Motion

Introduction

Motion:- If an object changes its position with respect to a reference point with elapse of time, the object is said to be in motion.

Rest:- When an object does not change its position with respect to a reference point with elapse of time, the object is said to be in rest.

Example – When a vehicle changes its position with respect to an electric pole (a reference point) with elapse of time, then vehicle is called in motion. And if the same vehicle does not change its position with respect to that electric pole, the vehicle is called in the state of rest.

Thus to observe the motion of any object; two things are necessary – a reference point and time.

In the above example; vehicle is the object and electric pole is the reference point. A building, tree, or any other static thing can be taken as reference point to observe the motion of an object.

Motion along a straight line:

When an object moves along a straight line, the motion of the object is called rectilinear motion. For example; motion of a vehicle along a straight road.

Distance and Displacement:

Distance is the length of path covered by a moving object in the given time irrespective of direction. Distance has only magnitude and no direction.

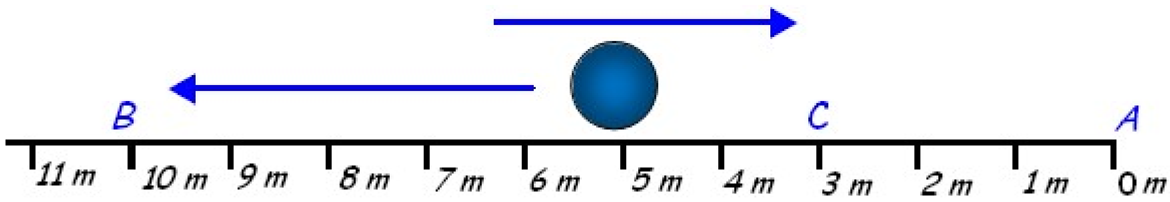
SI unit of distance is meter (m).

Kilometer is used to measure bigger distance and it is abbreviated as ‘km’.

Displacement is the shortest possible distance covered by a moving object from initial point in a particular direction. In other words, shortest distance between initial point and final point is called the displacement.

Displacement has both magnitude and direction while distance has only magnitude.

Suppose, a ball is rolling along a straight line.



Case – 1

Suppose, the ball starts moving from point A and reaches at point B.

Thus, distance covered by ball = 10 m

Displacement of ball = 10 m towards west.

Case - 2

Suppose, ball starts moving from point A and reaches to B. Again it returns on the same path from point B and reaches at A.

Thus, distance covered by the ball = distance from A to B + Distance from B to A

= 10 m + 10 m = 20 m

In this condition, distance covered by ball = 20 m.

Since, ball returns at point A, thus displacement of the ball = 0

Case – 3 –

Suppose, the ball starts moving from point A, reaches point B and returns back to point C.

Then, the distance covered by ball = distance from A to B + Distance from B to C

= 10 m + 7 m = 17 m

Displacement of ball = Distance of point C from A = 3 m towards west.

Uniform and Non-Uniform Motion:

Uniform Motion: – When an object covers equal distance in equal interval of time, the motion is called uniform motion. For example – if a moving vehicle covers a distance of 10 km every hour, the motion of the vehicle is called uniform motion.

Non-Uniform Motion: - When an object covers unequal distance in equal interval of time, the motion is called non-uniform motion. For example – If moving vehicle covers a distance of 10 km in the first hour, covers a distance of 20 km in the second hour, covers a distance of 5 km in the third hour, etc. the motion of the vehicle is called non-uniform motion.

Speed:

Distance covered by a moving object in unit time is called distance.

$$Speed = \frac{Distance\ covered}{Total\ time\ taken} \qquad \Rightarrow v = \frac{s}{t}$$

Where, v = speed, s = distance, t = total time.

SI unit of speed is meter per second (m/s).

Average speed:

sThe average distance covered in unit time by a moving object is called average speed. Average speed is the ratio of total distance covered and total time taken.

$$Average\ speed = \frac{Total\ distance\ covered}{Total\ time\ taken} \qquad \Rightarrow v = \frac{s}{t}$$

Where, v = Average Speed, s = Total distance covered, t = total time taken.

SI unit of average speed is meter per second (m/s).

Velocity:

The speed of a moving object in particular direction is called velocity. Velocity has both magnitude and direction while speed has only magnitude and no direction.

Velocity of an object is the distance covered in particular direction in unit time.

$$Velocity = \frac{Distance\ covered}{Time\ taken} \qquad \Rightarrow v = \frac{s}{t}$$

SI unit of velocity is meter per second.

Uniform velocity:

Uniform speed of an object in same direction is called uniform velocity.

Non-Uniform velocity: Velocity of an object is changed in following two conditions.

(a) When speed is changed

(b) When direction is changed.

Thus, non uniform speed of a moving object in same direction, or non-uniform speed in different directions or uniform speed in different directions is called non-uniform velocity.

Example – If a vehicle is moving on a circular path with uniform speed, then its velocity is said to be non-uniform, because on a circular path the direction of moving body changes along with direction of curve.

If a vehicle moving with uniform speed on a jig-jag path, the velocity of the vehicle will be non-uniform because direction of vehicle is changed with the change of direction of path.

Average Velocity: The arithmetic mean of velocity of an object moving along a straight line is called the average velocity.

$$Average\ velocity = \frac{Initial\ velocity + Final\ velocity}{2} \qquad \Rightarrow v_{av} = \frac{u+v}{2}$$

Where, u is the initial velocity and v is the final velocity.

The displacement of a moving object in unit time is also called the average velocity.

$$Average\ velocity = \frac{Displacement}{Total\ time\ taken}$$

Acceleration: The rate of change in velocity is called acceleration. Acceleration is generally denoted by 'a' or f.

$$Thus, \qquad Acceleration = \frac{Change\ in\ velocity}{Time\ taken}$$

$$\Rightarrow a = \frac{Final\ velocity - Initial\ velocity}{Time\ taken\ to\ change\ in\ velocity} \qquad \Rightarrow a = \frac{v-u}{t}$$

Where, 'a' is acceleration, 'v' is final velocity, 'u' is initial velocity and 't' is time taken for change.

A positive sign of the magnitude of acceleration shows increase in velocity and a negative sign show decrease in velocity. If there is decrease in acceleration, it is called Retardation. This means, rate of decrease in velocity is called Retardation.

SI unit of acceleration:

The SI unit of velocity is meter /second

The SI unit of time is second.

$$Thus, SI\ unit\ of\ acceleration\ (a) = \frac{m/s}{s} = m/s^2\ or\ m\,s^{-2}$$

Acceleration in the case of Uniform Velocity:

In the case of uniform velocity, the speed or direction of a moving object is not changed and thus there is no change in acceleration. Therefore, in the case of uniform velocity acceleration will be zero.

Equation of Motion:

Relation among velocity, distance, time and acceleration is called equations of motion. There are three equations of motion:

First Equation of Motion:

The final velocity (v) of a moving object with uniform acceleration (a) after time, t.

Let

The initial velocity = u.

Final velocity = v.

Time = t

Acceleration = a

$$We\ know\ that, \quad Acceleration = \frac{Change\ in\ velocity}{Time\ taken}$$

$$\Rightarrow Acceleration(a) = \frac{Final\ velocity(v) - Initial\ velocity\ (u)}{Time\ taken}$$

$$\Rightarrow a = \frac{v-u}{t} \qquad \Rightarrow at = v - u$$

$$\Rightarrow at - v = -u \qquad \Rightarrow -v = -u - at$$

$$\Rightarrow v = u + at - - - - - - - - (i)$$

This equation is known as first equation of motion.

Second Equation of Motion:

Distance covered in time (t) by a moving body.

Let,

Initial velocity of the object = u

Final velocity of the object = v

Acceleration = a

Time = t

Distance covered in given time = s

We know that,

$$Average\ velocity = \frac{Initital\ Velocity(u) + Final\ Velocity(v)}{2}$$

Therefore,

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

We know that, Distance covered (s) in given time = Average velocity x Time

Or, s = Average velocity x Time ----------------(iii)

After substituting the value of average velocity from equation (ii) we get

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

After substituting the value of 'v' from first equation of motion we get,

$$\Rightarrow s = \frac{(u+(u+at))}{2} \times t \qquad \Rightarrow s = \frac{u+u+at}{2} \times t$$

$$\Rightarrow s = \frac{2u+at}{2} \times t \qquad \Rightarrow s = \frac{(2u+at) \times t}{2}$$

$$\Rightarrow s = \frac{2ut + at \times t}{2} \qquad \Rightarrow s = \frac{2ut + at^2}{2}$$

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

$$\Rightarrow s = ut + \frac{1}{2}at^2 \ -------------- (iv)$$

The above equation is known as Second equation of motion.

Third Equation of Motion:

The third equation of motion is derived by substituting the value of time (t) from first equation of motion.

We know from first equation of motion,v=u+at

$$\Rightarrow v - u = at \qquad \Rightarrow at = v - u$$

$$\Rightarrow t = \frac{v-u}{a} - - - - - - - - - - - - - - - - -(v)$$

We know that the second equation of motion is, $s = ut + \frac{1}{2}at^2$

By substituting the value of ^' t^' from euqation (v) we get

$$s = u\left(\frac{v-u}{a}\right) + \frac{1}{2}a\left(\frac{v-u}{a}\right)^2$$

$$\Rightarrow s = u \times \frac{v-u}{a} + \frac{1}{2}a \times \frac{(v-u)^2}{a^2}$$

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

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

$$\Rightarrow s = \frac{uv - u^2}{a} + \frac{(v-u)^2}{2a}$$

$$\Rightarrow s = \frac{2(uv - u^2) + (v-u)^2}{2a}$$

$$\Rightarrow 2as = 2uv - 2u^2 + v^2 + u^2 - 2uv$$

$$\Rightarrow 2as = -2u^2 + v^2 + u^2$$

$$\Rightarrow 2as = -u^2 + v^2$$

$$\Rightarrow 2as + u^2 = v^2$$

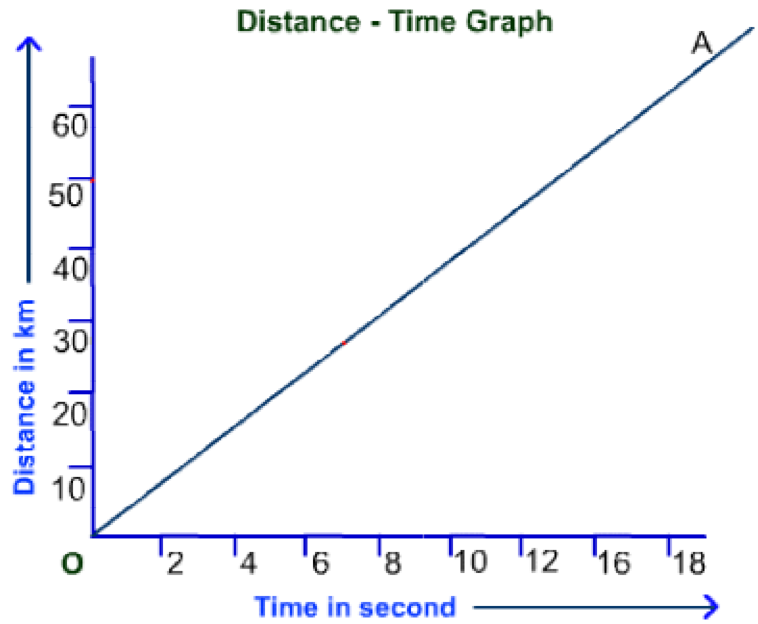
$$\Rightarrow v^2 = u^2 + 2as - - - - - - - \ (vi)$$

This is called the Third equation of motion.

Graphical Representation of Motion:

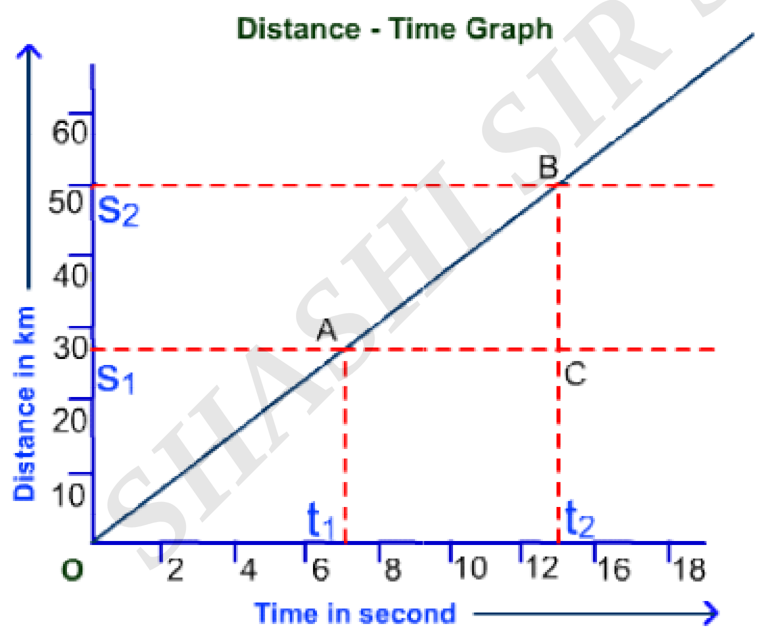
Distance – Time Graph:

When an object is moving with uniform velocity, the slope of graph is always a straight line. In other words slope of straight line of a distance-time graph shows that object is moving with uniform velocity.



In the above graph, straight slope line shows that object is moving with uniform velocity. Slope OB shows the velocity of the object.

Calculation of Velocity using distance-time graph:



To calculate the velocity, let take two points A and B on the slope OB.

Draw one line parallel to y-axis and another parallel to x-axis from B.

Again draw a line parallel to y-axis and another parallel to x-axis from point A.

Let, line parallel to x-axis from point B cut at a point, S2 at y-axis.

Line parallel to x-axis from point A cut at point, S1 at y-axis.

Let, line parallel to y-axis from point B cut at t2 at x-axis.

Line parallel to y-axis from point A cut at t1 at x-axis.

Now, BC= Distance = S2 – S1 and AC = time = t2 – t1

We know that slope of the graph is given by the ratio of change in y-axis and change in X-axis.

$$Or, Slope = \frac{Change\ in\ y - axis}{Change\ in\ x - axis}$$

$$Thus, slope, AB = \frac{BC}{AC}$$

$$Or, \quad v = \frac{(s_2 - s_1)}{(t_2 - t_1)}$$

$$Where, v = velocity, (s_2 - s_1) = interval\ of\ distance$$

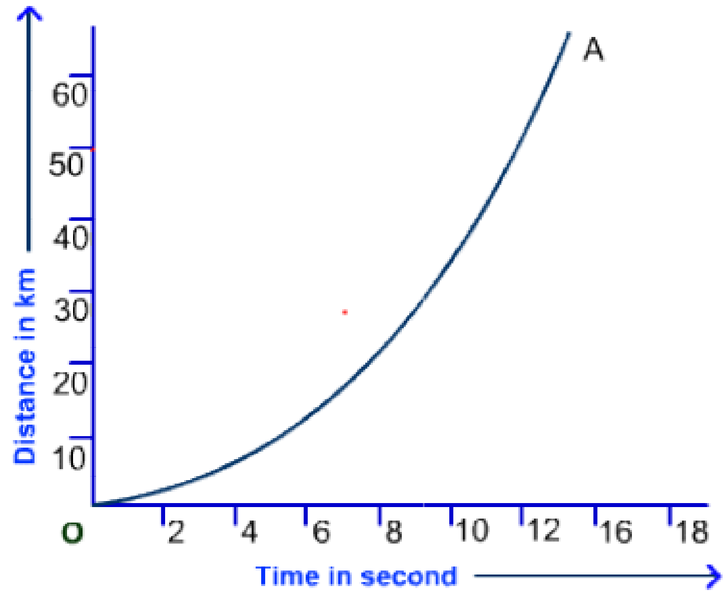
$$and\ (t_2 - t_1) = time\ interval$$

$$Thus, velocity = \frac{Distance}{Time}$$

Distance – Time Graph of a body moving with Accelerated motion:

When graph of distance Vs time is plotted for an object moving with accelerated motion, i.e. with increasing non-uniform speed, the slope of graph will not be a straight line. The rising trend of slope shows the increasing trend of velocity.

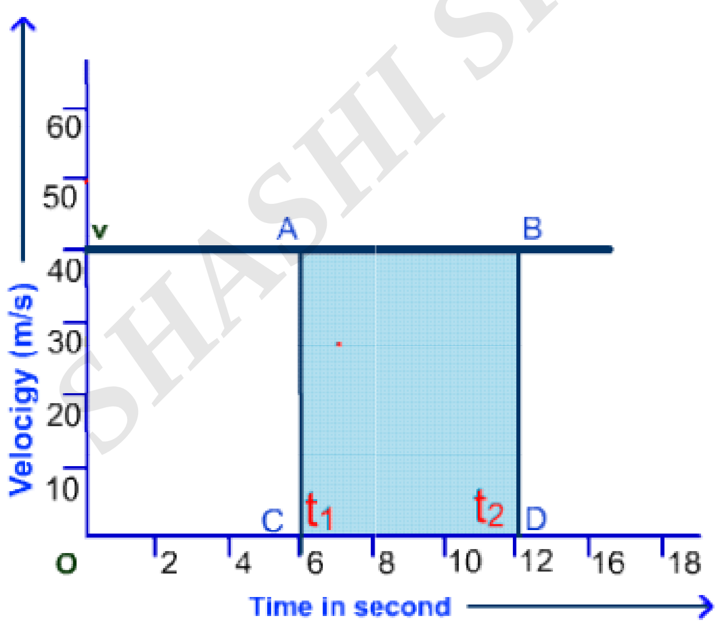
Distance - Time Graph of an object in accelerated motion



Velocity-Time Graph:

Velocity :– time graph of an object moving with uniform velocity:

The slope of a Velocity – time graph of an object moving in rectilinear motion with uniform velocity is straight line and parallel to x-axis when velocity is taken along y-axis and time is taken along x-axis.



Velocity - Time Graph of an object moving with constant velocity

Calculation of distance using velocity-time graph:

Let two points A and B on the slope of graph.

Draw two lines parallel to y-axis AC from point A, and BD from point B.

Let point D at the x-axis (time axis) is t2 and point C is t1.

Let AB meet at ‘v’ at y-axis, i.e. object is moving with a velocity, v.

Thus, distance or displacement by the object is equal to the area of the rectangle (shaded) ABCD.

Thus, Area of ABCD = BD x DC

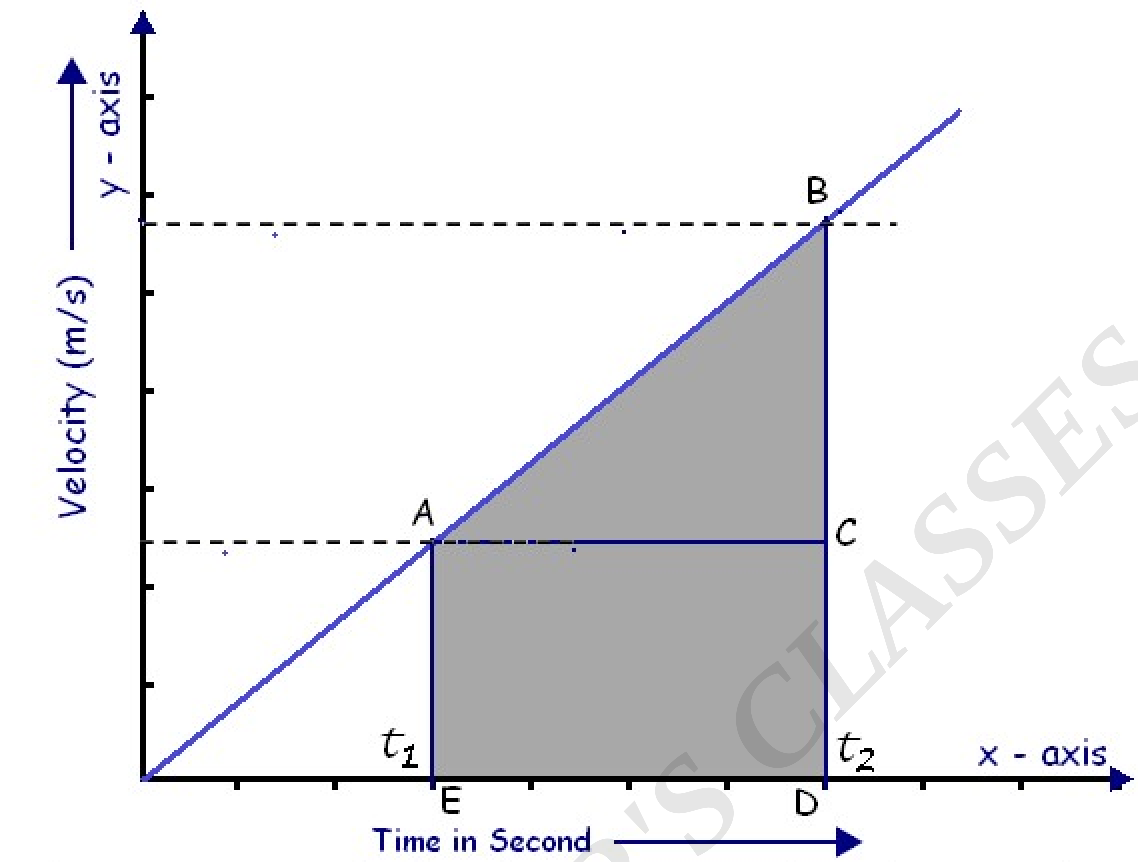
⇒ s = v (t2 – t1)

Since given object is moving with constant velocity along a straight line, thus displacement will be equal to distance covered.

Therefore, Distance or Displacement = velocity X time interval.

Velocity – Time Graph of an object moving with uniform acceleration:

When velocity – time graph is plotted for an object moving with uniform acceleration, the slope of the graph is a straight line.



Velocity - time graph of an object moving with uniform acceleration

The pattern of slope of the graph shows that object is moving with uniform acceleration.

Calculation of Displacement and Distance covered by the moving object using velocity time graph:

Let take two points, A and B at the slope of the graph.

Draw a line from B to BD and another from point A to AE parallel to y-axis.

Let AD meets at t2 and AE at t1 on the time axis.

Thus, Distance covered by the object in the given time interval (t2 – t1) is given by the area of ABCDE.

$$Therefore, Distance\ (s) = \ Area\ of\ \Delta\ ABD + Area\ of\ ACDE$$

$$\Rightarrow S = \frac{1}{2} \times BC\ \times AC + (AE\ \times ED)$$

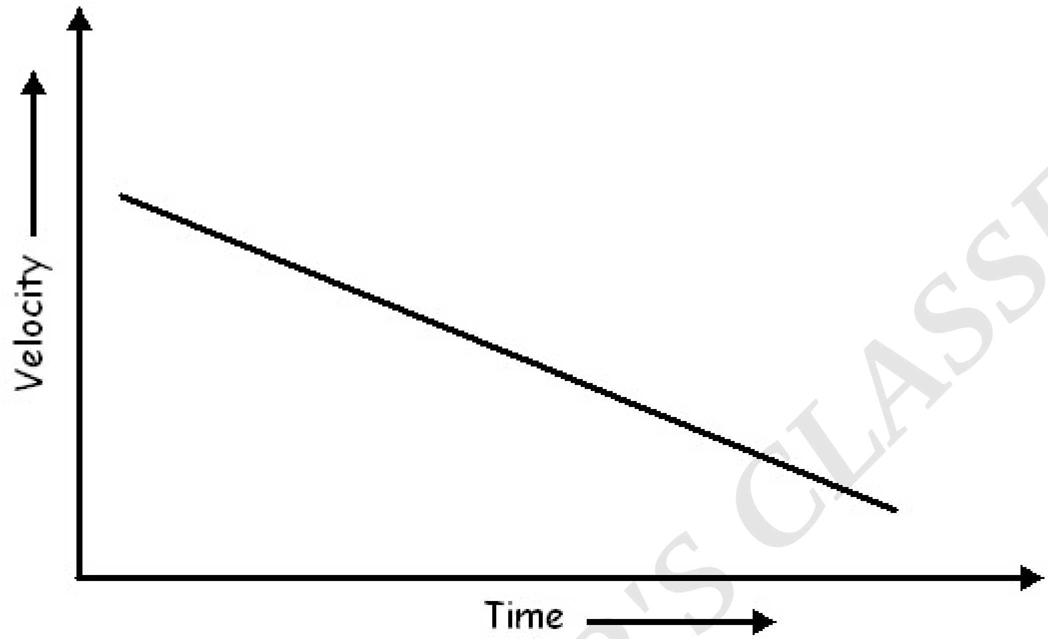
$$Displacement\ of\ the\ object\ during\ the\ given\ time\ interval\ (t_2 - t_1)$$

$$= Area\ of\ ACDE$$

$$Thus, Displacement = AE\ \times ED$$

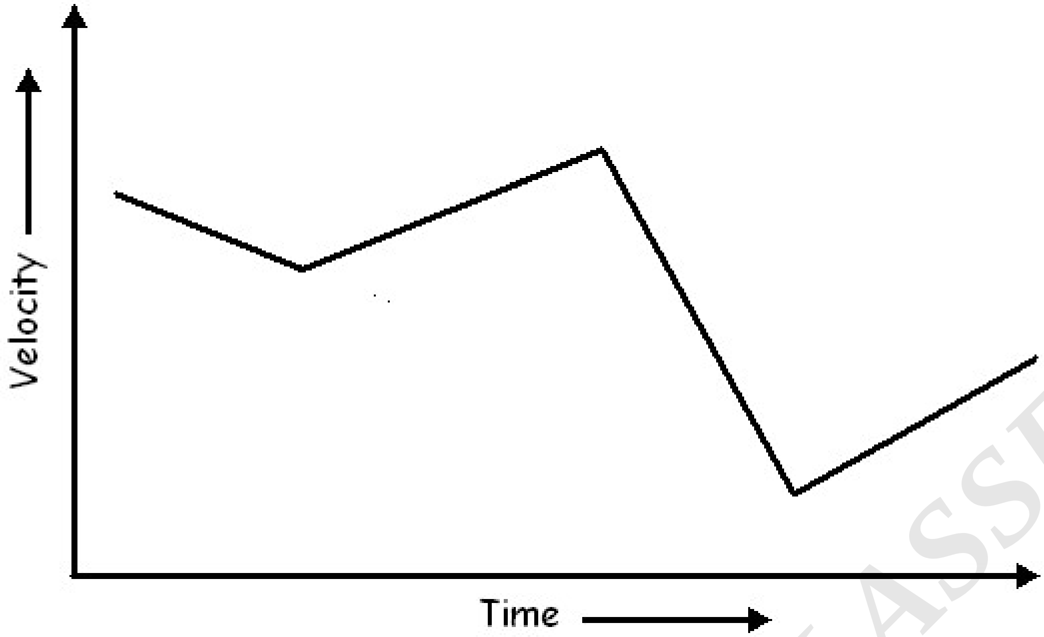
Velocity time graph of an object moving with uniform decreasing velocity:

The slope of the velocity time graph of an object moving with uniform decreasing velocity with uniform acceleration is a downwards straight line. The straight downward slope shows the decreasing velocity with uniform acceleration, i.e. retardation.



Velocity - Time Graph of an object moving with decreasing velocity with uniform acceleration

Velocity time graph of an object moving with non-uniform velocity:

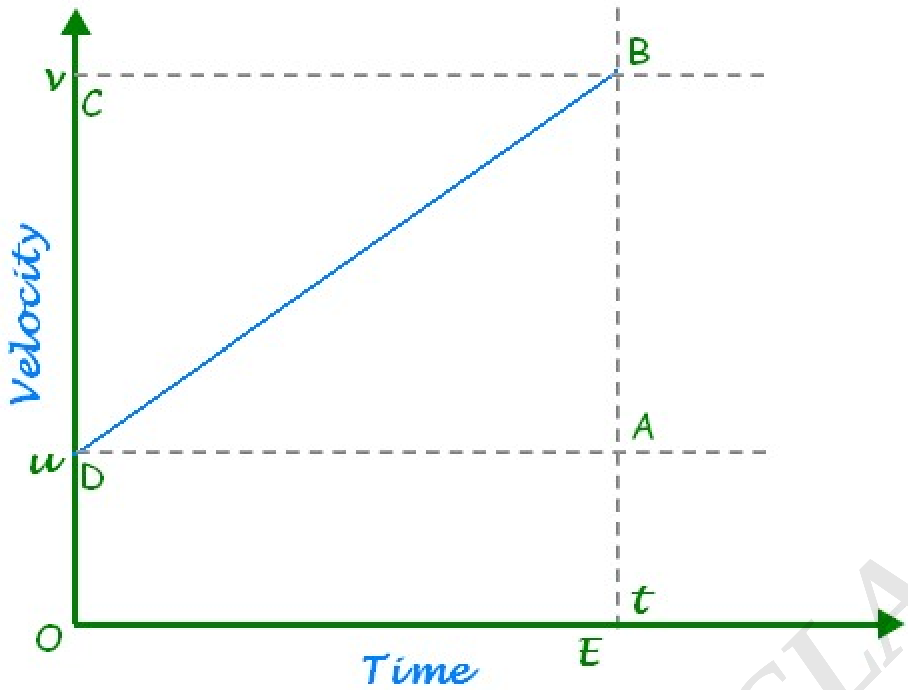


Velocity - Time Graph of an object moving with Non-uniform velocity

Jig – zag line of slope of graph shows that the object is moving with non-uniform velocity.

Equation for Velocity – Time relation by graphical method – First equation of Motion –

Let an object is moving with uniform acceleration.



Let the initial velocity of the object = u

Let the object is moving with uniform acceleration, a.

Let object reaches at point B after time, t and its final velocity becomes, v

Draw a line parallel to x-axis DA from point, D from where object starts moving.

Draw another line BA from point B parallel to y-axis which meets at E at y-axis.

Let OE = time, t

Now, from the graph,

BE = AB + AE

⇒ v = DC + OD (Since, AB = DC and AE = OD)

⇒ v = DC + u (Since, OD = u)

⇒ v = DC + u ------------------- (i)

$$Now, Acceleartion\ (a) = \frac{Change\ in\ velocity}{Time\ taken}$$

$$\Rightarrow a = \frac{v-u}{t} = \frac{OC-OD}{t} = \frac{DC}{t}$$

$$\Rightarrow at = DC ---------- (ii)$$

By subtituting the value of DC from (ii)in (i)we get

$$v = at + u$$

$$\Rightarrow v = u + at$$

Above equation is the relation among initial velocity (u), final velocity (u), acceleration (a) and time (t). It is called first equation of motion.

Equation for distance –time relation:

Distance covered by the object in the given time ‘t’ is given by the area of the trapezium ABDOE

Let in the given time, t the distance covered by the moving object = s

The area of trapezium, ABDOE

$$= Distance\ (s) = Area\ of\ \Delta ABD + Area\ of\ ADOE$$

$$\Rightarrow s = \frac{1}{2} \times AB \times AD + (OD \times OE)$$

$$\Rightarrow s = \frac{1}{2} \times DC \times AD + (u \times t)\ [Since, AB = DC]$$

$$\Rightarrow s = \frac{1}{2} \times at \times t + ut \quad [Since, DC = at\ from\ equation\ (ii)]$$

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

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

The above expression gives the distance covered by the object moving with uniform acceleration. This expression is known as second equation of motion.

Equation for Distance Velocity Relation: Third equation of Motion:

The distance covered by the object moving with uniform acceleration is given by the area of trapezium ABDO

Therefore,

$Area\ of\ trapezium\ ABDOE$

$= \frac{1}{2} \times sum\ of\ parallel\ sides + distance\ between\ parallel\ sides$

$\Rightarrow Distance\ (s) = \frac{1}{2}(DO + BE)\ \times OE$

$\Rightarrow s = \frac{1}{2}(u + v)\ \times t - - - - - - - - - - (iii)$

$Now, from\ equation\ (ii)\ a = \frac{v - u}{t}$

$Therefore, t = \frac{v - u}{a} - - - - - - -(iv)$

$After\ substituting\ the\ value\ of\ t\ from\ equation\ (iv) in\ equation\ (iii)$

$\Rightarrow s = \frac{1}{2}(u + v)\ \times \frac{(v - u)}{a}$

$\Rightarrow s = \frac{1}{2a}\ (v + u)(v - u)$

$\Rightarrow 2as =\ (v + u)(v - u)$

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

$\Rightarrow 2as + u^2 = v^2$

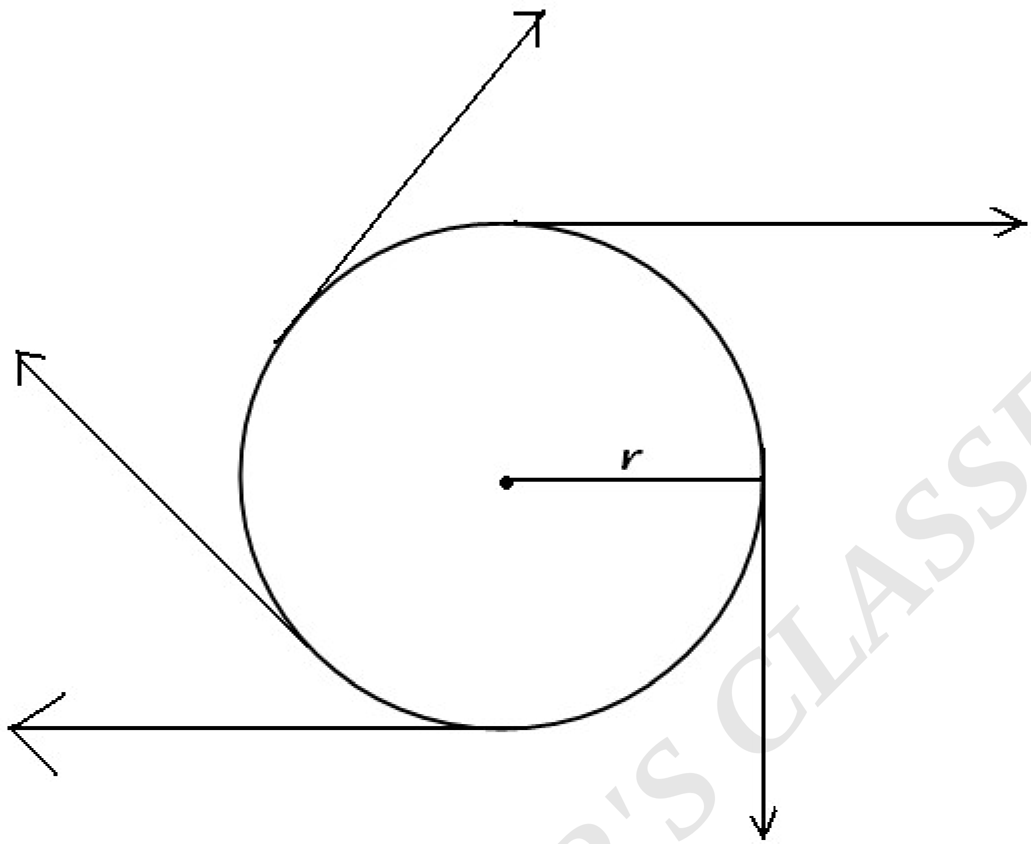
$\Rightarrow v^2 = u^2 + 2as$

The above expression gives the relation between position and velocity and is called the third equation of motion.

While solving the problems related to velocity, distance, time and acceleration following three points should be considered:

Motion along a circular path:

Motion of an object along a circular path is called circular motion. Since, on a circular path the direction of the object is changing continuously to keep it on the path, the motion of the object is called accelerated motion.



Direction at different point while circular motion

Velocity in the case of circular motion.

If the radius of circle is ‘r’

Therefore, circumference = 2πr

Let time ‘t’ is taken to complete one rotation over a circular path by any object

$$Therefore, velocity\ (v) = \frac{Distance}{time}$$

$$\Rightarrow v = \frac{Circumference}{t}$$

$$\Rightarrow v = \frac{2\pi r}{t}$$

Where, v = velocity, r = radius of circular path and t = time

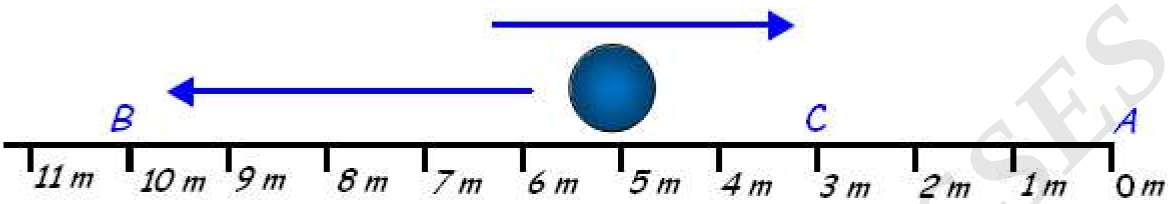
Motion of earth around the sun, motion of moon around the earth, motion of a top, motion of blades of an electric fan, etc. are the examples of circular motion.

Solution of In Text Questions - 1

Question : 1 - An object has moved through a distance. Can it have zero displacement? If yes, support your answer with an example.

Answer:-

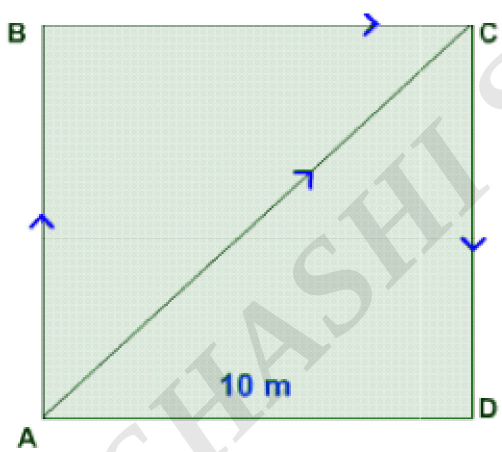
Yes, zero displacement is possible if an object has moved through a distance.



Suppose a ball starts moving from point A and it returns back at same point A, then the distance will be equal to 20 meters while displacement will be zero.

Question : 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?

Answer:-



Given, side of the square field = 10m

Therefore, perimeter = 10 m x 4 = 40 m

Farmer moves along the boundary in 40s.

Displacement after 2 m 20 s = 2 x 60 s + 20 s = 140 s =?

Since in 40 s farmer moves 40 m

$$Therefore, in\ 1\ s\ distance\ covered\ by\ farmer = \frac{40}{40} m = 1\ m$$

$$Therefore, in\ 140s\ distance\ covered\ by\ farmer = 1 \times 140\ m = 140\ m$$

$$Now, number\ of\ rotation\ to\ cover\ 140\ along\ the\ boundry = \frac{Total\ distance}{Perimeter}$$

$$= \frac{140m}{40m} = 3.5\ round$$

$Thus\ after\ 3.5\ round\ farmer\ will\ at\ point\ C\ of\ the\ field.$

$$Therefore, Displacement\ AC = \sqrt{(10m)^2 + (10m)^2}$$

$$= \sqrt{100m^2 + 100\ m^2}$$

$$= \sqrt{200m^2}$$

$$= \sqrt{2 \times 100m^2}$$

$$= 10\sqrt{2}\ m$$

$Thus, after\ 2\ minute\ 20\ second\ the\ displacement\ of\ farmer\ will\ be$

$equal\ to\ 10\sqrt{2}\ m\ north\ eastfrom\ initial\ position.$

Question : 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.

Answer: None

Question : 4 - Distinguish between speed and velocity.

Answer:

Speed has only magnitude while velocity has both magnitude and direction.

Question : 5 - Under what condition(s) is the magnitude of average velocity of an object equal to its average speed?

Answer: The magnitude of average velocity of an object will be equal to its average speed in the condition of uniform velocity.

Question : 6 - What does the odometer of an automobile measure?

Answer: In automobiles, odometer is used to measure the distance.

Question : 7 - What does the path of an object look like when it is in uniform motion?

Answer: In the case of uniform motion the path of an object will look like a straight line.

Solution of In Text Questions - 2

Question :- 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}.

Answer:-

$$Here\ we\ have, speed = 3 \times 10^8\ ms^{-1}$$

$$Time = 5\ minute = 5 \times 60\ s = 300\ second$$

$$We\ know\ that, Distance = Speed\ \times Time$$

$$\Rightarrow Distance = 3 \times 10^8\ ms^{-1} \times 300s = 1800\ \times 10^8 m = 1.8 \times 10^{11} m$$

Question : 9 - When will you say a body is in

(i) uniform acceleration?

(ii) non-uniform acceleration?

Answer:

(i) A body is said in uniform acceleration when its motion is along a straight line and its velocity changes by equal magnitude in equal interval of time.

(ii)A body is said in non-uniform acceleration when its motion is along a straight line and its velocity changes by unequal magnitude in equal interval of time.

Question : 10 - A bus decreases its speed from 80 km/h to 60 km/h in 5 s. Find the acceleration of the bus.

Answer:

$$Here\ we\ have,\ \ u = 80km/h,\ \ v = 60km/h,\ \ t = 5s$$
$$Therefore, acceleration, a = ?$$
$$We\ know\ that,\qquad v = u + at$$
$$\Rightarrow 60km/h = 80km/h + a \times 5s$$
$$\Rightarrow 60km/h - 80km/h = a \times 5s$$
$$\Rightarrow -20km/h = a \times 5s$$
$$\Rightarrow a = -\frac{20km/h}{5s}$$
$$\Rightarrow a = -4km/h/s$$
$$Therefore, Acceleration = -4km/h/s\ \ or, -1.1\ m/s^2$$

Question : 11 - A train starting from a railway station and moving with uniform acceleration attains a speed of 40 km/h in 10 minutes. Find its acceleration.

Answer:

Here we have,

Initial velocity, u = 0,

Final velocity, v = 40km/h = 11.11m/s

Time (t) = 10 minute = 60x10=600s

Acceleration (a) =?

$$We\ know\ that,\qquad v = u + at$$
$$\Rightarrow 40km/h = 0km/h + a \times 10m$$
$$\Rightarrow 11.11m/s = a \times 600s$$
$$\Rightarrow a = \frac{11.11m/s}{600s} = 0.0185\ m/s^2$$

Question : 12 - What is the nature of the distance-time graphs for uniform and non-uniform motion of an object?

Answer:

(a) The slope of the distance-time graph for an object in uniform motion is straight line.

(b) The slope of the distance-time graph for an object in non-uniform motion is not a straight line.

Question : 13 - What can you say about the motion of an object whose distance-time graph is a straight line parallel to the time axis?

Answer:

When the slope of distance-time graph is a straight line parallel to time axis, the object is moving with uniform motion.

Question : 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?

Answer:

When the slope of a speed time graph is a straight line parallel to the time axis, the object is moving with uniform speed.

Solution of In Text Questions - 3

Question : 15 - What is the quantity which is measured by the area occupied below the velocity-time graph?

Answer:-

The quantity of distance is measured by the area occupied below the velocity time graph.

Question :- 16 - A bus starting from rest moves with a uniform acceleration of 0.1 m s^{-2} for 2 minutes. Find (a)the speed acquired, (b) the distance travelled.

Answer:

Here we have,

Initial velocity (u) = 0

Acceleration (a) = 0.1ms-2

Time (t) = 2 minute = 120 second

(a) The speed acquired:

We know that, v = u + at

⇒ v = 0 + 0.1m/s2 x 120 s

⇒ v = 120 m/s

Thus, the bus will acquire a speed of 120 m/s after 2 minute with the given acceleration.

(b) The distance travelled:

$$We\ know\ that,\ s = ut + \frac{1}{2}at^2$$

$$= 0 \times 120\ s + \frac{1}{2} \times 0.1 m/s^2 \times (120s)^2$$

$$= \frac{1}{2} \times 14400m = 7200\ m\ or\ 7.2\ km$$

Thus, bus will tavel a distance of 7200 m or 7.2 km in the given time of 2 minute.

Question : 17 - A train is travelling at a speed of 90 km/h. Brakes are applied so as to produce a uniform acceleration of – 0.5 m s^{-2}. Find how far the train will go before it is brought to rest.

Answer:

Here,we have,

$$Initial\ velocity, u = 90km/h\ = \frac{90 \times 1000\ m}{60 \times 60\ s} = 25\ m/s$$

$$Final\ velocity, v = 0$$

$$Acceleration, a = -0.5\ m/s^2$$

Therefore, distance travelled =?

$$We\ know\ tha,\quad v^2 = u^2 + 2as$$

$$\Rightarrow 0 = (25m/s)^2 + 2 \times -0.5m/s^2 \times s$$

$$\Rightarrow 0 = 625\ m^2\ s^{-2} - 1m\ s^{-2}\ s$$

$$\Rightarrow 1m\ s^{-2}\ s = 625\ m^2\ s^{-2}$$

$$s = \frac{625\ m^2\ s^{-2}}{1m\ s^{-2}} = 625\ m$$

Therefore, train will go 625 m before it brought to rest.

Question : 18 - A trolley, while going down an inclined plane, has an acceleration of 2 cm s^{-2}. What will be its velocity 3 s after the start?

Answer:

Here we have,

Initial velocity, u = 0

Acceleration (a) = 2cm/s^2 = 0.02m/s^2

Time (t) = 3s

Therefore, Final velocity, v =?

$$We\ know\ that, v = u + at$$
$$Therefore, \quad v = 0 + 0.02m/s^2 \times 3s$$
$$\Rightarrow v = 0.06m/s$$
$$Therefore\ the\ final\ velocity\ of\ trolley\ will\ be\ 0.06\ m/s\ \ after\ start.$$

Question : 19 - A racing car has a uniform acceleration of 4 m s^{-2}. What distance will it cover in 10 s after start?

Answer:

Here we have,

Acceleration, a = 4m/s2

Initial velocity, u =0

Time, t = 10s

Therefore, Distance (s) covered =?

$$We\ know\ that, \quad s = ut + \frac{1}{2}at^2$$
$$\Rightarrow s = 0\ \times 10s + \frac{1}{2} \times 4m/s^2 \times (10s)^2$$
$$\Rightarrow s = \frac{1}{2} \times 4m/s^2 \times 100\ s^2$$
$$\Rightarrow s = 2\ \times 100\ m = 200\ m$$

Thus, racing car will cover a distance of 200m after start in 10 s with given acceleration.

Question : 20 - A stone is thrown in a vertically upward direction with a velocity of 5 m s^{-1}. If the acceleration of the stone during its motion is 10 m s^{-2} in the downward direction, what will be the height attained by the stone and how much time will it take to reach there?

Answer:

Here we have,

Initial velocity (u) = 5m/s

Final velocity (v) =0 (Since from where stone starts falling its velocity will become zero)

Acceleration (a) = $-10m/s^2$

(Since given acceleration is in downward direction, i.e. the velocity of the stone is decreasing, thus acceleration is taken as negative)

Height, i.e. Distance, s =?

Time (t) taken to reach the height =?

$$We\ know\ that, \quad v^2 = u^2 + 2as$$
$$\Rightarrow 0 = (5m/s)^2 + 2 \times -10m/s^2 \times s$$
$$\Rightarrow 0 = 25m^2s^2 - 20\ m/s^2\ \times s$$
$$\Rightarrow 20\ m/s^2\ \times s\ = 25m^2s^2$$
$$s = \frac{25m^2s^2}{20\ m/s^2}$$
$$\Rightarrow s = 1.25\ m$$
$$Now, we\ know\ that, v = u + at$$
$$\Rightarrow 0 = 5\ m\ s^{-1} + (-10m\ s^{-2})\ \times t$$
$$\Rightarrow 0 = 5\ m\ s^{-1} - 10m\ s^{-2}\ \times t$$
$$\Rightarrow 10m\ s^{-2}\ \times t\ =\ 5\ m\ s^{-1}$$
$$\Rightarrow t = \frac{5\ m\ s^{-1}}{10m\ s^{-2}} = \frac{1}{2}\ s = 0.5\ s$$
$$Thus, stone\ will\ attain\ a\ height\ of\ 1.25\ m$$
$$And\ time\ taken\ to\ attain\ the\ height\ is\ 0.5s$$

Solution of NCERT Exercise (Part 1)

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?

Answer:-

Here we have,

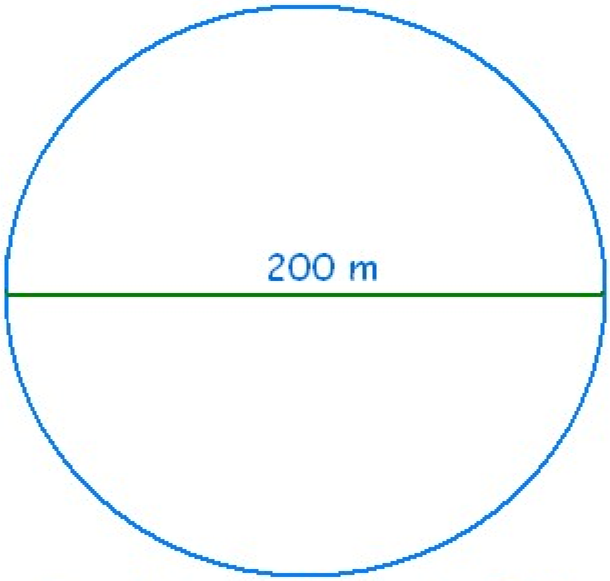
Diameter = 200 m, therefore, radius = 200m/2 = 100 m

Time of one rotation = 40s

Time after 2m20s = 2 x 60s + 20s = 140s

Distance after 140 s = ?

Displacement after 140s =?



Circular track with diameter of 200 m

$$We\ know\ that,\ velocity\ along\ a\ circular\ path = \frac{Circumference}{time}$$

$$\Rightarrow v = \frac{2\pi r}{40s}$$

$$\Rightarrow v = \frac{2 \times 3.14 \times 100m}{40s}$$

$$\Rightarrow v = \frac{628}{40}\frac{m}{s} = 15.7m/s$$

(a) Distance after 140s

We know that,distance=velocity ×time

⇒distance=15.7m/s ×140 s = 2198 m

(b) Displacement after 2 m 20 s i.e. in 140 s

Since,rotatin in 40 s=1

$$Therefore, rotation\ in\ 1\ s = \frac{1}{40}$$

$$Therefore, rotation\ in\ 140\ s = \frac{1}{40} \times 140 = 3.5$$

Therefore, in 3.5 rotations athlete will be just at the opposite side of the circular track, i.e. at a distance equal to the diameter of the circular track which is equal to 200 m.

Therefore,

Distance covered in 2 m 20 s = 2198 m

And, displacement after 2 m 20 s = 200m

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?

Answer:-

Here we have,

Distance from point A to B = 300 m

Time taken = 2 minute 30 second = 2 x 60 + 30 s = 150 s

Distance from point B to C = 100 m

Time taken = 1 minute = 60 s

(a) Average speed and velocity from point A to B

$$\text{We know that average speed} = \frac{\text{Total distance}}{\text{Time taken}}$$
$$\Rightarrow \text{Average speed} = \frac{300m}{150s} = 2\ m/s$$
$$\text{Therefore, velocity} = 2\ m/s\ \text{east}$$

(b) Average speed and velocity from B to C

$$\text{We know that average speed} = \frac{\text{Total distance}}{\text{Time taken}}$$
$$\Rightarrow \text{Average Speed} = \frac{100\ m}{60\ s} = 1.66 m/s$$

Therefore,average velocity=1.66 m/s west

3. Abdul, while driving to school, computes the average speed for his trip to be 20 km/h. On his return trip along the same route, there is less traffic and the average speed is 30 km/h. What is the average speed for Abdul's trip?

Answer:

Strategy: We need to calculate the time taken in each of the trip. After that, we can calculate the average speed.

Let the distance of the school = s km

Let time to reach the school in first trip = t_1

Let time to reach the school in second trip = t_2

$$We\ know\ that, Average\ speed = \frac{Total\ distance}{Total\ time\ taken}$$

$$Therefore, Average\ speed\ in\ first\ trip = \frac{s}{t_1}$$

$$\Rightarrow 20km/h = \frac{s}{t_1} \qquad \Rightarrow t_1 = \frac{s}{20}h$$

$$Therefore, Average\ speed\ in\ second\ trip = \frac{s}{t_2}$$

$$\Rightarrow 30km/h = \frac{s}{t_2} \qquad \Rightarrow t_2 = \frac{s}{30}h$$

$$Now, total\ time\ (t_1 + t_2) = \frac{s}{20} + \frac{s}{30}$$

$$\Rightarrow (t_1 + t_2) = \frac{3s + 2s}{60}h = \frac{5s}{60}h = \frac{s}{12}h$$

$$Now, average\ speed\ while\ both\ of\ trip = \frac{Total\ distance\ covered}{Total\ time\ taken}$$

$$= \frac{2s}{\frac{s}{12}}km/h \qquad = \frac{2s \times 12}{s}km/h \qquad = 24km/h$$

Therefore, average speed of Adbul = 24 km/h

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?

Answer:

Here we have,

Initial velocity (u) = 0

Acceleration (a) = 3.0m/s^2

Time = 8 s

Therefore, distance (s) covered =?

$$\text{We know that,} \quad s = ut + \frac{1}{2}at^2$$

$$\Rightarrow s = 0 \times 8 + \frac{1}{2} 3m/s^2 \times (8s)^2$$

$$\Rightarrow s = \frac{1}{2} \times 3 \times 64\ m$$

$$\Rightarrow s = 3 \times 32\ m$$

$$\Rightarrow s = 96m$$

Therefore, boat travel a distance of 96 m in the given time.

5. A driver of a car travelling at 52 km/h applies the brakes and accelerates uniformly in the opposite direction. The car stops in 5 s. Another driver going at 3 km/h 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?

Answer:

Given for first driver,

$Initial\ velocity, u = 52\ km\ h^{-1} = \frac{52 \times 1000\ m}{60 \times 60\ s} = 14.4\ m\ s^{-1}$

$Time, t = 5\ s$

$Final\ velocity, v = 0\ (Since\ car\ stops)$

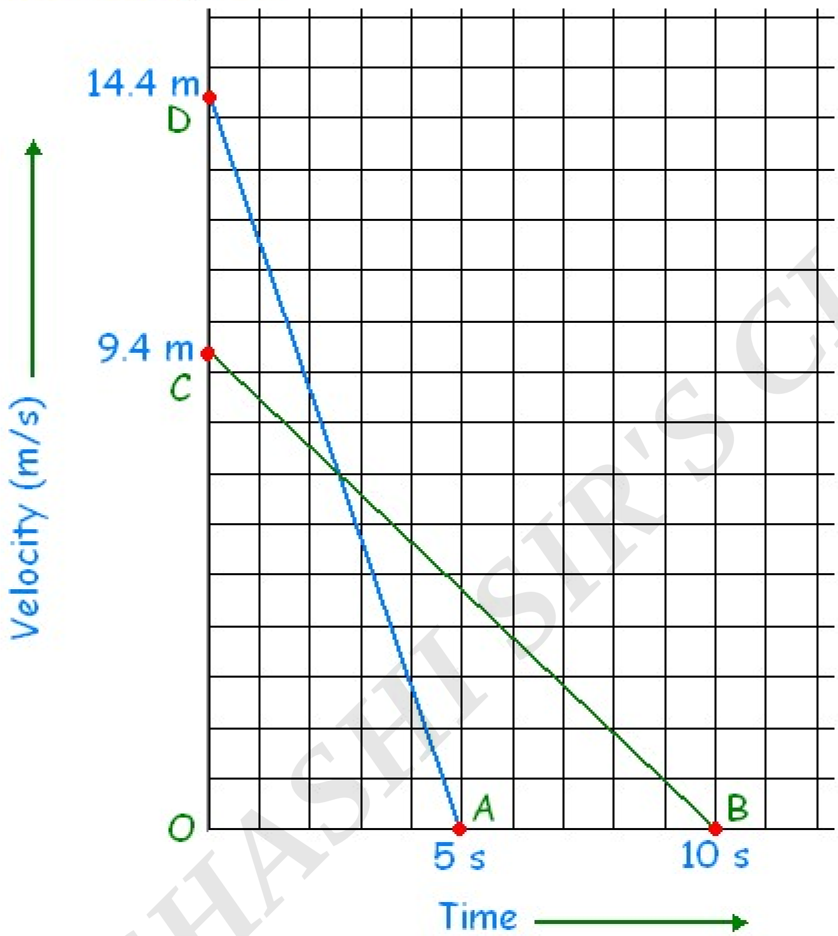
$Therefore, distance, s = ?$

$Given\ for\ second\ driver,$

$Initial\ velocity, u = 3\ km\ h^{-1} = \frac{3000\ m}{60 \times 60 s} = 9.4\ m\ s^{-1}$

$Time, t = 10\ s$

$Final\ velocity, v = 0$



In the graph, blue slope shows the velocity of the first car and green slope shows the velocity of the second car.

Distance is calculated by the area under the slope of the graph.

Thus, distance covered by 1st car = Area of ΔOAD

$$\Rightarrow Distance, s = \frac{1}{2} \times OD \times OA$$

$$\Rightarrow s = \frac{1}{2} \times 14.4\, m/s \times 5s = 7.2\, m/s \times 5s = 36m$$

Thus, distance covered by 2nd car = Area of ΔOBC

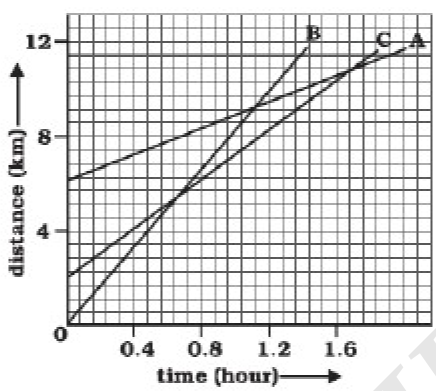
$$\Rightarrow Distance, s = \frac{1}{2} \times OC \times OB$$

$$\Rightarrow s = \frac{1}{2} \times 9.4\, m/s \times 10s = 4.7\, m/s \times 10s = 47m$$

Therefore, 2nd car travelled farther

Solution of NCERT Exercise (Part 2)

6. Fig 8.11 shows the distance-time graph of three objects A,B and C. Study the graph and answer the following questions:



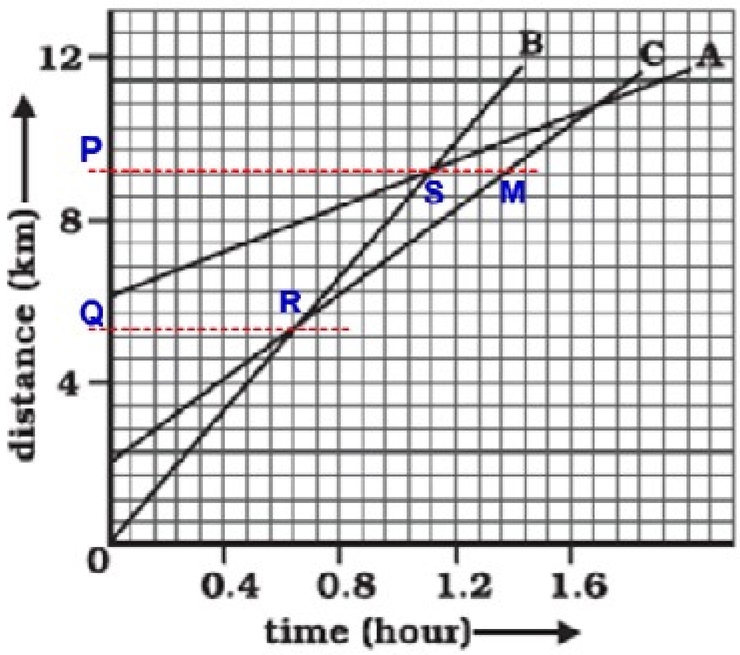
(a) Which of the three is travelling the fastest?

(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?

Answer:-



(a) It is clear from graph that B covers more distance in less time. Therefore, B is the fastest.

(b) All of them never come at the same point at the same time.

(c) According to graph; each small division shows about 0.57 km.

A is passing B at point S which is in line with point P (on the distance axis) and shows about 9.14 km

Thus, at this point C travels about

9.14 – (0.57 x 3.75) km = 9.14 km – 2.1375 km = 7.0025 km ≈ 7 km

Thus, when A passes B, C travels about 7 km.

(d) B passes C at point Q at the distance axis which is ≈ 4km + 0.57km x 2.25 = 5.28 km

Therefore, B travelled about 5.28 km when passes to 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?

Answer:-

Here we have,

Initial velocity,u=0

Distance,s=20m

Acceleration,a= 10 m s^{-2}

Final velocity,v=?

Time,t= ?

(a) Calculation of Final velocity, v

We know that, $v^2 = u^2 + 2as$

$\Rightarrow v^2 = 0 + 2 \times 10m/s^2 \times 20m$

$\Rightarrow v^2 = 400\ m^2s^{-2}$

$\Rightarrow v = \sqrt{400m^2s^{-2}}$

$\Rightarrow v = 20m\ s^{-1}$

(b) Calculation of time, t

We know that, $v = u + at$

$\Rightarrow 20m\ s^{-1} = 0 + 10\ m\ s^{-2} \times t$

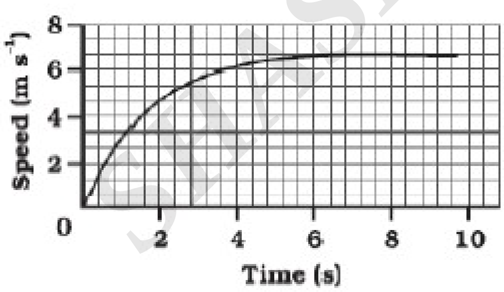
$$\Rightarrow t = \frac{20m\ s^{-1}}{10\ m\ s^{-2}} = 2\ s$$

Therefore,

Ball will strike the ground at the velocity of $20m\ s^{-1}$

Time taken to reach at the ground $= 2\ s$

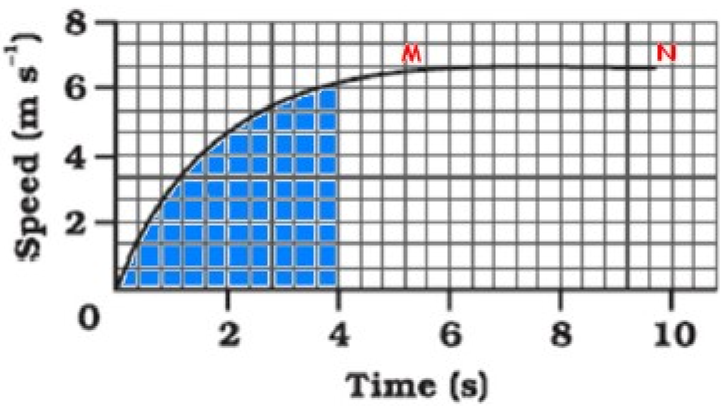
8. The speed-time graph for a car is shown is Fig. 8.12.



(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?

Answer:



(a) Distance travelled by car in the 4 second

The area under the slope of the speed – time graph gives the distance travelled by an object.

In the given graph

56 full squares and 12 half squares come under the area slope for the time of 4 second.

Total number of squares = 56 + 12/2 = 62 squares

The total area of the squares will give the distance travelled by the car in 4 second.

$$On\ the\ time\ axis, 5\ squares = 2s$$
$$Therefore, 1\ square = \frac{2}{5}s$$
$$On\ the\ speed\ axis\ 3\ squares = 2\ m/s$$
$$Therefore, 1\ square = \frac{2}{3}\ m/s$$
$$Thus, area\ of\ 1\ square = \frac{2}{5}s \times \frac{2}{3}\ m/s = \frac{4}{15}\ m$$
$$Therefore, area\ of\ 62\ squares = \frac{4}{15}\ m \times 62$$
$$= \frac{248}{15}\ m = 16.53\ m$$
$$Therefore, car\ travels\ 16.53\ m\ in\ first\ 4\ second.$$

(b) Part MN of the slope of the graph is straight line parallel to the time axis, thus this potion of graph represents uniform motion of 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.

Answer:

(a) The term acceleration implies that the velocity of the object is changing; inspite of that constant acceleration with zero velocity is impossible. When an object is thrown in upward direction, at the maximum height the velocity of the object becomes zero but still in that condition a constant acceleration due to gravity is working.

(b) Object moving in a certain direction with an acceleration in perpendicular direction is possible; in case of circular motion. When an object moves on a circular path, its direction is along the tangent of the circle but acceleration is towards the radius of the circle. We know, that a tangent always makes a right angle with the radius; so when an object is in circular motion, the acceleration and velocity are in mutually 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.

Answer:

Here we have,

Radius, r = 42250km

Time, t = 24 hours

Speed =?

$$We\ know\ that\ velocity\ along\ a\ circular\ path = \frac{2\pi r}{time}$$

$$\Rightarrow v = \frac{2 \times \frac{22}{7} \times 42250\ km}{24\ h}$$

$$\Rightarrow v = \frac{2 \times 22 \times 42250}{7 \times 24}\ km/h$$

$$\Rightarrow v = 11065.47\ km/h$$

$$Thus, speed\ of\ the\ given\ staelline = 11065.47\ km/h$$