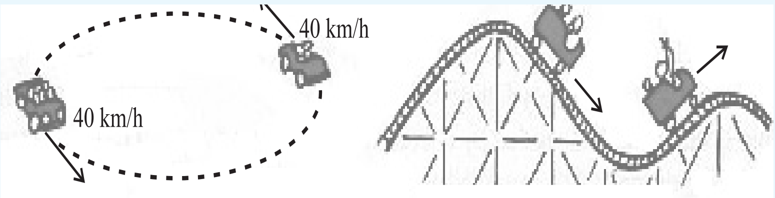
Chapter 1

Motion

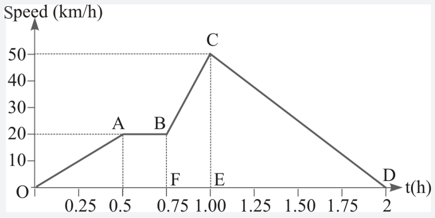
Learning Objectives

- Describing Motion
- Measuring the Rate of Motion
- Rate of Change of Velocity
- Graphical Representation of Motion
- Equations of Motion
- Uniform Circular Motion



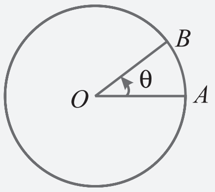
Exam Mirror

- Distance and Displacement
- Displacement-time Graphs
- Velocity-time Graphs



Critical Concepts

- Distance Covered by a Body in n^{th} Second
- Motion under Gravity
- Acceleration in Uniform Circular Motion



INTRODUCTION

Rest : An object is said to be at rest if it does not change its position with respect to its surroundings with the passage of time.

Motion : A body is said to be in motion if its position changes continuously with respect to the surroundings (or with respect to an observer) with the passage of time.

We know that earth is rotating about its axis and revolving around the sun. The stationary objects like your class-room, a tree and the lamp posts etc. do not change their position with respect to each other i.e. they are at rest. Although earth is in motion. To an observer situated outside the earth say in a space ship, your classroom, trees etc. would appear to be in motion. Therefore, all motions are relative. There is nothing like absolute motion. If you move with book in your hand, book is not moving with respect to you.

Rest and Motion are Relative Terms

Rest and motion are relative terms. A particle at rest with respect to an observer can be in motion with respect to another observer. To the passengers in a moving bus or train, trees, buildings and people on the roadsides observe that the bus or the train and its passengers are moving in the forward direction. At the same time, each passenger in a moving bus or train finds that fellow passengers are not moving, as the distance between them is not changing.

Frame of Reference

To locate the position of object we need a frame of reference. A convenient way to set up a frame of reference is to choose three mutually perpendicular axes and name them x-y-z axes. The co-ordinates (x, y, z) of the particle then specify the position of object w.r.t. that frame. If any one or more co-ordinates change with time, then we say that the object is moving w.r.t. this frame.

DESCRIBING MOTION

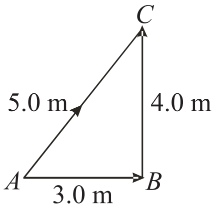
Motion is related to change of position. The length traveled in changing position may be expressed in terms of distance, the actual path length between two points. Distance is a scalar quantity, which has only a magnitude with no direction.

The direct straight line pointing from the initial point to the final point is called displacement (change in position). Displacement only measures the change in position, not the details involved in the change in position. Displacement is a vector quantity, which has both magnitude and direction.

In the figure shown, an object goes from point A to point C by following paths AB and BC.

The distance travelled is 3.0m + 4.0m = 7.0m, and the displacement is 5.0m in the direction of the arrow A→C.

If one states 'the car has travelled 200m', it means that the distance travelled by the car is 200m. But if one states 'the car has travelled 200m due east' it means that the displacement of the car is 200m towards east.



Distance ≥ Displacement

The **displacement can be zero even if the distance is not zero**. For example when a body is thrown vertically upwards from a point on the ground, after sometime it returns back to the same point, then the displacement of the body is zero but the distance travelled by the body is not zero, it is $2h$ if h is the maximum height attained by the body.

Similarly, if a body is moving in a circular or closed path and reaches its original position after one rotation, then the displacement in one rotation is zero, but the distance travelled is equal to the circumference of the circular path = $2\pi r$ if r is the radius of the circular path.

Let's Do Activity

Aim : *To determine the magnitude of the displacement between Bhubaneshwar and New Delhi using the odometer reading.*

Requirement : *Road map of India, Initial and final readings of the odometer.*

Procedure : *Note down the initial reading of the odometer at the starting point in Bhubaneshwar. Drive the car to New Delhi and record the final reading of the odometer upon reaching the destination.*

Calculate the difference between the final and initial readings of the odometer to determine the total distance travelled.

Refer to the road map of India to find the shortest distance between Bhubaneshwar and New Delhi.

Observation : *The odometer provides a measure of the total distance travelled by the car from Bhubaneshwar to New Delhi, as indicated by the difference between the initial and final readings.*

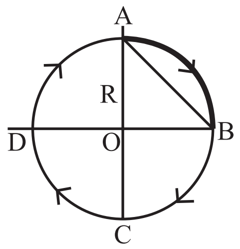
The road map of India provides information about the shortest distance between Bhubaneshwar and New Delhi.

Conclusion : *By comparing the total distance travelled (as per odometer reading) with the shortest distance on the road map, one can determine the magnitude of the displacement between two cities.*

CASE STUDY-1 : Understand Distance and Displacement in a Circular Path

Distance and displacement, both measure the length of the path between two points. But they are quite different from one another. While distance gives the actual path length, displacement is the shortest distance between two points. To understand this more clearly let's consider the case of a particle moving in circle of radius R.

CASE - I: Distance and displacement between point A and B



Distance = length of arc AB

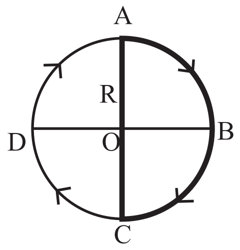
$$= \frac{2\pi R}{4} = \frac{\pi R}{2} \text{ unit.}$$

Displacement = length of line segment AB

$$AB = \sqrt{OA^2 + OB^2}$$

$$= \sqrt{R^2 + R^2} = \sqrt{2}R \text{ unit}$$

CASE - II: Distance and displacement between A and C



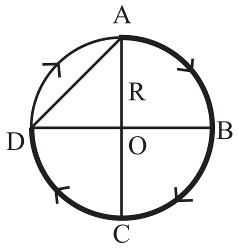
Distance = length of arc AC

$$= \frac{2\pi R}{2} = \pi R \text{ unit}$$

Displacement= length of line segment AC

AC = 2R unit.

CASE - III: Distance and displacement between point A and D



Distance = length of arc AD

$$= 2\pi R \times \frac{3}{4}$$

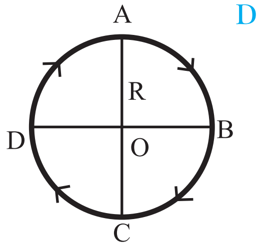
$$= \frac{3\pi R}{2} \text{unit.}$$

Displacement = length of line segment AD

$$AD = \sqrt{OD^2 + OA^2}$$

$$= \sqrt{R^2 + R^2} = \sqrt{2}R \text{ unit}$$

CASE - IV: Distance and displacement when object reaches initial point A



Distance = circumference of circle

$= 2\pi R$ unit

Displacement = 0 unit.

Think Out of the Box

Q 1. Can displacement of an object be greater than distance travelled by that object?

Ans. No. Displacement ≤ distance

Q 2. If the distance covered by a particle is zero what can be its displacement?

Ans. Zero. The distance covered by a particle is zero means there is no change in position, so initial position = final position. Hence displacement = 0.

Q 3. A cyclist moving on a circular path of radius 100 m completes one revolution in 4 minutes. Find its distance and displacement in one full revolution.

Ans. Distance = $2\pi r = 2\pi 100$ m

Displacement = 0 as the body returns to starting point after completing one revolution.

DID YOU KNOW?

Displacement of a particle gives no information regarding the nature of the path followed by the particle.

Illustration 1 :

A runner completes one round of a circular path of radius R in 40 seconds. What will be his displacement after 2 minutes 20 seconds ?

Solution :

$$\text{Time, } T = 2 \text{ min. } 20 \text{ sec.} = 140 \text{ sec} = \underset{\substack{\uparrow \\ \text{Time for} \\ \text{3 round}}}{120 \text{ sec}} + \underset{\substack{\uparrow \\ \text{Time for} \\ \frac{1}{2}\text{ round}}}{20 \text{ sec}}$$

$\therefore$ displacement = 2r

Illustration 2 :

Under what condition will the distance and displacement of a moving object have the same magnitude?

Solution :

If the object is moving along a straight line.

CHECK POINT-1

1. The numerical ratio of displacement to distance is

(a) always less than one (b) always equal to one

(c) always more than one (d) equal to or less than one

2. A particle covers half of the circle of radius r. Then the displacement and distance of the particle are respectively

(a) $2\pi r, 0$ (b) $2r, \pi r$

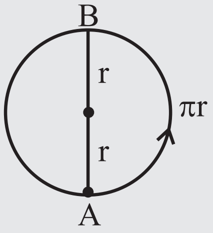
(c) $\frac{\pi r}{2}, 2r$ (d) $\pi r, r$

Solutions:

1. **(d)** As displacement ≤ distance, therefore, the ratio is equal to or less than one.

2. **(b)** When a particle cover half of circle of radius r, then displacement is AB = $2r$

& distance = half of circumference of circle = πr



Uniform Motion

It is a motion in which a material point moves in a straight line (rectilinear) and covers equal distances in equal intervals of time.

Non-uniform Motion

If a body covers unequal distances in equal intervals of time, it is said to be moving with a non-uniform motion.

MEASURING THE RATE OF MOTION

Speed

It is the distance covered by the particle in one second.

(i) It is a scalar quantity.

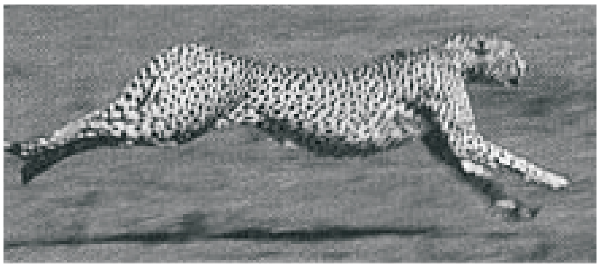
(ii) Unit : In SI system metre/second (ms^{-1}).

Average Speed

Average speed is defined as *the total distance traveled divided by the time interval to travel that distance.*

Average speed $V_{av} = \frac{d}{t}, d$ is distance travelled, and t is time interval (change in time).

It is a scalar quantity.



If a particle covers two consecutive equal distances with speeds v_1 and v_2 then,

$$\text{Average speed} = \frac{2v_1v_2}{v_1 + v_2}$$

If a particle covers three consecutive equal distances with speeds v_1, v_2 and v_3 then,

$$\text{Average speed} = \frac{3v_1v_2v_3}{v_1v_2 + v_2v_3 + v_3v_1}$$

If a particle has speed v_1 for time t_1 and speed v_2 for time t_2 then,

$$\text{Average speed} = \frac{v_1t_1 + v_2t_2}{t_1 + t_2}$$

Instantaneous Speed

Instantaneous speed is *the speed at a particular time instant* (t is infinitesimal small or close to zero). It is also a scalar quantity.

Uniform and Non-uniform Speed

A body is said to be moving with uniform speed if it covers equal distances in equal time intervals and with non-uniform or variable speed if covers unequal distances in the same time intervals.

Let's Do Activity

Aim : *To understand the delay between seeing lightning and hearing thunder during a thunderstorm and calculate the distance of nearest point of lightning.*

Requirement : *Digital wristwatch or stopwatch.*

Procedure : *Observe a thunderstorm and note the time interval between seeing and lightning and hearing thunder. Use a digital wristwatch or stopwatch to measure this time interval accurately. Record the time interval in seconds. The time interval represents the time taken for sound waves from the thunder to travel to the observer's location.*

Observation : *There is a noticeable delay between seeing lightning and hearing thunder.*

Conclusion : *The delay between seeing lightning and hearing thunder occurs because light travels much faster than sound. By measuring this time interval and knowing the speed of sound in air (346 m/s).*

One can calculate the distance of the nearest point of lightning. Using formula, Distance = Speed × Time, where speed is the speed of sound and time is measured time interval.

Velocity

It is defined as the rate of change of displacement.

(i) It is a vector quantity (ii) Its direction is same as that of displacement.

(iii) Its unit – in SI system metre per second (ms^{-1})

DID YOU KNOW?

The velocity of an object may be positive, zero or negative, but the speed of an object can never be negative.

Average Velocity

Average velocity is defined as *the ratio of change in position or displacement to the time taken.*

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

Here x_1 and x_2 are the positions of the particle at time t_1 and t_2 respectively.

Also, $\Delta x = x_2 - x_1$ = change in position and $\Delta t = t_2 - t_1$ = change in time.

It is a vector quantity, its unit is ms^{-1}, cms^{-1} or km h^{-1}.

Instantaneous Velocity

Velocity of a body at a particular instant or moment of time is called instantaneous velocity.

Instantaneous velocity is a vector quantity, as it has direction as well as magnitude, its unit is m/s, cm/s or km/h.

Remember that the magnitude of instantaneous velocity at an instant would always be equal to the instantaneous speed at that instant.

Illustration 3 :

Is it possible to have a constant velocity but a varying speed?

Solution :

No, velocity is equal to speed plus direction. So if speed of body is changing, velocity cannot remain constant.

Illustration 4 :

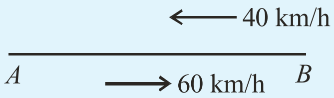
A particle moved from point A to point B, travelling some distance with speed 60 kmh^{-1}. Then it moves back from B to A with speed 40 km/h. Find displacement, distance covered, average velocity and average speed for the entire journey.

Solution :

Let us take, AB = s

As particle comes back to the same point, displacement = 0

Total distance covered = length of path = 2s = 2AB



Average velocity = $\dfrac{displacement}{time} = \dfrac{0}{\Delta t} = 0$ (As displacement is zero)

For average speed, total time = $\dfrac{s}{60} + \dfrac{s}{40}$ and total distance = s + s = 2s

So, average speed = $\dfrac{2s}{\dfrac{s}{60}+\dfrac{s}{40}} = 48$ km h^{-1}

RATE OF CHANGE OF VELOCITY

Acceleration

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

i.e., Acceleration, a = $\dfrac{\Delta v}{\Delta t}$

- It is a vector quantity. Its **SI unit** is ms^{-2}
- Its direction is same as that of change in velocity and not of the velocity (That is why acceleration in circular motion is towards the centre).

  There are three possible ways in which change in velocity may occur.

(i) When only direction charges	**(ii) When only magnitude changes.**	**(iii) When both direction and magnitude change.**
To change the direction net acceleration should be ⊥ to direction of velocity. **Ex. :** Uniform circular motion	In this case net acceleration should be ‖ or antiparallel to the direction of velocity (straight line motion) and another one is ⊥ to velocity. **Ex. :** When ball is thrown up under gravity	In this case net acceleration has two components one component is ‖ to velocity. **Ex. :** Projectile motion

Average Acceleration

Average acceleration is defined as *the change in velocity divided by the time interval to make the change.*

$\vec{a} = \dfrac{\Delta v}{\Delta t} = \dfrac{v - v_0}{t - t_0}$, where $\vec{a}$ is average acceleration, Δv is change in velocity, and Δt is time interval.

Instantaneous Acceleration

Instantaneous acceleration of the particle is the acceleration at particular instant, mathematically, it will be

$$a_{\text{inst.}} = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} = \frac{dv}{dt}$$

Instantaneous acceleration is also referred to as 'acceleration',

Positive acceleration : If the velocity of an object increases in the same direction, the object has a positive acceleration.

Negative acceleration (Retardation) : If the velocity of a body decreases in the same direction, the body has a negative acceleration or it is said to be retarding e.g, A train slows down.

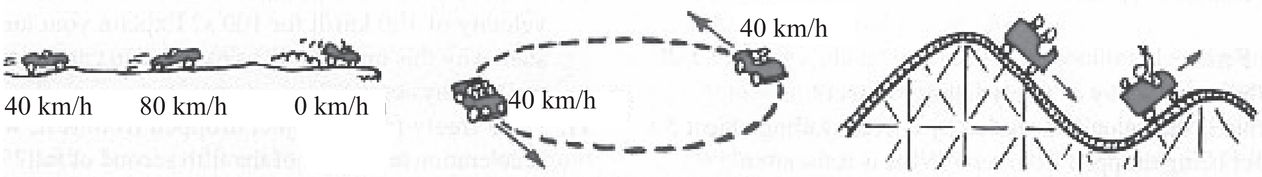
When velocity of a particle increases with time, it is said to be accelerated motion i.e. both acceleration and velocity will be positive and speed (magnitude of velocity) would increase.

When both acceleration and velocity are negative, that would mean that the direction of motion is in the opposite direction but in this case also speed of particle would increase with time.

If acceleration and velocity are of opposite signs, in that case speed of the particle would decrease. Deceleration is equivalent to negative of acceleration.

Three ways to accelerate

$$\text{Acceleration} = \left\{\begin{matrix}\text{Rate of}\\ \text{change in}\\ \text{velocity}\end{matrix}\right\} \quad \text{due to} \quad \left\{\begin{matrix}\text{change in speed}\\ \text{and/or direction}\end{matrix}\right\}$$



Change in speed but *not* direction

Change in direction but *not* speed

Change in speed and direction

General methods of approaching numerical problems.

1. Draw a 'sketch' diagram wherever possible.
2. Copy down the numerical information given in the question.
3. Write down the relevant formula.
4. Substitute the given values into the formula.
5. Calculate the answer, remembering to show all steps in the working out and giving the correct units for our final answer.

Illustration 5 :

The change in the velocity of a motor bike is 54 km h^{-1} in one minute. Calculate its acceleration in

(a) ms^{-2} (b) km h^{-2}

Solution :

(a) Given,

$$\text{Change in velocity} = 54\ \text{kmh}^{-1} = 54 \times \frac{1000}{3600}\ \text{ms}^{-1} = 15\ \text{ms}^{-1}$$

Time = 1 minute = 60 s

$$\text{Acceleration (a)} = \frac{\text{Change in velocity}}{\text{time}} = \frac{15}{60} = 0.25\ \text{ms}^{-2}$$

$$\text{(b) Acceleration in km h}^{-2} = \frac{54}{\frac{1}{60}} = 3240\ \text{km h}^{-2}$$

Illustration 6 :

An object moving to the right has a decrease in velocity from 5.0 m/s to 1.0 m/s in 2.0 s. What is the average acceleration ? What does your result mean ?

Solution :

Given $v_0 = +5.0$ m/s, $v = +1.0$ m/s, $t = 2.0$ s, $\vec{a} = ?$

According to the definition of average acceleration,

$$\vec{a} = \frac{\Delta v}{\Delta t} = \frac{v - v_0}{t} = \frac{+1.0\text{ m/s} - (+5.0\text{ m/s})}{2.0\text{s}} = \frac{-4.0\text{ m/s}}{2.0\text{ s}} = -2.0\text{ m/s}^2$$

The negative sign means the acceleration is opposite to velocity (deceleration). The result means that the object decreases its velocity by 2.0 m/s every s or 2.0 m/s^2.

GRAPHICAL REPRESENTATION OF MOTION

In physics we often use graphs as important tools for picturing certain concepts. Following are some graphs that help us picture the concepts of displacement, velocity and acceleration.

Displacement-Time Graphs

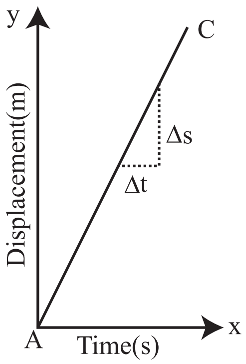
Below is a graph showing the displacement of the cyclist from *A* to *C*:

This graph shows us how, in *t* seconds time, the cyclist has moved from *A* to *C*.

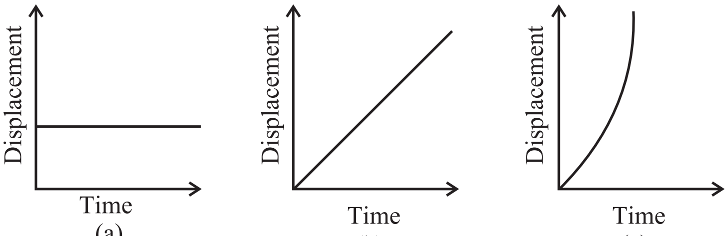
We know the gradient (slope) of a graph is defined as the change in *y* divided by the change in *x*, i.e $\frac{\Delta y}{\Delta x}$.

In this graph the gradient of the graph is just $\frac{\Delta s}{\Delta t}$ and this is just the expression for velocity.

The slope of a displacement-time graph gives the velocity.



The slope is the same all the way from *A* to *C*, so the cyclist's velocity is constant over the entire displacement he travels. Observe the following displacement-time graphs.



(a) (b) (c)

Graph (a) Shows the graph for an object stationary over a period of time. The gradient is zero, so the object has zero velocity.

Graph (b) Shows the graph for an object moving at a constant velocity. You can see that the displacement is increasing as time goes on. The gradient, however, stays constant (remember is the slope of straight line) so the velocity is constant. Here the gradient is positive, so the object is moving in the direction we have defined as positive.

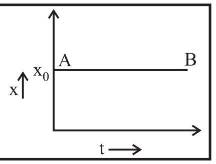
CASE STUDY-2 : Understand Position-time Graph

Position time graph is the graph between position of the object with respect to time. A lot of useful information can be collected about uniform motion along straight line of an object.

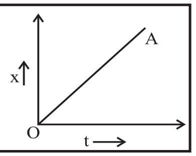
On y-axis → position denoted by x
On x-axis → time denoted by t

x_0 = initial position of object in motion.

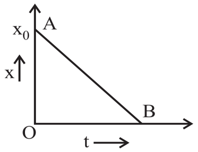
***CASE - I:* Object at rest**- If the object is at rest, its position will not change with time. The x-t graph is a straight line AB parallel to time axis.



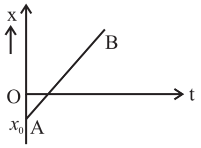
***CASE - II:* Object in uniform motion along a straight line**- The x-t graph will be a straight line, starting from origin, inclined to time axis.



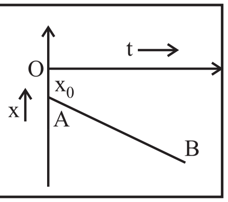
***CASE - III:* Object moving with a constant negative velocity starting from the positive position**- $x_0 = +ve \quad v_0 = -ve$
x-t graph will be a straight line AB, as shown.



CASE - IV: Object moving along a straight line having $x_0 = -ve$ and v_0 (velocity) $= +ve$
x - t graph will be an inclined straight line AB as shown.

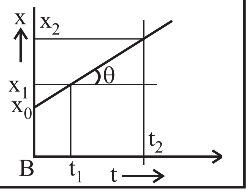


CASE - V: Object moving along a straight line having
$x_0 = -ve$ and $v_0 = -ve$
x - t graph will be an inclined straight line AB as shown.



CASE - VI: Slope of position-time graph. The importance of the position-time graph of uniform motion lies in the fact that its slope gives us velocity of the object.

$$\text{Slope} = \tan\theta = \frac{x_2 - x_1}{t_2 - t_1} = v$$



Think Out of the Box

Q. 1 What do you infer if distance time graph is zig-zag?

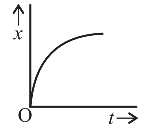
Ans. It means speed is non uniform.

Q. 2 If a particle travels distance s_1 and s_2 with speed v_1 and v_2 in the same direction, what is the average speed of the particle?

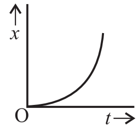
Ans. $\text{Average speed} = \frac{\text{Total dis tan ce}}{\text{total time}} = \left(\frac{s_1 + s_2}{s_1 / v_1 + s_2 / v_2}\right)$

Q. 3 Infer from the graph:

(a)



(b)



(a) (i) Velocity ____________ (ii) Acceleration ____________
(b) (i) Velocity ____________ (ii) Acceleration ____________

[**Hint:** In $x - t$ graph if θ decreasing, v decreasing, a is negative and if θ increasing, v increasing, a is positive.]

Graph (c) Shows the graph for an object moving at a constant acceleration. You can see that both the displacement and the velocity (gradient of the graph) increases with time. The gradient is increasing with time, thus the velocity is increasing with time and the object is accelerating.

Illustration 7 :

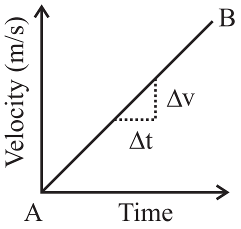
How is position-time graph of uniformly accelerated motion in one dimension helpful in studying the motion of the object?

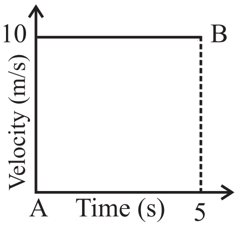
Solution :

Slope of position-time graph gives velocity of object and also we can determine the distance travelled by object during any interval of time.

Velocity-Time Graphs

This is the velocity-time graph of a cyclist travelling from A to B at a constant acceleration, i.e. with steadily increasing velocity. The gradient of this graph is just $\frac{\Delta s}{\Delta t}$ and this is just the expression for acceleration. Because the slope is the same at all points on this graph, the acceleration of the cyclist is constant.





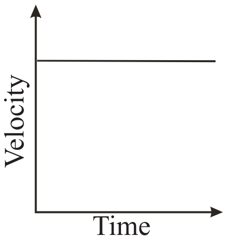
The slope of a velocity-time graph gives the acceleration.

We can also calculate displacement travelled from velocity-time graph.

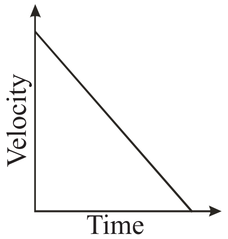
This graph shows an object moving at a constant velocity of 10m/s for a duration of 5s. The area between the graph and the time axis of the above plot will give us the displacement of the object during this time. In this case we just need to calculate the area of a rectangle with width 5s and height 10m/s.

$$\begin{aligned}\text{Area of rectangle} &= \text{height} \times \text{width}\\ &= \vec{v} \times t = 10\ \text{m/s} \times 5\text{s} = 50\ \text{m}\\ &= \text{displacement}\end{aligned}$$

Observe the following velocity-time graphs.



(a)



(b)

Graph (a) Shows an object moving at a constant velocity over a period of time. The gradient is zero, so the object is not accelerating.

Graph (b) Shows an object which is decelerating. You can see that the velocity is decreasing with time. The gradient, however, stays constant so the acceleration is constant. Here the gradient is negative, so the object is accelerating in the opposite direction to its motion, hence it is decelerating.

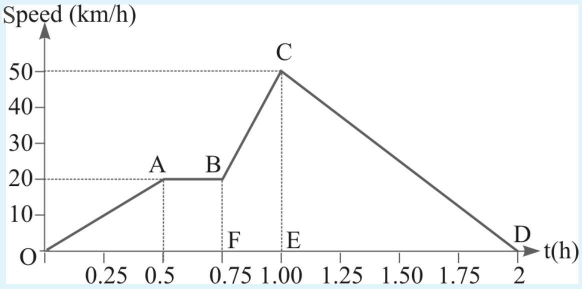
DID YOU KNOW?

The v-t graph of an object having uniform motion is a straight line parallel to time-axis. The area between v-t graph of an object and time-axis is numerically equal to distance covered by it.

Illustration 8 :

A train moves from one station to another in two hours time. Its speed time-graph during the motion is shown in figure.
Calculate the distance covered during the time interval from 0.75 hour to 1 hour.

Solution :



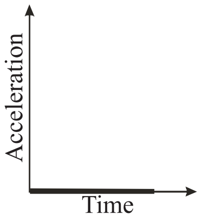
Distance travelled in the duration 0.75 to 1 hour.

$= \text{Area of trapezium BCEF} = \frac{1}{2}[20 + 50] \times (1.00 - 0.75)$

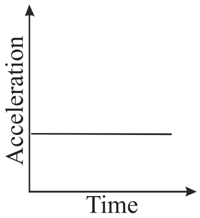
= 8.75 km.

Acceleration-Time Graphs

Observe the following acceleration-time graphs.



(a)

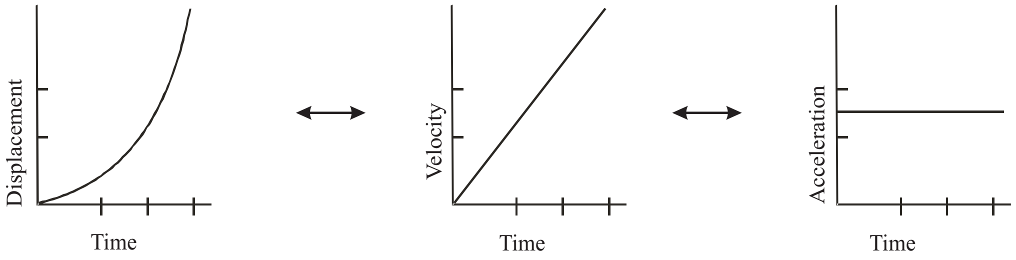


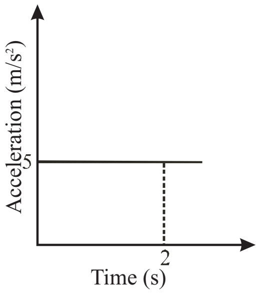
(b)

Graph (a) Shows an object which is either stationary or travelling at a constant velocity. Either way, the acceleration is zero over time.

Graph (b) Shows an object moving at a constant acceleration. In this case the acceleration is positive - remember that it can also be negative.

Its useful to remember the set of graphs below when working on problems. Figure shows how displacement, velocity, acceleration and time relate to each other. Given a displacement-time graph like the one on the left, we can plot the corresponding velocity-time graph by remembering that the slope of a displacement-time graph gives the velocity. Similarly, we can plot an acceleration-time graph from the gradient of the velocity-time graph.





We can obtain the velocity of a particle at some given time from an acceleration time graph-it is just given by the area between the acceleration and the time-axis. In the graph below, showing an object at a constant positive acceleration, the increase in velocity of the object after 2 seconds corresponds to the portion.

Area of rectangle $= a \times t = 5\frac{m}{s^2} \times 2s = 10\frac{m}{s} = \Delta v$

CHECK POINT-2

1. A graph is plotted showing the velocity of a car as a function of time. If the graph is a straight line, it means that

(a) the car started at rest
(b) acceleration was constant
(c) acceleration was increasing
(d) velocity was constant

2. Match the Column :

	Column I		Column II
(A)	Uniform speed	(p)	Unequal distance in equal time
(B)	Uniform acceleration	(q)	Unequal velocity in equal time change
(C)	Non-uniform acceleration	(r)	Equal distance in equal time
(D)	Non-uniform speed	(s)	Equal velocity change in equal time

(a) (A) → (s); (B) → (q); (C) → (r); (D) → (p)
(b) (A) → (r); (B) → (s); (C) → (q); (D) → (p)
(c) (A) → (p); (B) → (q); (C) → (r); (D) → (s)
(d) (A) → (q); (B) → (p); (C) → (r); (D) → (s)

3.

	Column I		Column II
(A)	Slope of displacement-time graph	(p)	Acceleration
(B)	Slope of velocity-time graph	(q)	Velocity
(C)	Area under velocity-time graph intercepted with time-axis.	(r)	Change in velocity
(D)	Area under acceleration-time graph intercepted with time-axis.	(s)	Displacement

(a) (A) → (r); (B) → (s); (C) → (q); (D) → (p)
(b) (A) → (q); (B) → (p); (C) → (s); (D) → (r)
(c) (A) → (p); (B) → (q); (C) → (r); (D) → (s)
(d) (A) → (s); (B) → (r); (C) → (p); (D) → (q)

4. The acceleration of a car that speeds up from 12 meters per second to 30 meters per second in 15 seconds–

(a) 2.4 m/s²
(b) 1.2 m/s²
(c) 2 m/s²
(d) 5.2 m/s²

Solutions:

1. **(b)**
2. **(b)** (A) → (r); (B) → (s); (C) → (q); (D) → (p)
3. **(b)** (A) → (q); (B) → (p); (C) → (s); (D) → (r)
4. **(b)**

EQUATIONS OF MOTION

Kinematic equations can be used to describe the motion with constant acceleration.

The symbols used in the kinematic are : *v_0 or u initial velocity; v, final velocity; a, acceleration; x, displacement; t, time interval.* Be aware that the terms initial and final are relative. The end of one event is always the beginning of another. There are three general equations and two algebraic combinations of these equations that provide calculation convenience.

$x = \vec{v}t$, displacement = average velocity × time interval

$\vec{v} = \dfrac{v+u}{2}$, average velocity = (final velocity + initial velocity) / 2

First equation (Equation for velocity-time relation) :

$v = u + at$, final velocity = initial velocity + acceleration × time interval,

By definition, acceleration $= \dfrac{\text{change in velocity}}{\text{time taken}} = \dfrac{\text{final velocity} - \text{initial velocity}}{\text{time taken}}$

or $a = \dfrac{v-u}{t} \Rightarrow at = v - u$

or $\boldsymbol{v = u + at}$ .... (1)

Second equation (Equation for position-time relation) : $s = ut + \frac{1}{2}at^2$

Displacement = initial velocity × time interval + $\frac{1}{2}$ × acceleration × time interval^2

Distance travelled = average velocity × time = $\left(\frac{\text{Initial velocity} + \text{final velocity}}{2}\right) \times \text{time}$

or $s = \frac{u+v}{2} \times t$

But from eq. (1), $v = u + at$

$\therefore \quad s = \frac{u+(u+at)}{2} \times t$ or $s = \frac{2u+at}{2} \times t$

or $\mathbf{s = ut + \frac{1}{2}at^2}$ .... (2)

Third equation (Equation for position-velocity relation) : $v^2 = u^2 + 2as$

Final velocity^2 = initial velocity^2 + 2 × acceleration × displacement

Distance travelled = average velocity × time

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

But from eq. (1), $v = u + at$

$t = \frac{v-u}{a} \qquad \therefore \quad s = \frac{u+v}{2} \times \frac{v-u}{a}$

or $s = \frac{v^2 - u^2}{2a}$ $v^2 - u^2 = 2as$ or $\mathbf{v^2 = u^2 + 2as}$ .... (3)

The three equations listed can be used to solve the majority of kinematic problems.

Which equation should you select for a particular problem ? The equation you select must have the unknown quantity in it and everything else must be given, because we can only solve for one unknown in one equation.

Tips to solve problems on kinematic equations

1. Make a drawing to represent the situation being studied.
2. Decide which directions are to be called positive (+) and negative (–) relative to a conveniently chosen coordinate origin. Do not change your decision during the course of a calculation.
3. In an organized way, write down the values (with appropriate plus and minus signs) that are given for any of the five kinematic variables (x, a, v, v_0 and t).
4. Before attempting to solve a problem, verify that the given informationw contains values for at least three of the five kinematics variables.
5. When the motion of an object is divided into segments, remember that the final velocity of one segment is the initial velocity for the next segment.

CONNECTING TOPIC

Distance Covered by a Body in Nth Second

$s = ut + \frac{1}{2}at^2$, is the distance covered by a body in t sec

or $\text{sn} = un + \frac{1}{2}an^2$ ....(i) distance covered by a body along straight line in n sec.

$S_{n-1} = u(n-1) + \frac{1}{2}a(n-1)^2$ ....(ii) distance covered by a body along straight line in (n – 1) sec.

$\therefore$ The distance covered by the body in nth second will be $S_{nth} = S_{n-1}$

$$\therefore \; S_{nth} = un + \frac{1}{2}an^2 - \{u(n-1) + \frac{1}{2}a(n-1)^2\}$$

$$S_{nth} = un + \frac{1}{2}an^2 - \{un - u + \frac{1}{2}a(n+1-2n)\}$$

$$\Rightarrow \quad un + \frac{1}{2}an^2 - \{nu - u + \frac{an^2}{2} + \frac{a}{2} - an\} \Rightarrow un + \frac{1}{2}an^2 - nu + u - \frac{an^2}{2} - \frac{a}{2} + an = u + a\left(n - \frac{1}{2}\right) = n + a\left(\frac{2n-1}{2}\right)$$

So, the distance covered by body in nth second, $\boldsymbol{S_{nth} = u + \frac{a}{2}(2n-1)}$

Let's Connect

1. A body starts from rest and travels ‘s’ m in 2nd second, then acceleration is

(a) $2s \text{ m/s}^2$ (b) $3s \text{ m/s}^2$ (c) $\frac{2}{3}s \text{ m/s}^2$ (d) $\frac{3}{2}s \text{ m/s}^2$

2. The distance travelled by a particle starting from rest and moving with an acceleration $\frac{4}{3}\text{ms}^{-2}$, in the third second is:

(a) 6 m (b) 4 m (c) $\frac{10}{3}$m (d) $\frac{19}{3}$m

Solutions:

1. **(c)** $S_n = u + \frac{a}{2}(2n-1)$ or, $S = \frac{a}{2}(2 \times 2 - 1) \Rightarrow a = \frac{2}{3}\text{m/s}^2$

2. **(c)** Distance travelled in the nth second is given by $t_n = u + \frac{a}{2}(2n-1)$

put $u = 0$, $a = \frac{4}{3}\text{ms}^{-2}$, $n = 3$

$$\therefore \quad d = 0 + \frac{4}{3 \times 2}(2 \times 3 - 1) = \frac{4}{6} \times 5 = \frac{10}{3}\text{m}$$

Illustration 9 :

The velocity of a body moving with a uniform acceleration of 2ms^{-2} is 10 ms^{-1}. What is its velocity after an interval of 4 second?

Solution :

$v = 10 + 2 \times 4 = 18 \text{ ms}^{-1}$.

Illustration 10 :

An automobile accelerates uniformly from rest to 25 m/s while traveling 100m. What is the acceleration of the automobile ?

Solution :

Given : $v_0 = 0$ (rest), $v = 25$ m/s, $s = 100$m, acceleration a =?

$$\text{Since} \quad v^2 = v_0^2 + 2as \Rightarrow a = \frac{v^2 - v_0^2}{2s} = \frac{(25\,\text{m/s})^2 - (0)^2}{2(100\,\text{m})} = 3.1 \text{ m/s}^2$$

Since a is positive, it is in the direction of the velocity or motion.

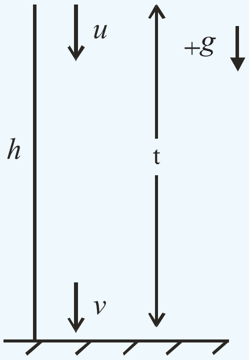
CONNECTING TOPIC

Motion under Gravity

It is a common experience that when a body is dropped form a certain height it experiences acceleration due to gravity and its motion is in a straight path. Similarly, when a body is thrown vertically up, it goes to a certain height and then starts falling again, experiencing acceleration due to gravity throughout the motion. The value of acceleration due to gravity (g) is taken as 9.8 m/s^2, 980 cm/s^2 or 32 ft/s^2. Let us consider the three cases discussed below.

Case-I : Body thrown downward :

In this case, initial motion of the body is downward so according to the sign convention, downward direction will be taken as positive and upward direction as negative. So, the kinematic equations will be :



$$v = u + gt$$
$$h = ut + \frac{1}{2}gt^2$$
$$v^2 = u^2 + 2gh$$
$$h^{\text{nth}} = h + \frac{1}{2}\,g\,(2n - 1)$$

In a special case when the body is dropped/let fall/allowed to fall we will take the initial velocity(u) as zero, then equation becomes

$v = gt$; $h = \frac{1}{2}gt^2$; $v^2 = 2gh$; $h^{\text{nth}} = \frac{1}{2}\,g\,(2n - 1)$

Case-II : Body thrown upward :

If a body is thrown vertically up with an initial velocity (u).

Hence $a = -g$. Kinematic equations will be:

(i) $v = u - gt$ (ii) $h = ut - \frac{1}{2}gt^2$

(iii) $v^2 - u^2 = -2gh$ (iv) $h_n = u - g\left(n - \frac{1}{2}\right)$

Let's Connect

1. A stone falls from a balloon that is descending at a uniform rate of 12 m/s. The displacement of the stone from the point of release after 10 sec is

(a) 490 m (b) 510 m (c) 610 m (d) 725 M

2. From a balloon moving upwards with a velocity of 12 ms^{-1}, a packet is released when it is at a height of 65 m from the ground. The time taken by it to reach the ground is (g = 10 ms^{-2})

(a) 5 s (b) 8 s (c) 4 s (d) 7 s

Solutions:

1. **(c)** u = 12m/s, g = 9.8 m/sec^2, t = 10 sec

Displacement = $ut + \frac{1}{2}gt^2$

$= 12 \times 10 + \frac{1}{2} \times 9.8 \times 100 = 610\text{m}$

2. **(a)** $s = ut + \frac{1}{2}at^2$

$-65 = 12t - 5t^2$ on solving we get, t = 5s

CHECK POINT-3

1. A particle experiences constant acceleration for 20 seconds after starting from rest. If it travels a distance s_1 in the first 10 seconds and distance s_2 in the next 10 seconds, then

(a) $s_2 = s_1$ (b) $s_2 = 2\ s_1$ (c) $s_2 = 3\ s_1$ (d) $s_2 = 4\ s_1$

2. If a car at rest accelerates uniformly to a speed of 144 km/h in 20 s, it covers a distance of

(a) 2880 m (b) 1440 m (c) 400 m (d) 20 M

3. A particle starting with certain initial velocity and uniform acceleration covers a distance of 12 m in first 3 seconds and a distance of 30 m in next 3 seconds. The initial velocity of the particle is

(a) $3\ \text{ms}^{-1}$ (b) $2.5\ \text{ms}^{-1}$ (c) $2\ \text{ms}^{-1}$ (d) $1\ \text{ms}^{-1}$

4. A bullet fired into a wooden block loses half of its velocity after penetrating 40 cm. It comes to rest after penetrating a further distance of

(a) $\frac{22}{3}$cm (b) $\frac{40}{3}$cm (c) $\frac{20}{3}$cm (d) $\frac{22}{5}$cm

Solutions:

1. **(c)** Let a be the constant acceleration of the particle. Then

$$s = u\,t + - a\,t \quad \text{or} \quad s_1 = 0 + \frac{1}{2} \times a \times (10)^2 = 50\ a \quad \text{and} \quad s_2 = \left[0 + \frac{1}{2}a(20)^2\right] - 50a = 150a$$

$\therefore\ s_2 = 3s_1$

2. **(c)** Initial velocity of car (u) = 0

Final velocity of car (v) = 144 km/hr = 40 m/s

Time taken = 20 s

We know that, v = u + at

$40 = a \times 20 \Rightarrow a = 2\ \text{m/s}^2$

Also, $v^2 - u^2 = 2as \Rightarrow s = \frac{v^2 - u^2}{2a} \Rightarrow s = \frac{(40)^2 - (0)^2}{2 \times 2} = \frac{1600}{4} = 400$ m.

3. **(d)** Let u be the initial velocity that have to find and a be the uniform acceleration of the particle.

For t = 3s, distance travelled S = 12 m and

for t = 3 + 3 = 6 s distance travelled S′ = 12 + 30 = 42 m

From, $S = ut + 1/2\ at^2$

$12 = u \times 3 + \frac{1}{2} \times a \times 3^2$ or $24 = 6u + 9a$ ...(i)

Similarly, $42 = u \times 6 + \frac{1}{2} \times a \times 6^2$ or $42 = 6u + 18a$ ...(ii)

On solving, we get $u = 1\ \text{m s}^{-1}$

4. **(b)** For first part of penetration, by equation of motion

$\left(\frac{u}{2}\right)^2 - (u)^2 = 2aS$ or $a = -\frac{3u^2}{8S}$ ...(i)

For latter part of penetration

$(0)^2 - \left(\frac{u}{2}\right)^2 = 2aS'$, $S' = -\frac{u^2}{8a}$

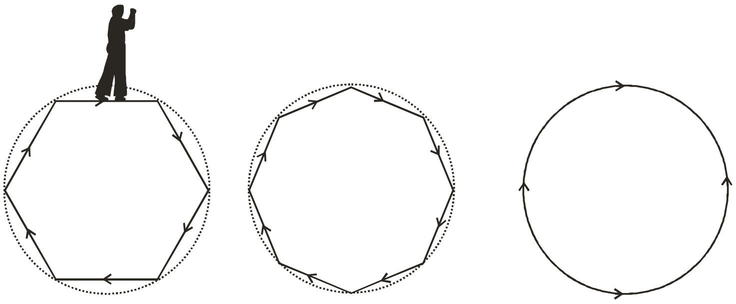
$S' = -\frac{u^2}{8}\left(\frac{8S}{-3u^2}\right)$ (Using (i))

$S' = \frac{S}{3}$ or $S' = \frac{40}{3}$cm

UNIFORM CIRCULAR MOTION

Motion of a particle (small body) along a circle (circular path), is called a circular motion. *If the body covers equal distances along the circumference of the circle, in equal intervals of time, the motion is said to be a* ***uniform circular motion***. A uniform circular motion is a motion in which speed remains constant but direction of velocity changes.

Explanation : Consider a boy running along a regular hexagonal track (path) as shown in fig. As the boy runs along the side of the hexagon at a uniform speed, he has take a turn at each corner changing direction but keeping the speed same. In one round he has to take six turns at regular intervals. If the same boy runs along the side of a regular octagonal track with same uniform speed, he will have to take eight turns in one round at regular intervals but the interval, will become smaller.



By increasing the number of sides of the regular polygon, we find the number of turns per round becomes more and the interval between two turns become still shorter. A circle is a limiting case of a polygon with an infinite number of sides on the circular track, the turning becomes a continuous process without any gap in between the boy running along the sides of such a track will be performing a circular motion. Hence, circular motion is the motion of a body along the sides of a polygon of infinite number of sides with uniform speed, the direction changing continuously.

Examples of uniform circular motion are:

(i) motion of moon around the earth. (ii) motion of satellite round its planet.

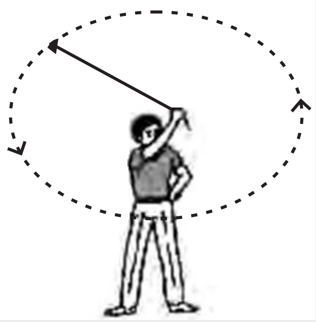
Let's Do Activity

Aim : *To observe the motion of a stone attached to a thread moving in a circular path and understand the direction of its motion after release.*

Requirement : *Piece of thread, small piece of stone.*

Procedure : *Tie a small piece of stone to one end of the thread. Hold the thread at the other end and move the stone to describe a circular path with constant speed. Repeat the thread and observe the direction in which the stone moves after release.*

Repeat the activity multiple times, releasing the stone at different positions along the circular path to check if the direction of motion remains the same.



Observation : *On being released, the stone moves along a straight line tangential to the circular path.*

The stone continues to move along the direction it was moving at the instant of release.

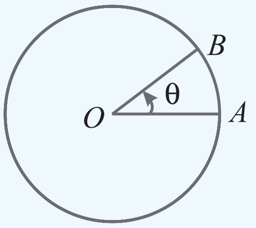
Conclusion : *The direction of motion changes at every point when the stone is moving along the circular path.*

When released, the stone moves along a straight line tangential to the circular path.

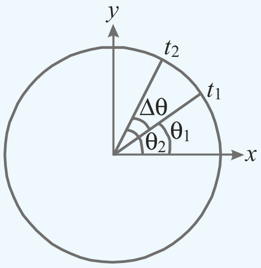
CONNECTING TOPIC

Angular Position, Displacement and Velocity

Angular position : Angle made by radius to the particle with a reference radius is known as angular position. In figure θ is known as angular position. *OA* is known as reference radius, with respect to which the angle is measured.



Angular displacement : Angular displacement is defined as the angle traced out by the radius vector at the axis of the circle in a given time. $\theta_1 \rightarrow$ angular position at time t_1, $\theta_2 \rightarrow$ angular position at time t_2. Time taken $\Delta t = t_2 - t_1$.



Here $\Delta\theta = \theta_2 - \theta_1$ is known as angular displacement. It is a vector quantity, provided $\Delta\theta$ is small because commutative law of vector addition is not valid for large $\Delta\theta$.

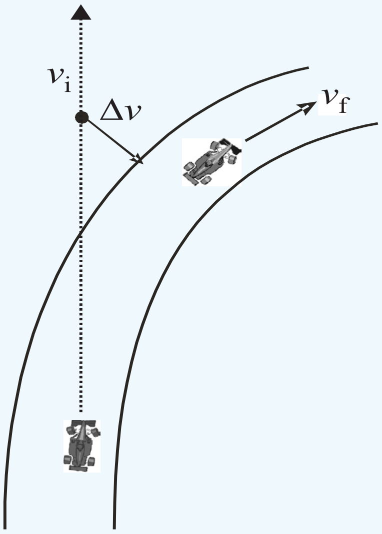
Its units are degree, radian revolution, etc.

Angular velocity: It is defined as the rate of change of angular displacement. If $\Delta\theta$ be the change in angular displacement during time Δt then angualr velocity (ω) is given by $\omega = \dfrac{\Delta\theta}{\Delta t}$

Unit of angular velocity : radian/second (rad/s), rotations per minute (rpm), rotation per second (rps), etc.

Acceleration in Uniform Circular Motion

When the car turns to the right, its acceleration is to the right, perpendicular to its velocity, this acceleration is called ***centripetal acceleration*** and its value is $\dfrac{v^2}{r}$ where *v* is the magnitude of the velocity and *r* is the radius of the path.



Let's Connect

1. A grinding wheel (radius 7.6 cm) is rotating at 1750 rpm. What is the speed of a point on the outer edge of the wheel ?

(a) 7 m/s	(b) 9 m/s	(c) 14 m/s	(d) 18 m/s

2. Rishabh, a 20 kg child on his bicycle moving with a speed of 10 ms^{-1} takes a turn on a circular turning of radius 20 m. Calculate the centripetal acceleration

(a) 2.5 ms^{-2}	(b) 5 ms^{-2}	(c) 10 ms^{-2}	(d) 15 ms^{-2}

Solutions:

1. **(c)** Speed, $v = \dfrac{2\pi r}{T}$

The period of motion is $T = (1/1750)\ (60\text{s}) = 3.43 \times 10^{-2}$ s

So, $v = \dfrac{2\pi\,(7.6 \times 10^{-2}\,\text{m})}{3.43 \times 10^{-2}\,\text{s}} = 14\ \text{m/s}$

2. **(b)** Here, $m = 20$ kg ; $v = 10\ \text{ms}^{-1}$; $r = 20$ m

Centripetal acceleration, $a_c = \dfrac{v^2}{r} = \dfrac{(10)^2}{20} = \dfrac{100}{20} = 5\,\text{ms}^{-2}$

CHECK POINT-4

1. If a body is moving at constant speed in a circular path, its
(a) velocity is constant and its acceleration is zero
(b) velocity and acceleration are both changing direction only
(c) velocity and acceleration are both increasing
(d) velocity is constant and acceleration is changing direction

2. In uniform circular motion, the velocity vector and acceleration vector are
(a) perpendicular to each other (b) same direction
(c) opposite direction (d) not related to each other

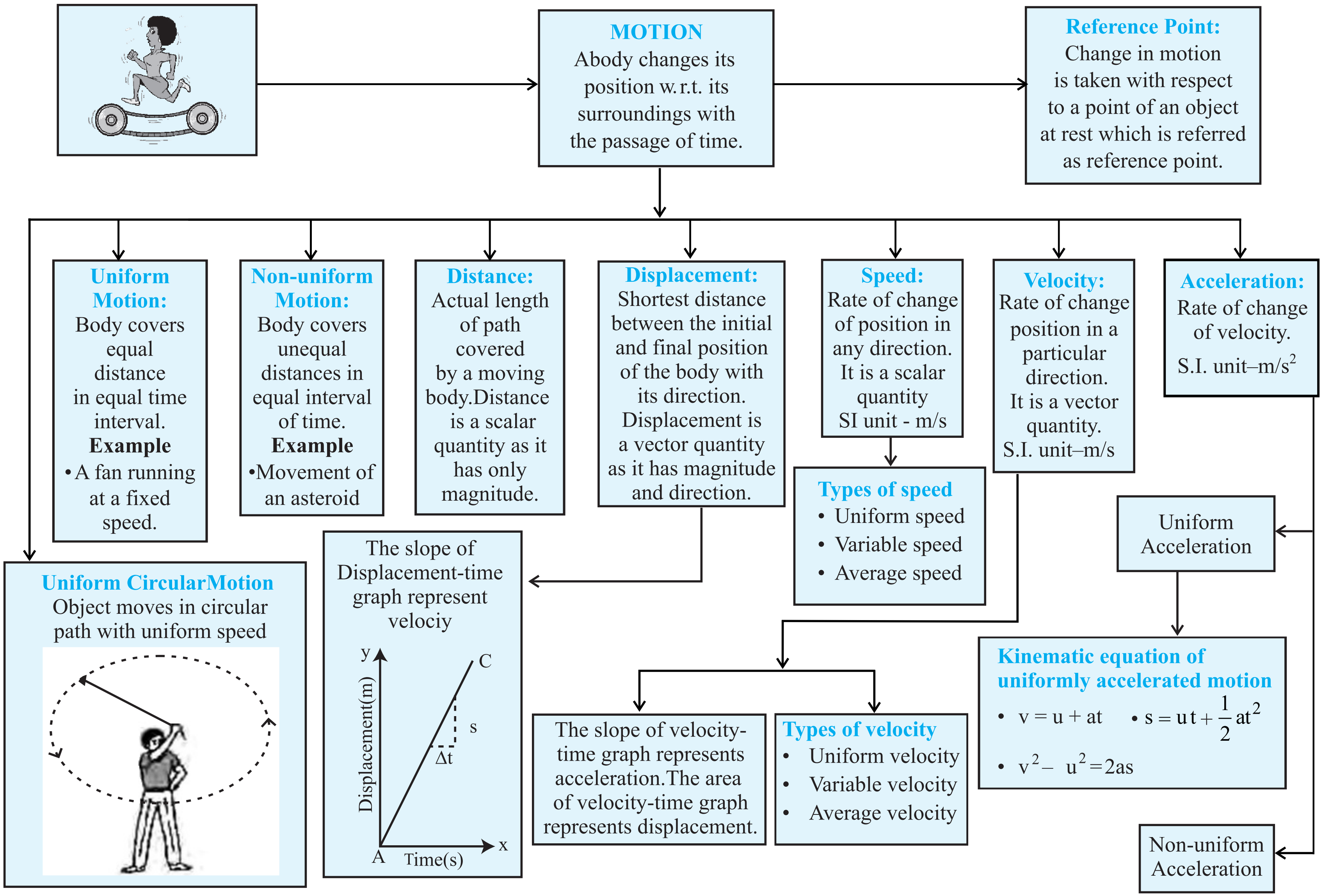
3. Which of the following is an example of uniform circular motion?
(a) The movement of a seconds hand of a watch
(b) The movement of a car on highway curves
(c) The movement of clothes in a dryer of a washing machine
(d) The movement of passenger cabin on a giant wheel

4. In uniform circular motion
(a) both velocity and acceleration are constant
(b) acceleration and speed are constant but velocity changes
(c) both acceleration and velocity change
(d) both acceleration and speed are constant

Solutions:

1. **(b)**
2. **(a)** In uniform circular motion speed is constant. So, no tangential acceleration.
3. **(a)** The movement of a seconds hand of a watch is a uniform circular motion.
4. **(c)** In circular motion with constant speed, acceleration is always inward, its magnitude is constant but direction changes, hence acceleration changes, so does velocity. K.E. is constant.

Walk Through the Chapter



MOTION
Abody changes its position w.r.t. its surroundings with the passage of time.

Reference Point:
Change in motion is taken with respect to a point of an object at rest which is referred as reference point.

Uniform Motion:
Body covers equal distance in equal time interval.
Example
- A fan running at a fixed speed.

Non-uniform Motion:
Body covers unequal distances in equal interval of time.
Example
- Movement of an asteroid

Distance:
Actual length of path covered by a moving body.Distance is a scalar quantity as it has only magnitude.

Displacement:
Shortest distance between the initial and final position of the body with its direction. Displacement is a vector quantity as it has magnitude and direction.

Speed:
Rate of change of position in any direction. It is a scalar quantity
SI unit - m/s

Types of speed
- Uniform speed
- Variable speed
- Average speed

Velocity:
Rate of change position in a particular direction. It is a vector quantity.
S.I. unit–m/s

Types of velocity
- Uniform velocity
- Variable velocity
- Average velocity

The slope of velocity-time graph represents acceleration.The area of velocity-time graph represents displacement.

Acceleration:
Rate of change of velocity.
S.I. unit–m/s^2

Uniform Acceleration

Non-uniform Acceleration

Kinematic equation of uniformly accelerated motion
- $v = u + at$
- $s = ut + \frac{1}{2}at^2$
- $v^2 - u^2 = 2as$

Uniform CircularMotion
Object moves in circular path with uniform speed

The slope of Displacement-time graph represent velociy

Let's Revise Through FIB & T/F

1. Motion is change in position of an object with ....
2. Magnitude of displacement can be equal to or lesser than distance. **(T/F)**
3. Distance travelled divided by elapsed time gives ....
4. If a particle travels with speed v_1 for first half time of its total motion and with speed v_2 for next half time then, average speed = $v_1 + v_2$. **(T/F)**
5. The magnitude of average velocity .... equal to the average speed.
6. A particle moving with a uniform velocity must be along a straight line. **(T/F)**
7. If a car is going northward and the driver jams on its brakes, the direction of its acceleration is ....
8. If particle speed is constant, acceleration of the particle must be zero. **(T/F)**
9. Area under velocity-time graph shows displacement. **(T/F)**
10. Slope of velocity-time graph = acceleration. **(T/F)**
11. The speed-time graph of a moving object is a straight line parallel to the time-axis. It means the speed is.............. .
12. If a car starts at rest and accelerates uniformly, the distance it travels is proportional to the .... of the time it travels.
13. The equation $s = ut + \frac{1}{2}at^2$ with the usual notation is vectorial in nature. **(T/F)**
14. In uniform circular motion, speed of moving particle is constant. **(T/F)**
15. In uniform circular motion direction of velocity does not change. **(T/F)**

EXERCISE-1 Master Board

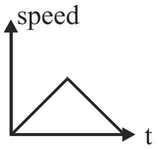
Multiple Choice Questions

DIRECTIONS : *This section contains multiple choice questions. Each question has 4 choices (a), (b), (c) and (d) out of which only one is correct.*

1. If distance covered by a particle is zero, what can you say about its displacement?
(a) It may or may not be zero
(b) It cannot be zero
(c) It is negative (d) It must be zero

2. Which of the following speed time graphs is not possible?

(a)



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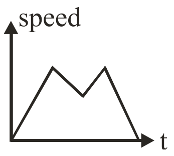
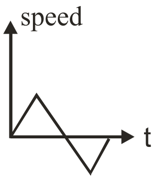
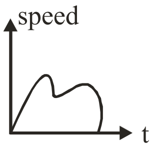


(c)



(d)



3. Which of the following changes when a particle is moving with uniform velocity?
(a) Speed (b) Velocity
(c) Acceleration (d) Position vector

4. The numerical ratio of average velocity to average speed is
(a) always less than one (b) always equal to one
(c) always more than one (d) equal to or less than one

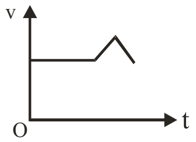
5. The slope of velocity-time graph for motion with uniform velocity is equal to
(a) final velocity (b) initial velocity
(c) zero (d) none of these

6. The location of a particle has changed. What can we say about the displacement and the distance covered by the particle?
(a) Neither can be zero (b) One may be zero
(c) Both may be zero (d) One is +ve, other is –ve

7. Which of the following can be zero, when a particle is in motion for some time?
(a) Distance (b) Displacement
(c) Speed (d) None of these

8. Which of the following velocity time graph is not possible?

(a)



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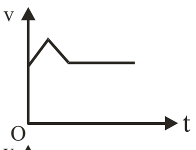

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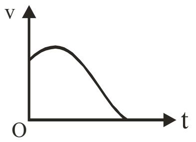
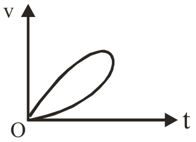


(d)



9. A particle has moved from one position to another position
(a) its distance is zero
(b) its displacement is zero
(c) neither distance nor displacement is zero
(d) average velocity is zero

10. Which of the following decreases in motion along a straight line with constant retardation while the body is moving away from the origin?
(a) Speed (b) Acceleration
(c) Displacement (d) None of these

11. The velocity of a particle at an instant is 10 m/s. After 5 sec, the velocity of the particle is 20 m/s. Find the velocity at 3 seconds before from the instant when velocity of a particle is 10m/s.
(a) 8 m/s (b) 4 m/s (c) 6 m/s (d) 7 m/s

12. A particle travels half the distance with a velocity of 6 ms^{-1}. The remaining half distance is covered with a velocity of 4 ms^{-1} for half the time and with a velocity of 8 ms^{-1} for the rest of the half time. What is the velocity of the particle averaged over the whole time of motion ?
(a) 9 ms^{-1} (b) 6 ms^{-1} (c) 5.35 ms^{-1} (d) 5 ms^{-1}

13. A point traversed half of the distance with a velocity v_0. The half of remaining part of the distance was covered with velocity v_1 & second half of remaining part by v_2 velocity. The mean velocity of the point, averaged over the whole time of motion is
(a) $\frac{v_0 + v_1 + v_2}{3}$ (b) $\frac{2v_0 + v_1 + v_2}{3}$
(c) $\frac{v_0 + .2v_1 + 2v_2}{3}$ (d) $\frac{2v_0(v_1 + v_2)}{(2v_0 + v_1 + v_2)}$

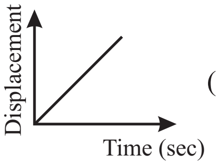
14. A body dropped from a height 'h' with an initial speed zero, strikes the ground with a velocity 3 km/hour. Another body of same mass dropped from the same height 'h' with an initial speed u' = 4 km/hour. Find the final velocity of second mass, with which it strikes the ground
(a) 3 km/hr (b) 4 km/hr (c) 5 km/hr (d) 6 km/hr

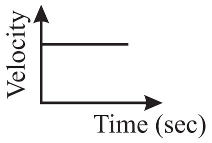
15. A passenger travels along the straight road for half the distance with velocity v_1 and the remaining half distance with velocity v_2. Then average velocity is given by
(a) $v_1 v_2$ (b) v_2^2 / v_1^2
(c) $(v_1 + v_2)/2$ (d) $2v_1 v_2 / (v_1 + v_2)$

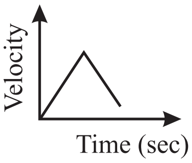
16. If a car at rest accelerates uniformly to a speed of 144 km/h in 20 sec., it covers a distance of
(a) 20 cm (b) 400 m (c) 1440 cm (d) 2980 cm

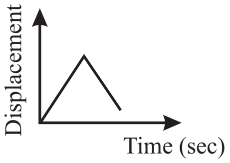
17. A particle experience constant acceleration for 20 seconds after starting from rest. If it travels a distance s_1 in the first 10 seconds and distance s_2 in the next 10 seconds, then
(a) $s_2 = s_1$ (b) $s_2 = 2s_1$
(c) $s_2 = 3s_1$ (d) $s_2 = 4s_1$

18. Which of the following represents graph for zero acceleration?

(i)


(ii)


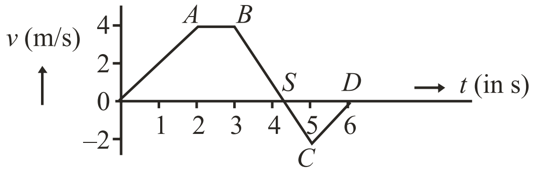
(iii)


(iv)


(a) (iii) and (iv) (b) (i) and (iii)
(c) (i) and (ii) (d) (ii) and (iv)

19. Acceleration in a particle moving in uniform circular motion is due to
(a) Change in velocity (b) Change is speed
(c) Acceleration is zero
(d) Change is speed as well as direction

20. The velocity (*v*) and time (*t*) graph of a body in a straight line motion is shown in the figure. The point S is at 4.333 seconds. The total distance covered by the body in 6 s is:



(a) $\frac{37}{3}$m (b) 12 m (c) 11 m (d) $\frac{49}{4}$m

Assertion & Reason Questions

DIRECTIONS : *The questions in this segment consists of two statements, one labelled as "Assertion A" and the other labelled as "Reason R". You are to examine these two statements carefully and decide if the Assertion A and Reason R are individually true and if so, whether the reason is a correct explanation of the assertion. Select your answers to these items using the codes given below.*
(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true but R is not the correct explanation of A.
(c) A is true but R is false.
(d) A is false but R is true.

1. **Assertion (A) :** Displacement of a body may be zero when distance travelled by it is not zero.
Reason (R) : The displacement is the longest distance between initial and final position.

2. **Assertion (A) :** Position-time graph of a stationary object is a straight line parallel to time axis.
Reason (R) : For a stationary object, position does not change with time.

3. **Assertion (A) :** An object can have constant speed but variable velocity.
   Reason (R) : Speed is scalar but velocity is a vector quantity.
4. **Assertion (A) :** A body may be accelerated even when it is moving uniformly.
   Reason (R) : When direction of motion of the body is changing, the body must have acceleration.
5. **Assertion (A) :** The equation of motion can be applied only if acceleration is perpendicular to the direction of velocity and is constant.
   Reason (R) : If the acceleration of a body is non zero then its motion is known as uniform motion.
6. **Assertion (A) :** Acceleration of a body can be associated with '*slowing down*' of the body.
   Reason (R) : Acceleration is a vector quantity.
7. **Assertion (A) :** The speed of a body can never be negative.
   Reason (R) : The speed of an object is the distance travelled by it in unit time.

Passage/Case Based Questions

DIRECTIONS : *Read the passage (s) given below and answer the questions that follow.*

1. The velocity of any moving body, in ordinary circumstances, does not always remain constant. For example, a bus gains velocity while leaving a station and loses velocity while approaching a station. Similarly, when a stone is dropped from a certain height, its velocity goes on increasing as it comes to the ground. But if a stone is thrown upwards its velocity goes on decreasing, till it becomes zero and then its velocity starts increasing as it approaches the ground.

   (i) The rate of change of velocity with time is known as

   (a) Acceleration (b) Speed
   (c) Intial velocity (d) Final velocity

   (ii) What can be concluded about acceleration if velocity increases continously ?

   (a) Acceleration is positive
   (b) Acceleration is constant
   (c) Acceleration is negative
   (d) Acceleration is zero

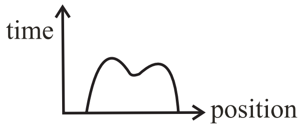
   (iii) Which of the following case represents a negative acceleration?

   (a) Car starting from rest
   (b) A stone falling from height
   (c) Train coming to halt
   (d) Bus moving with uniform velocity

Very Short Answer Questions

DIRECTIONS : *Give answer in one word or one sentence.*

1. When the magnitude of average velocity is same as that of average speed?
2. Can a particle has varying speed but a constant velocity?
3. When a particle returns to the starting point, its average speed is zero but the average velocity is not zero. **[Reasoning Based]**
4. What is the acceleration of a particle moving with uniform velocity?
5. Can time variation of position graph shown in figure, possible? **[Reasoning Based]**



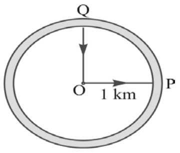
6. What does the slope of position and time graph represent for uniform motion?
7. Does the magnitude of average velocity means average speed?
8. Out of velocity or acceleration decides the direction of motion of a body? **[Reasoning Based]**
9. What does slope of v-t graph represent ?
10. Can an object be accelerated without speeding up or slowing down? **[Reasoning Based]**

Short Answer Questions

DIRECTIONS : *Give answer in 2-3 sentences.*

1. A motor car moving with a uniform velocity of 20 ms^{-1} comes to a stop, on the application of brakes, after travelling a distance of 10 m. What is its acceleration?
2. Draw the position time graph for particle moving with positive and negative velocities.
3. A car travels half the distance with constant velocity 30 km h^{-1} and another half with a constant velocity of 40 km h^{-1} . What is the average velocity of the car ?
4. A cyclist moving due north takes a turn and starts moving towards east with same speed. There will be no change in the velocity. Yes or No. why? **[Reasoning Based]**
5. A cyclist travels from centre O of a circular park of radius 1 km and reaches point P. After cycling 1/4 th of the circumference along PQ, he returns to the centre of the park QO. If the total time taken is 10 minute, calculate

   (i) net displacement
   (ii) average velocity and
   (iii) average speed of the cyclist.

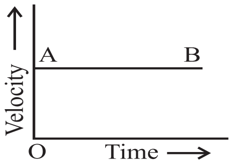


6. A bus moving with a velocity of 60 km/h is brought to rest in 20 seconds by applying brakes. Find its acceleration.
7. A car acquires a velocity of 72 kmh^{-1} in 10 s starting from rest. Calculate
   (i) the acceleration
   (ii) the average velocity
   (iii) the distance travelled in this time
8. An athlete runs a distance of 1500 m in the following manner. (i) Starting from rest, he accelerates himself uniformly at $2m/s^2$ till he covers a distance of 900 m. (ii) He, then runs the remaining distance of 600 m at the uniform speed developed. Calculate the time taken by the athlete to cover the two parts of the distance covered.

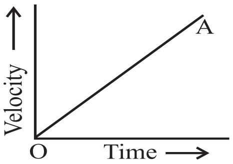
Long Answer Questions

DIRECTIONS : *Give answer in 4-5 sentences.*

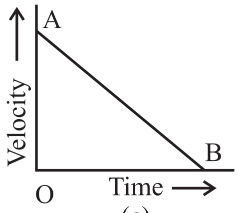
1. What types of motions are represented by the following velocity-time graphs?



(a)



(b)



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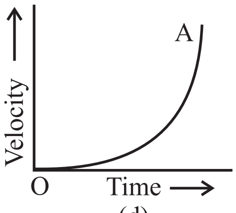
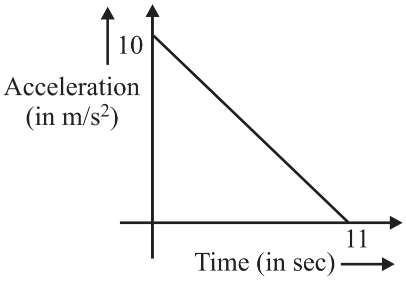


(d)

2. A circular track has a circumference of 3140 m with *AB* as one of its diameter. A scooterist moves from *A* to *B* along the circular path with a uniform speed of 10 m/s. Find
   (a) distance covered by the scooterist,
   (b) displacement of the scooterist, and
   (c) time taken by the scooterist in reaching from *A* to *B*.
3. (a) Draw velocity-time graph of a uniformly accelerated motion.
   (b) Draw position-time graph of an uniformly accelerated motion.
4. Define (a) average velocity and (b) average acceleration.
5. What do you mean by the distance and displacement covered by a particle? Explain with examples.

HOTS Questions

1. Sailing fun, especially on a windy day. Consider the top views of the two boats below, one sailing with the wind and the other across the wind. Which can sail faster than wind speeds?
2. A rocket is fired upward from the earth's surface such that it creates an acceleration of 19.6 ms^{-2}. If after 5 s, its engine is switched off, what would be the maximum height of the rocket from earth's surface?
3. A particle starts from rest. Its acceleration (a) versus time (t) graph is as shown in the figure. What will be the maximum speed of the particle ?



EXERCISE-2 NCERT Questions

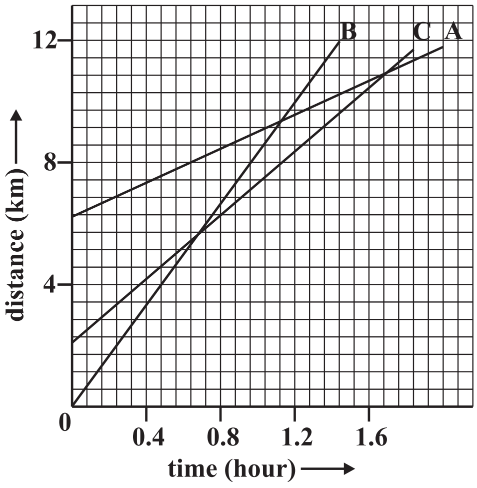
In-text Book Questions

1. An object has moved through a distance. Can it have zero displacement ? If yes, support your answer with an example.
2. 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 from his initial position ?
3. 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.
4. Distinguish between speed and velocity.
5. Under what condition (s) is the magnitude of average velocity of an object equal to its average speed ?
6. What does the odometer of an autombile measure?

7. What does the path of an object look like when it is in uniform motion?
8. 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, that is, 3×10^8 ms^{-1}.
9. When will you say a body is in (i) uniform acceleration, (ii) non-uniform acceleration?
10. A bus decreases its speed from 80 kmh^{-1} to 60 kmh^{-1} in 5s. Find the acceleration of the bus.
11. A train starting from the railway station and moving with a uniform acceleration attains a speed of 40 kmh^{-1} in 10 minutes. Find its acceleration.
12. What is the nature of the distance-time graphs for uniform and non-uniform motion of an object?
13. What can you say about the motion of an object whose distance-time graph is a straight line parallel to the time axis?
14. What can you say about the motion of an object if its speed-time graph is a straight line parallel to the time axis?
15. What is the quantity which is measured by the area occupied below velocity-time graph?
16. A bus starting from rest moves with a uniform acceleration of 0.1 ms^{-2} for 2 minutes. Find (a) the speed acquired, (b) the distance travelled.
17. A train is travelling at a speed of 90 kmh^{-1}. Brakes are applied so as to produce a uniform acceleration of -0.5 ms^{-2}. Find how far the train will go before it is brought to rest ?
18. A trolley while going down an inclined plane has an acceleration of 2 cms^{-2}. What will be its velocity 3 s after the start ?
19. A racing car has a uniform acceleration of 4ms^{-2}. What distance will it cover in 10 s after start?
20. A stone is thrown in a vertically upward direction with a velocity of 5ms^{-1}. If the acceleration of the stone during its motion is 10ms^{-2} in the downward direction, what will be the height attained by the stone and how much time will it take to reach there?

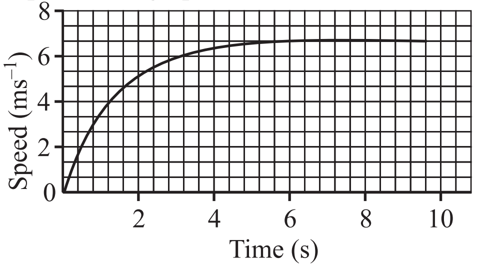
Text-Book Exercise

1. 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 ?
2. Joseph jogs from one end A to the other end B of a straight 300 m road in 2 minutes 30 seconds and then turns around and jogs 100 m back to point C in another 1 minute. What are Joseph's average speeds and velocities in jogging (a) from A to B and (b) from A to C?
3. Abdul, while driving to school, computes the average speed for his trip to be 20 km h^{-1}. On his return trip along the same route, there is less traffic and the average speed is 30 km h^{-1}. What is the average speed for Abdul's trip?
4. A motorboat starting from rest on a lake 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?
5. A driver of a car travelling at 52 km h^{-1} applies the brakes and accelerates uniformly in the opposite direction. The car stops in 5 s. Another driver going at 34 km h^{-1} in another car applies his brakes slowly and stops in 10 s. On the same graph paper, plot the speed versus time graphs for the two cars. Which of the two cars travelled farther after the brakes were applied?
6. Fig. shows the distance-time graph of three objects A, B and C. Study the graph and answer the following questions:



   (a) Which of the three is travelling the fastest?
   (b) Are all three ever 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?
7. A ball is gently dropped from a height of 20 m. If its velocity increases uniformly at the rate of 10 m s^{-2}, with what velocity will it strike the ground? After what time will it strike the ground?

8. The speed-time graph for a car is shown in Fig.



(a) Find how far does the car travel in the first 4 seconds. Shade the area on the graph that represents the distance travelled by the car during the period.

(b) Which part of the graph represents uniform motion of the car?

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

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

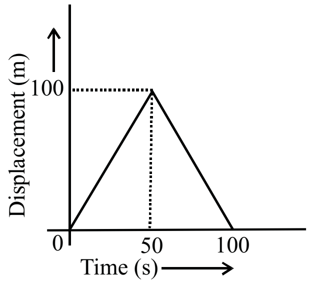
(b) an object moving in a certain direction with an acceleration in the perpendicular direction.

10. 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.

Exemplar Questions

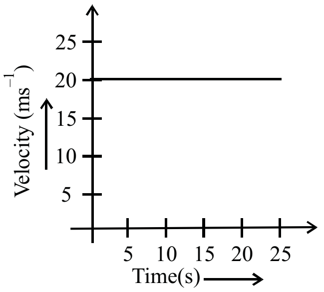
1. The displacement of a moving object in a given interval of time is zero. Would the distance travelled by the object also be zero? Justify your answer.

2. A girl walks along a straight path to drop a letter in the letterbox and comes back to her initial position. Her displacement-time graph is shown in Fig. Plot a velocity-time graph for the same.



3. A car starts from rest and moves along the x-axis with constant acceleration 5 m s–2 for 8 seconds. If it then continues with constant velocity, what distance will the car cover in 12 seconds since it started from the rest?

4. The velocity-time graph (Fig) shows the motion of a cyclist. Find (i) its acceleration (ii) its velocity and (iii) the distance covered by the cyclist in 15 seconds.



5. An object is dropped from rest at a height of 150 m and simultaneously another object is dropped from rest at a height of 100 m. What is the difference in their heights after 2s if both the objects drop with same accelerations? How does the difference in heights vary with time?

6. An object starting from rest travels 20 m in first 2s and 160 m in next 4s. What will be the velocity after 7s from the start?

EXERCISE -3 Foundation Builder

Multiple Choice Questions

DIRECTIONS : *This section contains multiple choice questions. Each questions has 4 choices (a), (b), (c) and (d) out of which only one is correct.*

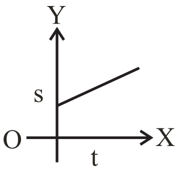
1. A person travels along a straight road for the first half time with a velocity v_1 and the second half time with a velocity v_2. Then the mean velocity $\bar{v}$ is given by

(a) $\bar{v} = \dfrac{v_1 + v_2}{2}$ (b) $\dfrac{2}{v} = \dfrac{1}{v_1} + \dfrac{1}{v_2}$

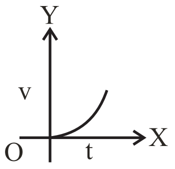
(c) $\bar{v} = \sqrt{\dfrac{v_2}{v_1}}$ (d) $\bar{v} = \sqrt{\dfrac{v_2}{v_1}}$

2. Which one of the following graph indicates that the body is at rest?

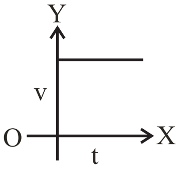
(a)



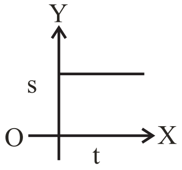
(b)



(c)



(d)



3. A bus starts moving with acceleration 2 m/s^2. A cyclist 96 m behind the bus starts simultaneously towards the bus at 20 m/s. After what time will he be able to overtake the bus?

(a) 4 sec (b) 8 sec (c) 12 sec (d) 16 sec

4. When the speed of a car is v, the minimum distance over which it can be stopped is s. If the speed becomes nv, what will be the minimum distance over which it can be stopped during same retardation

(a) s/n (b) ns (c) s/n^2 (d) n^2s

5. The velocity of a particle at an instant is 10 m/s. After 5 sec, the velocity of the particle is 20 m/s. The velocity at 3 seconds before from the instant when velocity of a particle is 10 m/s.

(a) 8 m/s (b) 4 m/s (c) 6 m/s (d) 7 m/s

6. A rubber ball is dropped from a height of 5 metre on a plane where the acceleration due to gravity is not known. On bouncing, it rises to a height of 1.8 m. On bouncing, the ball loses its velocity by a factor of

(a) $\frac{3}{5}$ (b) $\frac{9}{25}$ (c) $\frac{2}{5}$ (d) $\frac{16}{25}$

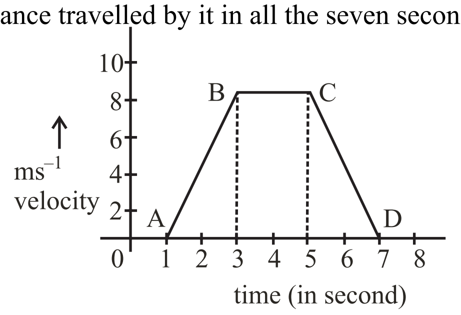
7. A body covers 26, 28, 30, 32 meters in 10th, 11th, 12th and 13th seconds respectively. The body starts

(a) from rest and moves with uniform velocity
(b) from rest and moves with uniform acceleration
(c) with an initial velocity and moves with uniform acceleration
(d) with an initial velocity and moves with uniform velocity

8. A car moving with a speed of 40 km/hour can be stopped by applying brakes after at least 2m. If the same car is moving with a speed of 80km/hour, what is the minimum stopping distance.

(a) 8m (b) 6m (c) 4m (d) 2m

9. For the velocity time graph shown in the figure below the distance covered by the body in the last two seconds of its motion is what fraction of the total distance travelled by it in all the seven seconds?

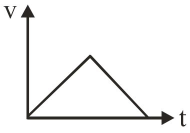


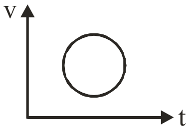
(a) $\frac{1}{2}$ (b) $\frac{1}{4}$
(c) $\frac{2}{3}$ (d) $\frac{1}{3}$

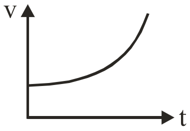
10. If a car is traveling north on a straight road and its brakes are applied, it will

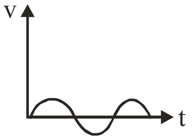
(a) have no acceleration
(b) accelerate to the south
(c) accelerate to the north
(d) accelerate either east or west

11. Which of the following curves do not represent motion of a body?

(a)


(b)


(c)


(d)


12. If a body covers 26 m and 30 m in the 6th and 7th seconds of its travel, then the initial velocity and acceleration of the body are

(a) 4 ms^{-1}, 4 ms^{-2} (b) 6 ms^{-1}, 4 ms^{-2}
(c) 10 ms^{-1}, 8 ms^{-2} (d) 0, 4 ms^{-2}

13. The ratio of maximum heights reached by two bodies projected vertically up is $a : b$, then the ratio of initial velocities of is

(a) $a : b$ (b) $a^2 : \sqrt{b}$
(c) $\sqrt{b} : \sqrt{a}$ (d) $\sqrt{a} : \sqrt{b}$

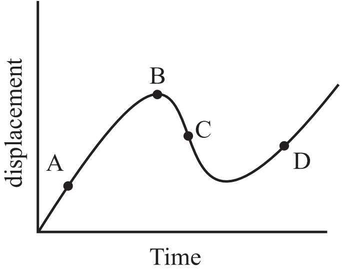
14. A body moving along a straight line at 20 m/s undergoes an acceleration of –4 m/s^2. After two seconds its speed will be

(a) –8 m/s (b) 12 m/s (c) 16 m/s (d) 28 m/s

15. In which of the following cases, the object does not possess an acceleration or retardation when it moves in

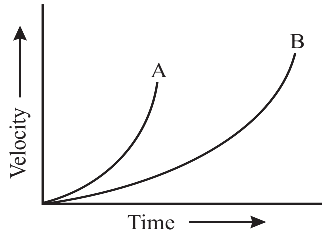
(a) upward direction with decreasing speed
(b) downward direction with increasing speed
(c) with constant speed along circular path
(d) with constant speed along horizontal direction.

16. The displacement-time graph of a moving particle is show below. The instantaneous velocity of the particle is negative at the point?



(a) A (b) B (c) C (d) D

17. V-F graph of two vehicles A and B starting at the same time from rest is given as under. Which of the following statements can be deduced from the graph as correct?



(a) Velocity of B is higher than that of A
(b) Acceleration of A is higher than that of B
(c) Acceleration of B is higher than that of A
(d) Acceleration of A is increasing at a slower rate than that of B

18. A ball is thrown vertically upwards with a given velocity 'v' such that it rises for T seconds (T > 1). What is the distance traversed by the ball during the last one second of ascent (in meters)? (Acceleration due to gravity is g m/s^2.)

(a) $\frac{1}{2}gT^2$
(b) $vT+\frac{1}{2}g[T^2-(T-1)^2]$
(c) $\frac{g}{2}$
(d) $\frac{1}{2}g[T^2-(T-1)^2]$

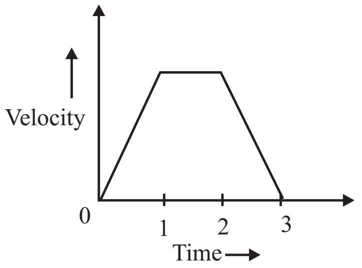
19. A person walks 25.0° north of east for 3.18 km. How far would she have to walk due north and then due east to arrive at the same location?

(a) Towards north 2.88 km and towards east 1.34 km
(b) Towards north 2.11 km and towards east 2.11 km
(c) Towards north 1.25 km and towards east 1.93 km
(d) Towards north 1.34 km and towards east 2.88 km

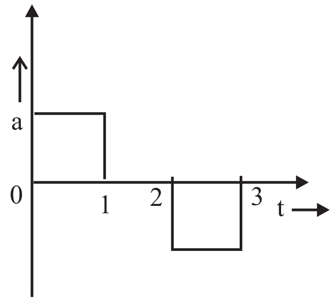
20. A ball of mass m is thrown from a height h with a speed v. For what initial direction of the ball will its speed on hitting the ground be maximum?

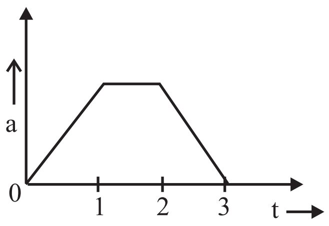
(a) horizontally
(b) vertically downwards
(c) at an angle of 45° from the vertical in the downward direction
(d) speed does not depend on the direction in which the ball is thrown

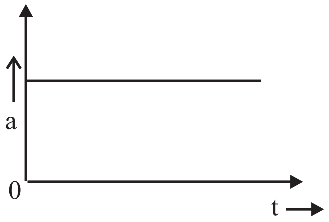
21. The velocity-time graph of an object moving along a straight line is shown below :

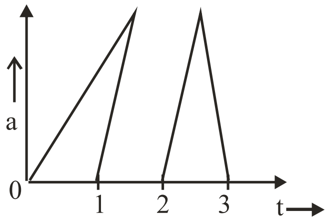


Which one of the following graphs represents the acceleration (a) - time (t) graph for the above motion?

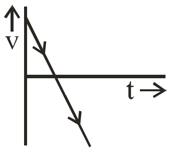
(a)


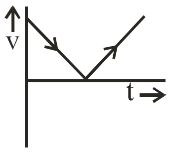
(b)


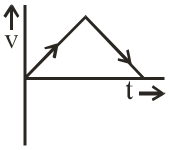
(c)


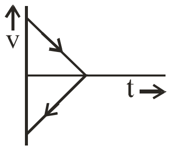
(d)


22. A body is thrown vertically upwards. Which one of the following graphs correctly represent the velocity vs time?

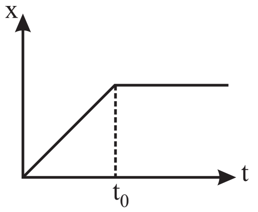
(a)


(b)


(c)


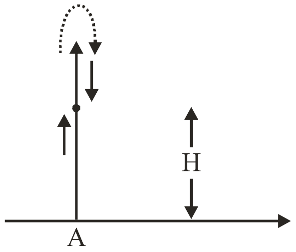
(d)


23. Displacement time graph of a particle moving on x-axis is -



(a) Particle is continuously going in +ve x-direction
(b) Particle is at rest
(c) Velocity increases upto time t_0 then becomes constant
(d) The particle moves at constant velocity upto a time t_0 and then stops.

24. A ball is thrown vertically up from the point A (see figure). A person, standing at a height H on the roof a of a building, tries to catch it, He misses the catch, the ball overshoots and simultaneously the person starts a stop-watch.



The ball reaches its highest point and he manages to catch it upon its return. By this time, a time interval T has elapsed as recorded by the stop-watch. If g is the acceleration due to gravity at this place, the speed with which the ball was thrown from point A will be:

(a) $\sqrt{gH}+gT$ (b) $\dfrac{\left(\sqrt{g^2T^2+4gH}\right)}{2}$

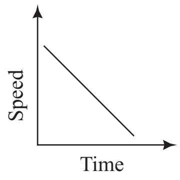
(c) $\dfrac{\left(\sqrt{g^2T^2+8gH}\right)}{2}$ (d) $\left(\sqrt{g^2T^2+2gH}\right)$

25. An athlete completes one round of a circular track of radius R in 40 seconds. The displacement at the end of 2 minutes 20 seconds will be

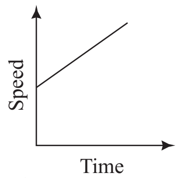
(a) Zero (b) 2R (c) πR (d) 7πR

26. Which of the graph represents non-uniform acceleration?

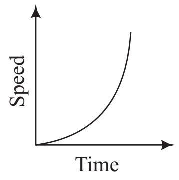
(a)



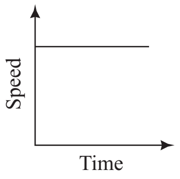
(b)



(c)



(d)



27. The initial velocity of a particle is 10 m/s. It is moving with an acceleration of 4m/s^2. The distance covered by the particle after 2s is

(a) 6 m (b) 18 m (c) 22 m (d) 28 m

28. A body dropped from a height '*h*' with an initial speed zero, strikes the ground with a velocity 3 km/hour. Another body of same mass dropped from the same height '*h*' with an initial speed *u*' = 4 km/hour. Find the final velocity of second mass, with which it strikes the ground

(a) 3 km/h (b) 4 km/h (c) 5 km/h (d) 6 km/h

29. A ball is dropped downwards, after 1 sec another ball is dropped downwards from the same point. What is the distance between them after 3 sec?

(a) 25 m (b) 20 m (c) 50 m (d) 9.8 m

30. A stone is thrown vertically upwards. When the particle is at a height half of its maximum height, its speed is 10 m/sec; then maximum height attained by particle is (g = 10 m/sec^2)

(a) 8 m (b) 10 m (c) 15 m (d) 20 m

31. A parachutist after bailing out falls 50 m without friction. When parachute opens, it decelerates at 2 m/s^2 . He reaches the ground with a speed of 3 m/s. At what height, did he bail out ?

(a) 182 m (b) 91 m (c) 111 m (d) 293 m

32. Which of the following statements is FALSE for a particle moving in a circle with a constant angular speed ?

(a) The acceleration vector points to the centre of the circle

(b) The acceleration vector is tangent to the circle

(c) The velocity vector is tangent to the circle

(d) The velocity and acceleration vectors are perpendicular to each other.

33. A ball is moving uniformly in a circular path of radius 1 m with a time period of 1.5 s. If the ball is suddenly stopped at $t = 8.3$ s, the magnitude of the displacement of the ball with respect to its position at $t = 0$ s is closest to

(a) 1 m (b) 33 m (c) 3 m (d) 2 m

34. A body moves with constant retardation along a straight line. Which of the given physical quantities of the body decrease during its motion? **[Olympiad]**

A. Speed B. Velocity

C. Displacement

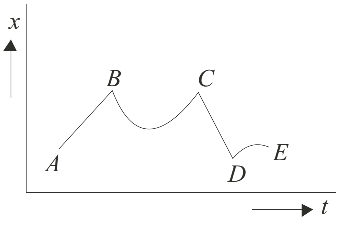
(a) Only A and B (b) Only B and C

(c) Only A and C (d) A, B and C

35. A stone is thrown vertically upward with a velocity of 25 m s^{-1} from the top of a tower. It hits the ground after some time with a velocity of 90 m s^{-1}. The total time taken by the stone during this journey is (Take g = 10 m s^{-2}) **[Olympiad]**

(a) 5.75 s (b) 5.0 s (c) 6. 5 s (d) 11. 5 s

36. Figure shows the displacement (x) of a particle going along the x-axis as function of time (t). The force acting on the particle is zero in the region **[Olympiad]**



(a) *AB* (b) *BC* (c) *CE* (d) *DE*

37. A particle moving along a straight line covers first one third distance with a speed of 3 m s^{-1}. The rest of the distance is covered in two equal time intervals with speed of 4.5 m s^{-1} and 7.5 m s^{-1}. The average speed of the particle is **[Olympiad]**

(a) 5.0 m s^{-1} (b) 5. 5m s^{-1}
(c) 4.5 m s^{-1} (d) 4.0 m s^{-1}

38. Read the given statements and select the correct option.

Statement 1: Reducing the initial velocity to half the initial value, the stopping distance of a moving object decreases by a factor of 2 (for the same deceleration).

Statement 2: Here, the stopping distance is proportional to the square of initial velocity. **[Olympiad]**

(a) Both statements 1 and 2 are true and statement 2 is the correct explanation of statement1.
(b) Both statements 1 and 2 are true but statement 2 is not the correct explanation of statement 1.
(c) Statement 1 is true but statement 2 is false.
(d) Statement 1 is false but statement 2 is true.

More than One Option Correct

DIRECTIONS : *This section contains multiple choice questions each question has 4 choices (a), (b), (c) and (d) out of which ONE OR MORE may be correct.*

1. Average velocity of a body moving with constant acceleration can be calculated by

(a) $\dfrac{\text{Distance travelled along given direction}}{\text{Time taken}}$

(b) $\dfrac{\text{Initial velocity}}{2}$

(c) $\dfrac{\text{Initial velocity + Final velocity}}{2}$

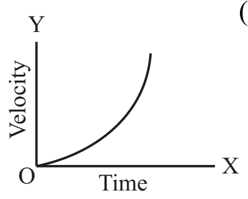
(d) $\dfrac{\text{Final velocity}}{2}$

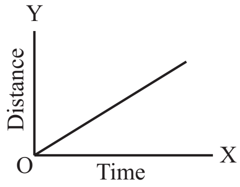
2. Which of the following are vector quantities ?
(a) Speed (b) Distance
(c) Velocity (d) Acceleration

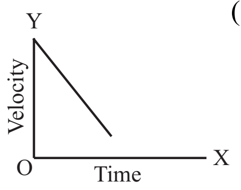
3. If a body starts from rest, its
(a) $u = 0$ (b) $a = 0$
(c) velocity increases (d) velocity decreases

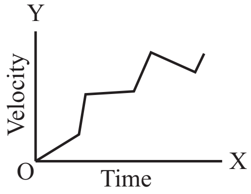
4. If a body moves with uniform velocity, its
(a) $u = v$ (b) $v = 0$ (c) $u = 0$ (d) $a = 0$

5. Velocity time graph of a body moving with variable acceleration is

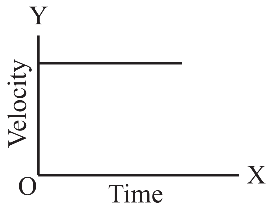
(a)


(b)


(c)


(d)


6. Which of the following is correct about the given below graph?



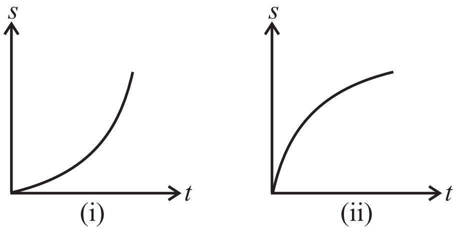
(a) Velocity is zero
(b) Velocity is constant
(c) Acceleration is zero
(d) Acceleration is variable

7. Which of the following statements are true for displacements?
(a) It can be zero
(b) It cannot be zero
(c) Its magnitude is greater than distance travelled
(d) Its magnitude is lesser than or equal to the distance travelled

8. The speed of an object is
(a) distance per unit time
(b) a scalar quantity
(c) displacement per unit time
(d) a vector quantity

9. A balloon starts rising from the ground with an acceleration of 2.5ms^{-2}. After 4 seconds, a stone is released from the balloon. If g = 10 m/s^2, the stone will
(a) have a displacement of 25 m
(b) cover a total distance of 30 m
(c) reach the ground in 3.2 s
(d) begin to move down after being released.

10. Displacement (s)–time (t) graphs of two particles moving in a straight line along the X-axis are shown below:
It may be stated the



(i) (ii)

(a) particle (i) has uniform acceleration
(b) particle (i) has non-uniform acceleration
(c) particle (ii) has uniform motion
(d) particle (ii) has a retarded motion

11. The following quantities may remain constant during uniform circular motion :
(a) magnitude of acceleration
(b) acceleration
(c) speed
(d) velocity

12. A bullet is fired vertically upwards. After 10 s it returns to the point of firing. Which of the following statements are correct? Take g = 10 m s^{-2}
(a) The net displacement of the bullet in 10 s is zero
(b) The total distance travelled by the bullet in 10 s is 250 m
(c) The rate of change of velocity with time is constant throughout the motion of bullet
(d) The bullet is fired with an initial velocity of 50 ms^{-1} directly vertically upwards

13. Let a_r and a_t represent radial and tangential acceleration. The motion of a particle may be circular if
(a) $a_r \neq 0$ and $a_t \neq 0$ (b) $a_r \neq 0$ and $a_t = 0$
(c) $a_r = a_t = 0$ (d) $a_r = 0$ and $a_t \neq 0$

Passage/Case Based Questions

DIRECTIONS : *Read the passage (s) given below and answer the questions that follow.*

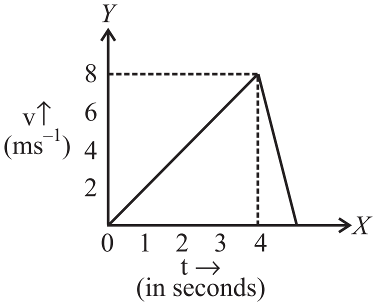
1. Consider the motion of a batsman in a cricket game. The length of the pitch is 18 m. Suppose the batsman complete one run and he is now 18 m away from his batting crease or his starting point. Then he turns back and gets run out, when he is exactly mid way through his second run.

(i) The total distance travelled by batsman is
(a) 18 m (b) 36 m
(c) 9 m (d) 27 m

(ii) How far is the batsman from his starting point ?
(a) 9 m (b) 0 m
(c) 18 m (d) 27 m

(iii) What is the net displacement of the batsman ?
(a) 9 m (b) 0 m
(c) 18 m (d) 27 m

2. From the below figure, answer the following:



(i) Acceleration of the body during the first three seconds of its motion is:
(a) $\frac{8}{3}ms^{-2}$ (b) $\frac{9}{5}ms^{-2}$
(c) 12 m/s^2 (d) 19 m/s^2

(ii) Deceleration of the body during the last second of its motion.
(a) –3 m/s^2 (b) –8 m/s^2
(c) –2 m/s^2 (d) –6 m/s^2

(iii) Displacement of the body at the end of 4 s.
(a) 5 m (b) 12 m
(c) 16 m (d) 18 m

3. A particle is moving along a circular track of radius 3.5 m with a constant speed 4 ms^{-1}. Answer the following for the motion of the particle.

(i) How much time will it take to complete one complete round ?
(a) 5.5 s (b) 11 s
(c) 22 s (d) 3.5 s

(ii) What is the average velocity of the particle in one complete round ?
(a) 4 ms^{-1} (b) 2.6 ms^{-1}
(c) 2 ms^{-1} (d) Zero

(iii) The acceleration of the particle is
(a) $\frac{42}{7}ms^{-2}$ (b) $\frac{32}{7}ms^{-2}$
(c) $\frac{18}{7}ms^{-2}$ (d) 0

Assertion & Reason Questions

DIRECTIONS : *The questions in this segment consists of two statements, one labelled as "Assertion A" and the other labelled as "Reason R". You are to examine these two statements carefully and decide if the Assertion A and Reason R are individually true and if so, whether the reason is a correct explanation of the assertion. Select your answers to these items using the codes given below.*

(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true but R is not the correct explanation of A.
(c) A is true but R is false.
(d) A is false but R is true.

1. Assertion (A) : The distance-time graph of uniform motion is a straight line.
Reason (R) : Independent variable is taken along x-axis and dependent variable along y-axis.

2. Assertion (A) : The velocity of a body is a vector quantity.
Reason (R) : A vector quantity has only magnitude and no direction.

3. **Assertion (A) :** Motion of moon around earth is a non-uniform motion.

   Reason (R) : The size of moon is smaller than that of earth.

4. **Assertion (A) :** If a body moves with uniform velocity, its acceleration is zero.

   Reason (R) : Rate of change of velocity is zero in case of body moving with uniform velocity.

5. **Assertion (A) :** Instantaneous speed is the speed of a body over a long period of time.

   Reason (R) : The graph representing non-uniform speed will be a curve with increasing or decreasing slope.

6. **Assertion (A) :** In a uniform circular motion, magnitude acceleration of the body is constant.

   Reason (R) : In uniform circular motion, the body has only centripetal acceleration.

Multiple Matching Questions

DIRECTIONS : *Following question has four statements (A, B, C and D) given in Column I and four statements (p, q, r and s) in Column II. Any given statement in Column I can have correct matching with one or more statement(s) given in Column II. Match the entries in column I with entries in column II.*

1.

Column I	Column II
(A) v	(p) $ut + ½ at^2$
(B) u	(q) $v – u/t$
(C) a	(r) Final velocity
(D) s	(s) $u + at$
	(t) Initial velocity
	(u) $\sqrt{u^2 + 2as}$

	A	B	C	D
(a)	r, s, u	t	q	p
(b)	p, q, r, s	q	p, q, r, s	p, q, r, s
(c)	p, s	q	r, s, t	r
(d)	p,	q, r	r	s

2.

Column I	Column II
(A) Acceleration	(p) m/s^2
(B) Speed	(q) centripetal force
(C) Circular motion	(r) m
(D) Displacement	(s) m/s
	(t) scalar quantity
	(u) vector quantity

	A	B	C	D
(a)	p,q	q	r, s	q, r
(b)	p, u	s, t	q	r, u
(c)	p, s	q	r, s, t	r
(d)	r, t	t, u	s	r

3. A body is in motion for some time, then at a certain instant of time

Column I	Column II
(A) Distance	(p) may be positive
(B) Displacement	(q) may be negative
(C) Speed	(r) may be zero
(D) Velocity	(s) may be increasing
	(t) may be decreasing

	A	B	C	D
(a)	s, p	r, t, s	p, t	r
(b)	p, q, r, s	q	p, q, r, s	p, q, r, s
(c)	p, s	q	r, s, t	r
(d)	p, s	p, q, r, s, t	p, r, s, t	p, q, r, s, t

Numeric/Integer Type Questions

1. A train is travelling with a velocity of 40 km h^{-1}
   (i) What should be the acceleration on it so that it may reach a point 10 km ahead in 8 minutes?
   (ii) What will be its velocity on reaching that point?
2. Find the initial velocity of a car which is stopped in 10 seconds by applying brakes. The retardation due to brakes is 2.5 m/s^2.
3. A person travels the total distance in two parts in the ratio 2 : 1 with a constant speed of 30 kmh^{-1} in the first part and 40 kmh^{-1} in the second part. What is the average speed of the journey?
4. Usha swims in a 90 m pool. She covers 180 m in one minute by swimming from one end to the other and back along a straight path. Find the average velocity of Usha.
5. The angular velocity of a particle moving in a circle of radius 50 m is increased in 5 minutes from 100 revolutions per minute to 400 revolution per minute. Find angular acceleration.
6. A stone tied to the end of string 80 cm long is whirled in a horizontal circle with a constant speed. If the stone makes 14 revolutions in 25 seconds, what is the magnitude of the acceleration of the stone ?

SOLUTIONS

Brief Explanations of Selected Questions

Let's Revise Through FIB & T/F

1. Time
2. True
3. average speed
4. False
5. may or may not be
6. True
7. south
8. False
9. True
10. True
11. Uniform
12. Square
13. True
14. True
15. False

EXERCISE-1 Master Board

Multiple Choice Questions

1. **(d)** Distance covered by a particle is zero only when it is at rest. Therefore, its displacement must be zero.

2. **(c)** This is because speed can never be negative.

3. **(d)**

4. **(d)** From the previous question, it follows that average velocity is equal to or less than one.

5. **(c)** The velocity-time graph for a uniform motion is a st. line parallel to time axis. Its slope is zero.

6. **(a)** When location of a particle has changed, it must have covered some distance and undergone some displacement.

7. **(b)** Displacement may be zero because final position of the particle may coincide with its initial position.

8. **(d)** is not possible, because at a particular time t, velocity cannot have two values.

9. **(c)**

10. **(a)** When a body moves along a straight line with constant retardation, its speed goes on decreasing.

11. **(b)** u = 10 m/s, t = 5 sec, v = 20 m/s, a = ?

$$a = \frac{20-10}{5} = 2\ \text{ms}^{-2}$$

From the formula $v_1 = u_1 + a\,t$, we have

$10 = u_1 + 2 \times 3$ or $u_1 = 4$ m/sec.

12. **(b)** Average velocity for the second half of the distance is $= \frac{v_1+v_2}{2} = \frac{4+8}{2} = 6\,\text{ms}^{-1}$

Given that first half distance is covered with a velocity of 6ms^{-1}. Therefore, the average velocity for the whole time of motion is 6ms^{-1}

13. **(d)** Let the total distance be d. Then for first half distance, time $= \frac{d}{2v_0}$, next distance. = v_1t and last half distance = v_2t

$$\therefore\ v_1t + v_2t = \frac{d}{2};\quad t = \frac{d}{2(v_1+v_2)}$$

Now average speed

$$t = \frac{d}{\frac{d}{2v_0} + \frac{d}{2(v_1+v_2)} + \frac{d}{2(v_1+v_2)}}$$

$$= \frac{2v_0(v_1+v_2)}{(v_1+v_2)+2v_0}$$

14. **(c)** From third equation of motion, $v^2 = u^2 + 2as$ where v & u are final & initial velocity, a is acceleration, s is distance.

For first case v_1= 3km/hour, u_1= 0, a_1=g & s_1= ?

$$s_1 = \frac{9\times100}{36\times36\times20}\ \text{metre}$$

For second case v_2=?, u_2=4km/hour ,

a_2= g = 10m/sec

$$\&\ s_1 = s_2 = \frac{9\times100}{36\times36\times20}$$

$$\text{so}\ v_2^2 = \frac{16\times1000\times1000}{3600\times3600} + \frac{2\times10\times9\times100}{20\times36\times36}$$

or v_2 = 5 km/hour

15. **(d)** $$\frac{\frac{x}{2}+\frac{x}{2}}{\frac{x}{2v_1}+\frac{x}{2v_2}} = \frac{1}{\left(\frac{v_2+v_1}{2v_1v_2}\right)} = \frac{2v_1v_2}{v_1+v_2}$$

16. **(b)** v = [144 × 1000/(60 × 60)] m/sec.

$v = u + at$

or (144 × 1000)/(60 × 60) = 0 + a × 20

$$\therefore\ a = \frac{144\times1000}{60\times60\times20} = 2\,\text{m/sec}^2$$

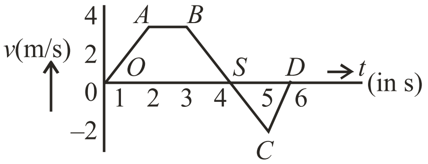
$$\text{Now}\ s = ut + \frac{1}{2}at^2 \ = 0 + \frac{1}{2}\times2\times(20)^2 \ = 400\ \text{m}$$

17. **(c)**

18. **(c)** Slope of displacement time graph gives velocity in (i) slope is not changing. In (ii) velocity is constant.

19. **(a)** In uniform circular motion speed remains constant only direction of velocity changes.

20. **(a)**



$$OS = 4 + \frac{1}{3} = \frac{13}{3}$$

$SD = 2 - \frac{1}{3} = \frac{5}{3}$

Distance covered by the body = area of v-t graph
= ar (OABS) + ar (SCD)

$= \frac{1}{2}\left(\frac{13}{3} + 1\right) \times 4 + \frac{1}{2} \times \frac{5}{3} \times 2 = \frac{32}{3} + \frac{5}{3} = \frac{37}{3}$ m

Assertion & Reason Questions

1. **(c)** The displacement is the shortest distance between initial and final position. When final position of a body coincides with its initial position, displacement is zero, but the distance travelled is not zero.
2. **(a)** Position-time graph for a stationary object is a straight line parallel to time axis showing that not change in position with time.
3. **(a)** Since velocity is a vector quantity, hence as its direction changes keeping magnitude constant, velocity is said to be changed. But for constant speed in equal time interval distance travelled should be equal.
4. **(a)** In uniform circular motion, there is acceleration of constant magnitude.
5. **(d)** Equation of motion can be applied if the acceleration is in opposite direction to that of velocity and uniform motion mean the acceleration is zero.
6. **(b)** A body having acceleration can be associated with slowing down, as time rate of change of velocity decreases.
7. **(a)**

Passage/Case Based Questions

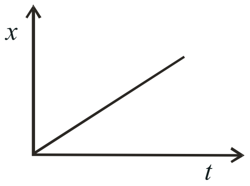
1. **(i) (a) (ii) (a) (iii) (c)**

Very Short Answer Questions

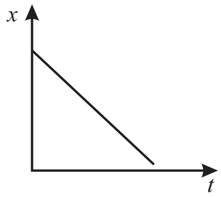
1. When the body is moving with a constant velocity, the magnitude of average velocity is same as that of average speed.
2. No since both speed and velocity remain constant in uniform motion.
3. No. If a particle returns to the starting point its average velocity is zero but average speed is not zero.
4. Zero.
5. No, because with the increase of position, the time first increases and then decreases which is not possible.
6. Velocity.
7. No, it does not. Because average speed is total distance travelled divided by time whereas magnitude of average velocity = displacement/time. As distance is always greater than or equal to displacement, hence average speed ≥ | average velocity |
8. Velocity of body decides the direction of motion of a body. The acceleration gives the rate of change of velocity.
9. Acceleration.
10. Acceleration = speed + direction. If direction changes, while speed remains constant, body can accelerate. A body moving in circle, changes its direction continuously. therefore, if that body maintain a constant speed, we can say that it is accelerating.

Short Answer Questions

1. $u = 20\ \text{ms}^{-1}$, $s = 10\text{m}$
   We know, $v^2 - u^2 = 2as$.
   Therefore, $a = -400/(2 \times 10)\ \text{ms}^{-2} = -20\ \text{ms}^{-2}$
2. The *x-t* graph for an object moving with a positive velocity.



The *x-t* graph for an object moving with a negative velocity.



3. Let s be the total distance covered by the car; and t_1 and t_2 be the time taken by the car to cover first half and second half respectively. Then, total time taken, $t = t_1 + t_2$

   $= \frac{S/2}{30} + \frac{S/2}{40} = \frac{S}{60} + \frac{S}{80} = \frac{7S}{240}$ h

   Therefore, average velocity,

   $v_{av} = \frac{S}{t} = \frac{S}{7S/240} = \frac{240}{7} = 34.3\ \text{km h}^{-1}$
4. No. Infact velocity will change when a cyclist takes a turn from north to east due to change in direction.
5. (i) The net displacement becomes zero.
   (ii) As net displacement is zero, so average velocity

   $v_{\text{av}} = \frac{\text{Net displacement}}{\text{time taken}} = 0.$

   (iii) Total distance covered = OP + Arc PQ + OQ

   $= r + \frac{2\pi r}{4} + r = 1 + \frac{2 \times 22 \times 1}{7 \times 4} + 1 = \frac{25}{7}\ km$

Time taken = 10 min = 1/6 h.

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

$$\frac{\left(\frac{25}{7}\right)}{\left(\frac{1}{6}\right)} = 21.43 \text{ km/h}$$

6. Here v_0 = 60 km/h = $60 \times \frac{5}{18} = \frac{50}{3}$ m/s ; time t = 20s;
acceleration a = ?
v = 0 (as bus comes to rest)

as $a = \frac{v - v_0}{t}$

$$\therefore \; a = \frac{0 - \frac{50}{3}}{20} = \frac{-50}{3 \times 20} = \frac{-5}{6} = -0.83 \text{ m/s}^2 \text{ retardation}$$

7. Given: Initial velocity, u = 0 ms^{-1}

Final velocity, v = 72 km h^{-1} $\frac{72 \times 1000 \text{m}}{3600 \text{s}}$ = 20 ms^{-1}

Time taken, t = 10 s

(i) Acceleration, $a = \frac{v - u}{t}$

$$= \frac{(20 \text{ms}^{-1} - 0 \text{ms}^{-1})}{10 \text{s}} = \frac{20 \text{ms}^{-1} 10 \text{s}}{10 \text{s}} = 2 \text{ms}^{-2}$$

∴ Acceleration a = 2 ms^{-2}

(ii) Average velocity $= \frac{u + v}{2}$

$$= \frac{0 \text{ms}^{-1} + 20 \text{ms}^{-1}}{2} = 10 \text{ms}^{-1}$$

(iii) Distance travelled

s = Average velocity × Time = (10 ms^{-1}) × (10s)

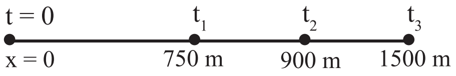
= 100m

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

$= 0 \text{ ms}^{-1} \times 10 \text{ s} + \frac{1}{2} \times 2 \text{ ms}^{-2} \times 10 \text{ s} \times 10 \text{ s}$

= 0 m + 100 m = 100 m]

8. The situation is shown in figure.



For the motion between $t = 0$ to t_1; s = 750 m. We know that

$$s = ut + \frac{1}{2} at^2 \qquad 750 = 0 + \frac{1}{2} \times 2 \times t_1^2$$

$$\therefore \quad t_1 = 27.4 \text{ s}$$

(i) For the motion from $t = 0$ to $t = t_2$; s = 900 m

$$900 = 0 + \frac{1}{2} \times 2 \times t_2^{\,2} \qquad \therefore \quad t_2 = 30 \text{ s.}$$

(ii) Let v is the velocity of the athlete at $t = t_2$, then

v =0 + 2 × 30 = 60 m/s.

For the motion between t_2 and t_3; s = 600 m.

If t is the time of motion, then

$$t = \frac{\text{distance}}{\text{speed}} = \frac{600}{60} = 10 \; s.$$

Long Answer Questions

1. (a) The body has uniform velocity.

(b) The body has uniform acceleration and its initial velocity is zero.

(c) The body has some initial velocity and is under uniform retardation.

(d) The body has zero initial velocity and it has variable acceleration.

2. (a) Distance covered $= \frac{1}{2} \times$ circumference

$$= \frac{1}{2} \times 3140 = 1570 \text{ m}$$

(b) Displacement = Diameter AB

$$= \frac{\text{Circumference}}{\pi} = \frac{3140 \text{ m}}{3.14} = 1000 \text{ m}$$

(c) Time taken $= \frac{\text{Distance}}{\text{Speed}} = \frac{1570 \text{ m}}{10 \text{ ms}^{-1}} = 157 \text{ s}$

3. Refer to theory
4. Refer to theory
5. Refer to theory

HOTS Questions

1. The boat that sails directly with the wind can sail no faster than wind speed. Why? Even sailing as fast as the wind, there would be no wind impact against the sail. It would sag. But when sailing crosswind, there would still be wind impact against the sail, and speeds greater than wind speed can be achieved.

2. Velocity when the engine is switched off

$v = 19.6 \times 5 = 98 \, m \, s^{-1}$

$$h_{max} = h_1 + h_2 \text{ where } h_1 = \frac{1}{2} at^2 \;\&\; h_2 = \frac{v^2}{2a}$$

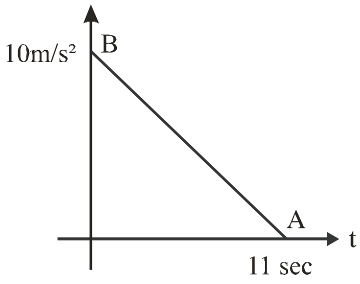
$$\text{h}_{max} = \frac{1}{2} \times 19.6 \times 5 \times 5 + \frac{98 \times 98}{2 \times 9.8}$$

= 245 + 490 = 735 m

3. The area under acceleration time graph gives change in velocity. As acceleration is zero at the end of 11 sec.

i.e. v_{max} = Area of D OAB

$$\frac{1}{2}\times 11\times 10 = 55\ m/s$$



EXERCISE-2 **NCERT Questions**

In-text Book Questions

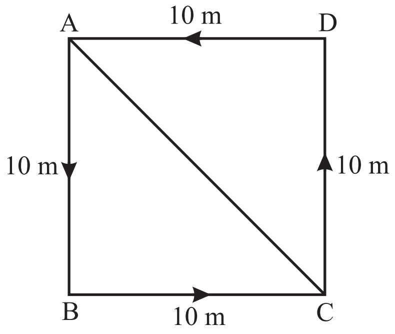
1. Yes, it can have zero displacement.

If we take a round trip and reach back at the starting point, then we have travelled some distance, but our displacement will be zero.

2. If the farmer starts from point A, then at the end of 2 minutes and 20 seconds (= 140 seconds), he will reach the diagonally opposite corner C. The magnitude of displacement of the farmer is :

$$AC = \sqrt{AB^2+BC^2} = \sqrt{10^2+10^2}$$

$$= 10\sqrt{2} = 10\times 1.414 = 14.14\ m$$



3. Neither (a) nor (b) is true.

4.

	Speed	Velocity
1.	The distance travelled by a moving body per unit time is called its speed.	The distance travelled by a moving body in a particular direction per unit time is called its velocity.
2.	Speed is a scalar quantity.	Velocity is a vector quantity.

5. Average speed = $\frac{\text{Total path length}}{\text{Time interval}}$

Average velocity = $\frac{\text{Displacement}}{\text{Time interval}}$

When an object moves along a straight line in the same direction, its total path length is equal to the magnitude of displacement. Hence, its average speed is equal to the magnitude of average velocity.

6. The odometer of an automobile measures the distance moved by it.

7. Straight line path.

8. Here, t =5 minutes = 300 s, $v = 3\times 10^8\ ms^{-1}$

Distance of spaceship, $s = vt = 3\times 10^8\times 300$

$= 9\times 10^{10}$ m.

9. (i) If a body travels in a straight line and its velocity changes by equal amounts in equal intervals of time, however small these time intervals may be, then the body is said to be in uniform acceleration.

(ii) If the velocity of a body changes by unequal amounts in equal intervals of time, then the body is said to be in non-uniform acceleration.

10. Initial speed, $u = 80\frac{km}{h} = \frac{80\times 1000\,m}{3600\,s}$

$$= \frac{800}{36}ms^{-1} = 22.22\ ms^{-1}$$

Final speed, $v = 60\frac{km}{h} = \frac{60\times 1000\,m}{3600\,s}$

$$= \frac{600}{36}ms^{-1} = 16.66\,ms^{-1}$$

Acceleration, $a = \frac{v-u}{t} = \frac{(16.66-22.22)}{5} = -1.11\ ms^{-2}$

11. Intitial speed, $u = 0$

Final speed, $v = 40\frac{km}{h}$

$$= \frac{40\times 1000\,m}{3600\,s} = \frac{100}{9}ms^{-1}$$

Time, t = 10 min = 600 s

Acceleration, $a = \frac{v-u}{t} = \frac{\frac{100}{9}-0}{600}$

$$= \frac{100}{9\times 600}ms^{-2}$$

$$= \frac{1}{54}ms^{-2} = 0.018\,ms^{-2}$$

12. (i) For uniform motion, the distance-time graph is a straight line inclined with the time-axis.

(ii) For non-uniform motion, the distance-time graph is a curve.

13. The object is at rest.

14. The object is moving with a uniform speed.

15. Displacement covered by the body in the given time interval.

16. Here, $u = 0$, $a = 0.1\ ms^{-2}$, $t = 2$ min $= 120s$

(a) $v = u + at = 0 + 0.1 \times 120 = 12ms^{-1}$

(b) $s = ut + \frac{1}{2}at^2 = 0 \times 120 + \frac{1}{2} \times 0.1 \times (120)^2$

$= 720m$

17. Here, $u = 90$ km/h $= 90 \times \frac{5}{18}\ ms^{-1} = 25\ ms^{-1}$

$a = -0.5\ ms^{-2}$, $v = 0$

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

∴ $0^2 - 25^2 = 2 \times (-0.5) \times s$

or $s = \frac{25 \times 25}{2 \times 0.5} = 625m$

18. Here, $u = 0, a = 2\ cm\ s^{-2}$, $t = 3s$

$v = u + at = = 0 + 2 \times 3 = 6\ cm\ s^{-1}$

19. Here, $u = 0, a = 4ms^{-2}, t = 10s$

$$s = ut + \frac{1}{2}at^2 = 0 \times 10 + \frac{1}{2} \times 4 \times (10)^2 = 200\,m.$$

20. Here , $u = 5ms^{-1}$

As the acceleration acts in the opposite direction of initial velocity, so it is negative.

$a = -10\ ms^{-2}$

At the highest point, $v = 0$

Using, $v^2 - u^2 = 2as$, we get

$0^2 - 5^2 = 2 \times (-10) \times s$

$s = \frac{25}{20} = 1.25$ m

∴ Height attained by the stone = 1.25 m.

Again, $v = u + at$

$\Rightarrow 0 = 5 - 10 \times t$

or $t = \frac{5}{10} = 0.5\,s$

∴ Time taken by the stone to reach the highest point = 0.5 s.

Text-Book Exercise

1. Diameter of circular path (d) = 200 m

∴ Radius of circular path, $r = 100$ m

Time period (T) = 40 s

Time (t) = 2 min, 20 s

= (120 + 20)s = 140 s

Therefore, number of revolutions

$= \frac{\text{Time taken}}{\text{Time period}} = \frac{140s}{40s/\text{revolution}} = 3.5$ revolution

Distance travelled

$= 2\pi r \times$ No. of revolutions

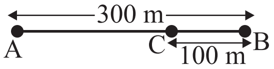
$= 2 \times \frac{22}{7} \times 100\ m \times 3.5 = 2200$ m

Now during 3 revolutions, the displacement is zero, since the athlete has reached the starting point.

Therefore, **actual displacement** is due to half revolution

= Diameter of circular track = 200 m

2. (a) For motion from A to B :



Distance covered = 300 m

Displacement = 300 m

Time taken = 2 minutes 30 seconds

= 2 × 60 + 30 = 150 s

Average speed $= \frac{\text{Distance covered}}{\text{Time taken}}$

$= \frac{300\ m}{150\ s} = 2\ ms^{-1}.$

Average velocity $= \frac{\text{Displacement}}{\text{Time taken}} = \frac{300\ m}{150\ s}$

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

(b) For motion from A to B to C :

Distance covered = 300 + 100 = 400 m

Displacement = $AB - CB$

= 300 – 100 = 200 m

Time taken = 150 + 60 = 210 s

Average speed $= \frac{300\ m}{150\ s} = \frac{400\ m}{210\ s} = 1.90\ ms^{-1}.$

Average velocity $= \frac{\text{Displacement}}{\text{Time taken}}$

$= \frac{200\ m}{210\ s} = 0.952\ ms^{-1}.$

3. Let one way distance = x km

Time taken in forward trip at a speed of 20 km/h

$= \frac{\text{Distance}}{\text{Speed}}$

$t_1 = \frac{x}{20}h$

Time taken in return trip at a speed of 30 km/h

$t_2 = \frac{x}{30}h$

Total time for the whole trip

$= \frac{x}{20} + \frac{x}{30} = \frac{3x + 2x}{60} = \frac{5x}{60}h$

Total distance covered = x + x = 2x km

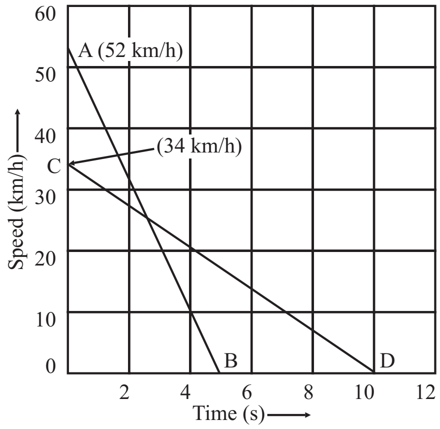
Average speed $= \frac{\text{Total distance}}{\text{Total time}} = \frac{2x}{5x/60}$

$= \frac{2x \times 60}{5x} = 24\ km\ h^{-1}.$

4. Here, $u = 0$, $a = 3\ ms^{-2}$, $t = 8$ s

$$s = ut + \frac{1}{2}at^2 = 0 \times 8 + \frac{1}{2} \times 3 \times (8)^2 = 96\text{ m.}$$

5. In the given Fig. AB and CD represent the speed-time graphs for the two cars whose initial speeds are 52 km/h and 34 km/h, respectively.



Distance covered by first car before coming to rest = Area of triangle AOB

$$= \frac{1}{2} \times AO \times BO = \frac{1}{2} \times 52\text{ km/h} \times 5\text{ s}$$

$$= \frac{1}{2} \times \frac{52 \times 5}{18}\text{ m/s} \times 5\text{ s} = 36.1\text{ m}$$

Distance covered by the second car before coming to rest

$$= \text{Area of triangle COD} = \frac{1}{2} \times CO \times DO$$

$$= \frac{1}{2} \times 34\text{ km/h} \times 10\text{ s}$$

$$= \frac{1}{2} \times \frac{34 \times 5}{18}\text{ m/s} \times 10\text{ s} = 47.2\text{ m.}$$

Thus, the second car travelled farther than the first car after the brakes were applied.

6. (a) Speed of A = Slope of PN $= \frac{10-6}{1.1-0}$

$$= \frac{40}{11}\text{ km/h} = 3.63\text{ km/h}$$

Speed of B = Slope of OM $= \frac{6-0}{0.7-0}$

$$= \frac{60}{7}\text{ km/h} = 8.57\text{ km/h}$$

Speed of C = Slope of QM $= \frac{6-2}{0.7-0}$

$$= \frac{40}{7}\text{ km/h} = 5.71\text{ km/h}$$

The slope of line B is more than that of line A and C hence B is travelling the fastest.

(b) No, all three do not meet at any point on the road.

(c) When B passes A at point N (at 1.2 hours), C is at a distance of approximately 8 km from the origin O.

(d) B passes C at 0.7 hours. During this time B covers distance of 6 km.

7. Here, $u = 0$, $s = 20$ m, $a = 10\ ms^{-2}$, $v = ?$, $t = ?$

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

∴ $v^2 - 0^2 = 2 \times 10 \times 20 = 400$

or $v = 20\ ms^{-1}$.

and $v = u + at$, $t = \frac{v-u}{a} = \frac{20-0}{10} = 2$ s.

8. (a) On horizontal axis, 5 small divisions = 2 s

On vertical axis, 3 small divisions = $2\ ms^{-1}$

∴ Area of 15 small squares

$$= 2\text{ s} \times 2\text{ ms}^{-1} = 4\text{ m}$$

Area of 1 small square $= \frac{4}{15}$ m

Total area under the speed-time graph from time 0 to 4 s

$= 57$ small squares $+ \frac{1}{2} \times 6$ small squares

= 60 small squares

Distance travelled by the car in first 4 seconds

= Area under the speed-time graph from 0 to 4 s

= 60 small squares

$$= 60 \times \frac{4}{15}\text{ m}$$

= 16 m.

(b) After 6 s, the car has a uniform motion for straight part of graph BC.

9. (a) Yes, a body can have acceleration even if its velocity is zero. When a body is thrown up, at highest point its velocity is zero but it has acceleration equal to acceleration due to gravity.

(b) Yes, when an object moves on a circular path, it has centripetal acceleration which is perpendicular to displacement.

10. Here, $r = 42{,}250$ km $= 42{,}250 \times 1000$ m

$T = 24\text{ h} = 24 \times 60 \times 60$ s.

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

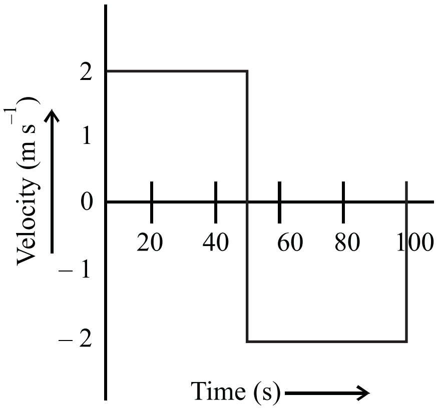
$$v = \frac{2\pi r}{T} = \frac{2 \times 3.14 \times 42{,}250 \times 1000}{24 \times 60 \times 60}\text{ m/s}$$

$= 3070.9$ m/s $\simeq 3.07$ km/s.

Exemplar Questions

1. No. Though the moving object comes back to its initial position the distance travelled is not zero.

2.



3. The distance travelled in first 8 s,

$$x_1 = 0 + \frac{1}{2}(5)(8)^2 = 160 \text{ m.}$$

At this point the velocity v = u + at = 0 + (5 × 8) = 40 ms^{-1}.

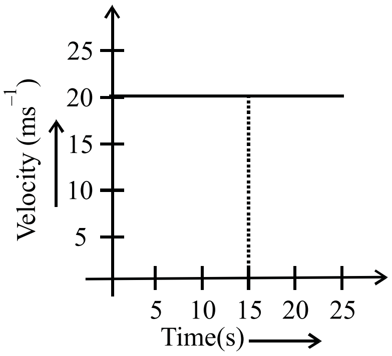
Therefore, the distance covered in last four seconds, x_2 = (40 × 4)m = 160 m

Thus, the total distance x = $x_1 + x_2$ = (160 + 160)m = 320 m

4. (i) Since velocity is not changing, acceleration is equal to zero.

(ii) Reading the graph, velocity = 20 ms^{-1}

(iii) Distance covered in 15 seconds, s = u × t = 20 × 15 = 300 m



5. Initial difference in height = (150 – 100)m = 50 m

Distance travelled by first body in 2s = h_1

$$= 0 + \frac{1}{2}g(2)^2 = 2g$$

Distance travelled by another body in 2s = h_2

$$= 0 + \frac{1}{2}g(2)^2 = 2g$$

After 2s, height at which the first body will be = h_1' = 150 – 2 g

After 2s, height at which the second body will be = h_2' = 100 – 2 g

Thus, after 2s, difference in height = 150 – 2 g – (100 – 2 g) = 50 m = initial difference in height

Thus, difference in height does not vary with time.

6. $s_1 = ut + \frac{1}{2}at^2$ or $20 = 0 + \frac{1}{2}a(2)^2$ or a = 10 ms^{-2},

v = u + at = 0 + (10 × 2) = 20 ms^{-1}

$$s_2 = 160 = vt' + \frac{1}{2}a'(t)^2 = (20 \times 4) + \left(\frac{1}{2}a' \times 16\right) \Rightarrow a' = 10 \text{ ms}^{-2}$$

Since acceleration is the same, we have v′ = u + at = 0 + (10 × 7) = 70 ms^{-1}

EXERCISE-3 Foundation Builder

Multiple Choice Questions

1. **(a)** Let for the first half time t, the person travels a distance s_1. Hence $v_1 = \frac{s_1}{t}$ or $s_1 = v_1 t$

For second half time, $v_2 = \frac{s_2}{t}$ or $s_2 = v_2 t$

$$\text{Now, } \bar{v} = \frac{\text{Total displacement}}{\text{Total time}} = \frac{s_1 + s_2}{2t}$$

$$= \frac{v_1 t + v_2 t}{2t} = \frac{v_1 + v_2}{2}$$

2. **(d)**

3. **(b)** Let after a time t, the cyclist overtake the bus.

Then $96 + \frac{1}{2} \times 2 \times t^2 = 20 \times t$ or $t^2 - 20t + 96 = 0$

$$\therefore t = \frac{20 \pm \sqrt{400 - 4 \times 96}}{2 \times 1}$$

$$= \frac{20 \pm 4}{2} = 8 \text{sec and } 12 \text{ sec}$$

4. **(d)** $v^2 = u^2 + 2as$ or $v^2 - u^2 = 2as$

Maximum retardation, $a = v^2/2s$

When the initial velocity is nv, then the distance over which it can be stopped is given by

$$s_n = \frac{u_0^2}{2a} = \frac{(nv)^2}{2(v^2/2s)} = n^2 s$$

5. **(b)** u = 10 m/s, t = 5 sec, v = 20 m/s, a = ?

$$a = \frac{20 - 10}{5} = 2 \ ms^{-2}$$

From the formula $v_1 = u_1 + at$, we have

$10 = u_1 + 2 \times 3$ or u_1 = 4 m/sec.

6. **(c)** Downward motion

$$v^2 - 0^2 = 2 \times 9.8 \times 5 \quad \Rightarrow \quad v = \sqrt{98} = 9.9$$

Also for upward motion

$$0^2 - u^2 = 2\times(-9.8)\times 1.8 \quad \Rightarrow \quad u = \sqrt{3528} = 5.94$$

$$\text{Fractional loss } = \frac{9.9-5.94}{9.9} = 0.4 = \frac{2}{5}$$

7. **(c)** The distance covered in n^{th} second is

$$S_n = u + \frac{1}{2}(2n-1)a$$

where u is initial velocity & a is acceleration then

$$26 = u + \frac{19a}{2} \qquad ....(1)$$

$$28 = u + \frac{21a}{2} \qquad ....(2)$$

$$30 = u + \frac{23a}{2} \qquad ....(3)$$

$$32 = u + \frac{25a}{2} \qquad ....(4)$$

From equations (1) & (2) we get,
$u = 7$ m/sec,
$a = 2$ m/sec^2
∴ The body starts with initial velocity
$u = 7$ m/sec
and moves with uniform acceleration
$a = 2$ m/sec^2

8. **(a)** From third equation of motion : $v^2 = u^2 + 2as$

for first case $u = \dfrac{40\times10}{36}\text{m/sec}$,
$v = 0$, $a = ?$, $s = 2$ m

$$\text{So, } a = \left(\frac{40\times10}{36}\right)^2 \frac{1}{4}\text{m/sec}^2$$

for second case $u = \dfrac{80\times10}{36}\text{m/sec}$, $v = 0$,

$$\text{So } s_2 = \left(\frac{80\times10}{36}\right)^2 / 2\times\frac{1}{4}\times\left(\frac{40\times10}{36}\right)^2 = 8\,\text{meter}$$

9. **(b)** Distance in last two second

$$= \frac{1}{2} \times 10 \times 2 = 10 \text{ m.}$$

$$\text{Total distance} = \frac{1}{2} \times 10 \times (6+2) = 40 \text{ m.}$$

10. **(b)**

11. **(b)** At a particular time, two values of velocity are not possible.

12. **(a)** $S_n = u + \dfrac{a}{2}(2n-1)$

$n = 6$

$$S_6 = 26 = u + \frac{a}{2}(2\times6-1)$$

$2 \times 26 = 2u + a(12 - 1)$ ...(1)

$52 = 2u + 11a$

$n = 7$

$$S_7 = 30 = u + \frac{a}{2}(2\times7-1)$$

$60 = 2u + 13a$

Subtract (1) form (2)

$60 = 2u + 13a$

$52 = 2u + 11a$

$8 = 2a$

$a = 4$ ms^{-2}

$52 = 2u + 11(u)$

$2u = 52 - 44$

$2u = 8$

$u = 4$ ms^{-1}

13. **(d)** $\dfrac{h_1}{h_2} = \dfrac{a}{b}$ also $h \propto u^2$

$$\Rightarrow \frac{u_1}{u_2} = \frac{\sqrt{a}}{\sqrt{b}}$$

14. **(b)**

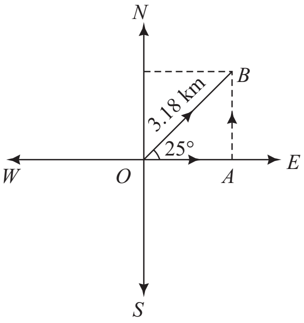
15. **(d)**

16. **(c)** As at C, the slope of curve is negative.

17. **(b)** Acceleration of A is higher than that of B.

18. **(c)**

19. **(d)** Person walks 25.0° north of east for 3.18 km



From figure, to arrive at the same location, distance travelled along north direction

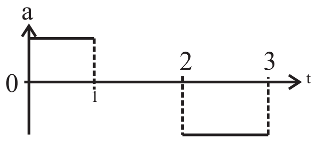
AB = OB sin 25° = 3.18 × sin 25° = 1.34 km

And distance travelled along east direction

OA = 3.18 × cos 25° = 2.88 km

20. **(d)**

21. **(a)**



from o to 1 second, acceleration will be constant.
a = o from time 1 to 2 second.
There is negative acceleration from 2 sec. to 3 sec.

22. **(a)** For a body thrown vertically upwards acceleration remains constant ($a = -g$) and velocity at anytime t is given by $V = u - gt$

During rise velocity decreases linearly and during fall velocity increases linearly and direction is opposite to each other.

Hence graph (a) correctly depicts velocity versus time.

23. **(d)**

24. **(c)** $v = u - g(T/2) \quad (\because v = 0)$

$$\Rightarrow u' = \frac{gT}{2}$$

$$\because v^2 = u^2 + 2gH$$

$$\text{or, } (u')^2 = u^2 - 2\,gH$$

$$\frac{g^2T^2}{4} + 2gH = u^2$$

$$\text{or, } u = \frac{\sqrt{g^2T^2 + 8gH}}{2}$$

25. **(b)** The displacement at the end of 2 minutes 20 seconds, i.e, 140s will be the diameter because the athlete will complete 3 and half rounds.

Therefore, for complete 3 rounds, displacement is zero.

For half round, the displacement will be the diameter.

Therefore displacement = 2R

26. **(c)** In graph 3, the slope is increasing. so acceleration is increasing. Thus it represents non-uniform acceleration.

27. **(d)** Given that, initial velocity of a particle, $u = 10$ m/s acceleration, a = 4 m/s^2

From motion 2nd Equation

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

$$s = 10 \times 2 + \frac{1}{2} \times 4 \times (2)^2$$

$$= 20 + \frac{1}{2} \times 4 \times 4$$

$$= 20 + \frac{1}{2} \times 16$$

$$s = 28\text{m}$$

28. **(c)** From third equation of motion, $v^2 = u^2 + 2as$ where v & u are final & initial velocity, a is acceleration, s is distance.

For first case v_1= 3km/hour

u_1= 0, a_1= g & s_1 = ?

$$s_1 = \frac{9 \times 100}{36 \times 36 \times 20} \text{ metre}$$

For second case v_2 = ?, u_2 = 4km/hour ,

a_2= g = 10m/sec

$$\& \ s_1 = s_2 = \frac{9 \times 100}{36 \times 36 \times 20}$$

$$\text{so} \quad v_2^2 = \frac{16 \times 1000 \times 1000}{3600 \times 3600} + \frac{2 \times 10 \times 9 \times 100}{20 \times 36 \times 36}$$

or v_2 = 5 km/hour

29. **(a)** $s = ut + \frac{1}{2}at^2$ here $a = g$

For first body $u_1 = 0 \Rightarrow s_1 = \frac{1}{2}g \times 9$

For second body $u_2 = 0 \Rightarrow s_2 = \frac{1}{2}g \times 4$

So difference between them after 3 sec.

$$= s_1 - s_2 = \frac{1}{2}g \times 5$$

If g = 10m/sec^2 then $s_1 - s_2$ = 25m.

30. **(b)** From third equation of motion

$$v^2 = u^2 - 2gh \quad (\because a = -g)$$

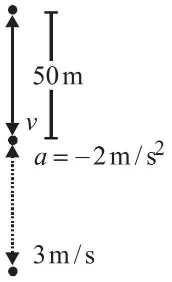
Given, v = 10 m/sec at $\frac{h}{2}$. But v = 0, when particle attained maximum height h.

$$\text{Therefore } (10)^2 = u - \frac{2gh}{2}$$

or 100 = 2gh – 2gh/2 $\quad (\because 0 = u^2 - 2gh)$

$\Rightarrow h$ = 10 m

31. **(d)** Initial velocity of parachute after bailing out,



$$u = \sqrt{2gh}$$

$$u = \sqrt{2 \times 9.8 \times 50} = 14\sqrt{5}$$

The velocity at ground,

v = 3m/s

$$S = \frac{v^2 - u^2}{2 \times 2} = \frac{3^2 - 980}{4} \approx 243\,\text{m}$$

Initially he has fallen 50 m.

∴ Total height from where he bailed out

= 243 + 50 = 293 m

32. **(b)** Acceleration vector is always radial (i.e. towards the centre) for uniform circular motion.

33. **(d)** Since time period is 1.5 sec, so ball takes approximately 5.5 round in 8.3 seconds.

Displacement in 5 round = 0

and in remaining 1/2 round, displacement = 2R = 2m

Hence total displacement in 8.3 s is approximately 2m

Since total time is 8.3 seconds so final remaining time is 8.3 –7.5 = 0.8 seconds

$$\Delta\theta = \omega\Delta t = \frac{2\pi}{1.5}\times 0.8 \quad \left[\because \omega = \frac{2\pi}{T}\right]$$

$$= \frac{16\pi}{15}\ \text{rad.} = \text{angle moved in last 0.8 sec}$$

$\Delta\theta \approx \pi$, so displacement $\approx 2R = 2$m

34. **(a)** During retardation speed and velocity will decrease.

35. **(d)** For A to C

Given Initial velocity (U) = 0

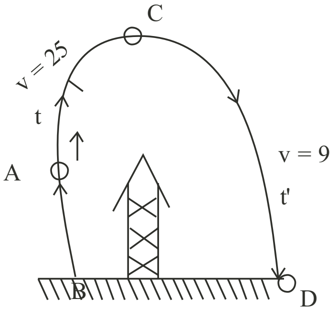
Final velocity (v) = 25 m/sec^2

for C to D

Given : Initial velocity (u′) = 0

Final velocity (v′) = 90 m/sec^2

g = 10 m/sec^2.



Let, the height of the tower be AB.

Let, the stone reaches to maximum height at C in time t.

Time taken by stone from distance A to C is v = u + at

$0 = 25 - 10 \times t \Rightarrow t = 2.5$ s

Now, from C to D

v = u + at’

90 = 0 + 10 t’

t’ = 9 s

Total time, T = t + t’ = 9 + 2.5 = 11.5 s

36. **(a)** In region AB, x – t graph is straight line, so velocity is constant and then acceleration is zero, so force is also zero in the region

$\because F = ma \Rightarrow F = m(0) \Rightarrow F = 0$

37. **(c)** Let total distance is d

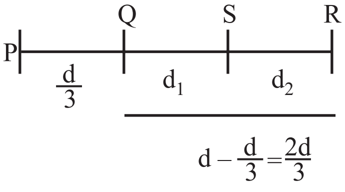
We known that,

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

Time taken by the particle to cover $\frac{1}{3}$ of the distance is,

$$t_1 = \frac{d}{3\times 3} = \frac{d}{9}$$

Now remaing distance is covered in two equal time intervals “t”



$$\frac{2d}{3} = d_1 + d_2.$$

$$\frac{2d}{3} = v_1\left(\frac{t}{2}\right) + v_2\left(\frac{t}{2}\right)$$

$$\frac{2d}{3} = \frac{4.5}{2}\times t + \frac{7.5}{2}\times t = \frac{45}{20}t + \frac{75}{20}t$$

$$\frac{2d}{3} = \frac{9}{4}t + \frac{15}{4}t = \frac{24}{4}t \qquad \therefore\ t = \frac{d}{9}.$$

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

$$\Rightarrow \frac{d}{t_1 + t} = \frac{d}{\frac{d}{9}+\frac{d}{9}} = \frac{9}{2} = 4.5\ \text{m/s}.$$

38. **(d)** Statement 1 :

$v^2 = u^2 + 2as$

v = 0

$u^2 = 2as$ ...(i)

$$s = \frac{u^2}{2a},\ \text{So, } s \propto u^2$$

$$\text{Therefore, } \frac{s}{s'} = \left(\frac{u}{u'}\right)^2$$

$$\text{Given, } u' = u/2 \Rightarrow \frac{s}{s'} = \frac{u^2}{\left(\frac{u^2}{4}\right)} \Rightarrow s' = \frac{s}{4}$$

So, $s' \propto \frac{u^2}{4}$ So, statement I is false.

Statement II.

Stopping distance ∵ (initial velocity)^2

So, it is true.

More Than One Option Correct

1. **(a, c)** **2.** **(c, d)**

3. **(a, c)** **4.** **(a, d)**

5. **(a, d)** **6.** **(b, c)**

7. **(a, d)** **8.** **(a, b)**

9. **(b, c)** Taking upward motion of the balloon for 4 seconds, we have, u = 0; a = 2.50 ms^{-2};

t = 4s; v = ?; s = ?

$v = u + at = 0 + 2.5 \times 4 = 10m^{s-1}$

$$s = ut + \frac{1}{2}at^2 = 0 + \frac{1}{2}\times 2.5 \times 4^2 = 20\text{m}.$$

When stone is released from the balloon at the height of 20m, it retains the velocity of balloon i.e. 10m/s upwards but not its acceleration.

Taking downward motion of stone, when released from balloon to ground, we have

u = – 10ms^{-1}; a = 10ms^{-2}, s = 20m, t = ?

As $s = ut + \frac{1}{2}at^2$; so $20 = -10t + \frac{1}{2} \times 10t^2$

or $5t^2 - 10t - 20 = 0$

On solving t = 3.2 s

Distance covered by stone after being released from balloon up to highest point of its path is

$v^2 = u^2 + 2as$

$0 = 10^2 + 2(-10)s$ or s = 5m

Total distance travelled = 5 + 5 + 20 = 30m.

10. (a, d)

11. (a, c) In uniform circular motion, magnitude of acceleration and velocity is constant but not their directions.

12. (a, b, c, d)

13. (a, b) For circular motion $a_r \neq 0$

Passage/Case Based Questions

1. **(i) (d)** The total distance travelled is (18 + 9) m = 27 m

(ii) (a) 9 m

(iii) (a) Net displacement = 9 m

2. **(i) (d)** Acceleration of body = slope of v – t graph

$$= \frac{8-0}{3-0} = \frac{8}{3}\text{ms}^{-2}$$

(ii) (b) Acceleration of body

= negative slope of velocity – time graph

$$= \frac{0-8}{4-3} = -8\text{ms}^{-2}$$

(iii) (c) Displacement of the body is the area under velocity – time graph = 1/2 × 8 × 3 + 1/2 × 8 ×1 = 12 + 4 = 16 m.

3. **(i) (a)** $t = \frac{2\pi r}{v} = \frac{2 \times \frac{22}{7} \times 3.5}{4} = 5.5\,\text{s}$

(ii) (d) Displacement of the particle in one complete round is zero, hence average velocity of the particle in one complete round is zero.

(iii) (b) Acceleration

$$a = \frac{v^2}{r} = \frac{4^2}{3.5} = \frac{32}{7}\text{ms}^{-2}$$

Assertion & Reason Questions

1. **(b)** **2. (c)** **3.** **(d)** **4.** **(a)** **5.** **(d)**

6. **(c)** Centripetal acceleration is not constant as it varies in direction.

Multiple Matching Questions

1. **(a)** (A) → (r, s, u); (B) → (t); (C) → (q); (D) → (p)

2. **(b)** (A) → (p, u); (B) → (s, t); (C) → (q); (D) → (r, u)

3. **(d)** (A) → (p, s); (B) → (p, q, r, s, t); (C) → (p, r, s, t); (D) → (p, q, r, s, t)

Numeric/Integer Type Questions

1. (i) 0.04 ms^{-2} (ii) 30.31 ms^{-1}

2. 25ms^{-1}

3. $32.7\,\text{kmh}^{-1}$ $V_{av} = \dfrac{2x + x}{\dfrac{2x}{30} + \dfrac{x}{40}} = 32.7\,\text{kmh}^{-1}$

4. 0 ms^{-1}

5. **(0.104 rad/s^2)** $\alpha = \dfrac{\omega - \omega_0}{t}$

$$= \frac{(400-100) \times 2\pi}{60 \times 5 \times 60} = \frac{\pi}{30}\text{ rad/s}^2$$

6. **(990.4 cm s^{-2})** Here, $r = 80$ cm ; $T = \frac{25}{14}s$

Now, $\omega = \dfrac{2\pi}{T} = \dfrac{2\pi}{25/14} = \dfrac{28\pi}{25}\text{ rad s}^{-1}$

The acceleration of uniform circular motion is given by

$$a = \omega^2 r = \left(\frac{28\pi}{25}\right)^2 \times 80 = 990.4\text{ cm s}^{-2}$$

The acceleration is directed along the radius of the circular path and *towards the centre* of the circle.