Motion

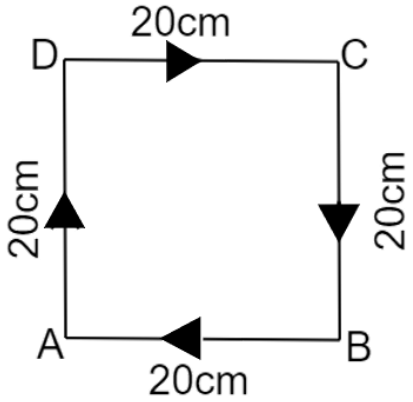
7 Chapter

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

Ans: Yes. An object can have zero displacement if it has moved through a distance. Displacement is defined as the shortest distance from the initial point to the final point.

Hence, if the starting (initial) point is the same as the final point then the displacement of the object is zero.

Suppose a man is walking in a square park of length 20m. He starts from point A and walks along all the corners of the park through points B, C and D and comes back to the same point A.



The total distance covered by the man $= 20\text{m} + 20\text{m} + 20\text{m} + 20\text{m} = 80\text{m}$.

As the starting point and final point are same, the shortest distance between his initial and final position is zero

Therefore, the displacement is zero.

2. A farmer moves along the boundary of a square field of side 10m in 40s .What will be the magnitude of displacement of the farmer at the end of 2 minutes 20 seconds?

Ans: It is given that,

Farmer takes 40s to cover a square field of side 10m.

$\Rightarrow \text{Distance} = 4 \times 10 = 40\text{m}$

It is known that, $\text{Speed} = \dfrac{\text{Distance}}{\text{Time}}$

$\Rightarrow \text{Speed} = \dfrac{40}{40} = 1$

Therefore, speed of the farmer is 1m/s.

In 2 minutes 20 seconds distance travelled is $\text{Speed} \times \text{Time}$.

$\Rightarrow \text{Distance} = 1 \times (2 \times 60 + 20)$

$\Rightarrow \text{Distance} = 140\text{m}$

Number of rounds farmer covered $= \dfrac{140}{40} = 3.5$

After 2 minutes 20 seconds the farmer will be at the opposite end of starting point, completing 3 and half rounds.

a) If the farmer starts from any corner of the field: The displacement will be equal to the diagonal of the field.

$\Rightarrow \text{Displacement} = \sqrt{10^2 + 10^2} = 14.14\text{m}$

b) If the farmer starts from the middle point of any side of the field: The final point will be the middle point of the side opposite to the initial point.

$\Rightarrow \text{Displacement} = 10\text{m}$

Therefore, the magnitude of displacement if the farmer starts at any corner is 14.14m and if the farmer starts from middle point of any side is 10m.

3. Which of the following is true for displacement?

a) It cannot be zero.

Ans: Not true. When the initial and final position of the object is the same, then the displacement is zero.

b) Its magnitude is greater than the distance travelled by the object.

Ans: Not true. Displacement is the measure of the shortest distance between initial and final position of an object.

Therefore, it is always smaller than or equal to the magnitude of distance travelled by the object.

4. Distinguish between speed and velocity.

Ans: The differences between speed and velocity are as follows:

Speed	Velocity
a) The distance travelled by an object in a given interval of time is speed. b) Speed does not have any direction. c) Speed is either positive or zero but not negative.	a) The displacement of an object in a given interval of time is velocity. b) Velocity has a unique direction. c) Velocity can be negative, positive or zero.

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

Ans: It is known that,

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

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

Therefore, the magnitude of average velocity of an object is equal to its average speed when total distance covered is equal to the displacement.

6. What does the odometer of an automobile measure?
Ans: The distance covered by an automobile is recorded by the odometer of an automobile.

7. What does the path of an object look like when it is in uniform motion?
Ans: An object has a straight-line path 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, $3\times10^{8}\,\text{ms}^{-1}$**.**
Ans: It is given that,
Time taken by a signal to reach ground from a spaceship $=5\,\text{min}=5\times60=300\,\text{sec}$
Speed of the signal is equal to speed of light $=3\times10^{8}\,\text{ms}^{-1}$
It is known that,

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

$$\Rightarrow \text{Distance travelled} = \text{Speed}\times\text{Time taken}$$

$$\Rightarrow \text{Distance travelled} = 3\times10^{8}\times300=9\times10^{10}\,\text{m}$$

Therefore, the distance of the spaceship from the ground station is $9\times10^{10}\,\text{m}$.

9. When will you say a body is in

a) uniform acceleration?
Ans: When the magnitude and the direction of acceleration of a body is constant i.e., velocity changes at equal rate then the body is said to be in uniform acceleration.

b) non-uniform acceleration?

Ans: When acceleration of a body changes in magnitude or direction or both i.e., velocity changes at unequal rate then the body is said to be in non-uniform acceleration.

10. A bus decreases its speed from $80kmh^{-1}$ to $60kmh^{-1}$ in $5s$. Find the acceleration of the bus.

Ans: It is given that,

Initial speed of the bus, $u = 80km/h$

$$\Rightarrow u = 80 \times \frac{5}{18} m/s = 22.22m/s$$

Final speed of the bus, $v = 60km/h$

$$\Rightarrow v = 60 \times \frac{5}{18} m/s = 16.66m/s$$

Time taken to decrease speed, $t = 5s$

It is known that,

$$\text{Acceleration}, a = \frac{v-u}{t}$$

$$\Rightarrow a = \frac{16.66 - 22.22}{5}$$

$$\Rightarrow a = -1.112m/s^2$$

Therefore, the acceleration of the bus is $-1.112m/s^2$. The negative sign indicates that the velocity of the car is decreasing. Decreasing acceleration is called retardation.

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

Ans: It is given that,

Initial velocity of the train, $u = 0$ (Train is starting from rest)

Final velocity of the train, $v = 40km/h$

$$\Rightarrow v = 40 \times \frac{5}{18} m/s = 11.11m/s$$

Time taken, $t = 10 \times 60 = 600s$

It is known that,

$$\text{Acceleration, } a = \frac{v - u}{t}$$

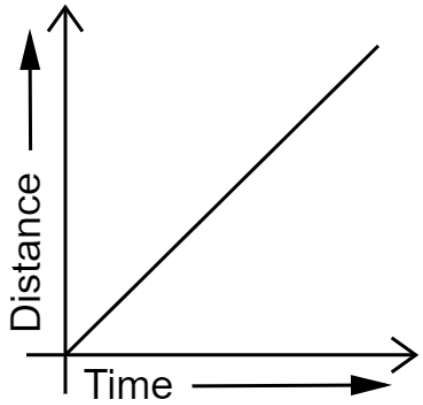
$$\Rightarrow a = \frac{11.11 - 0}{600}$$

$$\Rightarrow a = 0.0185 m/s^2$$

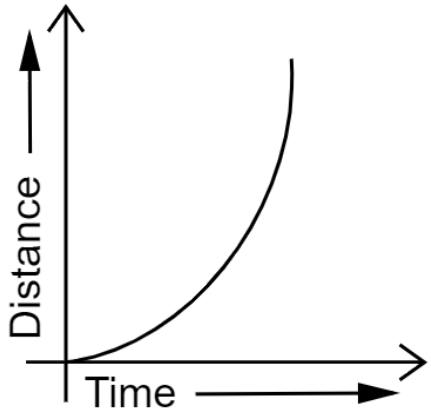
Therefore, the acceleration of the train is $0.0185 m/s^2$.

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

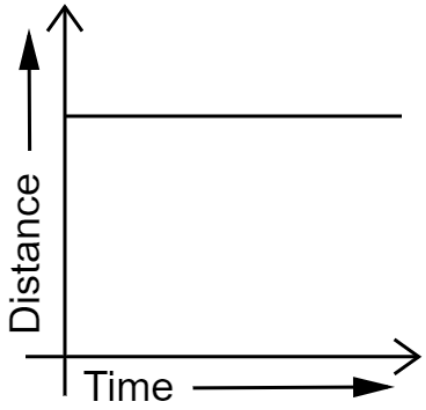
Ans: The distance-time graph for uniform motion of an object is a straight line.



The distance-time graph for non-uniform motion of an object is a curved line.

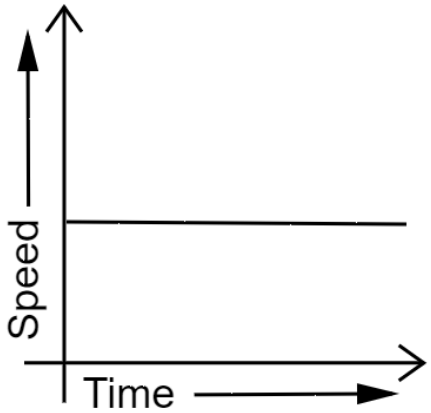


13. What can you say about the motion of an object whose distance-time graph is a straight line parallel to the time axis?
Ans: A straight line parallel to the x-axis in a distance-time graph indicates that the position of the object does not change with time.



Therefore, the object is said to be at rest.

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?
Ans: A straight line parallel to the time axis in a speed-time graph indicates that the speed of the object does not change with time.

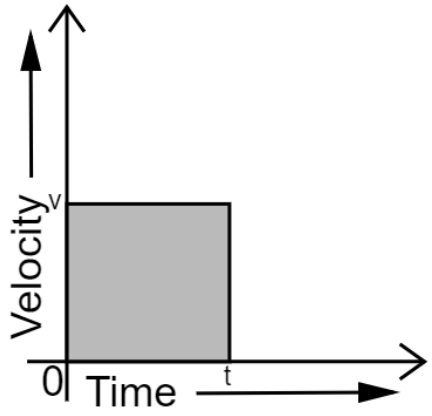


Therefore, the object is moving uniformly.

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

Ans: The area of the velocity-time graph is displacement.

Consider the following figure which shows the velocity-time graph of a uniformly moving body.



Let, the velocity of the body at time t be v.

Area of the shaded region $=$ Length $\times$ Breadth

Where,

$\text{Length} = l$

$\text{Breadth} = v$

$\Rightarrow \text{Area} = vt = \text{velocity} \times \text{time} \quad \ldots\ldots (1)$

It is known that,

$$\text{Velocity} = \frac{\text{Displacement}}{\text{time}}$$

$\Rightarrow \text{Displacement} = \text{Velocity} \times \text{Time} \quad \ldots\ldots (2)$

From equations (1) and (2)

$\Rightarrow \text{Area} = \text{Displacement}$

Hence, the area occupied below the velocity-time graph measures the displacement of the body.

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

Ans: It is given that,

Initial velocity of the bus, $u = 0$ (Bus is starting from rest)

Acceleration of bus, $a = 0.1 m/s^2$

Time taken, $t = 2 min = 120 sec$

Final velocity of the bus, $v = ?$

It is known that,

$$\text{Acceleration}, a = \frac{v - u}{t}$$

$$\Rightarrow 0.1 = \frac{v - 0}{120}$$

$$\Rightarrow v = 12 m/s$$

Therefore, the speed acquired is $v = 12 m/s$.

b) the distance travelled

Ans: It is known that,

From, third equation of motion: $v^2 - u^2 = 2as$

$$\Rightarrow (12)^2 - (0)^2 = 2 \times (0.1) \times s$$

$$\Rightarrow 144 = 0.2s$$

$$\Rightarrow s = 720 m$$

Therefore, the distance travelled is $s = 720 m$.

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.

Ans: It is given that,

Initial speed of a train, $u = 90 km/h$

$$\Rightarrow u = 90 \times \frac{5}{18} = 25 m/s$$

Final speed of the train, $v = 0$ (Train comes to rest finally)

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

Distance covered by the train, $s = ?$

It is known that,

From, third equation of motion: $v^2 - u^2 = 2as$

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

$\Rightarrow -625 = -s$
$\Rightarrow s = 625m$
Therefore, the train covers a distance of $625m$ before it comes to rest.

18. A trolley, while going down an inclined plane, has an acceleration of $2cm/s^2$. What will be its velocity $3s$ after the start?
Ans: It is given that,
Initial velocity of the trolley, $u = 0$ (Trolley is starting from rest)
Acceleration of the trolley, $a = 2cm/s^2 = 0.02m/s^2$
Time taken, $t = 3s$
Final velocity (after $3s$ of start) of the trolley, $v = ?$
It is known that,
From, first equation of motion: $v = u + at$
$\Rightarrow v = 0 + 0.02(3)$
$\Rightarrow v = 0.06m/s$
Thus, the velocity of the trolley is $0.06m/s$ after $3s$ from the start.

19. A racing car has a uniform acceleration of $4ms^{-2}$. What distance will it cover in $10s$ after start?
Ans: It is given that,
Initial velocity of the racing car, $u = 0$ (The racing car is initially at rest)
Acceleration of a racing car, $a = 4m/s^2$
Time taken, $t = 10s$
It is known that,
From, second equation of motion: $s = ut + \frac{1}{2}at^2$
$\Rightarrow s = 0 + \frac{1}{2}(4)(10)^2$
$\Rightarrow s = 200m$
Therefore, the distance covered by racing car after $10s$ from start is $200m$.

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

Initial velocity of the stone, $u = 5m/s$
Final velocity, $v = 0$ (Stone comes to rest after reaching maximum height)
Acceleration of the stone is equal to acceleration due to gravity, $a = -10m/s^2$ (Negative sign because of downward direction)
Maximum height reached by the stone, $s = ?$
It is known that,
From, first equation of motion: $v = u + at$
$\Rightarrow 0 = 5 + (-10)t$
$\Rightarrow 5 = 10t$
$\Rightarrow t = 0.5s$
From, third equation of motion: $v^2 - u^2 = 2as$
$\Rightarrow (0)^2 - (5)^2 = 2(-10)s$
$\Rightarrow -25 = -20s$
$\Rightarrow s = 1.25m$
Therefore, the height attained by the stone is $1.25m$ in $0.5s$.

21. An athlete completes one round of a circular track of diameter 200m in 40s. What will be the distance covered and the displacement at the end of 2 minutes 20s?

Ans: It is given that,
Diameter of a circular track, $d = 200m$
Radius of the circular track, $r = \frac{d}{2}$
$\Rightarrow r = \frac{200}{2} = 100m$
Circumference of the circular track, $c = 2\pi r$
$\Rightarrow c = 2\pi(100) = 200\pi m$
Time taken to cover one round, $t = 40s$
It is known that,
$\text{Speed} = \frac{\text{Distance travelled}}{\text{Time taken}}$
$\Rightarrow \text{Speed} = \frac{200\pi}{40}$
$\Rightarrow \text{Speed} = 50\pi$
Athlete runs for 2 minutes 20 s: Time in seconds $= 120 + 20 = 140s$

Total distance covered in $140\text{s} = \text{Speed} \times \text{Time}$

$$\Rightarrow \text{Distance} = \frac{200 \times 22 \times 140}{40 \times 7} = 2200\text{m}$$

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

Athlete will be diametrically opposite to the point where he started after completing three rounds.

The displacement will be equal to diameter i.e., 200m

Therefore, the distance covered is 2200m and the displacement is 200m at the end of 2 minutes 20 s.

22. Joseph jogs from one end A to the other end B of a straight road of 300m in 2 minutes 50 seconds and then turns around and jogs 100m back to point C in another 1 minute. What are Joseph's average speeds and velocities in jogging

a) from A to B

Ans: It is given that,

Distance from A to $\text{B} = 300\text{m}$

Time taken from A to $\text{B} \quad = 2\text{min}\,50\text{sec} = 170\text{sec}$

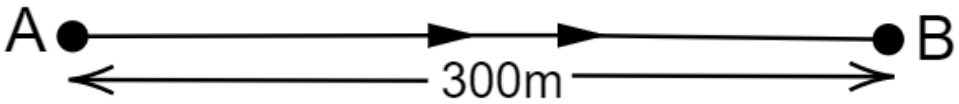


Image source: Self-created

It is known that,

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

$$\Rightarrow \text{Average speed} = \frac{300}{170} = 1.765\text{m/s}$$

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

Displacement from A to $\text{B} = \text{Distance} = 300\text{m}$

$$\text{Average velocity} = \frac{300}{170} = 1.765\text{m/s}$$

Therefore, the average speed and average velocity of Joseph from A to B are same and is equal to 1.765m/s.

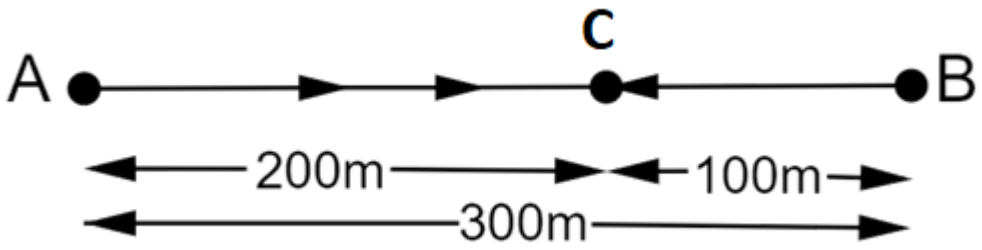
b) from A to C?

Ans: It is given that,

Distance from A to B $= 300\text{m}$

Distance from B to C $= 100\text{m}$

Total distance from A to C $= 300 + 100 = 400\text{m}$



Time taken from A to B $= 2\text{min}\,50\text{sec} = 170\text{sec}$

Time taken from B to C $= 1\text{min} = 60\text{sec}$

Total time taken from A to C $= 170 + 60 = 230\text{sec}$

It is known that,

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

$$\Rightarrow \text{Average speed} = \frac{400}{230} = 1.739\text{m/s}$$

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

Displacement from A to C $= \text{AB} - \text{BC} = 300 - 100 = 200\text{m}$

$$\text{Average velocity} = \frac{200}{230} = 0.87\text{m/s}$$

Therefore, the average speed and average velocity of Joseph from A to C are 1.739m/s and 0.87m/s respectively.

23. Abdul, while driving to school, computes the average speed for his trip to be 20kmh^{-1}. On his return trip along the same route, there is less traffic and the average speed is 40kmh^{-1}. What is the average speed for Abdul's trip?

Ans: It is given that,

Average speed of Abdul's trip $= 20\text{km/h}$

Let, the distance travelled by Abdul to reach school and to return home be d.

Case 1: While driving to school

Let, total time taken be t_1.

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

$$\Rightarrow 20 = \frac{d}{t_1}$$

$$\Rightarrow t_1 = \frac{d}{20} \quad \ldots\ldots (1)$$

Case 2: While returning from school

Let, total time taken be t_2.

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

$$\Rightarrow 40 = \frac{d}{t_2}$$

$$\Rightarrow t_2 = \frac{d}{40} \quad \ldots\ldots (2)$$

$$\text{Average speed for Abdul's trip} = \frac{\text{Total distance covered in the trip}}{\text{Total time taken}}$$

Where,

Total distance covered in the trip $= d + d = 2d$

Total time taken $= t_1 + t_2$

Substitute equation (1) and (2) in total time taken

$$\text{Total time taken} = \frac{d}{20} + \frac{d}{40}$$

$$\Rightarrow \text{Average speed} = \frac{2d}{\frac{d}{20} + \frac{d}{40}}$$

$$\Rightarrow \text{Average speed} = \frac{2}{\frac{2+1}{40}} = \frac{80}{3}$$

$$\Rightarrow \text{Average speed} = 26.67 m/s$$

Therefore, the average speed for Abdul's trip is $26.67 m/s$.

24. 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?

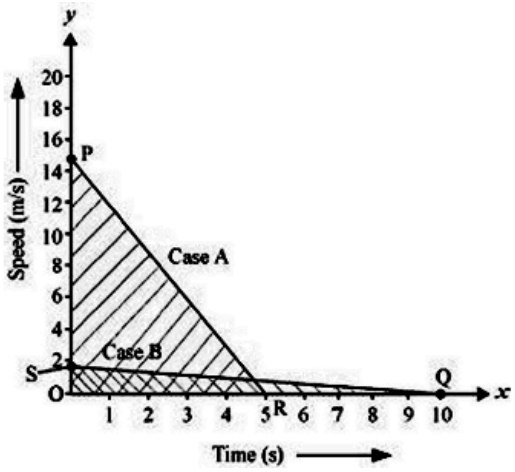
Ans: It is given that,
Initial velocity of the motorboat, $u = 0$ (Motor boat is initially at rest)
Acceleration of the motorboat, $a = 3m/s^2$
Time taken, $t = 8s$
Distance travelled by the motorboat, $s = ?$
It is known that,
From, second equation of motion: $s = ut + \frac{1}{2}at^2$

$\Rightarrow s = 0 + \frac{1}{2}(3)(8)^2$
$\Rightarrow s = (3)(8)(4)$
$\Rightarrow s = 96m$
Therefore, the boat travels a distance of $96m$.

25. A driver of a car travelling at $52kmh^{-1}$ applies the brakes and accelerates uniformly in the opposite direction. The car stops in 5 s. Another driver going at $3kmh^{-1}$ in another car applies his brakes slowly and stops in 10s. 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?
Ans: Car A: Initial speed of the car, $u_A = 52km/h$

$\Rightarrow u_A = 52 \times \frac{5}{18} = 14.4m/s$
Time taken for the car to stop, $t_A = 5s$
Final speed of the car becomes zero after $5s$ application of brakes.
Car B: Initial speed of the car, $u_B = 3km/h$

$\Rightarrow u_B = 3 \times \frac{5}{18} = 0.833m/s$
Time taken for the car to stop, $t_B = 10s$
Final speed of the car becomes zero after $10s$ application of brakes.
Plot of the two cars on a speed-time graph is shown below:



the brakes and accelerates uniformly opposite direction

Distance covered by each car is equal to the area under the speed-time graph.

Distance covered by car A: $s_A = \frac{1}{2} \times OP \times OR$

$\Rightarrow s_A = \frac{1}{2} \times 14.4 \times 5$

$\Rightarrow s_A = 36\text{m}$

Distance covered by car B: $s_B = \frac{1}{2} \times OS \times OQ$

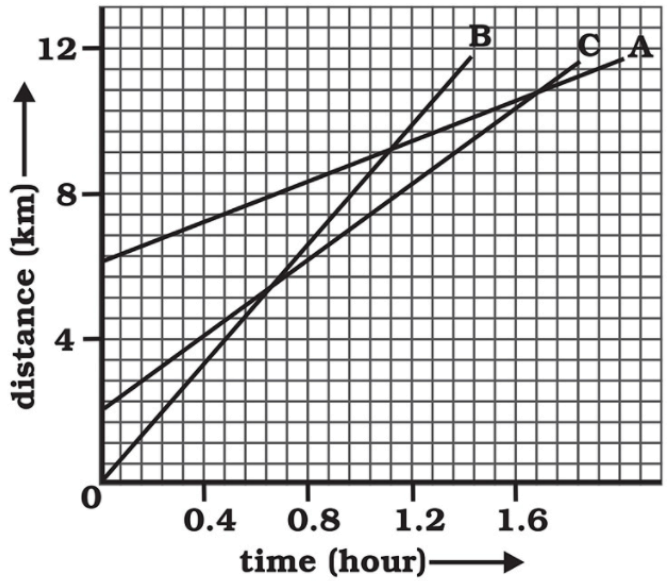
$\Rightarrow s_B = \frac{1}{2} \times 0.83 \times 10$

$\Rightarrow s_B = 4.15\text{m}$

Area of ΔOPR is greater than area of ΔOSQ.

Therefore, the distance covered by car A is greater than the distance covered by car B. Thus, the car travelling with a speed of 52km/h travels farther after the brakes were applied.

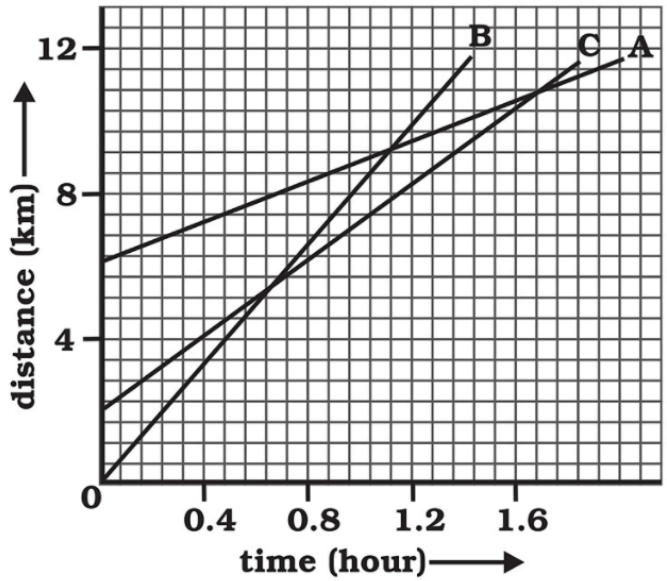
26. The following figure shows the distance-time graph of three objects A, B and C. Study the graph and answer the following:



a) Which of the three is travelling the fastest?

Ans: It is known that,

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



$$\text{Slope of graph} = \frac{\text{y}-\text{axis}}{\text{x}-\text{axis}} = \frac{\text{Distance}}{\text{Time}} = \text{Speed}$$

Slope of the graph of object B is greater than objects A and C.
Therefore, object B is travelling the fastest.

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

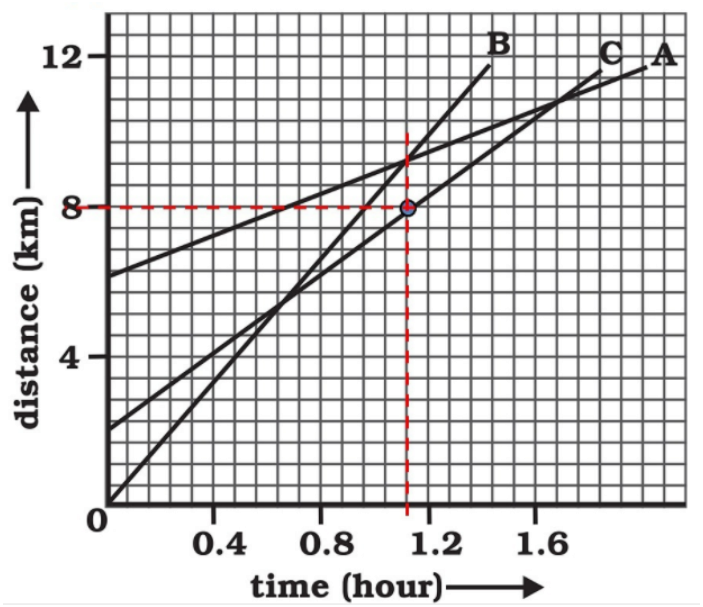
Ans: No, All the three objects A, B and C never meet at the same point.
Therefore, they were never at the same point on the road.

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

Ans: From the graph,

On distance axis: 7 small boxes $= 4\text{km}$

$$\Rightarrow 1 \text{ small box} = \frac{4}{7}\text{km}$$



Initially, object C is 4 blocks away from the origin $\Rightarrow \frac{16}{7}\text{km}$

Distance of object C from origin when B passes A is 8km.

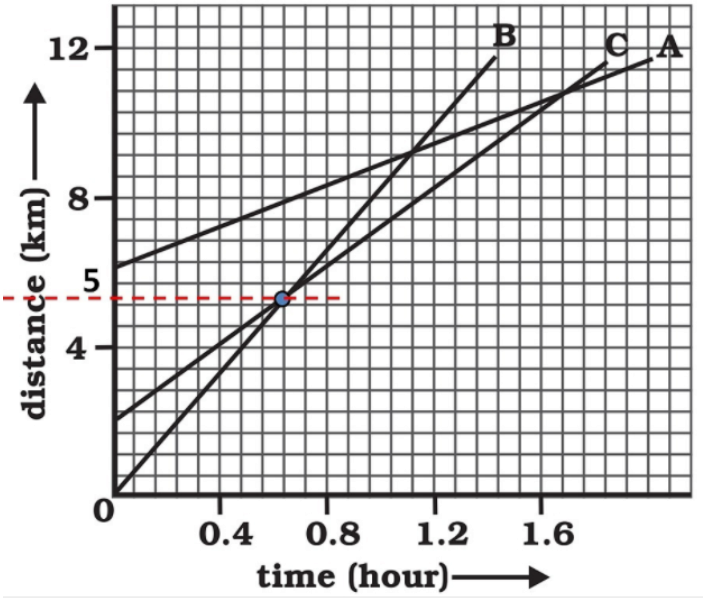
Distance covered by $\text{C} = 8 - \frac{16}{7} = 5.714\text{km}$

Therefore, C has travelled a distance of 5.714km when B passes A.

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

Ans: From the graph,

Distance covered by B at the time it passes C = 9boxes



$\text{Distance} = 9 \times \frac{4}{7} = \frac{36}{7} = 5.143\text{km}$

Therefore, B has travelled a distance of 5.143km when B passes A.

27. A ball is gently dropped from a height of 20m. If its velocity increases uniformly at the rate of 10m/s^2, with what velocity will it strike the ground? After what time will it strike the ground?

Ans: It is given that,

Distance covered by the ball, $s = 20\text{m}$

Acceleration of the ball, $a = 10\text{m/s}^2$

Initial velocity of the ball, $u = 0$ (Ball is initially at rest)

Final velocity of the ball, $v = ?$

Time taken by the ball to strike ground, $t = ?$

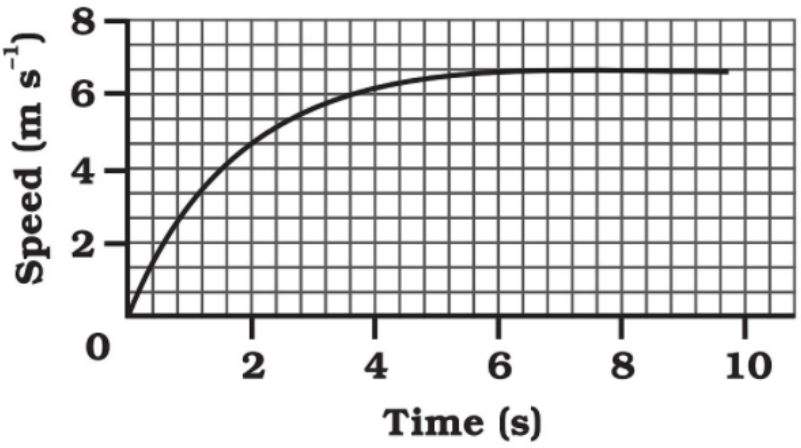
It is known that,

From, third equation of motion: $v^2 - u^2 = 2as$

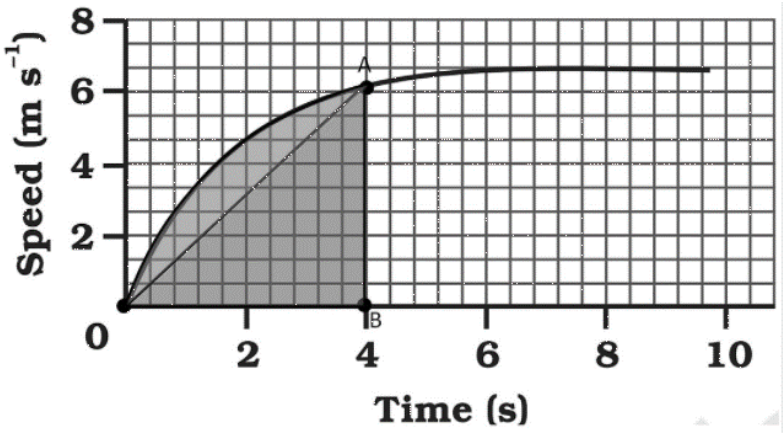
$\Rightarrow (v)^2 - (0)^2 = 2(10)(20)$

$\Rightarrow v^2 = 400$
$\Rightarrow v = 20 m/s$
From, first equation of motion: $v = u + at$
$\Rightarrow 20 = 0 + (10)t$
$\Rightarrow 20 = 10t$
$\Rightarrow t = 2s$
Therefore, the ball strikes the ground after $2s$ with a velocity of $20 m/s$.

28. The speed-time graph for a car is shown as a figure.



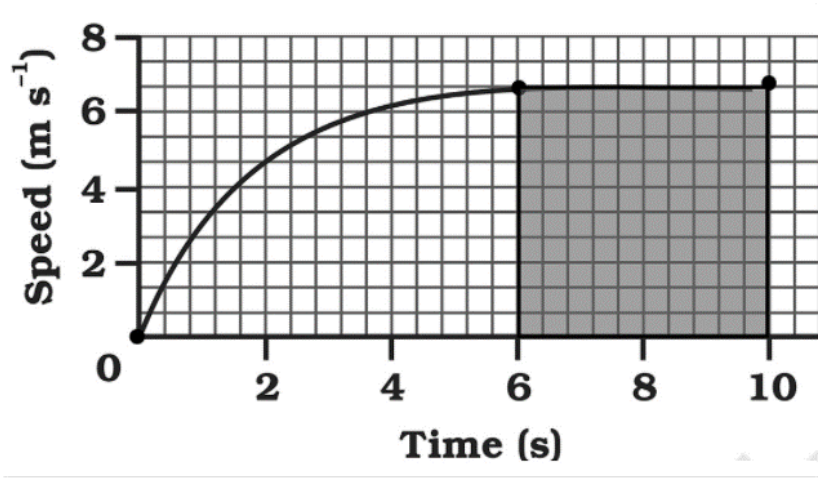
a) Find out how far the car travels in the first 4 seconds. Shade the area on the graph that represents the distance travelled by the car during the period.
Ans: Distance travelled by the car during the first 4 seconds is equal to the area of the shaded region on the graph.



$$\text{Area} = \frac{1}{2} \times 4 \times 6 = 12\text{m}$$

Therefore, the distance travelled by the car in first 4 seconds is 12m.

b) Which part of the graph represents uniform motion of the car?
Ans: Horizontal line after 6 seconds represents the constant motion.



Therefore, the shaded part of the graph between time 6 seconds to 10 seconds represent the uniform motion of the car.

29. 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.
Ans: Possible.
For example, when a ball is thrown up at maximum height, it has zero velocity, although it will have constant acceleration due to gravity, equal to $9.8\text{m}/\text{s}^2$.

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

Ans: Possible.

For example, when an object is moving in a circular track, its acceleration is perpendicular to the direction of velocity.

30.

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.

Ans:

Given, radius of the circular orbit, $r = 42250\ km$

Time taken to revolve around the earth,

$$t = 24\ hours$$

$$\text{Distance covered} = 2\pi r$$

We know,

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

∴ speed of the satellite,

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

$$= \frac{\left[2\times\frac{22}{7}\times 42250\right]}{24}$$

$$= \frac{\left[2\times\frac{22}{7}\times 42250\times 1000\right]}{(24\times 60\times 60)}$$

$$= 3073.74\ ms^{-1}$$