{-3}\text{ km}$, $1\text{ hour} = 60 \times 60\text{ sec} \Rightarrow 1\text{s} = \dfrac{1}{3600}\text{ hour}$

$$\text{Speed} = \frac{\text{Distance in km}}{\text{time in hours}} = \frac{6\times10^{-3}\text{km}}{\frac{1}{3600}\text{ hours}} = \frac{3600\times6}{1000} = \frac{216}{10} = 21.6\text{ km/hour}$$

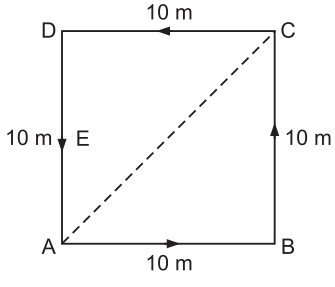
8. $$\text{Distance} = 100\text{ m} = \frac{100}{1000}\text{ km} = \frac{1}{10}\text{ km}$$

$$\text{Time} = 15\text{ min} = \frac{15}{60} = \frac{1}{4}\text{ hrs}$$

$$\text{Speed} = \frac{\text{Distance}}{\text{time}} = \frac{1}{10}\times\frac{4}{1} = 0.4\text{ km/hours}$$

9. Uniform motion.
10. $$\text{Speed} = \frac{\text{Distance in m}}{\text{time in seconds}} = \frac{360\times1000\text{ m}}{5\times60\times60\text{s}} = 20\text{ ms}^{-1}$$
11. $2r$ (It is equal to the diameter of a circle)
12. It will be equal or less than one.
13. $$v = \frac{s}{t} = \frac{60\times10^{-3}\text{ km}}{2(60\times60)\text{ hour}} = \frac{60\times60\times60\times10^{-3}}{2} = \frac{216}{2} = 108\text{ km/hour.}$$
14. Total distance= 4 S (side of square) = 4 × 10 = 40 m
Total time taken= 2 min 20 sec = 140 s
No. of round= 140 ÷ 40 = 3.5 rounds
He will reach at 'C'. Displacement = AC

$$AC^2 = AB^2 + BC^2 = 10^2 + 10^2$$
$$= 100 + 100 = 200$$
$$AC = \sqrt{200} = \sqrt{2}\sqrt{100} = 10\sqrt{2}\text{ m}$$
$$= 10 \times 1.414 = 14.14\text{ m}$$



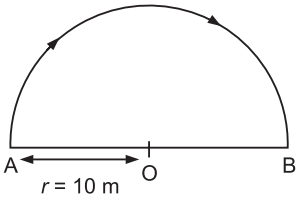
15.

Speed	Velocity
It is the distance travelled per unit time.	It is the distance travelled per unit time in a particular direction.
It is a scalar quantity.	It is a vector quantity.
It is always positive.	It may be positive, zero or negative.

16. Total distance covered = $\dfrac{1}{2}$ × Circumference of circle = πr

$$= \frac{22}{7}\times10 = \frac{220}{7} = 31.4\text{ m}$$

Displacement = AB = 2 × AO = 2 × 10 = 20 m



17. Let the total distance = $2x$ km

time for first half, $t_1 = \dfrac{x}{40}$

time to second half, $t_2 = \frac{x}{20}$

Total time $= \frac{x}{40} + \frac{x}{20} = \frac{x + 2x}{40} = \frac{3x}{40}$ hr

Air speed $= \frac{\text{Total distance}}{\text{Total time}} = \frac{2x}{3x} \times 40 = \frac{80}{3} = 26.66$ km/h

18. Average speed $= \frac{\text{Total distance covered}}{\text{Total time taken}} = \frac{180}{1 \times 60} = 3\ \text{ms}^{-1}$

Displacement of Usha in 1 min = 0 [$\because$ initial and final point is same]

$$\text{Velocity} = \frac{\text{Displacement}}{\text{Total time taken}} = \frac{0}{60} = 0$$

19. Average velocity and average speed will be same if a body moves in a straight line in the same direction. Displacement and distance travelled will be equal and that is why average velocity and average speed will be same.

20. Distance = speed × time

$t = 5$ min $= 5 \times 60 = 300$s

Distance $= 3 \times 10^8 \times 5 \times 60$ m $= 9 \times 10^{10}$ m

21.

Distance	Displacement
It is equal to the length of actual path travelled by an object.	It is shortest distance between the initial and final position of an object.
Distance is a scalar quantity.	Displacement is a vector quantity.
Distance is always +ve, can't be zero or negative.	Displacement can be +ve, –ve or zero.
Distance can be equal to the displacement in linear path in the same direction.	It can be equal to or less than distance but cannot be more than distance.

22. It will not be equal to zero. Distance can never be equal to zero.

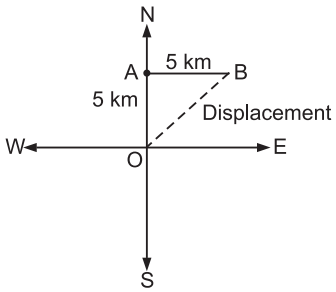
Let a body starts from 'A' and reaches back to 'A' after moving to 'B'. Its displacement is zero whereas distance covered will be 2AB, twice the distance between A and B.

23. Total distance = OA + AB = 5 + 5 = 10 km

Total displacement = OB

$$(OB)^2 = (AO)^2 + (AB)^2$$
$$(OB)^2 = (5)^2 + (5)^2$$
$$(OB)^2 = 50$$
$$(OB) = \sqrt{50} = 7.07 \text{ km}$$

direction in N-E.



24. Speed $= \frac{\text{Distance}}{\text{Time}} = \frac{40 \times 1000\text{m}}{5 \times 60 \times 60}$

$$= \frac{40}{5} \times \frac{5}{18} = \frac{400}{180} = \frac{20}{9} = 2.22\ \text{ms}^{-1}$$

25. Distance covered = 2400 – 2000 = 400 km

t = 8 hrs

Average speed in kmh^{-1} = $\frac{400}{8}$ = 50 km/hour

Average speed in ms^{-1} = $\frac{400\times1000}{8\times60\times60} = \frac{4000}{288} = \frac{500}{36} = \frac{250}{18}$ = 13.9 ms^{-1}

26. Time = 2 min 20 sec = 2 × 60 + 20 = 140s

Diameter = 200 m

$$r = \frac{d}{2} = \frac{200}{2} = 100 \text{ m}$$

Number of rounds = $\frac{140}{40}$ = 3.5 rounds

Distance covered = $3.5 \times 2\pi r = 3.5 \times 2 \times \frac{22}{7} \times 100 = 2200$ m

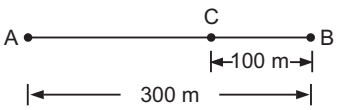
Displacement = diameter of the circle = 200 m after 3.5 rounds

27. (*a*) Distance covered A → B = 300 m; S = 300 m

Time taken = 2 min 50 sec = (2 × 60 + 50) second = 170 seconds

whereas from A → B

Average speed = $\frac{\text{Total distance}}{\text{Time interval}} = \frac{300\,\text{m}}{170\,\text{s}} = \frac{30}{17}$ = 1.76 m s^{-1}



Average velocity = $\frac{\text{Displacement}}{\text{Time interval}} = \frac{300\,\text{m}}{170\,\text{s}}$ = 1.76 m s^{-1}

(*b*) From A → C

Total distance = A to B + B to C = 300 + 100 = 400 m

Total time = 170 + 60 = 230 seconds

Average speed = $\frac{400}{230} = \frac{40}{23}$ = 1.74 ms^{-1}

Average velocity = $\frac{\text{Displacement}}{\text{Time taken}} = \frac{200\,\text{m}}{230} = \frac{20}{23}$ = 0.87 m/s

28. Distance covered by minute hand = $\frac{1}{2}$ × circumference

$$= \frac{1}{2} \times 2\pi r = \pi r = \frac{22}{7} \times 7 = 22 \text{ cm}$$

Displacement by minute hand = Diameter of clock = $2r = 2 \times 7 = 14$ cm

29. Distance = $v \times t = 3 \times 10^8 \times \frac{17}{2} \times 60$ m

$= 51 \times 30 \times 10^8$ m

$= 1530 \times 10^8 = 1.53 \times 10^{11}$ m

2. Rate of Change of Velocity, Graphical Representation of Motion

Acceleration

It is defined as a change in velocity per unit time i.e. rate of change of velocity per unit time in non-uniform motion. Acceleration is a vector quantity.

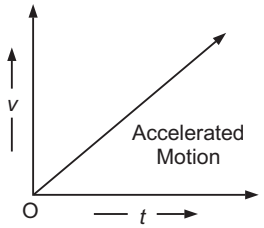
- In uniform motion, acceleration is zero.

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

Where 'v' is final velocity, 'u' is initial velocity, 't' is time

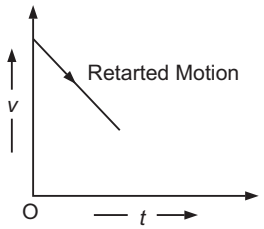
- SI unit of 'a' is ms^{-2} (metre per sec^2).

Accelerated Motion: When the velocity of a body increases with time, it is called accelerated motion. The acceleration is positive if it is in the direction of velocity. It is zero in a uniform motion.



Retarded Motion: When the velocity of a body decreases with time, it is called retarded motion. The value of 'a' is negative.

$$\boxed{a' = \frac{v-u}{t}} \qquad v - u = -\text{ve} \quad \because v \text{ is less than } u$$



Uniform Acceleration: When an object travels in a straight line and if its velocity increases or decreases by equal amounts in equal intervals of time, than the acceleration of the object is said to be uniform acceleration, e.g. The motion of a freely falling body is an example of uniformly accelerated motion.

Non-uniform acceleration: If its velocity changes at a non-uniform rate, it is called non-uniform acceleration. i.e. if velocity of a body increases or decreases by unequal amount in equal interval of time or the velocity changes by equal amount in unequal interval of time then acceleration is said to be non uniform acceleration.

Graphical Representation of Motion

Distance – Time Graph: In this graph time (t) is taken on x-axis and distance is taken on y-axis.

Uniform speed: When an object travels equal distance in equal interval of time, it moves with uniform speed.

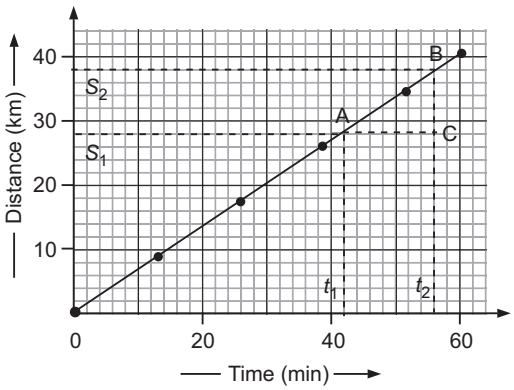
It means that distance travelled by an object is directly proportional to time in **uniform motion** (speed).

It will be represented by a straight line as shown in diagram.

It shows that the distance is increasing at a uniform rate.

If we take displacement instead of distance with time, it will be a graph for **uniform velocity**.

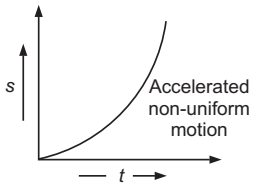
- We can determine the speed of an object in any given time interval with the help of a graph, e.g. if we want to know speed between point 'A' and 'B'



$$\text{Speed} = \frac{BC}{AC} = \frac{BM - CM}{OM - ON} = \frac{S_2 - S_1}{t_2 - t_1}$$

$$\text{Speed } (v) = \frac{BC}{AC} = \frac{S_2 - S_1}{t_2 - t_1}$$

Distance – Time Graph for a non uniform motion: The nature of a graph shows non-linear variation of distance travelled by a car with time. It represents non-uniform motion.



Velocity-Time Graph

- In the graph, time is taken on x-axis and velocity is taken on y-axis.
- If the object moves with uniform velocity, the velocity-time graph is parallel to time axis i.e. it will be a straight line parallel to x-axis.
- The product of velocity and time gives displacement of an object moving with a uniform velocity or the area enclosed by $(v - t)$ graph will be equal to magnitude of displacement.

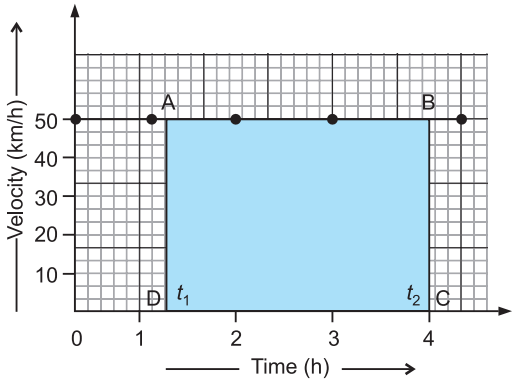
Distance moved by a car in time $(t_2 - t_1)$

$= AD \times CD$

$= 50 \text{ km } h^{-1} \times (t_2 - t_1)h$

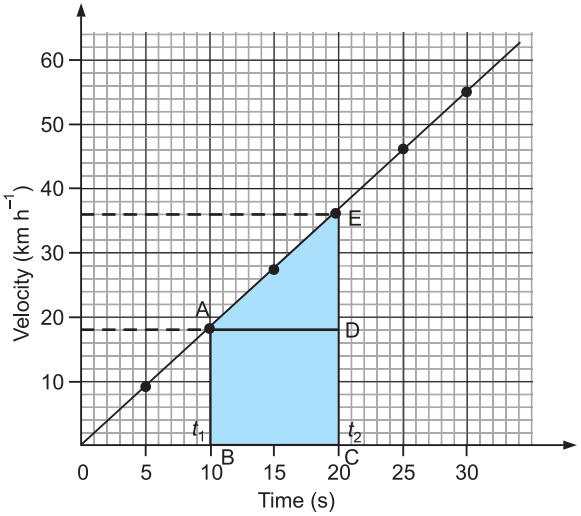
$= 50\ (t_2 - t_1) \text{ km}$

= area of rectangle ABCD



Velocity – Time Graph for uniform acceleration

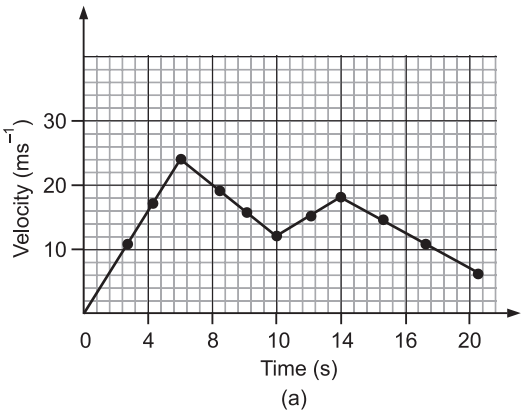
- The nature of graph shows that velocity changes by equal amount in equal intervals of time.
- The shape of graph $(v - t)$ for uniform acceleration is a straight line as shown in a given fig.
- The area under $(v - t)$ graph gives the distance (magnitude of displacement) moved by car in a given interval of time.
- Magnitude of velocity is changing therefore distance will be given by the area of ABCDE under $(v - t)$ graph.



$$S = \text{Area ABCDE} = \text{Area of rectangle ABCD} + \text{Area of triangle ADE}$$

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

- If motion is non-uniformly accelerated, ($v - t$) graph can have any shape as given below:



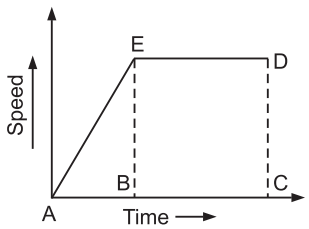
(a)

In the above figure velocity is first increasing, then decreasing, then again increasing and finally decreasing, i.e., non-uniform variation.

Exercise 8.2

I. Very Short Answer Type Questions (1 Mark)

1. What can you say about the motion of an object whose distance-time graph is a straight line parallel to the time axis? [*NCERT*]
2. What can you say about the motion of an object if its speed-time graph is a straight line parallel to the time axis? [*NCERT*]
3. What is the quantity which is measured by the area occupied below the velocity-time graph? [*NCERT*]
4. The graph illustrate the motion of an object. Which feature of the graph represents the distance travelled by the object whilst moving at constant speed? **[HOTS]**

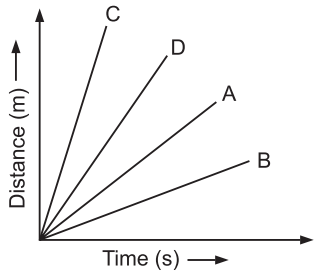


5. A stone is falling freely through the air. The acceleration of a free fall in 9.8 m/s^2. Ignoring air resistance what happen to the stone at each second during the fall?
6. Suppose a boy is enjoying a ride on merry go round which is moving with a constant speed of 10 ms^{-1}. What type of motion is associated with the merry go round?

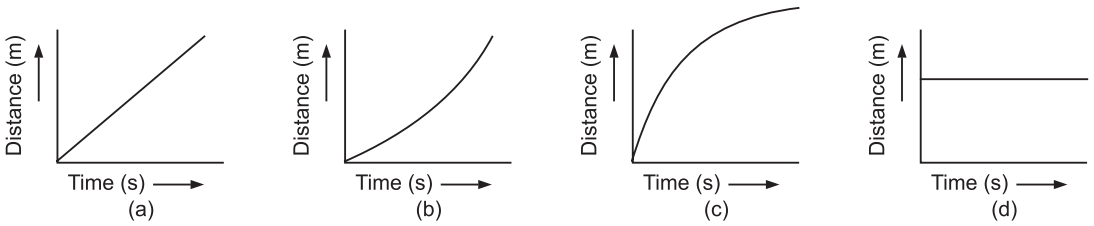
[*NCERT Exemplar Problem*] **[HOTS]**

7. Four cars A, B, C and D are moving on a levelled road. Their distance versus time graphs are shown in Fig. 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. [*NCERT Exemplar*]



8. Which of the following figures represent uniform motion of a moving object correctly? [*NCERT Exemplar*]



9. Slope of a velocity – time graph gives [*NCERT Exemplar*]

(*a*) the distance (*b*) the displacement

(*c*) the acceleration (*d*) the speed

10. In which of the following cases of motion, the distance moved and the magnitude of displacement are equal? [*NCERT Exemplar*]

(*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 fro (*d*) The earth is revolving around the Sun

II. Short Answer Type Questions–I (2 Marks)

11. A car speed increases from 40 km/hr to 60 km/hr in 5 seconds. Calculate the acceleration of car. [*DOE*]

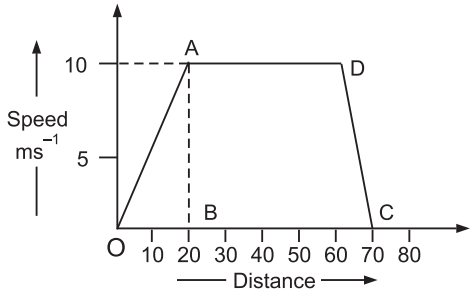
12. When will you say a body is in: (*i*) uniform acceleration (*ii*) non-uniform acceleration. [*NCERT*]

13. A bus decreases its speed from 80 km/hour to 60 km per hour in 5 s. Find the acceleration of the bus. [*NCERT*]

14. A train starting from a railway station and moving with uniform acceleration attains a speed of 40 km h^{-1} in 10 minutes. Find its acceleration. [*NCERT*]

15. What is the nature of the distance-time graphs for uniform and non-uniform motion of an object? [*NCERT*]

16. The graph shows the movement of car over a period of 50 s. What distance was travelled by the car when its speed was increasing? **[HOTS]**



III. Short Answer Type Questions–II (3 Marks)

17. A car travelling with a speed of 20 km/hr comes into rest in 0.5 hours. What will be the value of its retardation? [*DOE*]

18. Starting from a stationary position, Rahul paddles his bicycle to attain a velocity of 6 m s^{-1} in 30 s. Then he applies brakes such that the velocity of the bicycle comes down to 4 m s^{-1} in the next 5 s. Calculate the acceleration of the bicycle in both the cases.

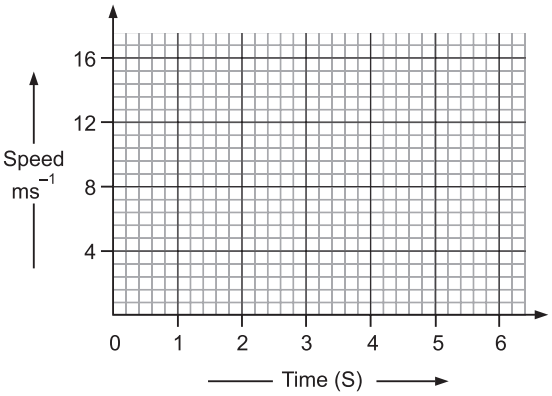
19. A car of mass 1500 kg starts from rest and moves along a straight road with a constant acceleration, reaching a speed of 12 m/s in 6.0 s.

(*a*) On the axis of the diagram shown, draw the speed against time for the first 6 seconds of the car motion.

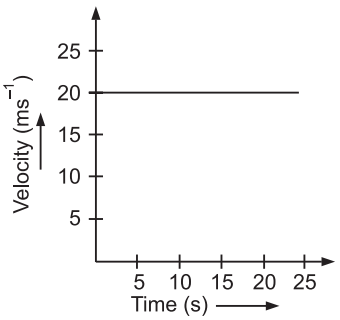
(*b*) Calculate:

(*i*) the distance travelled

(*ii*) the acceleration in the first 6 s.



20. The velocity-time graph shows the motion of a cyclist. Find (*i*) acceleration (*ii*) velocity (*iii*) distance covered by the cyclist in 15 seconds. [*NCERT Exemplar*]



21. On a position-time graph, draw three lines/curves to represent the motion of an object:

(*a*) remains at rest

(*b*) moving very slowly

(*c*) moving very fast [*CBSE* 2016]

22. Explain the following type of motion with one example for each:

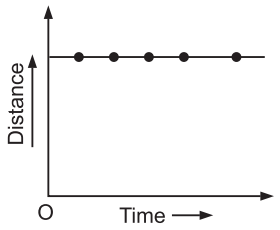
(*a*) acceleration is in the direction of motion.

(*b*) acceleration is against the direction of motion.

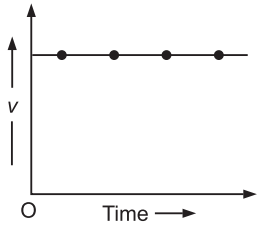
(*c*) acceleration is uniform. [*CBSE* 2016]

Answers 8.2

1. It shows body is at rest because there is no change in position distance with time.



2. It shows the body is in uniform speed with zero acceleration



3. It gives magnitude of displacement of the body.

4. Area BCDE represents the distance travelled by the object whilst moving at a **uniform speed** (constant speed) represented by a straight line.

5. The acceleration of a stone falling freely is constant i.e. acceleration due to gravity 9.8 m/s^2.

6. It is in accelerated motion. In circular path, when body is moving with constant speed, the direction of motion changes continuously at every point. It means change in velocity of a body with time give rise to an acceleration, that is why uniform circular motion of a body is known as accelerated motion.

7. (*b*) Car 'B' is slowest.

8. (*a*) It represents uniform motion.

9. (*c*) The acceleration.

10. (*a*) The car is moving on a straight road.

11. u = Initial velocity in ms^{-1} = $\dfrac{40\times1000}{60\times60}$ ms^{-1} = 11.1 ms^{-1}

v = Final velocity in ms^{-1} = $\dfrac{60\times1000}{60\times60} = \dfrac{50}{3}$ ms^{-1} = 16.66 ms^{-1}

$a = \dfrac{v-u}{t} = \dfrac{16.66-11.11}{5} = \dfrac{5.55}{5}$ ms^{-1} = 1.11 ms^{-2}

12. (*i*) If the velocity increases or decreases by equal amounts in equal intervals of time, the body is said to be moving with uniform acceleration, e.g. acceleration due to gravity. The graph between velocity and time will be a straight time.

(*ii*) If the velocity increases or decreases by unequal amounts in equal interval of time, the body is said to be non-uniform acceleration. (v – t) graph may have any shape depending upon the variation of the velocity.

13. $u = \dfrac{80\times1000\,\text{m}}{60\times60\,\text{s}} = \dfrac{800}{36} = \dfrac{200}{9} = 22.22\,\text{m s}^{-1}$

$v = \dfrac{60\times1000\,\text{m}}{60\times60\,\text{s}} = \dfrac{100}{6} = \dfrac{50}{3} = 16.66\,\text{m s}^{-1}$

t = 5s

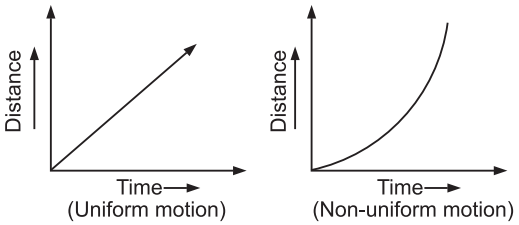
$a = \dfrac{v-u}{t} = \dfrac{16.66-22.22}{5} = \dfrac{-5.56}{5} = -1.11\ \text{m s}^{-2}$

14. $u = 0$ v = 40 km h^{-1} t = 10 min a = ?

$v = \dfrac{40\times1000\,\text{m}}{60\times60} = \dfrac{400}{36} = \dfrac{100}{9} = 11.11\ \text{m s}^{-1}$

$a = \dfrac{v-u}{t} = \dfrac{(11.11-0)\,\text{m s}^{-1}}{10\times60\,\text{s}} = \dfrac{11.11}{600}\ \text{m s}^{-2} = \dfrac{1111}{600}\times10^{-2}\ \text{m s}^{-2} = 1.85\times10^{-2}\ \text{m s}^{-2}$

15.



16. Area OBA represents distance travelled while speed was increasing

Distance = area under v-t curve = area ΔOAB

$$\text{Distance} = \frac{1}{2} \times \text{OB} \times \text{AB}$$

$$s = \frac{1}{2} \times 20 \times 10 = 100 \text{ m}$$

17. $v = 0$ km/hr

$u = 20$ km/hr

$v = 20$ km/h

$$v = \frac{20 \times 5}{18} = 5.53 \text{ m/s.}$$

$$a = \frac{(0 - 5.55)}{0.5 \times 60 \times 60} = 0.0031 \text{ m s}^{-2}$$

18. I. $u = 0$, $v = 6 \text{ ms}^{-1}$, $t = 30$ s

$$a = \frac{v - u}{t} = \frac{6 \text{ ms}^{-1} - 0 \text{ ms}^{-1}}{30} = 0.2 \text{ m s}^{-2}$$

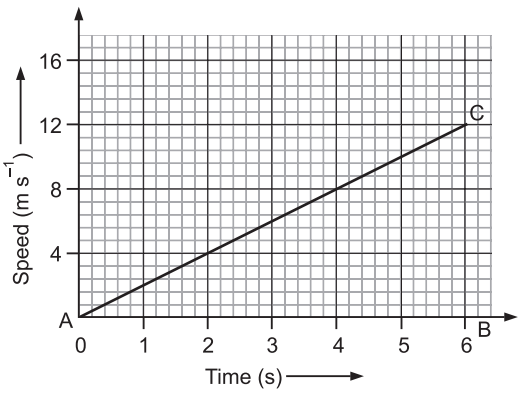
II. $u = 6 \text{ m s}^{-1}$

$v = 4 \text{ m s}^{-1}$

$t = 5$ s

$$a = \frac{v - u}{t} = \frac{4 - 6}{5} = \frac{-2}{5} = -0.4 \text{ m s}^{-2}$$

19. (*a*) Speed-time graph is shown below.



(*b*) (*i*) Distance travelled = Area under the graph

$$= \frac{1}{2} \times \text{AB} \times \text{BC} = \frac{1}{2} \times 6 \times 12 = 36 \text{ m}$$

(*ii*) Acceleration = slope of line = $\frac{\text{BC}}{\text{AB}} = \frac{12 \text{ ms}^{-1}}{6 \text{ s}} = 2 \text{ m s}^{-2}$

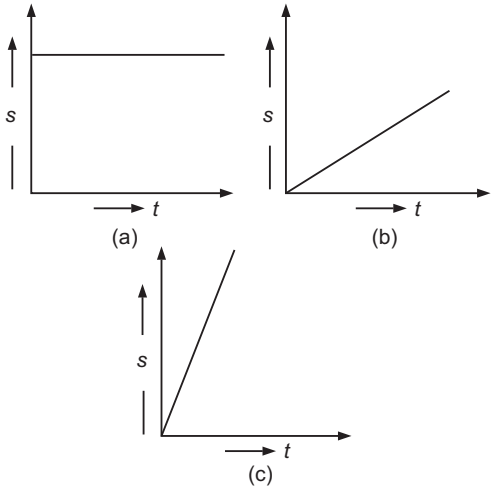
20. (*i*) acceleration = 0 [$\because$ velocity is constant]

(*ii*) velocity = 20 m s^{-1}

(*iii*) distance = 15 × 20= 300 m

Distance = 300 m

21.



22. (*a*) Car moves from rest, picks up the speed in the straight path in a particular direction.

(*b*) Breaks are applied to a moving car it will have acceleration against the motion.

(*c*) A stone thrown vertically down will have a uniform acceleration due to gravity.

3. Equations of Motion by Graphical Method & Uniform Circular Motion

Equation for Velocity – Time Relation

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

$$a = \frac{BD}{AD} = \frac{BD}{OC} = \frac{BD}{t} \quad \boxed{\because AD = OC}$$

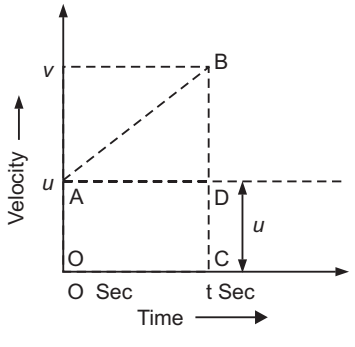
$$\boxed{BD = at} \qquad \ldots(i)$$

$$BC = BD + DC$$

$$BC = BD + AO \qquad [\because DC = AO]$$

$$v = BD + u \qquad AO = u$$

$$\boxed{BD = v - u} \qquad \ldots(ii)$$



From (*i*) and (*ii*) we get

$$v - u = at$$

or $$\boxed{v = u + at} \Rightarrow at = v - u \Rightarrow \boxed{t = \frac{v - u}{a}} \qquad \ldots(iii)$$

Equation for Position–Time Relation

s = Distance travelled by object = OABC

s = Area of rectangle OADC + Area of triangle ABD

$$s = (\text{OC} \times \text{OA}) + \frac{1}{2}(\text{AD} \times \text{BD})$$

$$s = t \times u + \frac{1}{2} \times t \times at \qquad [\text{AD} = \text{OC} = t]\ [\text{BD} = at \text{ from eqn (i)}]$$

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

Equation for Position – Velocity Relation

s = Area OABC (trapezium)

$$s = \frac{(\text{OA} + \text{BC}) \times \text{OC}}{2} \qquad [\text{OA} = u,\ \text{BC} = v,\ \text{OC} = t]$$

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

From Equation (iii)

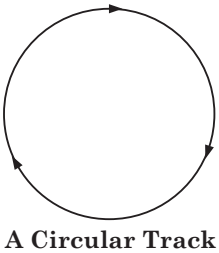
$$t = \frac{v-u}{a}$$

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

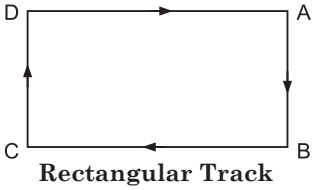
$$\boxed{2as = v^2 - u^2}$$

Uniform Circular Motion

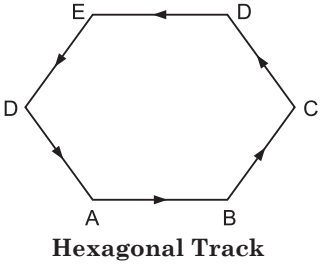
- When velocity of object changes, we say that object is accelerating. The change in velocity is due to change in its direction or magnitude or both.
- When objects moves in circular path with constant velocity, it is called uniform circular motion.



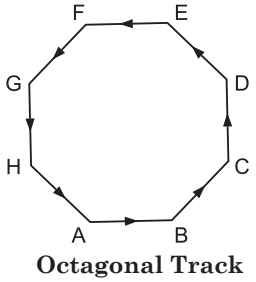
A Circular Track



Rectangular Track



Hexagonal Track



Octagonal Track

The motion of an athlete along closed tracks of different shapes.

- In uniform circular motion, magnitude of velocity does not change, only direction of velocity changes. So it is called accelerated motion.

$$\text{Circumference of circle} = 2\pi r$$

$$\text{Velocity} = \frac{2\pi r}{t}$$

- Let us take motion of a body along the rectangular path ABCD. If the athelete is moving with uniform speed, he has to change his speed four times at the corners to keep himself on the track and also changes the direction of motion four times the initial value.

  If the athlete is running along a hexagonal path ABCDEF he has to change his direction 6 times when he has to complete one round if it is a regular hexagon.

  If it is a regular octagon, he has to change his direction 8 times the initial value.

Example of uniform circular motion

- If we rotate a stone tied with a rope in a circular path, on being released, the stone moves along a straight line, tangential (at 90°) to the circular path.
- This is because once the stone is released, it continues to move along the direction it was moving at this instant.
- It shows that the direction of motion is changed at every point when stone is moving along the circular path.
- Athlete throws a shot put or discus, he rotates it in a circular motion before throwing. Once it is released in a desired direction, it moves in the direction in which it was moving at the time of release.
- Motion of moon around the earth, a satellite in a circular orbits around the earth, a cyclist moving on a circular track at a constant speed motion of hands of a clock are examples of circular motion.

Exercise 8.3

I. Very Short Answer Type Questions (1 Mark)

1. The brakes applied to a car produces an acceleration of 6 m s^{-2} in the opposite direction to the motion. If the car takes 2 s to stop after the application of brakes, calculate the distance it travels during this time. [*NCERT*]
2. A trolley, while going down at an inclined plane, has an acceleration of 2 cm s^{-2}. What will be its velocity 3 seconds after the start? [*NCERT*]
3. A racing car has a uniform acceleration of 4 m s^{-2}. What distance will it cover in 10 s after start? [*NCERT*]
4. A motor boat starts from the rest on a lake and accelerates in a straight line at a constant rate of 3.0 m s^{-2} for 8.0 s. How far does the boat travel during this time? [*NCERT*]
5. If a bus travelling at 20 m/s is subjected to a steady de-acceleration of 5 m/s^2, how long will it take to come to rest? [*DOE*]
6. A train 100 m long is moving with a velocity of 60 km h^{-1}. Find the time take by it to cross the bridge 1 km long. [*CBSE* 2010] **[HOTS]**
7. Differentiate between the terms: Acceleration and Velocity. [*CBSE* 2011]
8. A train is travelling at a speed of 90 km h^{-1}. Brakes are applied so as to produce a uniform acceleration of – 0.5 m s^{-2}. Find how far the train will go before it is brought to rest? [*NCERT*]

II. Short Answer Type Questions–I (2 Marks)

9. A car accelerates uniformly from 18 km h^{-1} to 36 km h^{-1} in 5 s. Calculate: (*i*) the acceleration and (*ii*) the distance covered by the car in that time. [*NCERT*]

10. A bus starting from rest moves with a uniform acceleration of 0.1 m s^{-2} for 2 minutes. Find (*a*) the speed acquired, (*b*) the distance travelled by the bus. [*NCERT*]

11. A train starting from rest attains a velocity of 72 km h^{-1} in 5 minutes. Assuming that the acceleration is uniform, find: (*i*) the acceleration and (*ii*) the distance travelled by the train for attaining this velocity. [*NCERT*]

12. A stone is thrown in vertically upward direction with a velocity of 5 m s^{-1}. If the acceleration of the stone during its motion is 10 m s^{-2} in the downward direction, what will be the height attained by the stone and how much time will it take to reach there? [*NCERT*] **[HOTS]**

13. A ball is gently dropped from a height of 20 m. If its velocity increases uniformly at a rate of 10 m s^{-2}, with what velocity will it strikes the ground? After what time will it strikes the ground? [*NCERT*]

14. An artificial satellite is moving in a circular orbit of radius 42250 km. Calculate its speed if it takes 24 hours to revolve around the earth. [*NCERT*]

15. A car starting from rest moves with a uniform acceleration of 0.1 m s^{-2} for 4 minutes. Find the speed and the distance travelled by the car. [*NCERT*] [*DOE*]

III. Short Answer Type Questions–II (3 Marks)

16. What is the difference between uniform linear motion and uniform circular motion?

17. State which of the following situations are possible and give an example for each of these:

(*a*) an object moving with a constant acceleration but with zero velocity.

(*b*) an object moving in a certain direction with an acceleration in the perpendicular direction. [*NCERT*]

18. A body starts from rest and attains a velocity of 12 m s^{-1} in 30 seconds. If the final velocity becomes 8 m s^{-1}, what will the de-acceleration after 5 seconds? [*CBSE* 2016]

IV. Long Answer Type Questions (5 Marks)

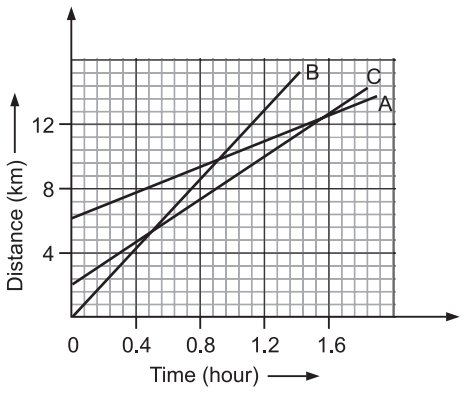
19. The figure alongside shows the distance-time graph of three objects A, B and C. Study the graph and answer the following questions: [*NCERT*]

(*a*) Which among the three is travelling the fastest?

(*b*) Are all three ever be at the same point on the road?

(*c*) How far has C travelled when B passes A?

(*d*) How far has B travelled by the time it passes C?



20. The distance-time graph of two trains are given below. The trains simultaneously moves in the same direction.

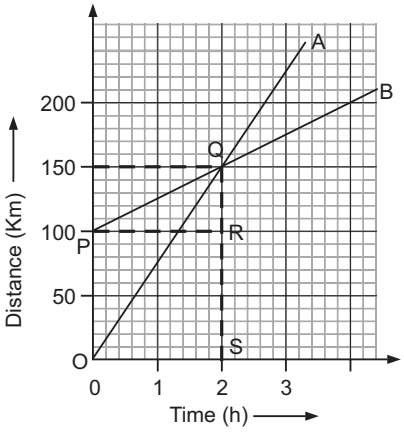
(*i*) How much ahead of A is B when the motion starts?

(*ii*) What is the speed of B?

(*iii*) When and where will A catch B?

(*iv*) What is the difference between the speeds of A and B?

(*v*) Is the speed of both the trains uniform or non-uniform? Justify your answer. [*CBSE* 2012]



Answers 8.3

1. $a = -6 \text{ m s}^{-2}$

$t = 2 \text{ s}$

$v = 0$

$v = u + at$

$0 = u - 6 \times 2$

$u = 12 \text{ m s}^{-1}$

$$S = ut + \frac{1}{2}at^2 = 12 \times 2 + \frac{1}{2} \times -6 \times (2)^2 = 24 - 12 = 12 \text{ m}$$

2. $a = 2 \text{ cm s}^{-2} = \dfrac{2}{100} = 0.02 \text{ m s}^{-2}$

$v = ?$

$t = 3\text{s} \quad u = 0$

$v = u + at$

$v = 0 + 0.02 \times 3 = 0.06 \text{ m s}^{-1}$

3. $a = 4 \text{ m s}^{-2}$

$S = ?$

$t = 10 \text{ s}$

$u = 0$

$$S = ut + \frac{1}{2}at^2 = 0 + \frac{1}{2} \times 4 \times 10 \times 10 = \frac{400}{2} = 200 \text{ m}$$

4. $u = 0$, $a = 3 \text{ m s}^{-2}$, $t = 8 \text{ s}$, $s = ?$

Method I: Best Method

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

or $$s = 0 + \frac{1}{2} \times 3 \times 8 \times 8$$

$$s = \frac{192}{2} = 96 \text{ m}$$

OR

Method II:

$$v = u + at$$

$$v = 0 + 3 \times 8 = 24 \text{ m s}^{-1}$$

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

$$24 \times 24 - 0 = 2 \times 3 \times s$$

$$s = \frac{24 \times 24}{6} = 96 \text{ m}$$

5. $t = ?, \quad a = -5 \text{ ms}^{-2}, \quad u = 20 \text{ ms}^{-1}, \quad v = 0$

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

$$-5 = \frac{0 - 20}{t}$$

$$t = \frac{20}{5} = 4 \text{ seconds.}$$

It will take 4 seconds to come to rest.

6. Total distance covered = 1 km + 100 m

= 1000 m + 100 m = 1100 m

$$v = 60 \text{ km/hr} = \frac{60 \times 1000}{60 \times 60} \quad \frac{50}{3} \text{ ms}^{-1}$$

$$= 16.67 \text{ m s}^{-1}$$

$$v = \frac{s}{t} \Rightarrow t = \frac{s}{v} = \frac{1100}{50} \times 3 = \frac{330}{5} = 66 \text{ s}$$

$t = 66\ s$

7.

Acceleration	Velocity
It is the change in velocity per unit time.	It is the displacement covered per unit time.
Its S.I unit is m s^{-2}.	Its SI unit is m s^{-1}.

8. $u = 90 \text{ km } h^{-1} = 90 \times \frac{5}{18} = 25 \text{ ms}^{-1}$

$v = 0$

$a = -0.5 \text{ ms}^{-2}$

$s = ?$

$$u = \frac{90 \times 1000 \text{m}}{60 \times 60} = \frac{900}{36} = 25 \text{ m s}^{-1}$$

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

$$-0.5 = \frac{0 - 25}{t}$$

$$t = \frac{-25}{-0.5} = 50 \text{ seconds}$$

$$s = ut + \frac{1}{2}at^2 = 25 \times 50 + \frac{1}{2} \times -0.5 \times 50 \times 50$$

$$= 1250 - 625 = 625 \text{ m}$$

or

- **Best Method**

$$v^2 - u^2 = 2a\,s$$
$$0 - (25 \times 25) = 2 \times -0.5 \times s$$
$$-625 = -1 \times s$$
$$s = 625 \text{ m}$$

9. (*i*) $u = 18 \text{ km } h^{-1} = \dfrac{18 \times 1000}{60 \times 60} = \dfrac{18000}{3600} = 5 \text{ m s}^{-1}$

$v = 36 \text{ km } h^{-1} = \dfrac{36 \times 1000}{60 \times 60} = \dfrac{36000}{3600} = 10 \text{ m s}^{-1}$

$a = \dfrac{u - v}{t} = \dfrac{10 - 5}{5} = \dfrac{5}{5} = 1 \text{ m s}^{-2}$

(*ii*) $s = ut + \dfrac{1}{2}at^2 = 5 \times 5 + \dfrac{1}{2} \times 1 \times 5 \times 5 = 25 + \dfrac{1}{2} \times 25 = 25 + 12.5 = 37.5 \text{ m}$

10. $u = 0 \quad a = 0.1 \text{ m s}^{-2}$,

$t = 2 \text{ minutes} = 2 \times 60 \text{ s} = 120 \text{ s}$

(*a*) $v = u + at$

$v = 0 + 0.1 \times 120 = 12 \text{ m s}^{-1}$

(*b*) $s = ut + \dfrac{1}{2}at^2$

$= 0 + \dfrac{1}{2} \times 0.1 \times 120 \times 120$

$= \dfrac{1440}{2} = 720 \text{ m}$

11. $u = 0$

$v = 72 \text{ km } h^{-1}$

$v = 72 \text{ km/hour} = \dfrac{72 \times 1000}{60 \times 60} = 20 \text{ m s}^{-1}$

$t = 5 \text{ min} = 5 \times 60\,s$

(*i*) $a = \dfrac{v - u}{t} = \dfrac{20 - 0}{5 \times 60} = \dfrac{20}{300} = \dfrac{1}{15} = 0.066 \text{ m s}^{-2}$

(*ii*) $s = ut + \dfrac{1}{2}\,at^2 = 0 + \dfrac{1}{2} \times \dfrac{1}{15} \times 300 \times 300 = 3000 \text{ m} = 3 \text{ km}$

12. At maximum height

$v = 0$

$v = 5 \text{ m/s}$

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

$\therefore \quad 2g = v^2 - u^2$

$2s = 0 - \dfrac{25}{20} = 1.25 \text{ m}$

$\boxed{s = 1.25 \text{ m}}$

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

$$1.25 = 0 + \frac{1}{2} \times 10 \times t^2 \qquad \Rightarrow \qquad t^2 = \frac{2.5}{10}$$

$$t^2 = \frac{25}{20} = \frac{1}{4}$$

$$t = \frac{1}{2} = 0.5 \text{ seconds.}$$

13. $s = 20$ m $\quad u = 0 \quad a = 10$ ms^{-2}

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

$$v^2 - 0 = 2 \times 10 \times 20$$

$$v^2 = 400$$

$$v = 20 \text{ ms}^{-1}$$

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

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

$$t = \frac{20 - 0}{10} = 2 \text{ s.}$$

14. $$v = \frac{2\pi r}{24} = \frac{2 \times 22}{7} \times \frac{42250}{24} \text{ km hr}^{-1} = \frac{2 \times 22 \times 42250 \times 1000 \text{ m}}{7 \times 24 \times 60 \times 60 \text{ s}}$$

$$= \frac{44 \times 422500}{7 \times 24 \times 36} = \frac{18590000}{6048} = 3073.74 \text{ m s}^{-1}$$

15. $u = 0$, $\quad a = 0.1$ ms^{-2},

$t = 4$ min $= 4 \times 60 = 240$ s

$v = u + at$

$v = 0 + 0.1 \times 240 = 24$ m s^{-1}

Distance

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

$$s = 0 \times t + \frac{1}{2} \times 0.1 \times 240 \times 240$$

$s = 2880$ m

16. In uniform linear motion, there is no acceleration.
In uniform circular motion, there is accelerated motion.

17. (*a*) An object thrown upward at maximum height velocity is zero but it possesses constant acceleration due to gravity.
(*b*) Motion of blades of a fan.

18. $u = 0, \quad v = 12$ m s^{-1}

$$v = u + at$$

$$12 = 0 + 30 \times a \quad \Rightarrow \quad a = \frac{12}{30} = 0.4 \text{ m s}^{-2}$$

Now $\quad u = 12$ m/s

$v = 8$ m/s

$t = 5$ s

$\therefore \quad v = u + at$

$8 = 12 + 5a \Rightarrow 5a = -4$

$\Rightarrow \quad a = -0.8 \text{ m s}^{-2}$

19. (*a*) Slope of B is maximum so 'B' is travelling the fastest.

(*b*) No because all of these lines are not intersecting.

(*c*) When 'B' passes 'A', 'C' has travelled 6 km (approximately).

(*d*) When 'B' passes 'C', 'B' has travelled nearly 5 km.

20. (*i*) 100 km

(*ii*) Speed $= \frac{QR}{PR} = \frac{50 \text{ km}}{2 \text{ hr}} = 25$ km/hour

(*iii*) After 2 hrs A will catch 'B'.

(*iv*) Speed of A $= \frac{QS}{OS} = \frac{150}{2} = 75$ km/hour

Difference in speed of A and B = 75 – 25 = 50 km/hr.

(*v*) Speed of both the trains is uniform because the graphs for A and B are straight line, i.e. velocity is directly proportional to time.

VALUE BASED QUESTIONS

1. Neeraj was driving a car on highway. He was driving at speed of 90 km/hour. He always keeps his car away from the other vehicles and slows down in crowded place. When he was at 40 km/hour in a crowded place, suddenly a person came in front of his car. He applied breaks and person got scared.

(*i*) What values are associated with Neeraj?

(*ii*) Why should we drive at slow speed in crowded places and keep proper distance between the vehicles?

2. A driver in Hyderabad was driving a bus on highway. 34 people were travelling in the bus suddenly a driver felt chest pain. He slowed down his vehicle and brought it halt on a safe side of the highway. Passengers went to driver and got surprised, driver had collapsed due to cardiac arrest but he saved lives of all passengers.

(*i*) What values are associated with the driver?

(*ii*) Why did he slowed down the vehicle before halt?

(*iii*) Why should we stop the car at the safe side of high way with parking lights on?

Answers

1. (*i*) He is concerned about safety of other people.

(*ii*) It is because, it is safe to drive at slow speed in crowded place and it takes time for vehicle to stop, therefore, proper distance from the people and vehicles must be maintained.

2. (*i*) He saved life of all the passengers. He was a good human being and did not bother about his pain.

(*ii*) Vehicle must be slowed down before halt, sudden breaks may topple the vehicle if it is high speed and other vehicle coming at high speed may collide.

(*iii*) As other vehicle are moving at high speed so their way should not be obstructed and parking light indicate vehicle is stationary and parked.

IMPORTANT FORMULAE

1. $\text{Speed} = \dfrac{\text{Distance}}{\text{Time}}$, S.I. unit = m s^{-1}

2. $\text{Velocity} = \dfrac{\text{Displacement}}{\text{Time taken}}$, S.I. unit = m s^{-1}

3. $\text{Average speed} = \dfrac{\text{Total distance travelled}}{\text{Total time taken}}$

4. $\text{Average velocity} = \dfrac{\text{Total displacement}}{\text{Total time taken}}$

5. Uniform motion:

$\text{Velocity} = \dfrac{x_f - x_i}{t}$ [x_f is final position of a moving body; x_i is initial position of a moving body]

6. For uniformly accelerated motion:

$v = u + at$

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

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

'v' is final velocity
'u' is initial velocity
'a' is acceleration
'S' is displacement or distance
't' is time

7. The slope of displacement-time graph gives the velocity. $\boxed{\text{Slope} = \tan\theta}$

8. The slope of velocity-time graph gives the acceleration of motion.

9. Area below $v - t$ graph is the measure of displacement or distance moved by the moving body in a straight line.

10. $\text{Angular velocity} = \dfrac{\text{Angular displacement}}{\text{Time taken}}$

11. $\text{Angular Acceleration} = \dfrac{\text{Change in angular velocity}}{\text{Time taken}}$

12. In circular motion:

(*i*) Angular displacement $\theta = \dfrac{\text{arc length}}{\text{radus}} = \dfrac{x}{r}$

(*ii*) Angular velocity $\omega = \dfrac{\theta_f - \theta_i}{t}$

[θ_f = Final angle; θ_i = initial angle]

(*iii*) Linear velocity v= radius × angular velocity

$V = r \times \omega$ (ω is omega)

(*iv*) Angular acceleration $\alpha = \dfrac{\omega_f - \omega_i}{t}$

(*v*) Linear acceleration = radius × angular acceleration

$a = r\,\alpha$

13. When a body has free fall or moving under the effect of gravitational force the acceleration may be treated acceleration due to gravity g, as constant and is given by g = 9.8 m s^{-2}. The equation may be modified as

$$v = u \pm gt$$
$$v^2 = u^2 \pm 2\,gS$$
$$S = ut \pm \frac{1}{2}gt^2$$

IMPORTANT NUMERICAL PROBLEMS

Q1. For a body starting from rest, what will be the displacement is 10 seconds, when it acquires a speed of 4 ms^{-1} in 2 seconds?

Sol. $u = 0, \quad v = 4\ ms^{-1}, \quad t = 2$ seconds

$$a = \frac{v-u}{t} = \frac{4-0}{2} = 2\ m\ s^{-2}$$

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

$$S = 0 + \frac{1}{2} \times 2 \times (10)^2 = 100\ m$$

Q2. A ship is moving at a speed of 56 km/h. One second later is moves at 58 km per hour. What is its acceleration?

Sol.

$$u = 56\ km/h = \frac{56 \times 1000}{60 \times 60}\ m\ s^{-1}$$

$$v = 58\ km/h = \frac{58 \times 1000}{60 \times 60}\ m\ s^{-1}$$

$$a = \frac{v-u}{t} = \frac{(58-56)}{1} \times \left(\frac{1000}{60 \times 60}\right)$$

$$a = \frac{2 \times 1000}{60 \times 60} = \frac{20}{36} = \frac{5}{9} = 0.55\ m\ s^{-2}$$

Q3. A 150 m long train crosses a bridge of length 250 m in 25 seconds. What is its velocity?

Sol. Total distance covered = Length of train + Length of bridge

$$= 150\ m + 250\ m = 400\ m$$

$$t = 25\ s$$

$$v = \frac{\text{distance}}{\text{time}} = \frac{400\,m}{25\,s} = 16\ m\ s^{-1}$$

Q4. How long will it take for a body accelerating by 2 m s^{-2} to gain a velocity of 10 m s^{-1}, starting from rest?

Sol. $v = 10\ m\ s^{-1}, \quad u = 0, \quad a = 2\ m\ s^{-1}, \quad t = ?$

$$a = \frac{v-u}{t} \quad \Rightarrow \quad 2\ m\ s^{-1} = \frac{10\ m\ s^{-1} - 0}{t}$$

$$t = \frac{10}{2} = 5\ s$$

Q5. A body moving along a straight line at 20 m s^{-1} undergoes an acceleration of 4 m s^{-2}. After 2 second what will be its speed? Also find the displacement.

Sol. $u = 20\ m\ s^{-1}, a = 4\ m\ s^{-2}, t = 2$ sec, $v = ?$ m, $S = ?$

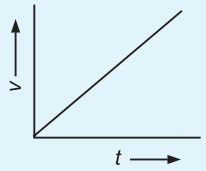
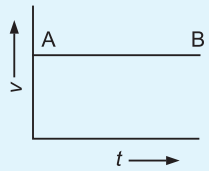
$$v = u + at$$

$$v = 20\ ms^{-1} + 4\ m\ s^{-2} \times 2\ s = 20 + 8 = 28\ m\ s^{-1}$$

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

$$S = 20 \times 2\ m\ s^{-1} + \frac{1}{2} \times 4 \times (2)^2 = 40 + 8 = 48\ m$$

COMMON ERRORS

Errors	Corrections
• Units are not mentioned in the answer.	☞ Always write correct units with answer to avoid loss of marks.
• If the initial point and final point are same, children take displacement and distance same.	☞ Displacement will be zero and not equal to distance.
• Children make graphs without writing variables on x-axis and y-axis.	☞ Proper variable on both axis must be written along with the units.
• For velocity time graph for uniform motion, most of children give the following diagram. 	☞ This graph is not for uniform motion, it is for accelerated motion. The correct graph is as follows: 
• Children do not change time from minutes to seconds.	☞ Time should always be taken in seconds.

REVISION CHART

- Speed = $\frac{\text{Distance travelled}}{\text{Time}}$,

Speed = $\frac{d}{t}$, SI unit = ms^{-1}

Speed with Direction

- Velocity = $\frac{\text{Distance travelled in Particular direction}}{\text{Time}}$,

$v = \frac{S}{t}$, SI unit = ms^{-1}

Rate of Change of Velocity

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

$a = \frac{v-u}{t}$, SI unit = ms^{-2}

Average Velocity

= (initial velocity + final velocity) / 2

$v_{av} = (u + v) / 2$

Motion

A body is said to be in motion if it changes its position with time w.r.t. its surounding.

Uniform Circular Motion

A body moving on a circular path which continuously changes its direction, e.g. motion of a moon around the earth.

Equation of Motion by Graphical Method

- **Velocity-Time Relation:** First equation of motion

$$v = u + at$$

- **Position-Time Relation:** Second equation of motion

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

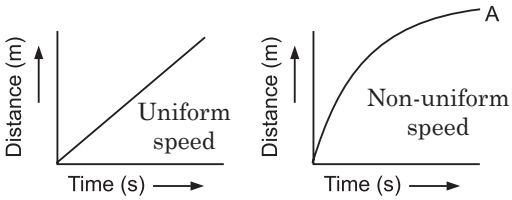
- **Position-Velocity Relation:** Third equation of motion

$$2aS = v^2 - u^2$$

Graphical Representation of Motion

Distance-Time graph:

- Time is shown on X-axis and distance travelled on Y-axis.
- Speed = Slope of the graph = tan θ



Velocity-time graphs:

- Time is shown on X-axis and velocity on Y-axis.
- Acceleration = slope of the graph = tan θ
- Distance/Displacement = Area under the curve.