LECTURE 1

Motion

- Motion and Rest
- Motion is relative

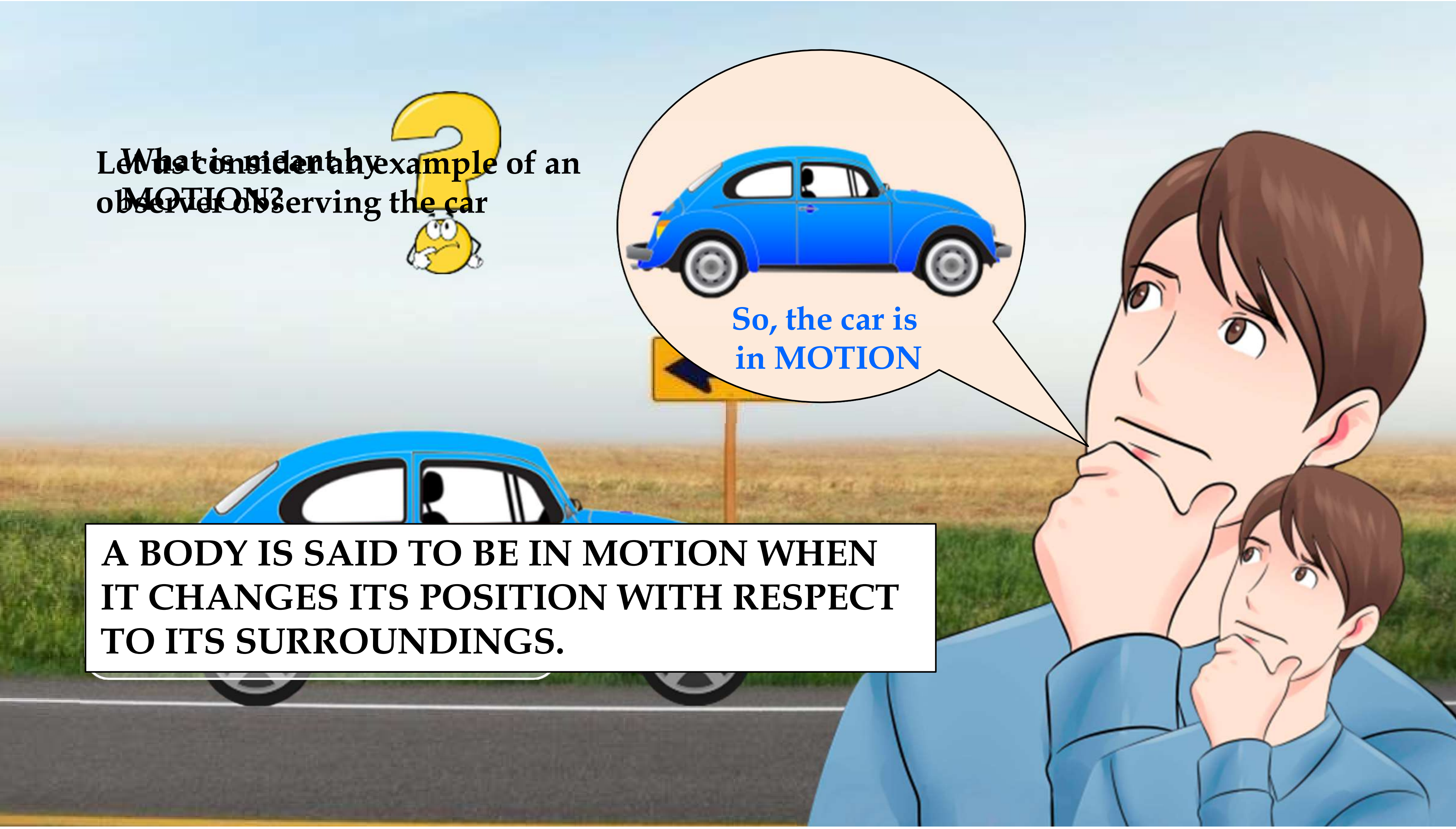
What do we observe ?

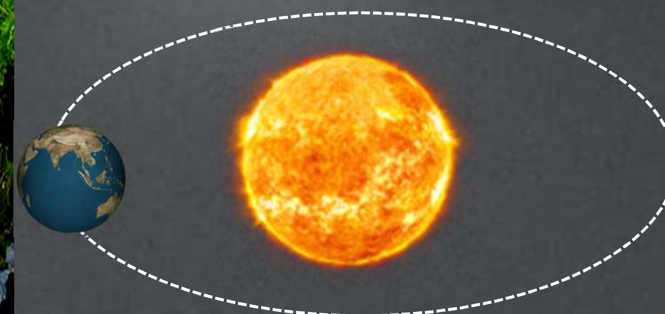
Let's learn in this chapter

MOTION

We observe that the objects are in MOTION

Why do we say these objects are in motion


What is meant by MOTION?
Let us consider an example of an observer observing the car
So, the car is in MOTION
A BODY IS SAID TO BE IN MOTION WHEN IT CHANGES ITS POSITION WITH RESPECT TO ITS SURROUNDINGS.



The position of the hands of the clock CHANGES continuously

So, the hands of the clock are in **MOTION.**

In a river, the position of water CHANGES continuously

So, water is in **MOTION**

Due to revolution, the position of the earth with respect to the sun CHANGES continuously

So, the earth is in **MOTION.**

A BODY IS SAID TO BE AT REST WHEN IT DOES NOT CHANGE ITS POSITION WITH RESPECT TO ITS SURROUNDINGS.


MOTION IS RELATIVE

MOTION IS RELATIVE

Depends on the observer

A body can be moving for one observer, and at the same time at rest for another observer.

MOTION IS RELATIVE

MCQ's

1. Motion is said to be

a) Relation b) Relative c) Changing d) None

2. When in motion the body changes its _______ with respect to its surroundings.

a) Size b) Shape c) Position d) No change

3. An object may appear to be moving for one person and ____________ for another person.

a) stationary b) motion c) changing d) relation

1. Define Motion

Ans. A body is said to be motion if it changes its position with respective to its surroundings.

2. Define Rest

Ans. A body is said to be at rest if it does not change its position with respective to its surroundings.

3. Motion is relative

Ans. A body can be moving for one observer, and at the same time at rest for another observer.

Motion

- Uniform and Non-uniform motion
- Activity on motion

MOTION

Uniform Motion

1. The motion in which the object covers **equal distances in equal intervals of time** is called **uniform motion.**

2. In uniform motion **acceleration is zero**

The hands of the clock cover equal distances in equal intervals of time

Non-Uniform Motion

1. The motion in which the object covers **unequal distances in equal intervals of time** is called **Non-uniform motion.**

2. In non-uniform motion **acceleration is not constant**

A flying bird covers unequal distances in equal intervals of time

IDENTIFY THE TYPE OF MOTION

Uniform Motion

Non-Uniform Motion

Unequal distances in equal intervals of time

Unequal distances in equal intervals of time

Equal distances in ual intervals of time.

Motion of the bird

Activity

Amar , Akbar and Anthony are travelling by their own cars.
Lets us understand whose car is moving with uniform motion.

Amar

Akbar

Anthony

Clock Time		Distance covered by Amar in kilometer		Distance covered by Akbar in kilometer		Distance covered by Anthony in kilometer	
5.00		0		0		0	
	30		20		18		14
5.30		20		18		14	
	30		20		18		14
6.00		40		36		28	
	30		20		6		14
6.30		60		42		42	
	30		20		28		14
7.00		80		70		56	
	30		20		25		14
7.30		100		95		70	
	30		20		25		14
8.00		120		120		84	

LECTURE 2

Motion

- Physical quantities
- System of Units

Physical Quantities

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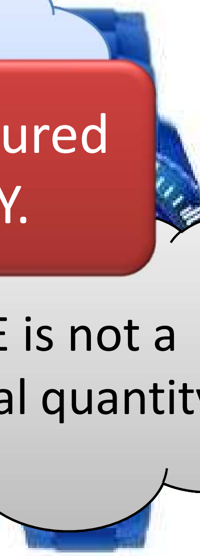
Anything that can be measured is a PHYSICAL QUANTITY.



LOVE is not a physical quantity

Physical Quantities

Physical quantities
are of two ty

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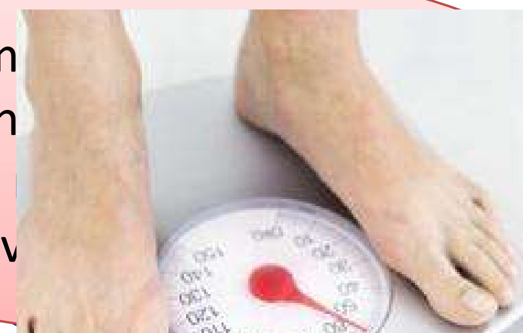


Ex

etc

Examples:

ment etc

UNITS

Units are a system of measurement.

M.K.S. System

Two systems of measurement

tem

meter – kilogram – second

centimeter – gram – second

It is also called as

S.I. System

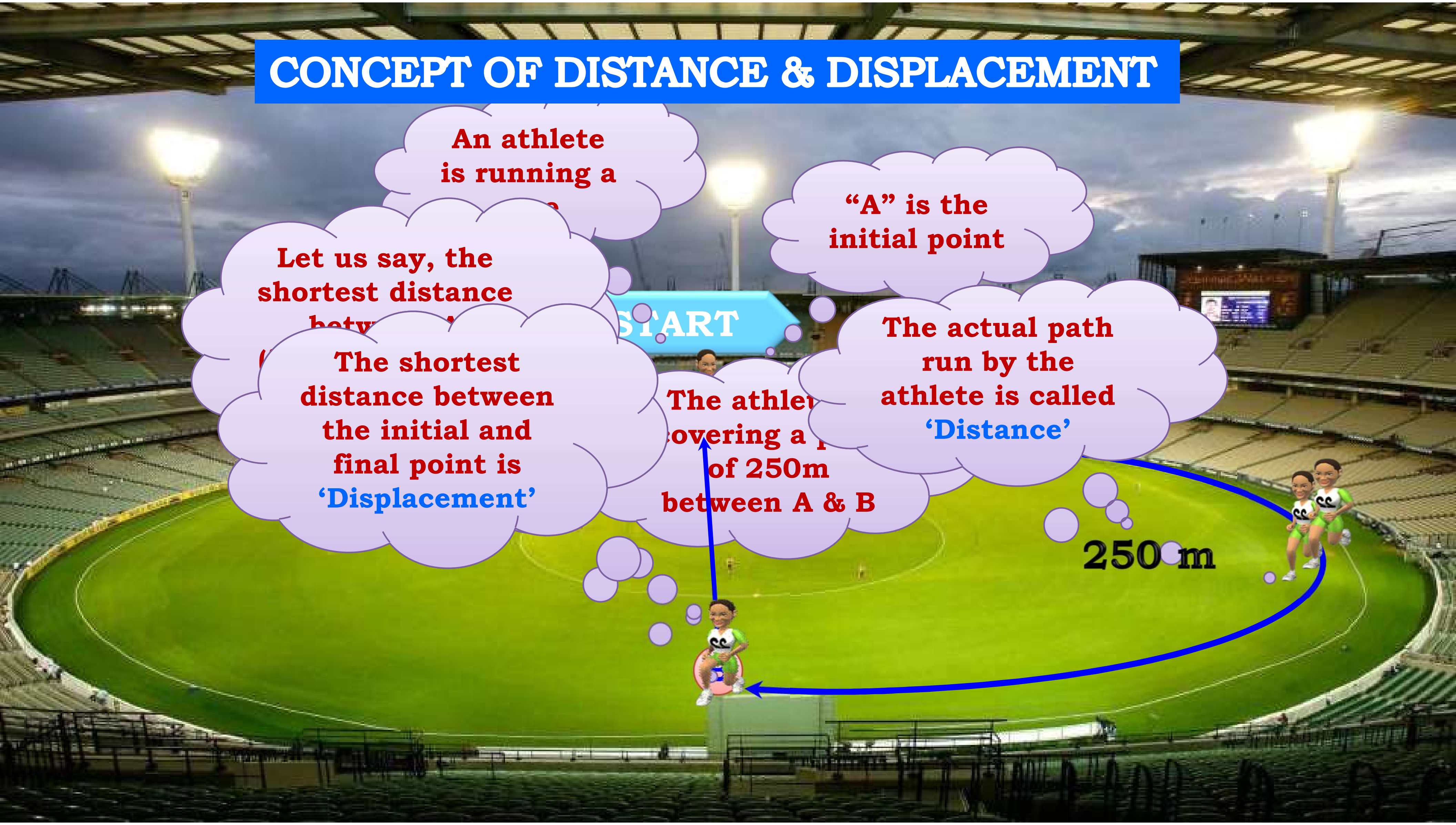
System International

OR

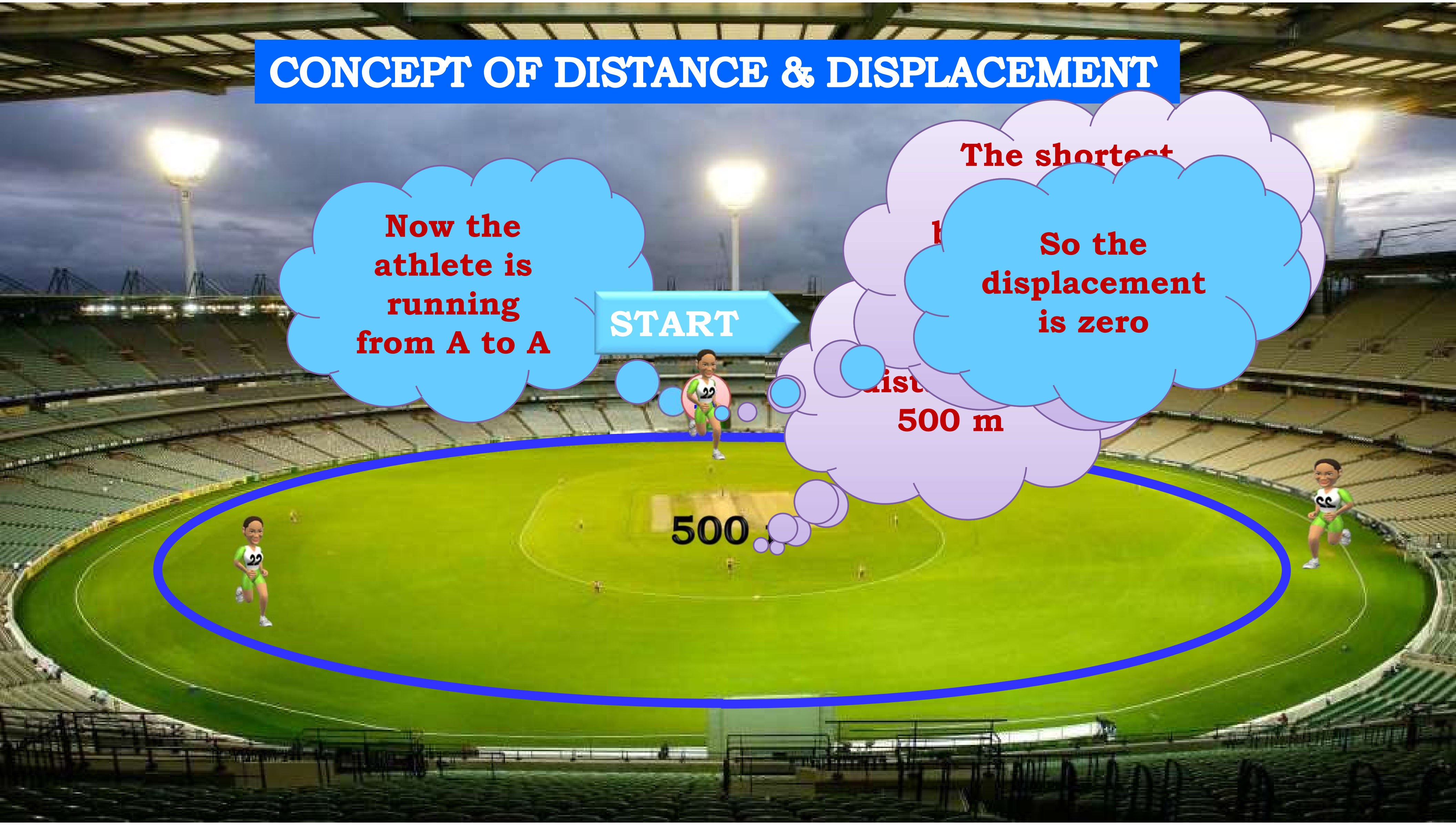
Standard International units

Motion

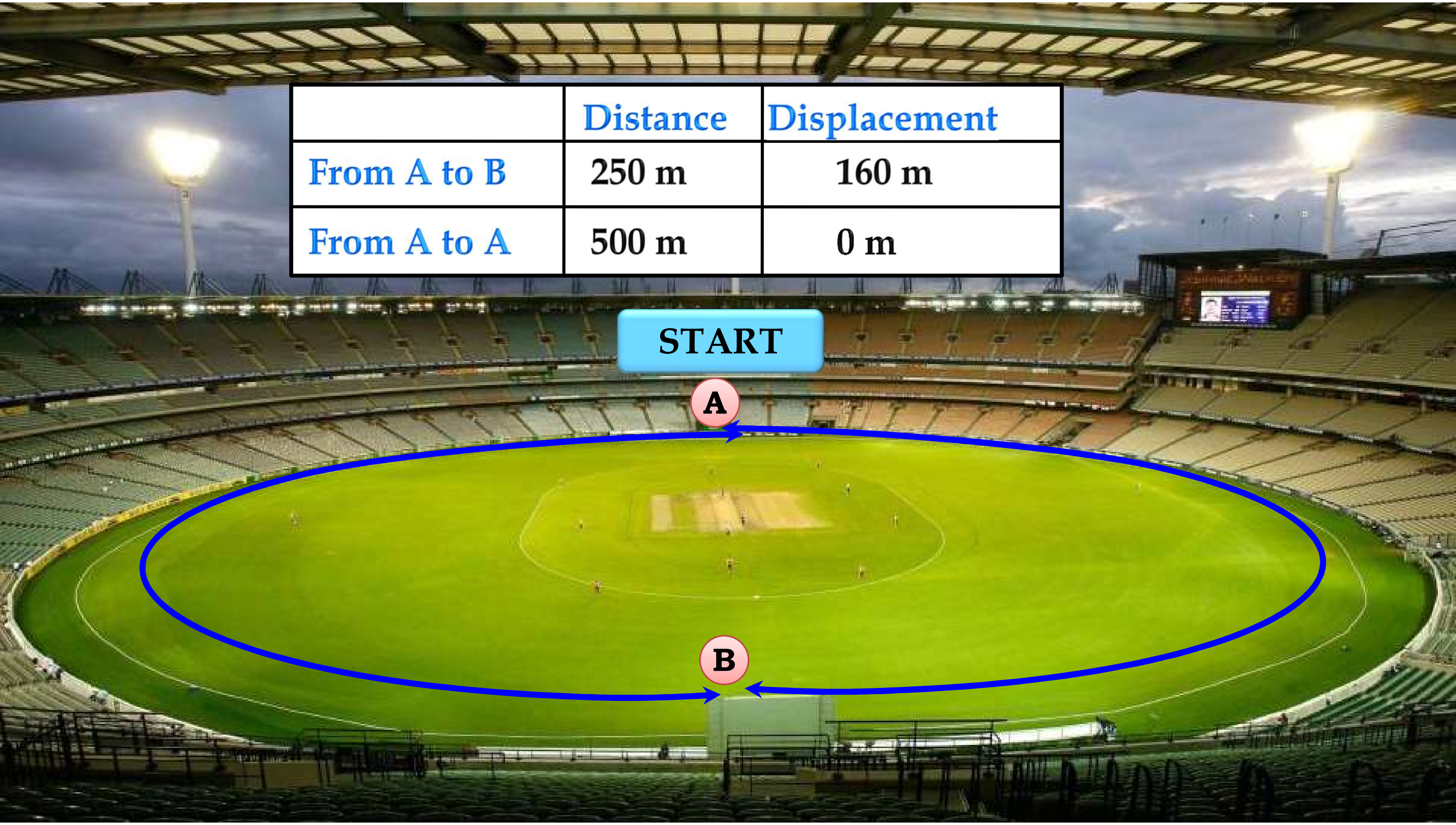
- **Distance and Displacement**



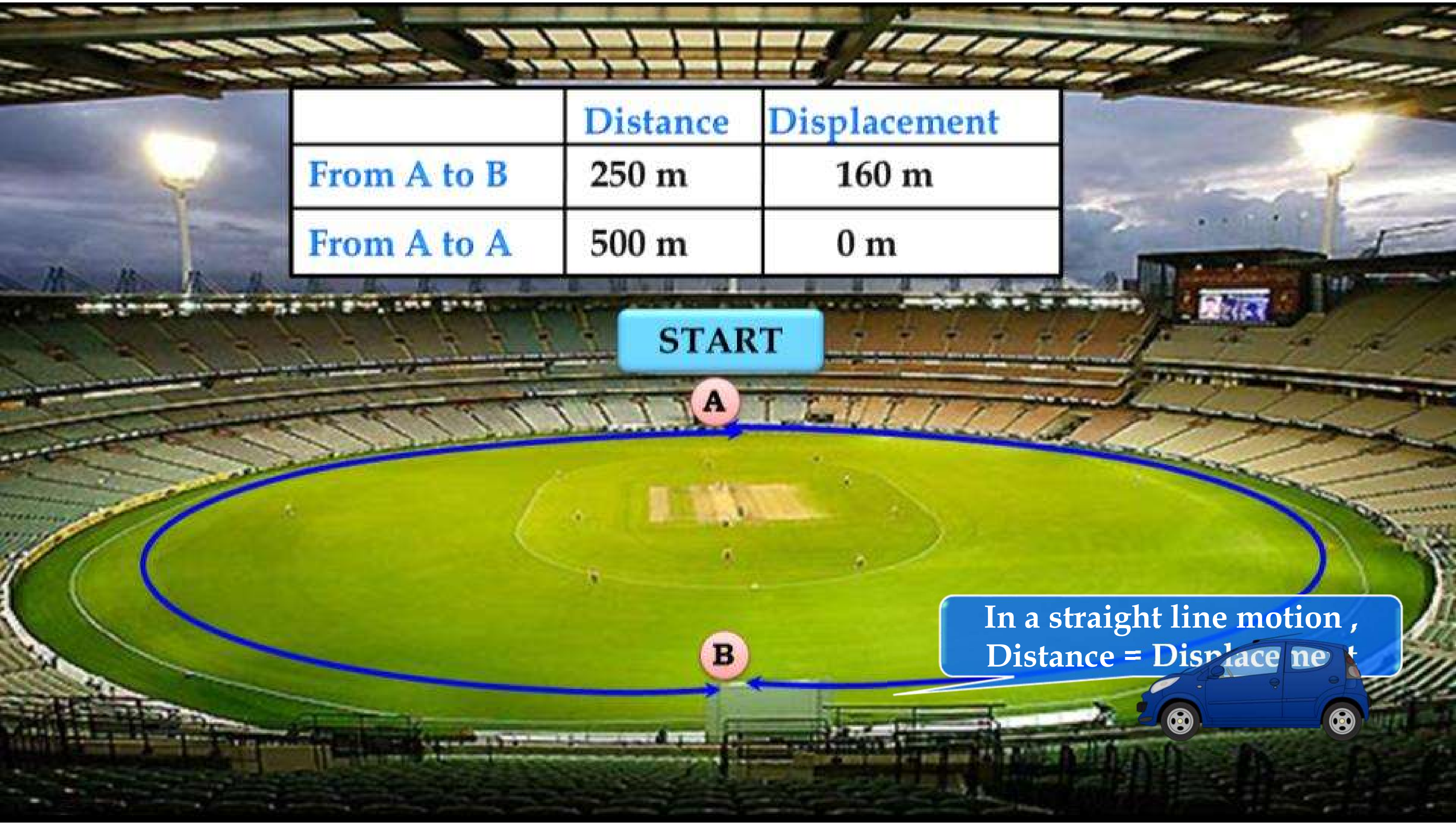
CONCEPT OF DISTANCE & DISPLACEMENT
An athlete is running a
"A" is the initial point
Let us say, the shortest distance
START
The shortest distance between the initial and final point is 'Displacement'
of 250m between A & B
The actual path run by the athlete is called 'Distance'
250 m


CONCEPT OF DISTANCE & DISPLACEMENT
Now the athlete is running from A to A
START
500 m
So the displacement is zero
500

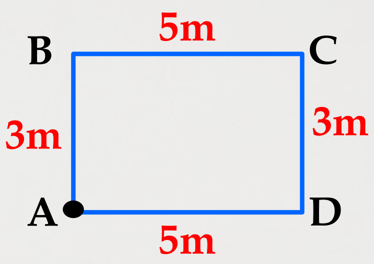
	Distance	Displacement
From A to B	250 m	160 m
From A to A	500 m	0 m



	Distance	Displacement
From A to B	250 m	160 m
From A to A	500 m	0 m



1 - In the given figure, object starts its motion at point A, goes to B-C-D and again came back to A. Find DISTANCE at point A.



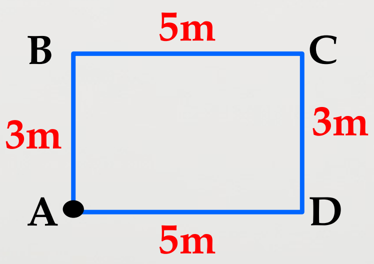
A 0

B 16

C can't say

D 8

2 - In the given figure, object starts its motion at point A, goes to B-C-D and again came back to A. Find DISPLACEMENT at point A.



A 0

B 16

C can't say

D 8

3 - Vectors are physical quantities which possess …………..

A magnitude

B magnitude & direction

C direction

D either magnitude are direction

4 - When a athlete runs on a circular track and reaches the same point …………..

A Displacement = distance

B Distance > displacement

C Displacement > 0

D Distance < displacement

5 - Displacement is ______________ quality.

A vector

B scalar

C Both of these

D none of these

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

Ans. **Yes, even when an object moves through a distance it can have zero displacement.**

Total distance travelled = AB + BA = 30 + 30 = 60 km.

But as the final position coincides with the initial position, the displacement is zero.

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.

Ans. Both these statements are not true, because

(a) Its magnitude can be zero.

(b) Its magnitude is either less than or equal to the distance travelled by the object.

Motion

- Speed and Velocity
- Units and their relation

Speed and Velocity

SPEED

1. The distance travelled by the object in unit time is called speed.
2. Speed = $\frac{\text{distance}}{\text{time}}$
3. It is a scalar quantity
4. It is either equal to or greater than velocity.

Needs only magnitude no direction

VELOCITY

1. The displacement of a body in unit time is called velocity Or Speed of an object in a particular direction.
2. Velocity = $\frac{\text{displacement}}{\text{time}}$
3. It is a vector quantity
4. It is either equal to or less than speed.

Needs both magnitude & direction

Speed and Velocity

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

cm m
s

UNIT

M.K.S —— = m/s

C.G.S —— = cm/s

∴ **Units of speed & velocity are the same**

- Speed is related to distance.
- Velocity is related to displacement

Commercial unit of Speed and Velocity is km/h

Conversion of commercial unit to SI unit

1 km	=	1000 m
1 hr	=	60 min
1 min	=	60 sec
1 hr	=	60×60 sec
$\therefore$ 1 hr	=	3600 sec

$$1\ \text{km/hr} = \frac{\overset{5}{\cancel{1000}}\ \text{m}}{\underset{18}{\cancel{3600}}\ \text{s}}$$

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

Example

$$90\ \text{km/hr} = \overset{5}{\cancel{90}} \times \frac{5}{\underset{1}{\cancel{18}}}$$

$$= 25\ \text{m/s}$$

$$18\ \text{km/hr} = \overset{1}{\cancel{18}} \times \frac{5}{\underset{1}{\cancel{18}}}$$

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

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

Ans. **The magnitude of average velocity of an object is equal to its average speed only if the object is moving in a straight line.**

A cheetah is the fastest land animal and can achieve a peak velocity of 100 km/h up to distances less than 500 m. If a cheetah spots its prey at a distance of 100 m, what is the minimum time it will take to get its prey, if the average velocity attained by it is 90 km/h?

Ans. Average velocity $= 90 \text{ km/h} = \dfrac{90 \text{ km}}{1 \text{ h}} = \dfrac{90 \times 5 \text{ m}}{18 \text{ s}} = 25 \text{ ms}^{-1}$

Also, Average velocity $= \dfrac{\text{Displacement}}{\text{Time taken}}$

$\because$ Cheetah moves in a straight line displacement is equal to 100 m

$\therefore$ Time taken $= \dfrac{100}{25} = 4 \text{ s}$

LECTURE 3

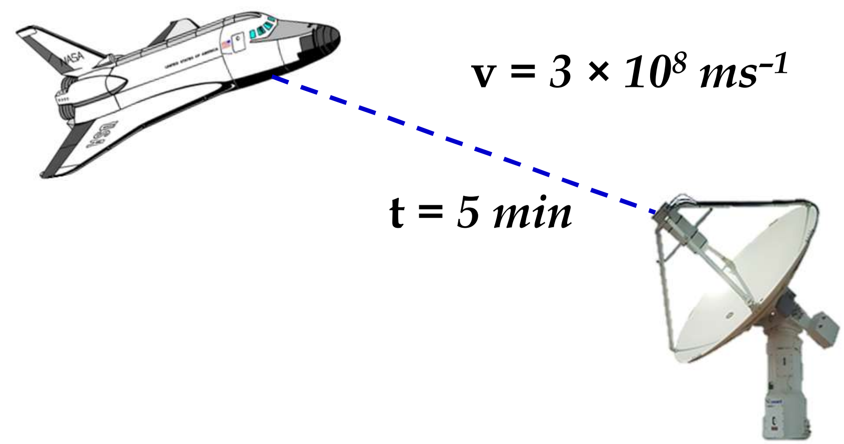
1 During an experiment, a signal from a spaceship reached the ground station in five minutes. What was the distance of the spaceship from the ground station? The signal travels at the speed of light, that is, 3×10^8 m s^{-1}.

Given : Time (t) $= 5$ min

$= 5 \times 60$

$= 300$ s

Speed of the signal $= 3 \times 10^8$ m s^{-1}



To find : Distance = ?

Formula :

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

Solution :

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

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

$$= 3 \times 10^8 \times 300$$

Ans : The distance of the spaceship from the ground station is 9×10^{10} m.

2

An object travels 16 m in 4 s and then another 16 m in 2 s. What is the average speed of the object?

Given : Total distance travelled = 16 + 16 = 32m

Total Time = 4 + 2 = 6 s

To find : Average speed = ?

Formula : Average speed = $\dfrac{\text{Total distance travelled}}{\text{Total time taken}}$

$t_1 = 4\ s$ $\qquad$ $t_1 = 2\ s$

A $\quad$ *16 m* $\quad$ B $\quad$ *16 m* $\quad$ C

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

$= \dfrac{32}{6}$

$= 5.33\ m\ s^{-1}$

Ans : The average speed of the object is $5.33\ m\ s^{-1}$.

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

Given : Total distance = 180 m

Total di…

To… = 60 s

Usha swims back to the same position

To find : Average speed = ?

Average velocity = ?

Formulae :

Distance covered
s = 90 + 90 = 180 m

$\frac{\text{Total distance covered}}{\text{Total time taken}}$

…ve… …velocity = $\frac{\text{Total displacement}}{\text{…}}$

Solution : …peed = $\frac{\text{To… …ance covered}}{\text{Total time taken}}$

Total time
t = 1 min

$$\text{Average speed} = \frac{\cancel{180}^{\,3}}{\cancel{60}_{\,1}} = 3 \text{ m s}^{-1}$$

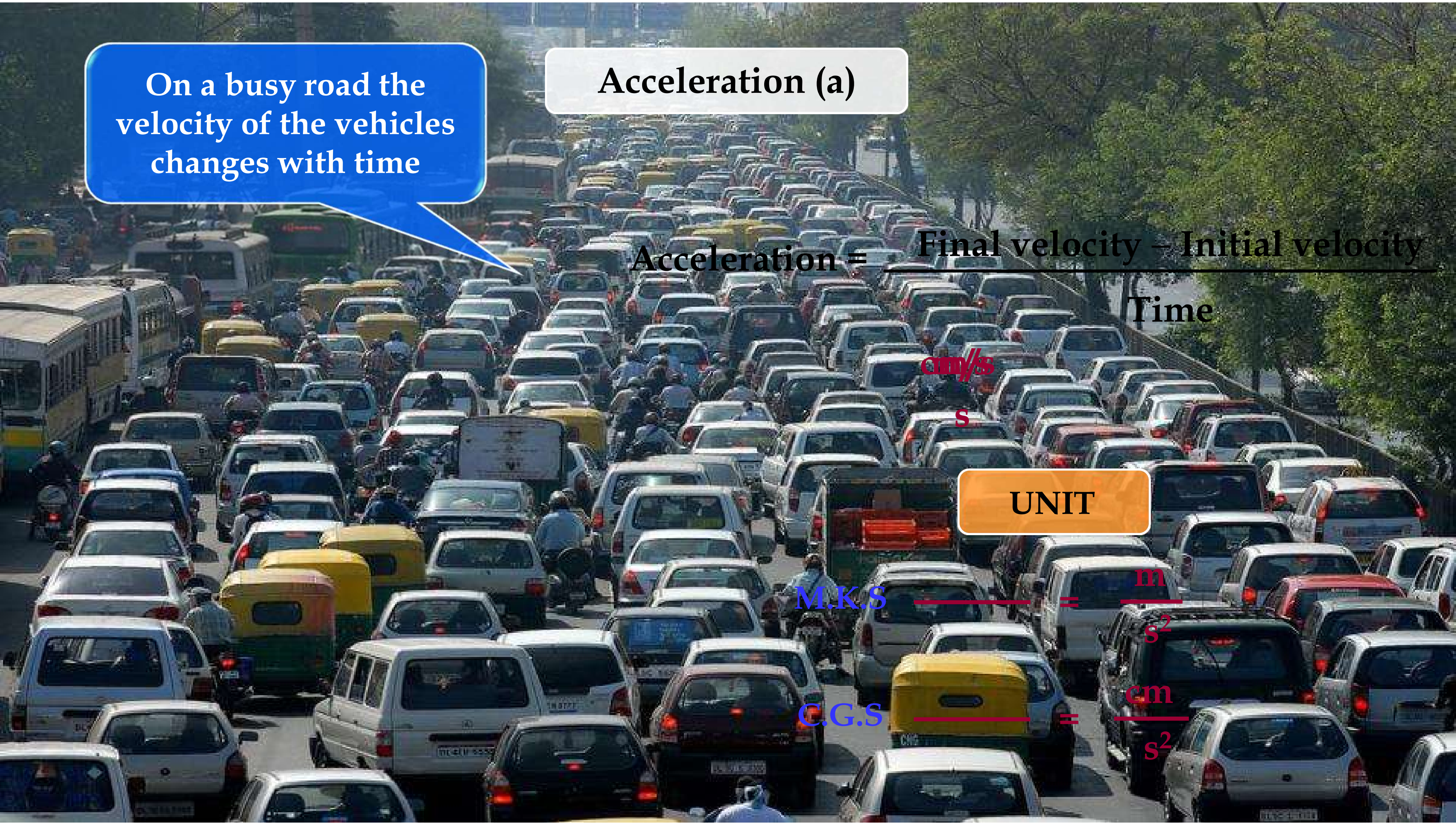
As displacement is zero,

Average velocity = 0 m s^{-1}

Ans : The average speed of Usha is 3 m s^{-1} and her average velocity is 0 m s^{-1}.

Motion

- Acceleration
- Types of acceleration



On a busy road the velocity of the vehicles changes with time

Acceleration (a)

$$\text{Acceleration} = \frac{\text{Final velocity} - \text{Initial velocity}}{\text{Time}}$$

$$\frac{cm/s}{s}$$

UNIT

M.K.S $\frac{\quad}{\quad} = \frac{m}{s^2}$

C.G.S $\frac{\quad}{\quad} = \frac{cm}{s^2}$

Plane moving with constant speed

1 – Earth rotating on its axis is an example of ……….

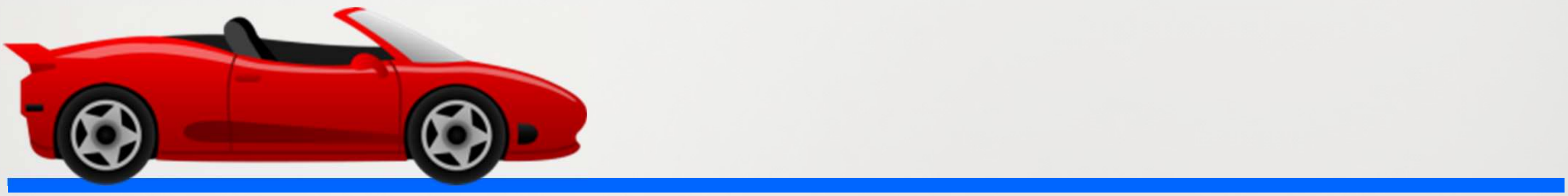
A Positive acceleration

B Negative acceleration

C Zero acceleration

D None of these

1 – A car starting from rest and moving is an example of



A Positive acceleration

B Negative acceleration

C Zero acceleration

D None of these

3 - The distance travelled by a body in a given direction in unit time is called ___________.

A velocity

B speed

C velocity or speed

D acceleration

4 - Which of the following statements is correct.

A Units of speed & velocity are different

B Units of velocity & acceleration all same

C Units of speed & velocity are same

D Units of speed & velocity are same only in MKS system

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

Given : Initial speed (u) $= 80$ km h^{-1}

$$= \cancel{80}^{40} \times \frac{5}{\cancel{18}_{9}} \text{ m s}^{-1}$$

$$= 22.22 \text{ m s}^{-1}$$

Final speed (v) $= 60$ km h^{-1}

$$= \cancel{60}^{10} \times \frac{5}{\cancel{18}_{3}} \text{ m s}^{-1}$$

$$= 16.66 \text{ m s}^{-1}$$

Time taken (t) $= 5$ s

To find : Acceleration (a) $= ?$

Formula : $a = \dfrac{v - u}{t}$

Solution :

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

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

$$\therefore \quad a = -1.112 \text{ m s}^{-2}$$

Ans : The acceleration of the bus is -1.112 m s^{-2}.
The negative sign indicates that the velocity of bus is decreasing.

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

Given : Initial speed (u) = 0 km h^{-1}

Final speed (v) = 40 km h^{-1}

$= \cancel{40}^{20} \times \frac{5}{\cancel{18}_{9}}$ m s^{-1}

= 11.11 m s^{-1}

Time taken (t) = 10 min

= 10 × 60 s

= 600s

To find : Acceleration (a) = ?

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

Solution :

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

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

$$= \frac{11.11}{600}$$

$$\therefore a = 0.0185 \text{ m s}^{-2}$$

Ans : The acceleration of the train is 0.0185 m s^{-2}

Motion

- **Uniform and non uniform Acceleration**

UNIFORM AND NON-UNIFORM ACCELERATION

UNIFORM ACCELERATION

...equal changes in velocity of body ...ime, then it possesses ...cce...

Time in second		Velocity in m/sec.	
0	5	0	
5	5	8	
10	5	16	
15	5		
20	5	32	8
25	5	40	8
30	5	48	8
35		56	

The ...
...of time

The change in velocity in the time interval is constant.

So, there i...
intervals

Equal changes in
velocit...

To start with the
van is at re...

At zero time,
velocity is zero

At 10 seconds,

At 35 seconds,
velocity is 56 m/sec

...l...ion

	Velocity

NON-UNIFORM ACCELERATION

Time in second		Velocity in m/s	
0	5	0	
5	5	7	8
10	5	15	11
15	5	26	4
20	5	30	10
25	5	40	8
30	5	48	4
35		52	

...re unequal changes in ...qual intervals ...possesses ...celeration.

The change in velocity in time interval varies.

Velocity changes with time

At zero sec... velocity is zer...

...acceleration

When will you say a body is in (i) uniform acceleration, (ii) non-uniform acceleration?

Ans. (i) -If an object travels in a straight line and its velocity increases or decreases by equal amounts in equal intervals of time, then the body is said to be in uniform acceleration.

-For example, the motion of a freely falling body.

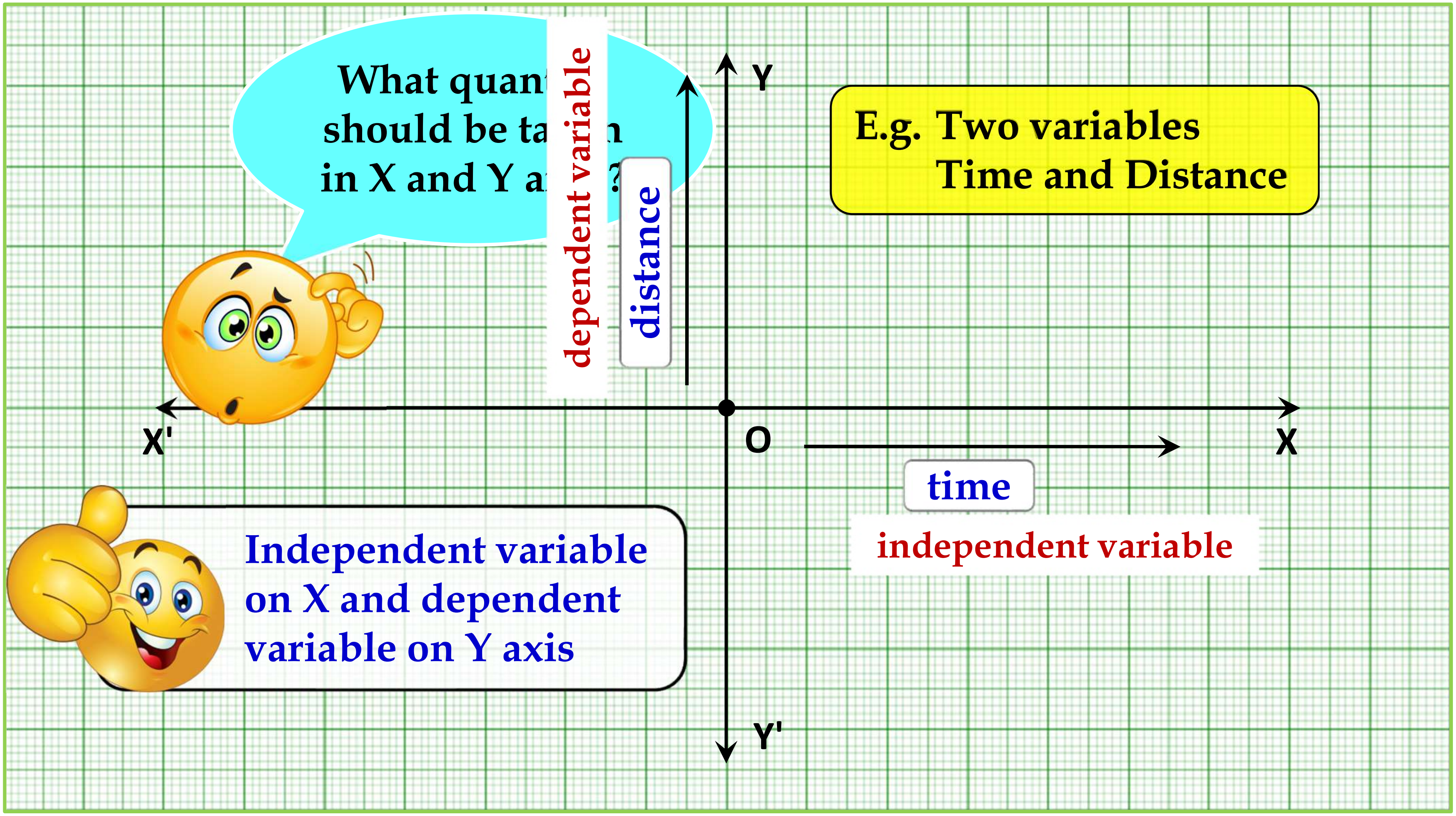
(ii) -If an object travels in a straight line and its velocity changes by unequal amounts in equal intervals of time, then the body is said to be in non-uniform acceleration.

-For example, if a car is travelling along a straight road and passes through a crowd, suffers unequal change in velocity, in equal intervals of time, so the car is moving with non-uniform acceleration.

LECTURE 4

Motion

- Basic concept of graph
- Distance time graph for uniform motion

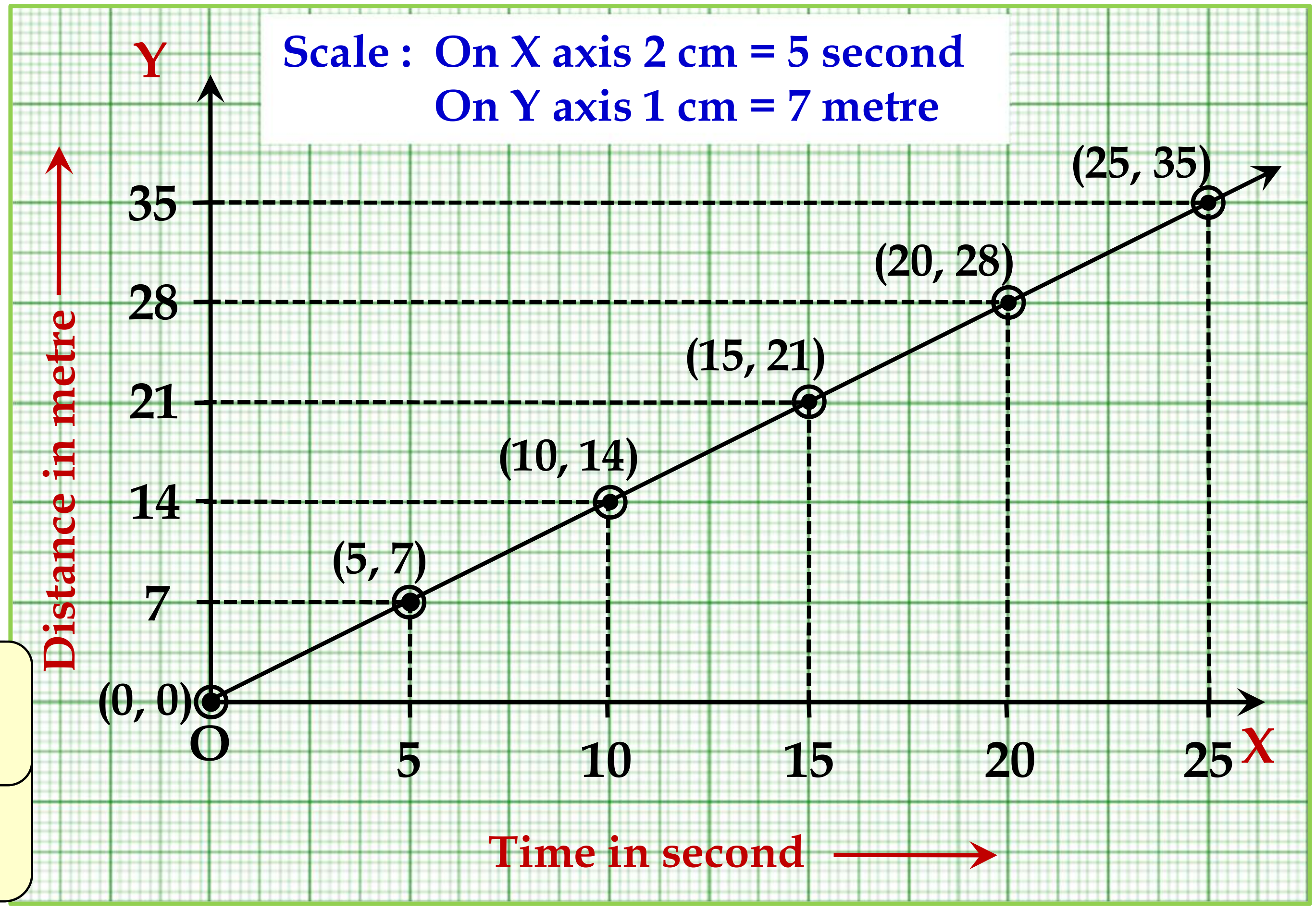

What quan
should be ta n
in X and Y a ?
dependent variable
distance
Y
E.g. Two variables
Time and Distance
X'
O
X
time
independent variable
Independent variable
on X and dependent
variable on Y axis
Y'

Distance-time Graph for Uniform motion

Time (sec)	Distance (metre)
0	0
5	7
10	14
15	21
20	28
25	35

The body is said to have a uniform motion

shows that the distance is increasing with time



Motion

- Finding velocity in distance-time graph by slope method
- Distance time graph for non-uniform motion

Find the velocity of the object in given graph

Velocity = Slope of distance-time graph

For example :

Consider points A (5, 7) and B (10, 14)

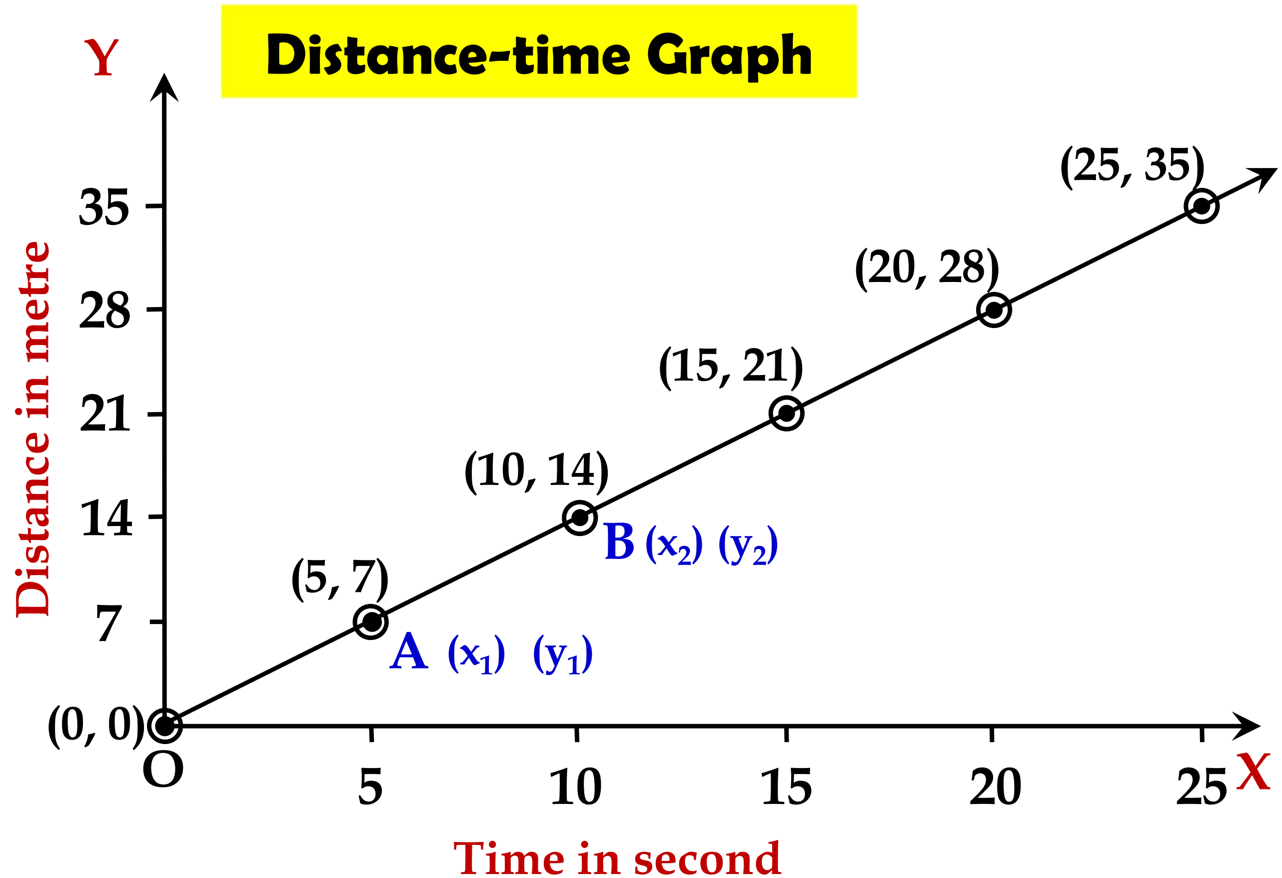
A: (x_1) (y_1); B: (x_2) (y_2)

Then slope $= \dfrac{y_2 - y_1}{x_2 - x_1}$

$= \dfrac{s_2 - s_1}{t_2 - t_1}$

$= \dfrac{\text{...re}}{5 \quad \text{second}}$

= **1.4 m/sec**



Find the velocity of the object in given graph

Velocity = Slope of distance - time graph

For example :

Consider points A (5, 7) and B (10, 14)

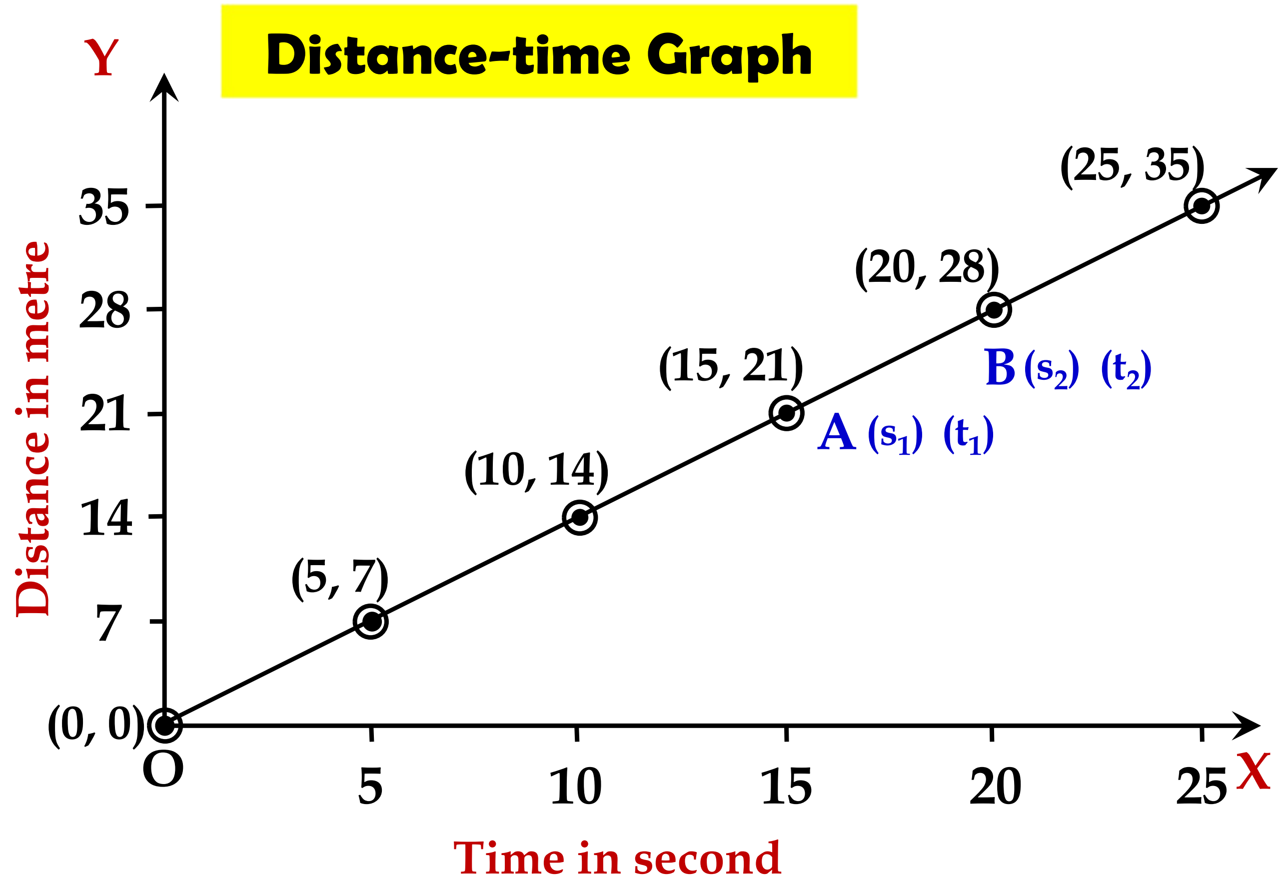
$(x_1)\ (y_1)$ for A; $(x_2)\ (y_2)$ for B

$$\text{Then slope} = \frac{s_2 - s_1}{t_2 - t_1}$$

$$= \frac{28 - 21}{20 - 15}$$

$$= \frac{7}{5}\ \frac{\text{metre}}{\text{second}}$$

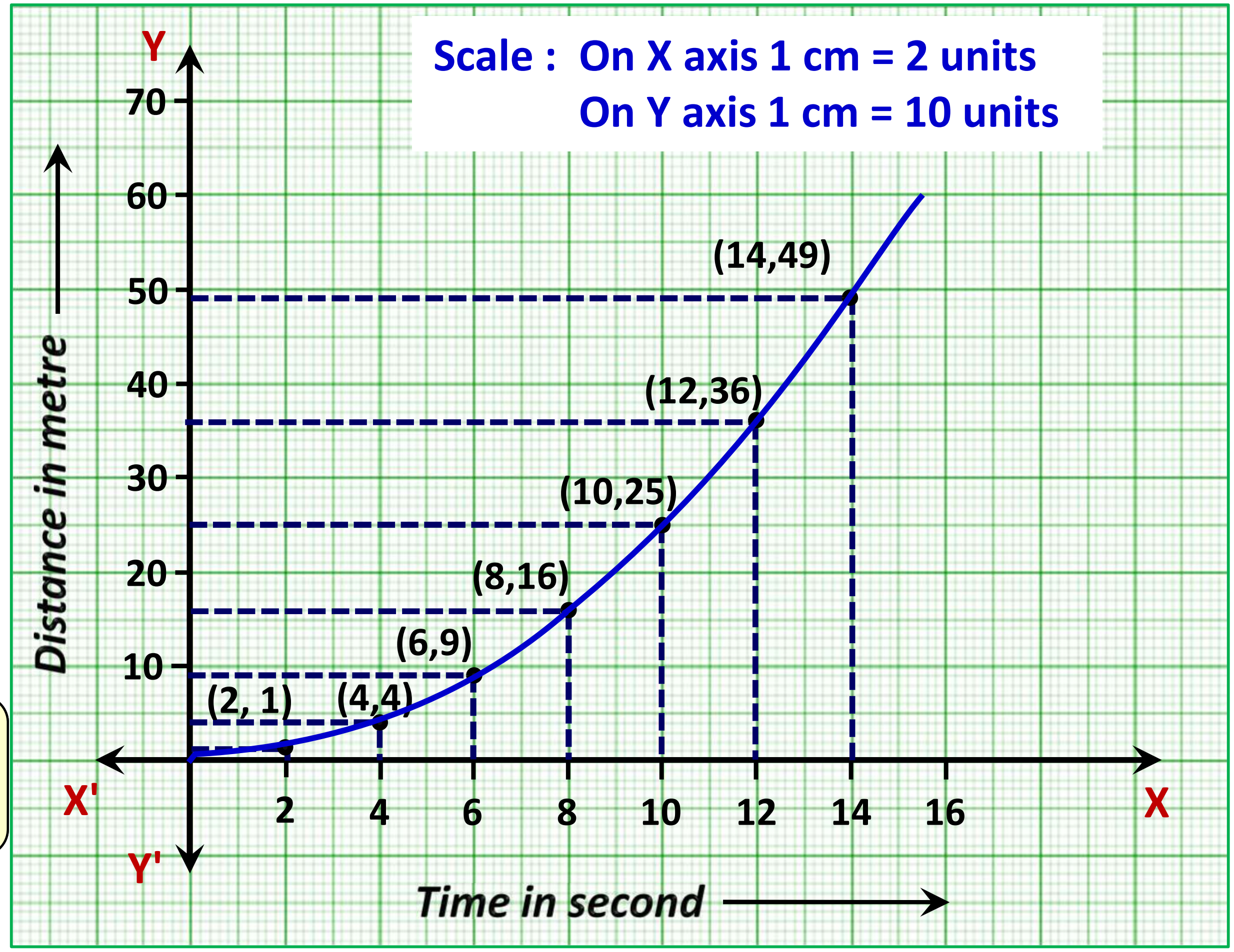
$$= 1.4 \text{ m/sec}$$



Distance-time graph for Non-uniform motion

Time (sec)	Distance (metre)
0	0
2	1
4	4
6	9
8	16
10	25
12	36

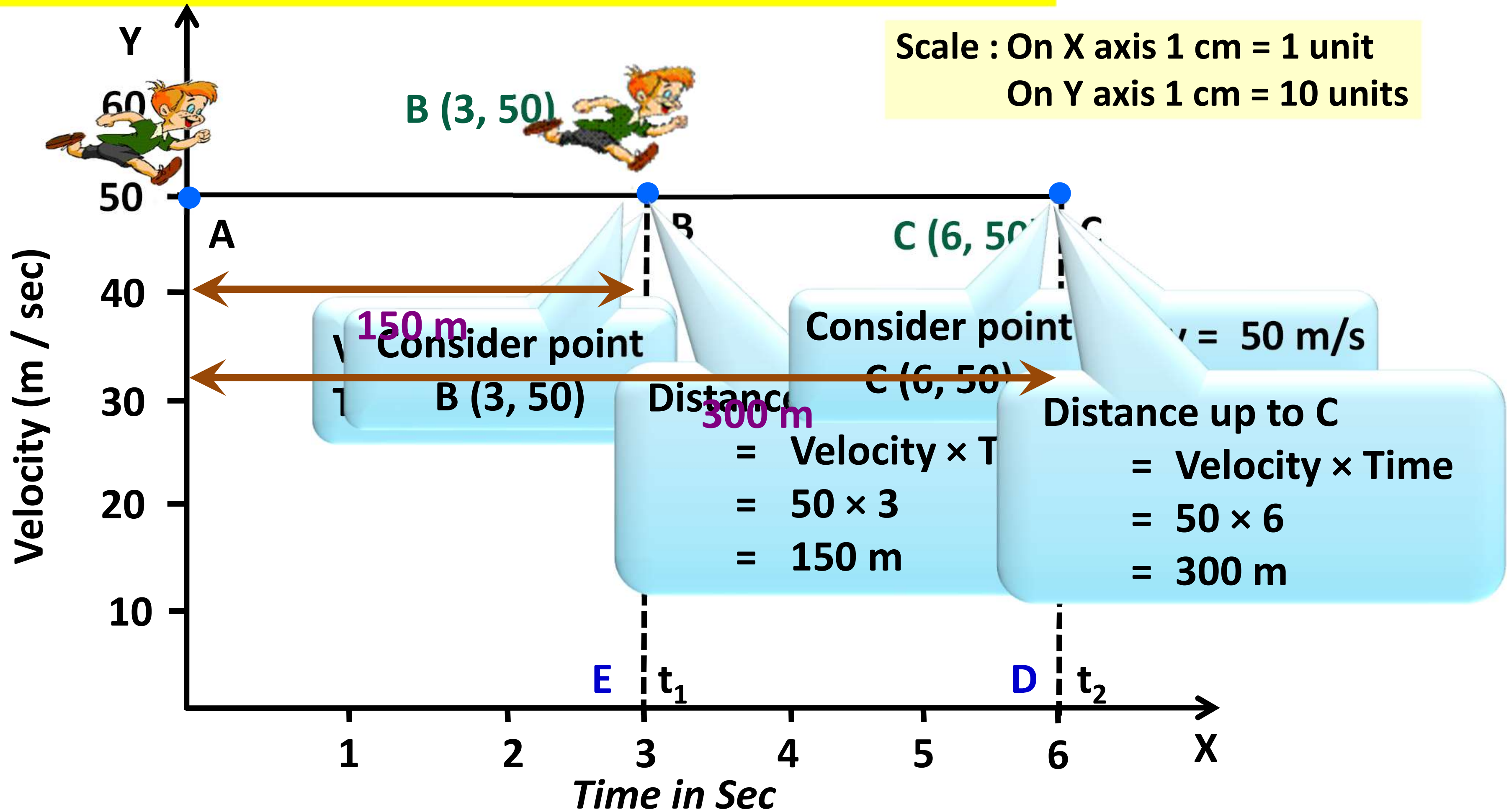
Hence this graph is for non-uniform motion



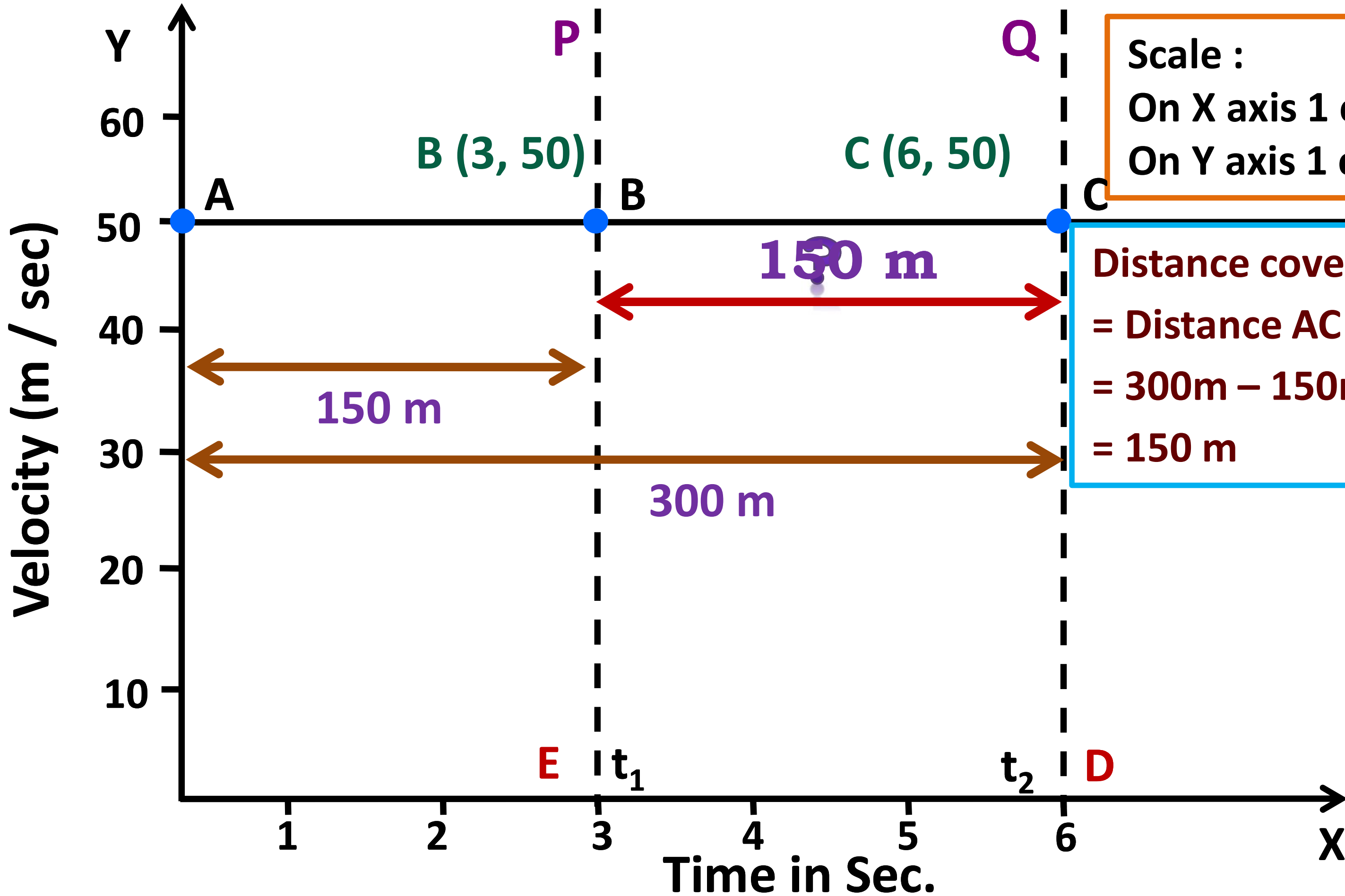
Motion

- Velocity time graph for uniform motion
- Finding distance travelled by an object in velocity-time graph for uniform motion

VELOCITY - TIME GRAPH FOR UNIFORM MOTION



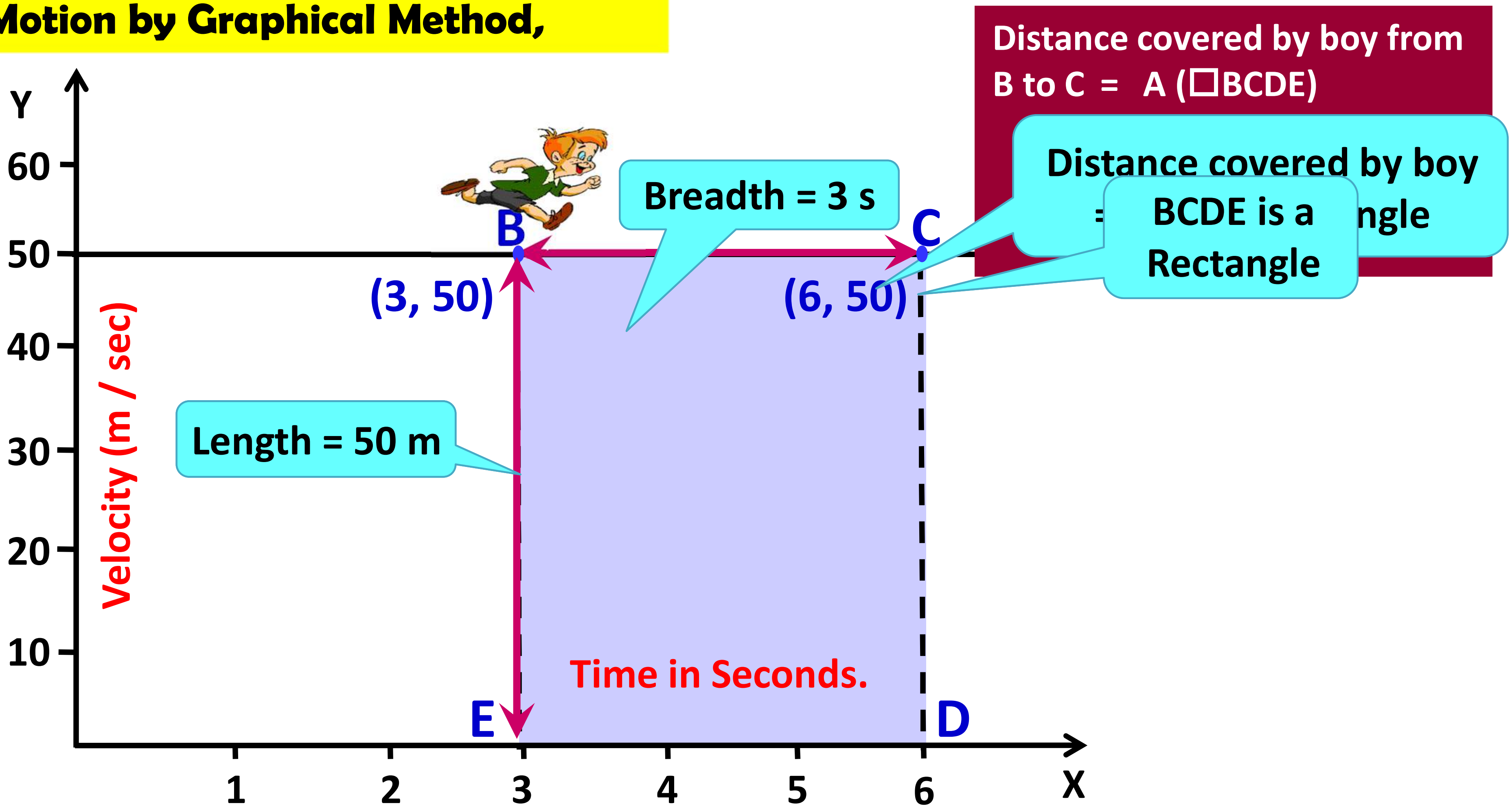
VELOCITY TIME GRAPH FOR UNIFORM MOTION



Scale :
On X axis 1 cm = 1 unit
On Y axis 1 cm = 10 units

Distance covered by boy from B to C
= Distance AC – Distance AB
= 300m – 150m
= 150 m

Velocity Time Graph For Uniform Motion by Graphical Method,



Motion

- Velocity-time graph for uniformly accelerated motion

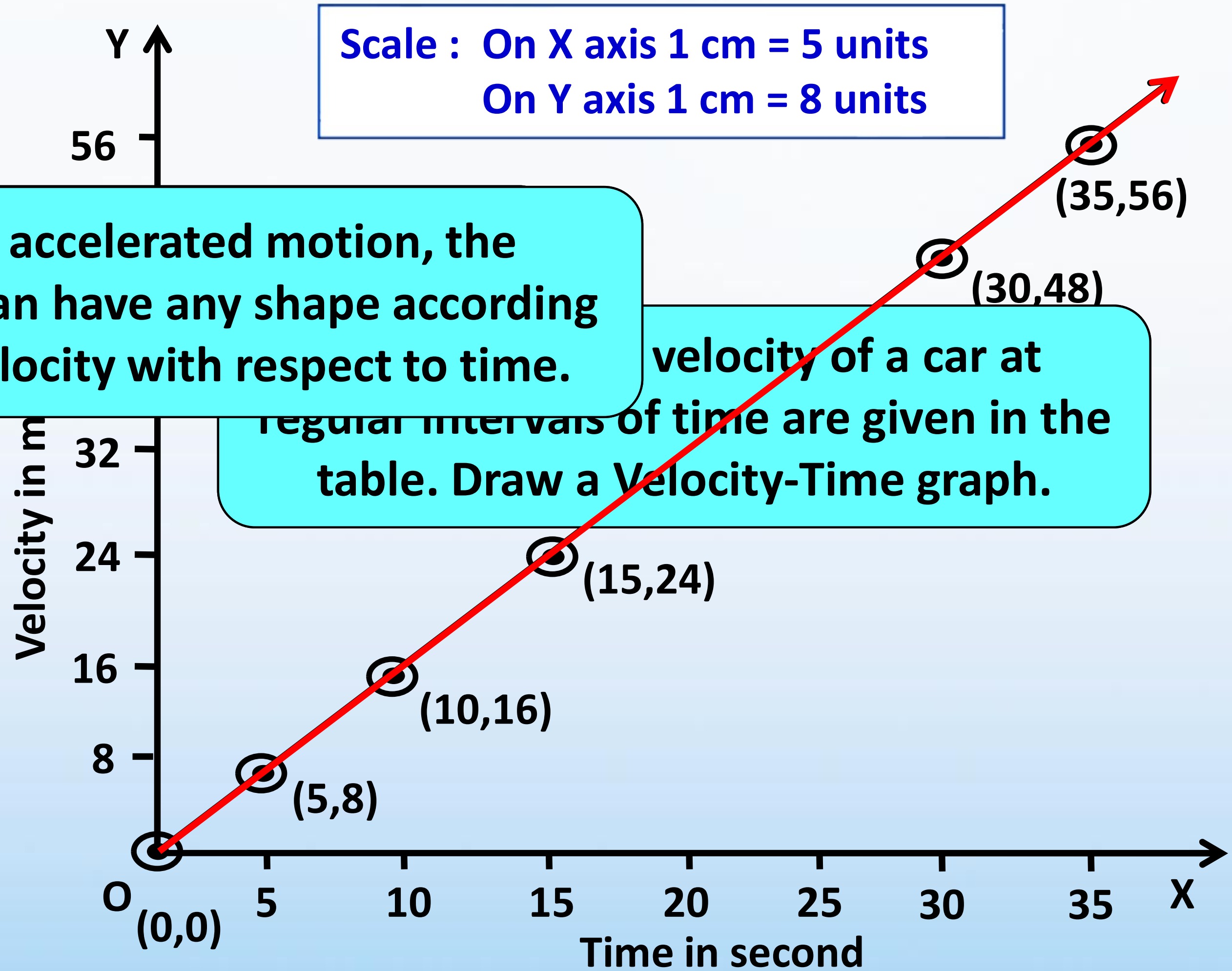
Velocity - Time Graph for Uniformly Accelerated Motion

Time in second	Velocity in m/sec.
[illegible]	[illegible]
[illegible]	[illegible]
10	16
15	24
20	32
25	40
30	48
35	56

For non-uniformly accelerated motion, the Velocity-Time graph can have any shape according to the variation in velocity with respect to time.

Scale : On X axis 1 cm = 5 units
On Y axis 1 cm = 8 units

... velocity of a car at regular intervals of time are given in the table. Draw a Velocity-Time graph.



Velocity - Time Graph for Uniformly Accelerated Motion

Distance travelled Consider time interval from 10 seconds to 20 seconds

Distance travelled Between D and C

$$= A(\square ABCD)$$

$$= A(\square AECD) + A(\Delta ABE)$$

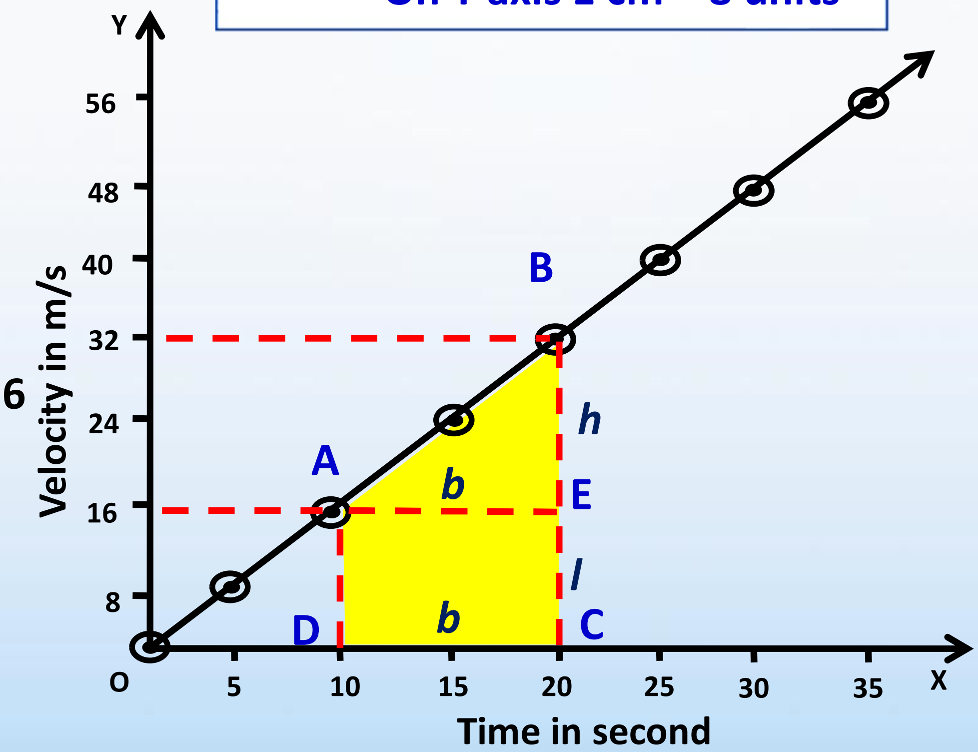
$$= (l \times b) + \frac{1}{2} \times b \times h$$

$$= (16 \times 10) + \frac{1}{2} \times 10 \times 16$$

$$= 160 + 80$$

$$= 240 \text{ m}$$

Scale : On X axis 1 cm = 5 units
On Y axis 1 cm = 8 units



Velocity - Time Graph for Uniformly Accelerated Motion

Acceleration = Slope of Velocity-Time graph

Scale : On X axis 1 cm = 5 units
On Y axis 1 cm = 8 units

Consider points A (10, 16) and B (20, 32)

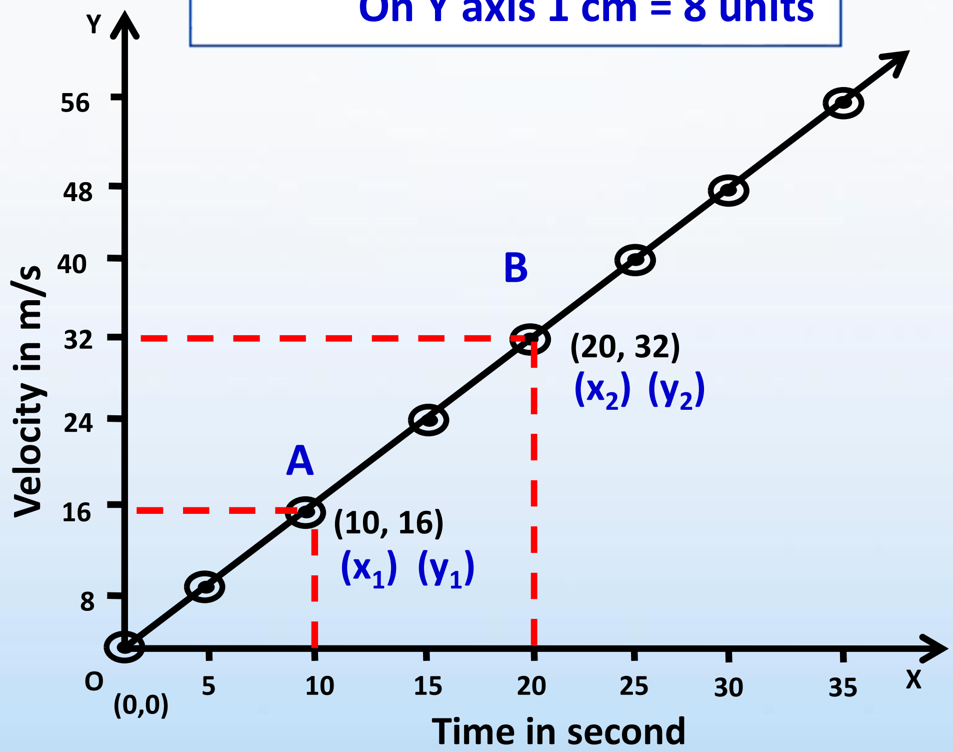
$(x_1)\ (y_1)$ $\quad$ $(x_2)\ (y_2)$

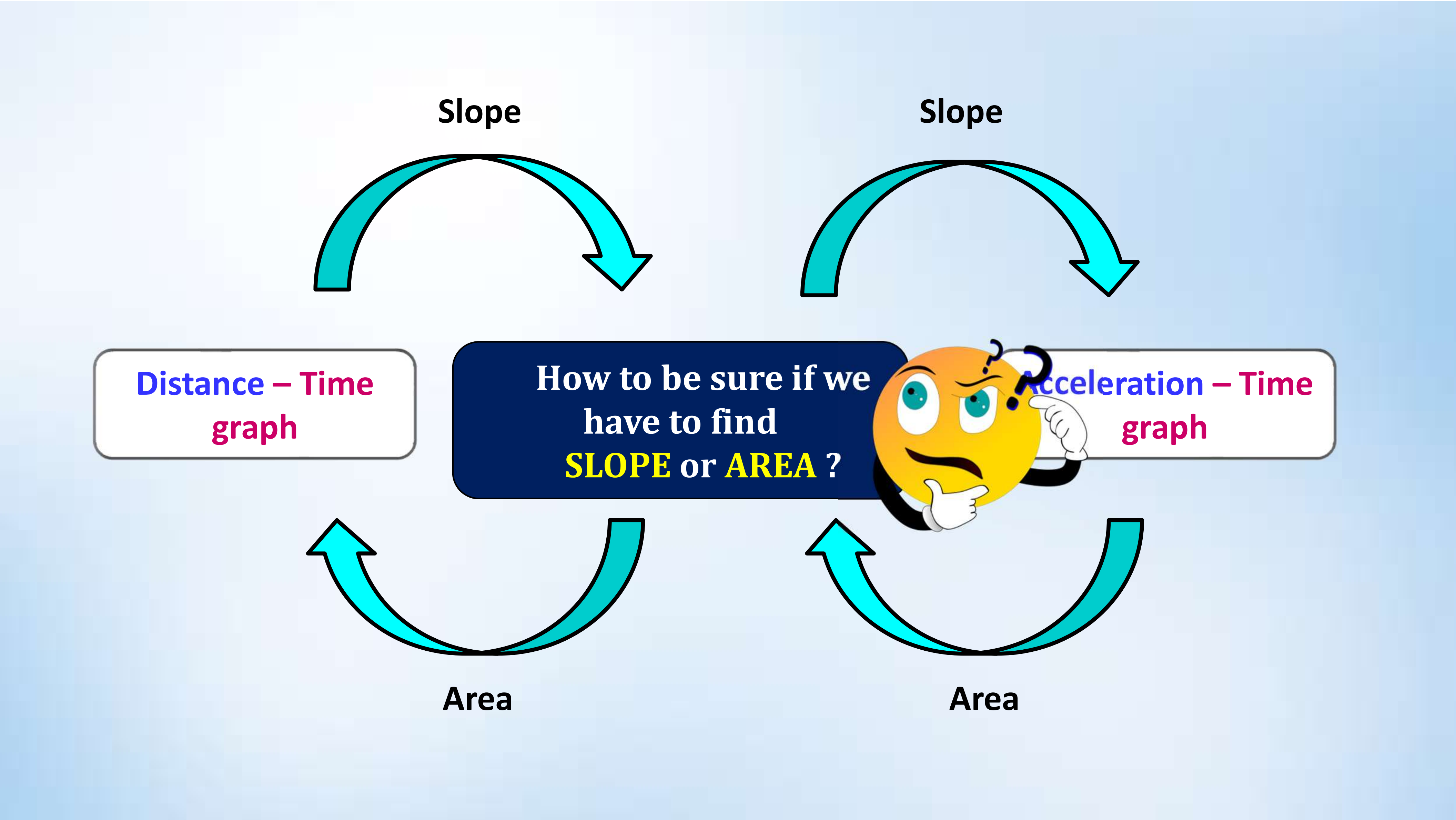
$$\text{Then slope} = \frac{y_2 - y_1}{x_2 - x_1}$$

$$= \frac{32 - 16}{20 - 10}$$

$$= \frac{16}{10}$$

$$= 1.6\ m/s^2$$

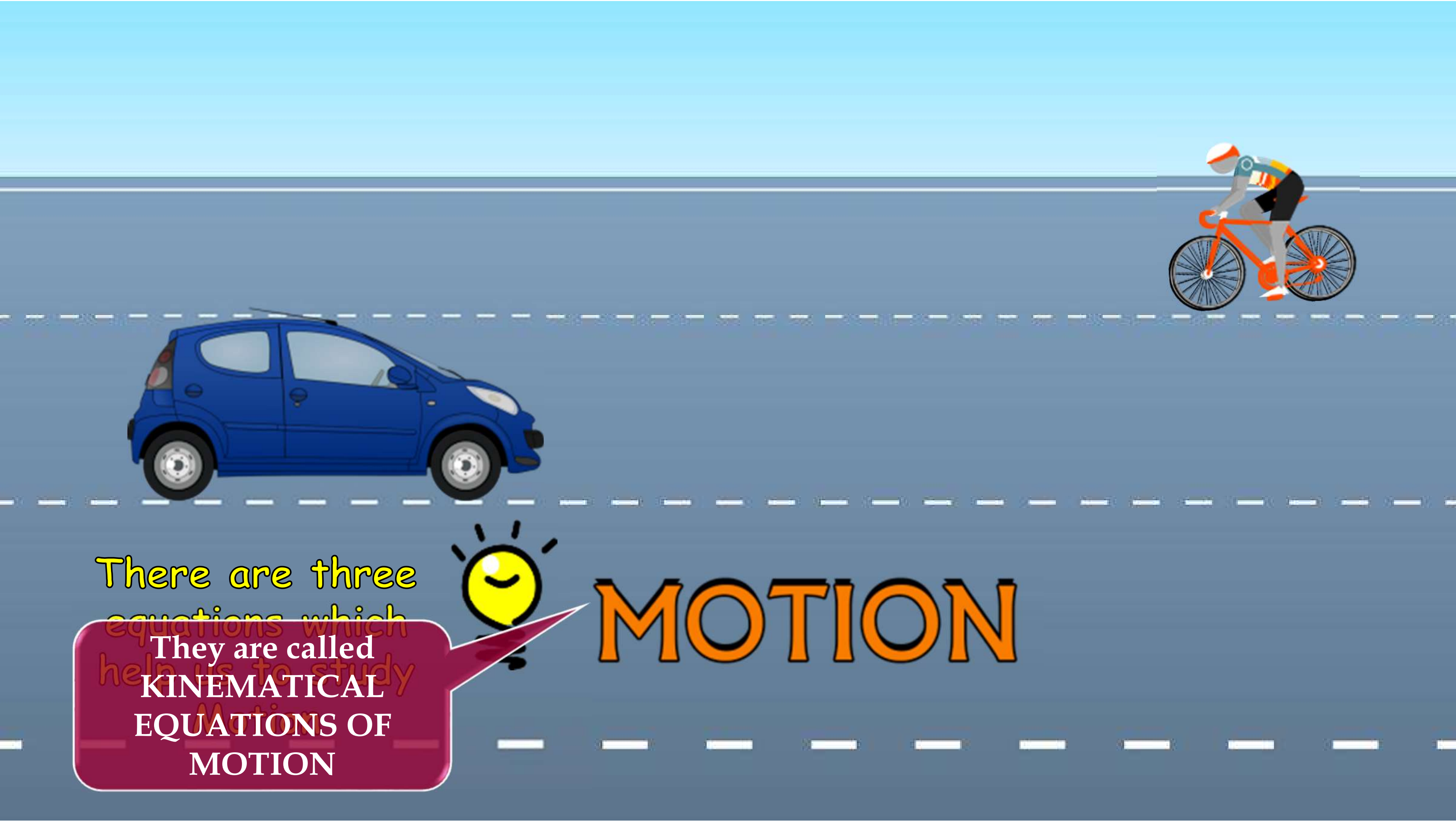



Slope
Slope
Distance – Time graph
How to be sure if we have to find SLOPE or AREA ?
cceleration – Time graph
Area
Area

LECTURE 5

Motion

- **Equations of motion**


There are three
equations which
They are called KINEMATICAL EQUATIONS OF MOTION
MOTION

EQUATIONS OF MOTION

Final velocity = v

Does not depend on MASS

Initial velocity = u

Acceleration = a

Time = t

Displacement = s

$$v = u + at$$

Since this equation gives the relation between VELOCITY and TIME, it is called the VELOCITY-TIME RELATION

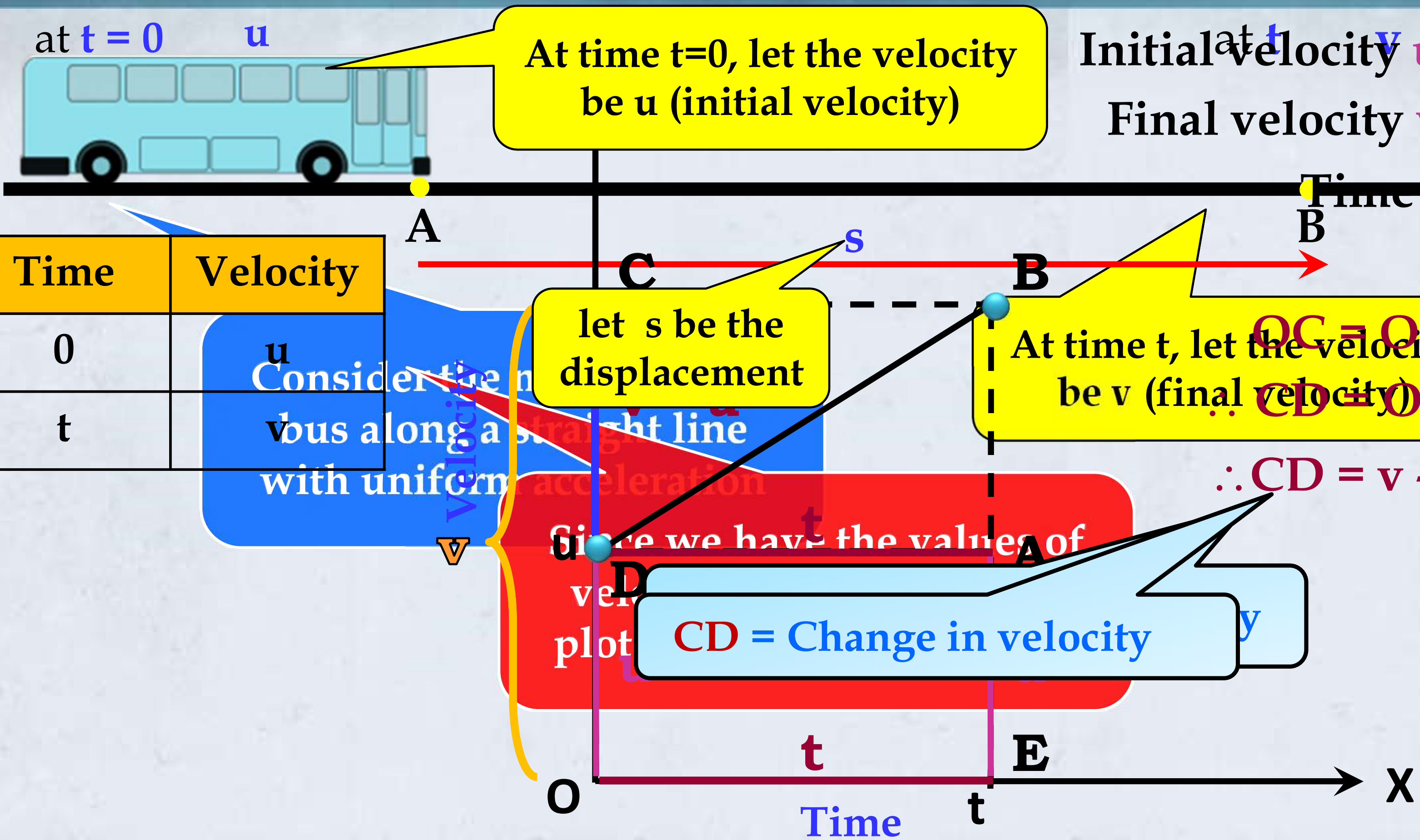
$$s = ut + \frac{1}{2}at^2$$

Since this equation gives the relation between DISPLACEMENT and TIME, it is called the DISPLACEMENT -TIME RELATION

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

Since this equation gives the relation between DISPLACEMENT and VELOCITY, it is called the DISPLACEMENT -VELOCITY RELATION

EQUATIONS OF MOTION BY GRAPHICAL METHOD



Time	Velocity
0	u
t	v

Initial velocity u = OD

Final velocity v = OC

Time t = OE

OC = OD + CD

$\therefore$ CD = OC - OD

$\therefore$ CD = v - u ..... (1)

1. Equation for velocity-time relation

1^{st} kinematical equation :- $v = u + at$

Acceleration = $\dfrac{\text{Change in velocity}}{\text{Time}}$

CD

Change in velocity = CD

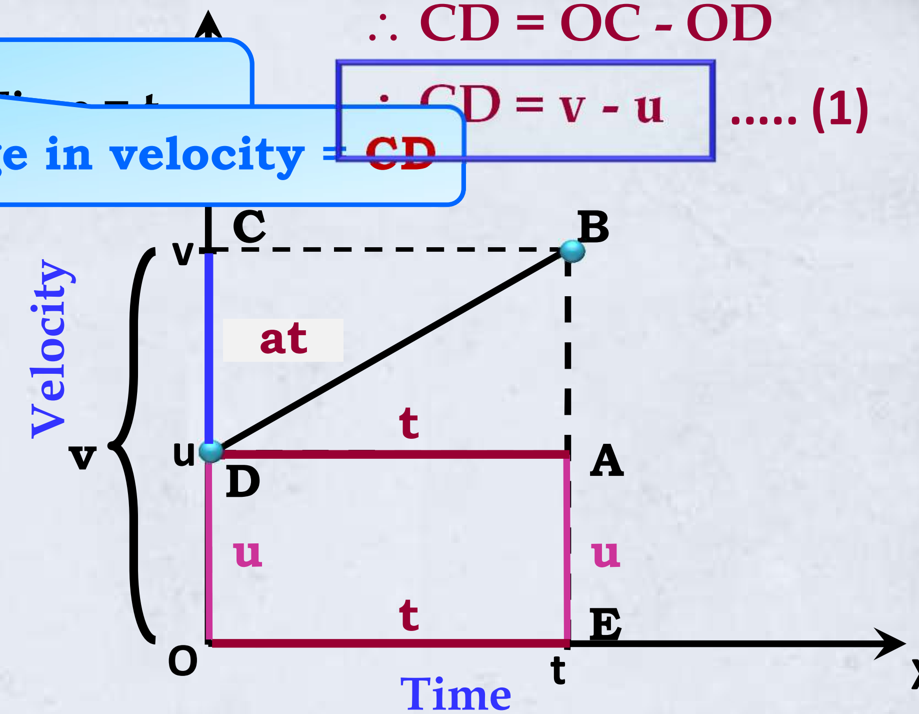
Acceleration = a

∴ CD = at ……….(2)

OC = OD + CD

∴ CD = OC - OD

∴ CD = v - u ….. (1)



From eq. 1 and 2,

v - u = at

v = u + at

First kinematical equation

2. Equation for Displacement-time relation

2nd kinematical equation :- $s = ut + \frac{1}{2}at^2$

Distance travelled = Area of quadrilateral DOEB

s = A (quadrilateral DOEB)

s = A (□DOEA) + A (ΔDAB)

s = (l × ... + ½ (b × h)

s = (... + ½ (DA × AB) ....(Eq.1)

But,

A of rectangle

u

A of triangle

= ½ (b× h)

OE is the length of rectangle

t

at

DA is the base of triangle

triangle

is made up of

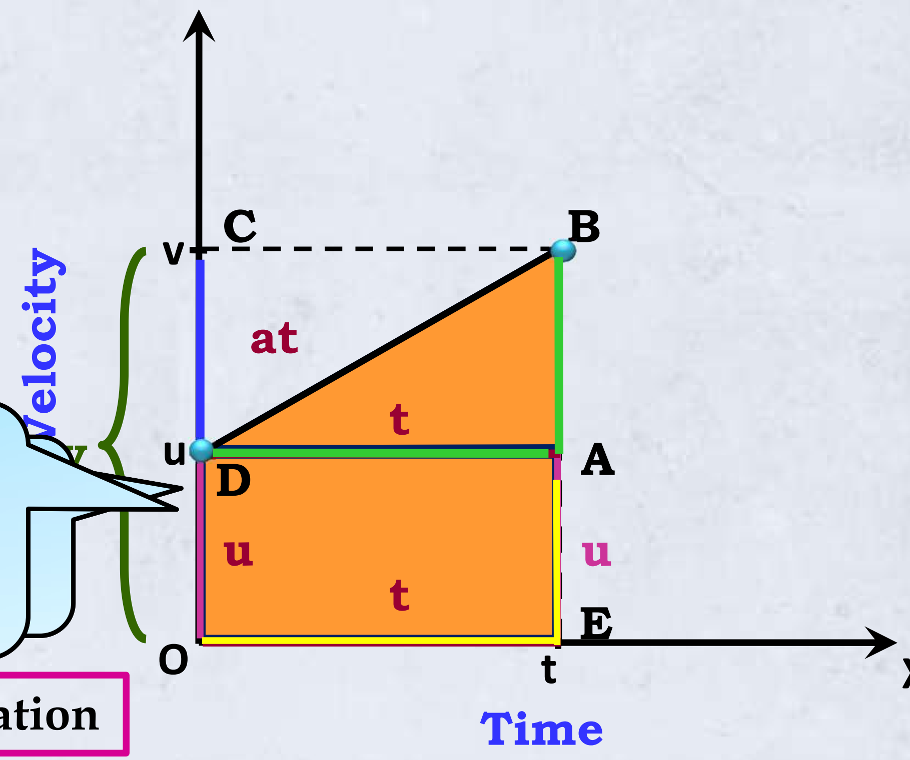
□DOEA & ΔDAB

Substituting value in eq. 1

s = (×) + ½ (×) ....(Eq.1)

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

Second kinematical equation



3. Equation for Displacement-velocity relati

3^{rd} kinematical equation :- $v^2 = u^2 + 2as$

Distance travelled = Area of □DOEB

s = Area of trapezium DOEB

$$s = \frac{1}{2}(OD + BE) \times OE$$

But, OD = u, BE = v, OE = t

$$s = \frac{1}{2}(v + u) \times t \qquad .....(i)$$

Now, $a = \dfrac{v - u}{t}$

i.e. $t = \dfrac{v - u}{a} \qquad .....(ii)$

Substituting equation (ii) in equation (i) ,

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

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

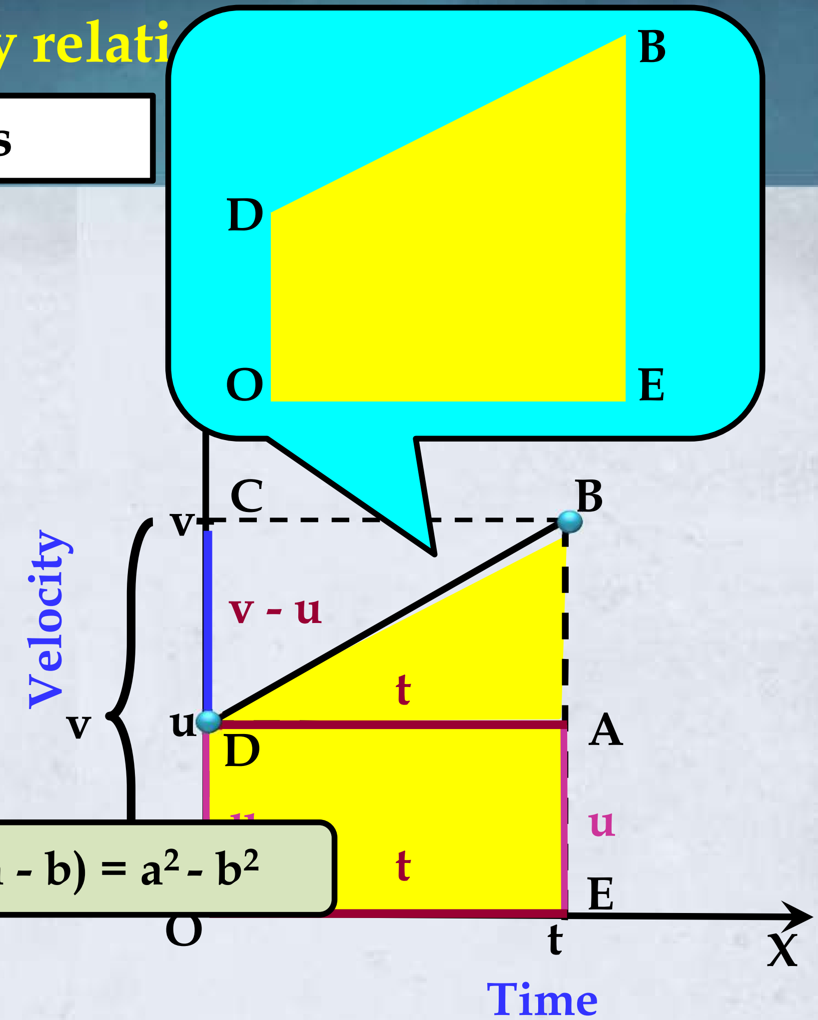
$(a + b) \times (a - b) = a^2 - b^2$

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

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

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

Third kinematical equation



1 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?

Given : Initial velocity (u) $= 0 \text{ m s}^{-1}$

Acceleration (a) $= 2 \text{ cm s}^{-2}$

$$= \frac{2}{100} \text{ m s}^{-2}$$

$$= 0.02 \text{ m s}^{-2}$$

Time (t) $= 3$ s

To find : Final velocity (v) = ?

Formula : $v = u + at$

Solution : $v = u + at$

$$\therefore \quad v = 0 + (0.02 \times 3)$$

$$\therefore \quad v = 0.06 \text{ m s}^{-1}$$

Ans : The velocity of the trolley after 3 seconds from start is 0.06 m s^{-1} .

1

A motorboat starting from rest on a lake accelerates in a straight line at a constant rate of 3.0 m/s² for 8 s. How far does the boat travel during this time?

Given : Initial velocity (u) = 0 m/s
Acceleration (a) = $3.0\ m/s^2$
Time (t) = 8 s

To find : Distance covered (s) = ?

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

At rest, u = 0

(i) $v = u + at$

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

This formula is best suited as u, a and t are given

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

Solution : Distance covered (s) $= ut + \frac{1}{2}at^2$

$= 0 \times 8 + \frac{1}{2}$ ...

Di

$= 0 + \frac{1}{\cancel{2}_1} \times 3 \times 8 \times \cancel{8}^4$

$= 3 \times 8 \times 4 = 96\ m$

Ans : Boat travels a distance of 96 m

LECTURE 6

Motion

- Circular motion
- Uniform circular motion
- Finding velocity of an object moving along a circular path

Uniform Circular Motion

Circular Motion

Let us consider a body moving along a closed path.

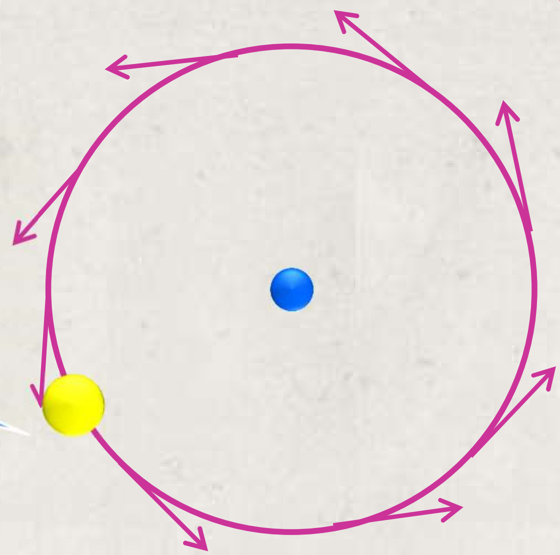
Motion of the body along the circumference of the circle is called circular motion.

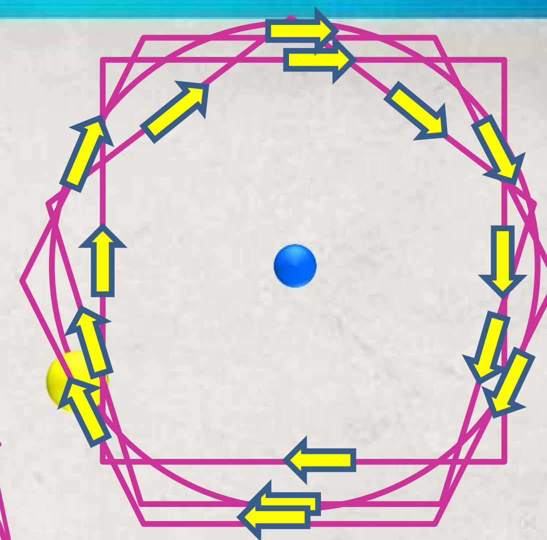
Uniform Circular Motion

Motion of the body along the circumference of the circle with constant speed is called uniform circular Motion.

Direction keeps on changing but magnitude of speed always remains same

This motion is also called as accelerated motion.

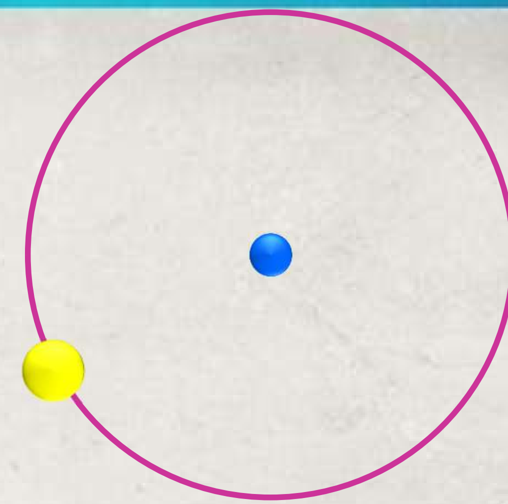




Uniform Circular Motion

Let us consider a body moving along a circular path of radius 'r'.

Let the body take 't' seconds to go once round the path. If v is the speed then ……



$$\text{Speed} = \frac{\text{Circumference of the circle}}{\text{Time taken}}$$

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

Motion

- **Numerical based on average speed and average velocity**

Type - A

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

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

1 The odometer of a car reads 2000 km at the start of a trip and 2400 km at the end of the trip. If the trip took 8 h, calculate the average speed of the car in km h^{-1} and m s^{-1}.

Given : Initial odometer reading = 2000 km
Final odometer reading = 2400 km
Time (t) = 8 h

To find : Average speed (v_{av}) = ?

Formula : $v_{av} = \frac{s}{t}$

Solution : Distance covered by the car, (s) = Change in odometer reading
= 2400 − 2000
= 400 km

Average speed of the car $v_{av} = \frac{s}{t} = \frac{400}{8}$

n h^{-1}

Final odometer reading

Initial odometer reading

1 km = 1000m

1 h = 3600s

= m = $50 \times \frac{5}{18}$

$\therefore$ v_{av}

$t_1 = 8\ h$

A B

Ans : The average speed of the car is 50 km h^{-1} or 13.9 m s^{-1}.

2 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 40 km h^{-1}. What is the average speed for Abdul's trip?

Given :

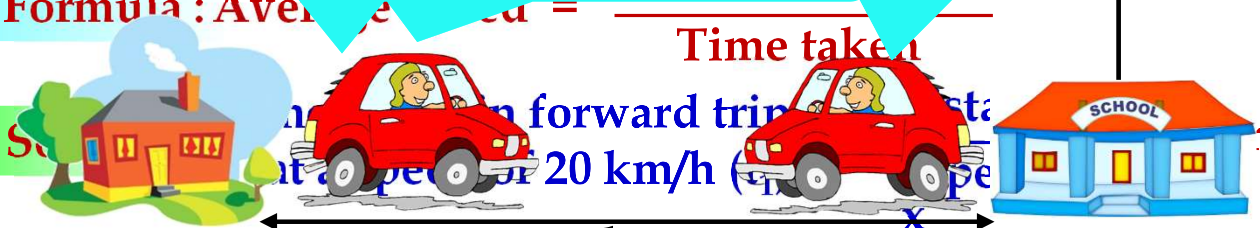
Distance covered $= x + x = 2x$ km

Average speed to school $=$ 20 kmh^{-1}

Average speed from school $=$ 40 kmh^{-1}

To find :

Formula : Average speed $= \dfrac{\text{Distance covered}}{\text{Time taken}}$



Time taken in forward trip at a speed of 20 km/h (t_1) $= \dfrac{x}{20}$ h … (i)

Time taken in return trip at a speed of 40 km/h (t_2) $= \dfrac{x}{40}$ h … (ii)

Total time for the whole trip (T) $= t_1 + t_2$

$= \dfrac{x}{20} + \dfrac{x}{40}$

$= \dfrac{2x + x}{40} = \dfrac{3x}{40}$

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

$= \dfrac{2x}{3x/40}$

$= \dfrac{2\cancel{x}}{3\cancel{x}} \times 40 = \dfrac{80}{3}$

Ans Average speed for Abdul's trip is 26.67 kmh^{-1}.

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

Given :

Distance A to B = 300 m

Distance B to C = 100 m

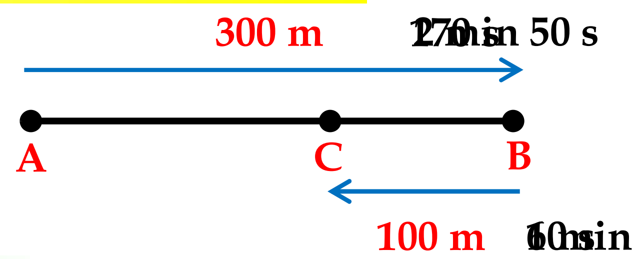
Time taken A to B = 2 min 50 s
= $(2 \times 60) + 50$
= 170 s

Time taken B to C = 1 min
= 60 s

To find : Average speed and velocity from (i) A to B (ii) A to C

Formula : (i) $\text{Average speed} = \dfrac{\text{Distance}}{\text{Time}}$

(ii) $\text{Average velocity} = \dfrac{\text{Displacement}}{\text{Time}}$



Solution : (i) From A to B

$$\text{Average speed} = \frac{\text{Distance A to B}}{\text{Time A to B}}$$

$$= \frac{30\cancel{0}}{17\cancel{0}} = 1.765 \text{ m s}^{-1}$$

Shortest distance between A and B

$$\text{Average velocity} = \frac{\text{Displacement A to B}}{\text{Time A to B}}$$

$$= \frac{30\cancel{0}}{17\cancel{0}} = 1.765 \text{ m s}^{-1}$$

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

(ii) From A to C

Distance A to C = AB + BC
= 300 + 100
= 400 m

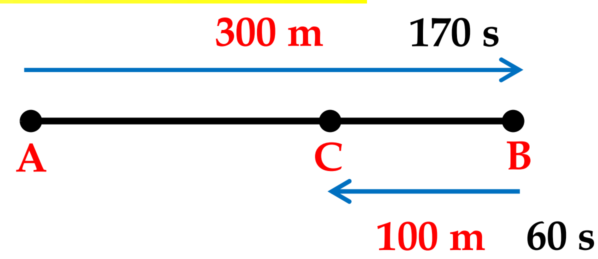
Total time A to C = Time A to B + Time B to C
= 170 + 60
= 230 s

Averag... = $\frac{\text{Distance A to C}}{\text{... A to C}}$

= $\frac{...}{23\cancel{0}}$ = 1.739 m s^{-1}

Shortest distance between A and C

Displacement A to C = AB – BC
= 300 – 100 = 200 m



Average velocity = $\frac{\text{Displacement A to C}}{\text{Total Time A to C}}$

= $\frac{20\cancel{0}}{23\cancel{0}}$ = 0.87 m s^{-1}

Ans : (i) The average speed and average velocity of Joseph from A to B are 1.765 m s^{-1}

(ii) The average speed of Joseph from A to C is 1.739 m s^{-1} and average velocity is 0.87 m s^{-1}

LECTURE 7

Motion

- **Numerical based on acceleration and equation of motion**

Type - B

(i) $a = \dfrac{v - u}{t}$

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

(iii) $v = u + at$

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

Given : Initial velocity (u) $= 18 \text{ km h}^{-1}$

$$= \cancel{18}^{1} \times \frac{5}{\cancel{18}_{1}}$$

$$= 5 \text{ m s}^{-1}$$

Final velocity (v) $= 36 \text{ km h}^{-1}$

$$= \cancel{36}^{2} \times \frac{5}{\cancel{18}_{1}}$$

$$= 10 \text{ m s}^{-1}$$

Time (t) $= 5$ s

To find : Acceleration (a) = ?

Distance covered (s) = ?

Formulae : (i) $a = \dfrac{v - u}{t}$

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

Solution : (i) $a = \dfrac{v - u}{t}$

$$= \frac{10 - 5}{5} = \frac{5}{5}$$

$$\therefore \quad a = 1 \text{ ms}^{-2}$$

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

$$= 5 \times 5 + \frac{1}{2} \times 1 \times (5)^2$$

$$= 25 + 12.5$$

$$= 37.5 \text{ m}$$

Ans : The acceleration of the car is 1 m s^{-2} and the distance covered is 37.5 m.

3

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.

Given : Initial velocity (u) = $0\ m\ s^{-1}$

Acceleration (a) = $0.1\ m\ s^{-1}$

Time (t) = 2 min

= 2×60 s

= 120 s

To find : Speed acquired (v) = ?

Distance travelled (s) = ?

Formulae : (i) $v = u + at$

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

Solution : (i) $v = u + at$

$= 0 + (0.1 \times 120)$

$\therefore\ v = 12\ m\ s^{-1}$

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

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

$= \frac{1}{\cancel{2}_{1}} \times 0.1 \times \cancel{120}^{60} \times 120$

$= 6 \times 120$

$= 720\ m$

Ans : The speed of the bus is $12\ m\ s^{-1}$ and the distance travelled is 720 m.

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

Given : Initial velocity (u) = 0 m s^{-1}

Acceleration (a) = 4 m s^{-2}

Time (t) = 10 s

To find : Distance travelled (s) = ?

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

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

$= 0 \times 10 + \frac{1}{\cancel{2}_{1}} \times \cancel{4}^{2} \times (10)^2$

$= 2 \times 100$

$= 200$ m

Ans : The distance covered by the racing car in 10 s is 200 m.

5 The brakes applied to a car produce an acceleration of 6 m s^{-2} in the opposite direction to the motion. If the car takes 2 s to stop after the application of brakes, calculate the distance it travels during this time.

Given :

Acceleration (a) = – 6 m s^{-2}

Time (t) = 2 s

Final velocity (v) = 0 m s^{-1}

To find :

Initial velocity (u) = ?

Distance travelled (s) = ?

Formulae :

(i) $v = u + at$

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

Solution :

(i) $v = u + at$

$\therefore \quad 0 = u + (-6) \times 2$

$\therefore \quad u = 12 \text{ ms}^{-1}$

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

$\therefore \quad s = 12 \times 2 + \frac{1}{2} \times (-6) \times 2^2$

$= 24 - 12$

$\therefore \quad s = 12 \text{ m}$

Ans : Thus, the car will move 12 m before it stops after the application of brakes.

Motion

- Numerical based on uniform circular motion

TYPE - C

$$\text{Speed} = \frac{\text{Circumference of the circle}}{\text{Time}}$$

$$\text{Speed} = \frac{\text{Perimeter of field}}{\text{Time}}$$

1 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.

Given : Radius of the circular path (r) = 42250 km

Time taken to complete one round (t) = 24 hours

To find : Speed (v) = ?

Formula : $$\text{Speed} = \frac{\text{distance}}{\text{Time}}$$

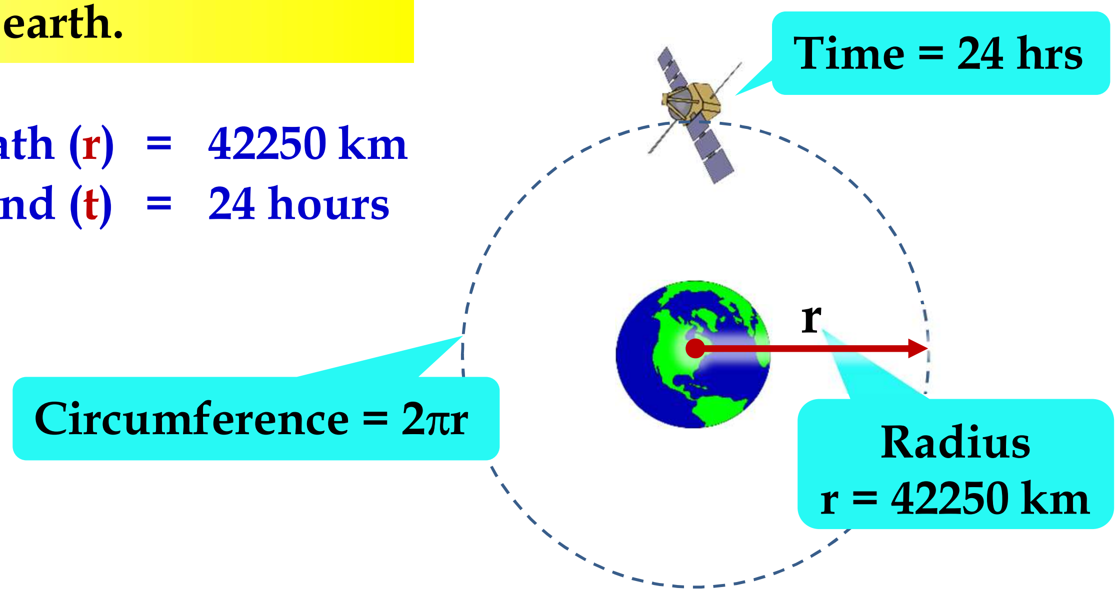
Solution :

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

$$= \overset{1}{\cancel{2}} \times \frac{\overset{11}{\cancel{22}} \times \overset{21125}{\cancel{42250}}}{7 \times \underset{\underset{3}{\cancel{6}}}{\cancel{\cancel{24}}^{12}}}$$

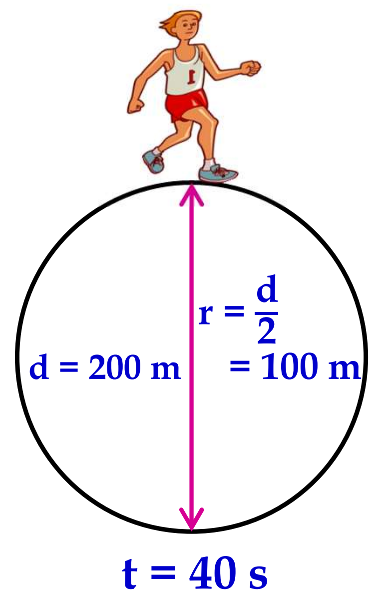
$$\therefore \; v = \frac{11 \times 21125}{7 \times 3}$$

Ans : The speed of satellite = 11065 km h^{-1}



2

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?



Given : Diameter (d) = 200 m

Radius (r) $= \frac{d}{2} = \frac{200}{2} = 100$ m

Time for 1 round (t) = 40 s

To find : (i) Distance after 2 min 20 sec

(ii) Displacement after 2 min 20 sec

1 round of the circular track

Solution : (i) Distance covered in 40 s = Circumference of circle

$= 2\pi r$

$= 2 \times \pi \times 100$

$= 200\pi$ m

Distance covered in 1 s $= \frac{\text{Circumference of circle}}{40}$

$= \frac{\cancel{200}^{5}\,\pi}{\cancel{40}_{1}} = 5\pi$ m

Total time athlete run = 2 min 20 s

$= (2 \times 60) + 20$

$= 140$ s

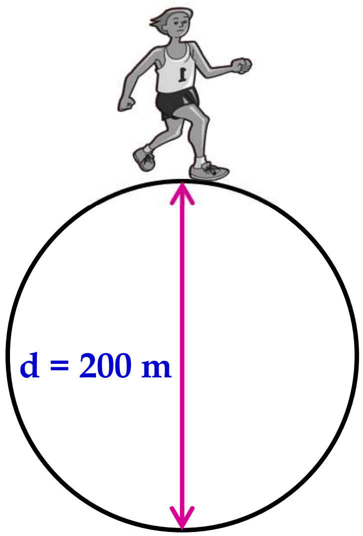
2 An athlete completes one round of a circular track of diameter 200 m in 40 s. what will be the distance covered and the displacement at the end of 2 minutes 20 s?

$\therefore$ Distance covered in 140 s $= 5\pi \times 140$

$= 700\pi$ m

$= \cancel{700}^{100} \times \dfrac{22}{\cancel{7}_{1}}$

$= 2200$ m



(ii) Number of rounds athlete runs $= \dfrac{\text{Distance covered in 140 s}}{\text{Distance covered in 40 s}}$

$= \dfrac{700\pi}{200\pi} = 3.5$ rounds

3.5 rounds = 3 full rounds + 1 half round

Person is at the opposite side of the track after 3.5 round.

Displacement = Diameter of track = 200 m

Ans : After 2 min 20 s, the distance covered in 2200 m and displacement is 200 m

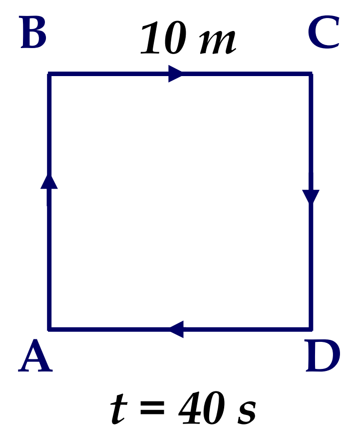
3 A farmer moves along the boundary of a square field of side 10 m in 40 s. What will be the magnitude of displacement of the farmer at the end of 2 minutes 20 seconds?

Given : Side of the square field = 10 m

perimeter = 10×4

= 40 m

Time for 1 round (t) = 40 s



To find : (i) Displacement after 2 min 2

1 round of the field

Solution : (i) Distance covered in 40 s = Perimeter of field

40 m

Distance covered in 1 s = $\dfrac{\text{Perimeter of field}}{40}$

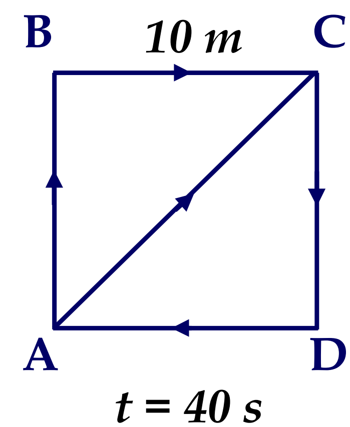
$= \dfrac{\cancel{40}^{1}}{\cancel{40}_{1}} = 1\text{ m}$

Total time farmer moves = 2 min 20 s

= $(2 \times 60) + 20$

= 140 s

3 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?



$\therefore$ Distance covered in 140 s $= 1 \times 140$

$= 140$ m

Number of rounds farmer completes $= \dfrac{\text{Distance covered in 140 s}}{\text{Distance covered in 40 s}}$

$= \dfrac{140}{40} = 3.5$ rounds

3.5 rounds = 3 full rounds + 1 half round

Person is at the opposite side of the track after 3.5 round.

Displacement (AC) $= \sqrt{AD^2 + DC^2} = \sqrt{10^2 + 10^2}$

$= \sqrt{200}$

Ans : Displacement of farmer after 2min 20sec will be equal to $10\sqrt{2}$ m north east from initial position.

LECTURE 8

Motion

- **Numerical based on acceleration and equation of motion**

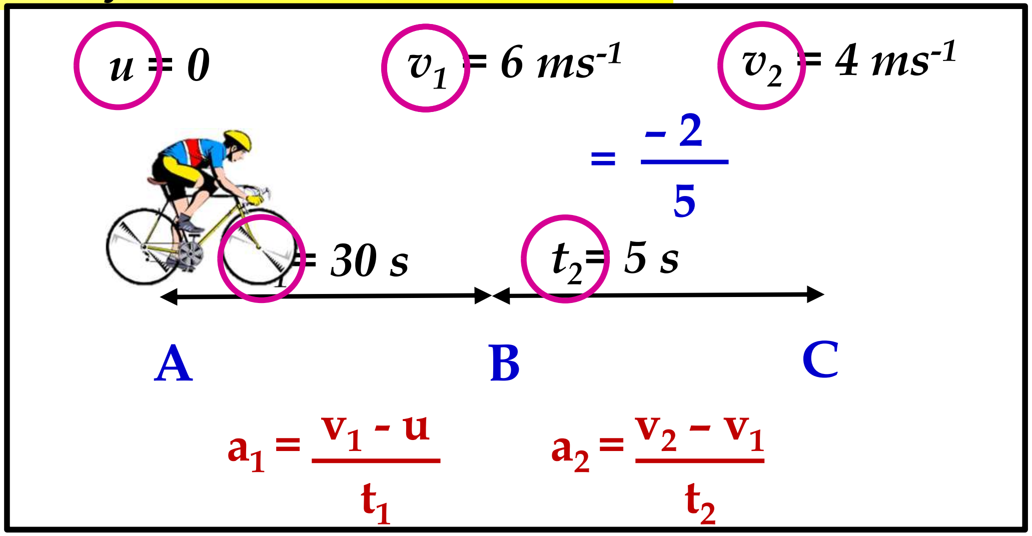
Type - D

NUMERICAL

$$\text{(i) } 2as = v^2 - u^2$$

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

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



Given : Initial velocity (u) = 0 m s^{-1}

Velocity (v_1) = 6 m s^{-1}

Velocity (v_2) = 4 m s^{-1}

Time (t_1) = 30 s

Time (t_2) = 5 s

To find : Acceleration a_1 and a_2 = ?

Formula : $a = \dfrac{v - u}{t}$

Solution : Case 1 : As Rahul paddles

$$a_1 = \frac{v_1 - u}{t_1} = \frac{6 - 0}{30}$$

$$\therefore \quad a_1 = 0.2 \text{ m s}^{-2}$$

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

Given :

Initial velocity (u) = $0 \ m \ s^{-1}$

Displacement (s) = 20 m

Acceleration (a) = $10 \ m \ s^{-2}$

To find :

Velocity (v) = ?

Time (t) = ?

Formulae :

(i) $v^2 = u^2 + 2as$

(ii) $a = \dfrac{v - u}{t}$

Solution :

(i) $v^2 = u^2 + 2as$

$\therefore \ v^2 = (0)^2 + 2 \times 10 \times 20$

$\therefore \ v^2 = 400$

$\therefore \ v = \sqrt{400}$

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

(ii) $a = \dfrac{v - u}{t}$

$\therefore \ t = \dfrac{v - u}{a} = \dfrac{20 - 0}{10}$

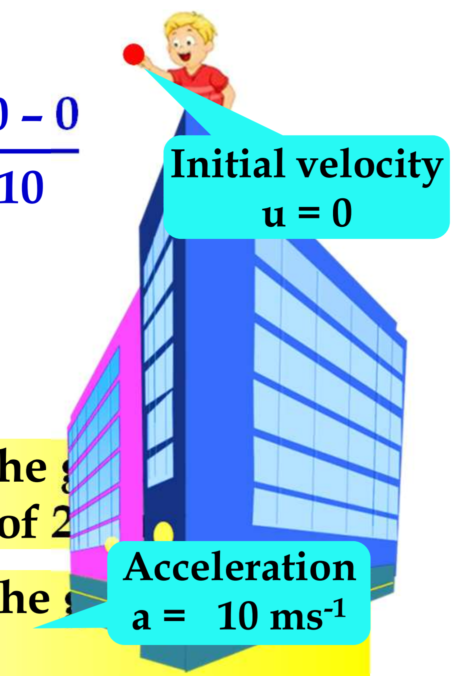
$\therefore \ t = \dfrac{20}{10}$

$\therefore \ t = 2$ sec

Ans :

(i) It strikes the
a velocity of 2

(ii) It strikes the
2 sec.



3

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

Given : Initial velocity (u) = 0

Final velocity (v) = 72 km h^{-1}

$$= \cancel{72}^{4} \times \frac{5}{\cancel{18}_{1}} \text{ m s}^{-1}$$

$$= 20 \text{ m s}^{-1}$$

Total time (t) = 5 minutes

= 5 × 60 s.

= 300 s.

To find : Acceleration (a) = ?

distance travelled (s) = ?

Formulae : (i) $a = \dfrac{v - u}{t}$

Solution : (i)

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

$$= \frac{20 - 0}{300} = \frac{\cancel{20}^{1}}{\cancel{300}_{15}}$$

$$\therefore \quad a = \frac{1}{15} \text{ ms}^{-2}$$

u = 0

(ii) $2as = v^2 - u^2$

$2as = v^2 - 0$

$$s = \frac{v^2}{2a} = \frac{(20)^2}{2\times(1/15)} = \frac{\cancel{400}^{200} \times 15}{\cancel{2}_{1}}$$

= 3000 m

= 3 km

Ans : The acceleration of the train is $\frac{1}{15}$ m s^{-2} and the distance travelled is 3 km.

4 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?

Given :

Initial velocity (u) = 5 m s^{-1}

Final velocity (v) = 0 m s^{-1}

Downward Acceleration = 10 m s^{-2}

Upward Acceleration (a) = - 10 m s^{-2}

To find :

Height attained (s) = ?

Time taken (t) = ?

Formulae :

(i) $2as = v^2 - u^2$

(ii) $a = \dfrac{v - u}{t}$

Solution :

(i) $2as = v^2 - u^2$

$$\therefore \quad s = \frac{v^2 - u^2}{2a} = \frac{0^2 - 5^2}{2(-10)} = \frac{-25}{-20}$$

$$\therefore \quad s = 1.25 \text{ m}$$

(ii) $a = \dfrac{v - u}{t}$

$$t = \frac{v - u}{a} = \frac{0 - 5}{-10} = \frac{-5}{-10}$$

$$t = 0.5 \text{ s}$$

Ans : The stone attains a height of 1.5m in 0.5 s

5

A train is travelling at a speed of 90 km h^{-1}. Brakes are applied so as to produce a uniform acceleration of – 0.5 m s^{-2}. Find how far the train will go before it is brought to rest.

Given : Initial velocity (u) = 90 km h^{-1}

$$= \cancel{90}^{5} \times \frac{5}{\cancel{18}_{1}} \text{ m s}^{-1}$$

$$= 25 \text{ m s}^{-1}$$

Final velocity (v) = 0 m s^{-1}

Acceleration (a) = – 0.5 m s^{-2}

To find : Distance travelled (s) = ?

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

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

$$\therefore \quad s = \frac{v^2 - u^2}{2a} = \frac{0^2 - 25^2}{2(-0.5)} = \frac{\cancel{-}25^2}{\cancel{-}1}$$

$$\therefore \quad s = 625 \text{ m}$$

Ans : The train travels a distance of 625 m.

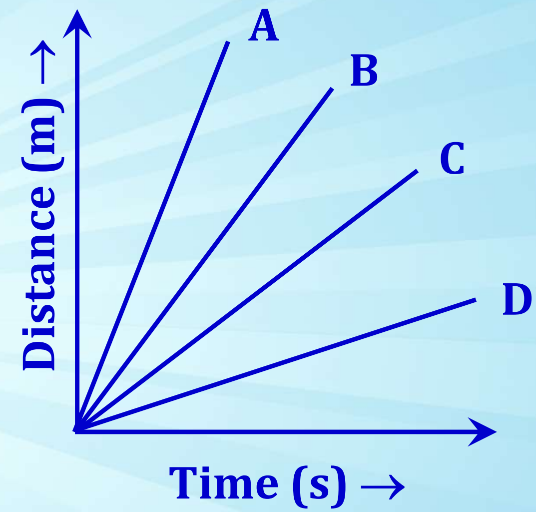
Motion

- Numerical based on graph

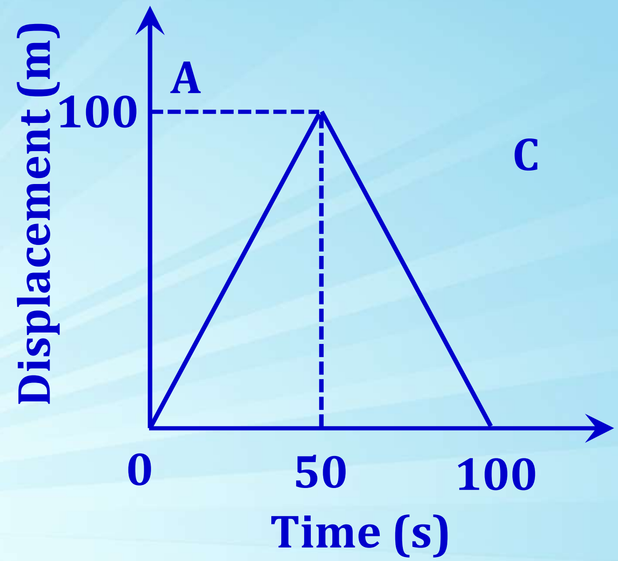
Four cars A, B, C and D are moving on a levelled road. Their distance versus time graphs are shown in figure. Which car is the slowest?

Ans. Speed = Slope of distance-time graph. The smaller the slope, the smaller is the speed.

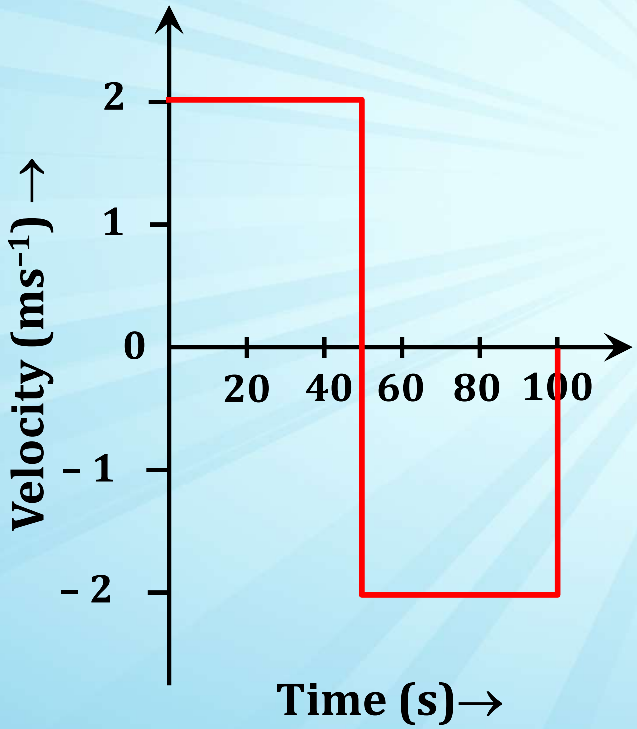
From the figure, slope is minimum for car D. So, D is the slowest car.



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



Ans.



1

The distance-time graph of three objects A, B and C is shown. 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) ... C travelled when B passes A ?

(d) ... B travelled by the time it passes ... 'C' ... travelled ?

To find this we draw a line parallel to X- Axis

From points O, P and Q

a) 'B' travelling the fastest

b) Thus no, there are never at the same point on the road

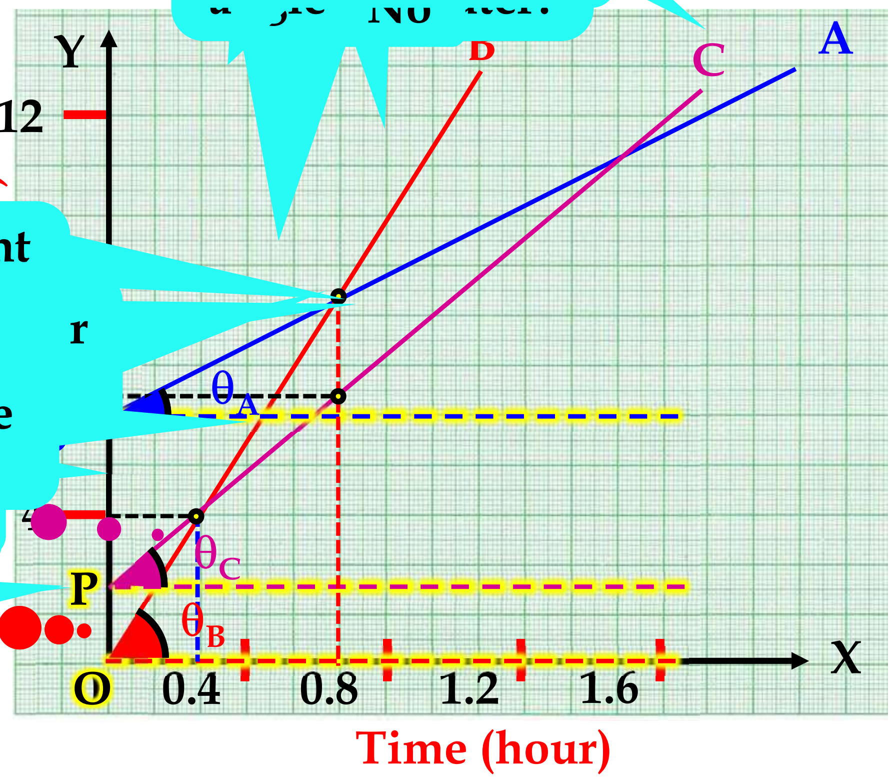
c) Thus 'C' travels a ... when 'B' passes 'A'

d) Thus 'B' travels a ... when it passes 'C'

Is there is a common point of intersection for the objects 'A', 'B' & 'C'?

Which intersects Y- axis at 4 km

Made by the object B



Motion

- **Numerical based on graph**

1

A driver of a car travelling at 52 kmh^{-1} applies the brakes & accelerator uniformly in the opposite direction, the car stops in 5 sec. Another driver going at 34 kmh^{-1} in another car applies his brakes slowly & stops in 10 sec. On the same graph paper plot the speed versus time graphs for two cars. Which of the two cars travelled further after the brakes were applied?

Given : Velocity of car_1 (u_1) = 52 km h^{-1}

Velocity of car_2 (u_2) = 34 km h^{-1}

Time (t_1) = 5 sec

Time (t_2) = 10 sec

To find : Distance covered by first car = ?

Distance covered by second car = ?

Distance covered = Ar ΔOCD

The area under speed time graph represents distance travelled.

$1\ kmh^{-1} = \frac{5}{18}\ ms^{-1}$

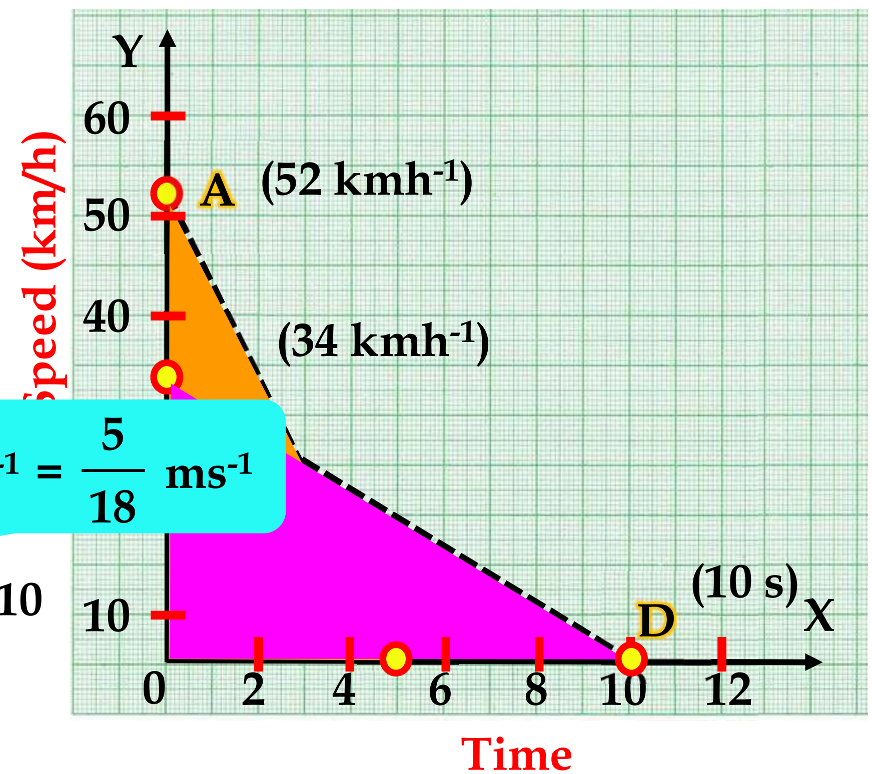
= $\frac{1}{2}$ 52km

× 10

= 36.1m

= 47.2m

Ans : The second car travels further after the brakes are applied



2 The speed-time graph for a car is shown below.

(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?

To find : (i) Distance travelled in first 4 s = ?

(ii) Part which represents uniform motion = ?

Solution :

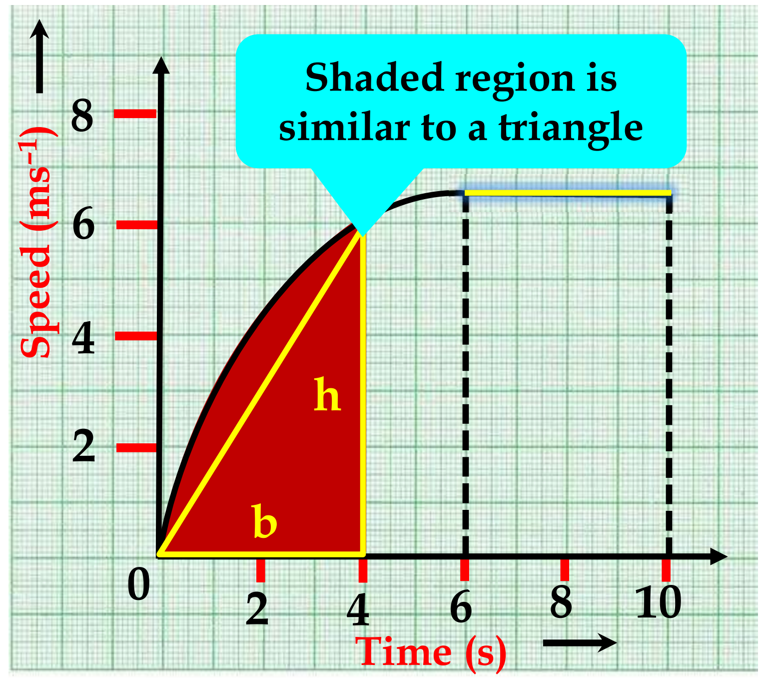
(i) The area under speed time graph represents distance travelled.

Distance travelled in first 4 s

Area of shaded region = Area of triangle

$= \frac{1}{2} \times b \times h$

$= \frac{1}{\cancel{2}_{1}} \times \cancel{4}^{2} \times 6 = 12$ m



(ii) Part of graph between 6 s to 10 s represents uniform motion of car.

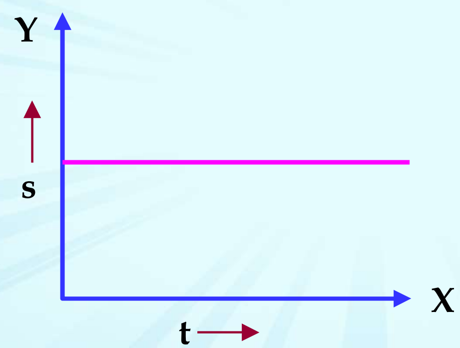
For uniform motion speed-time graph is a straight line parallel to x-axis.

Ans : (i) Distance travelled in first 4 s is 12 m

(ii) Motion is uniform after the 6th second.

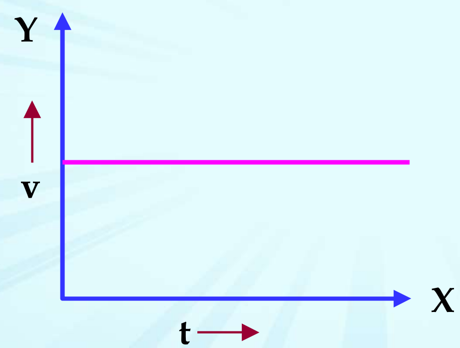
What can you say about the motion of an object whose distance time graph is a straight lint parallel to the time axis?

Ans. The object is stationary, i.e., at rest.



What can you say about the motion of an object if its speed-time graph is a straight line parallel to time axis?

Ans. It indicates that the object is moving with uniform speed.

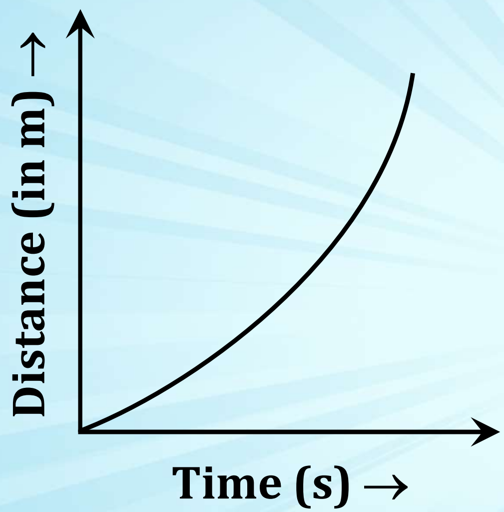


What is the shape of velocity-time graph for non-uniformly accelerated motion?

Ans. **The velocity-time graph for non-uniformly accelerated motion can have any shape.**

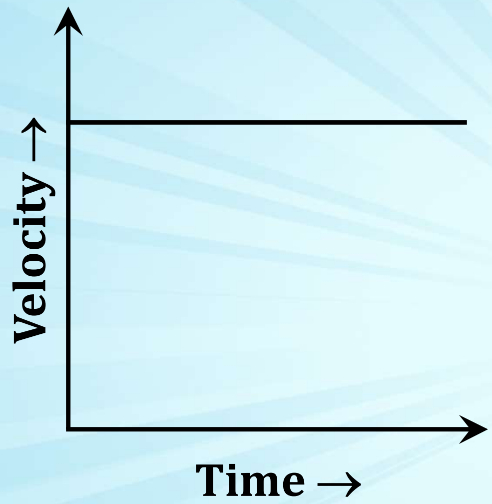
Draw the distance-time graph for a car moving with non-uniform speed.

Ans.



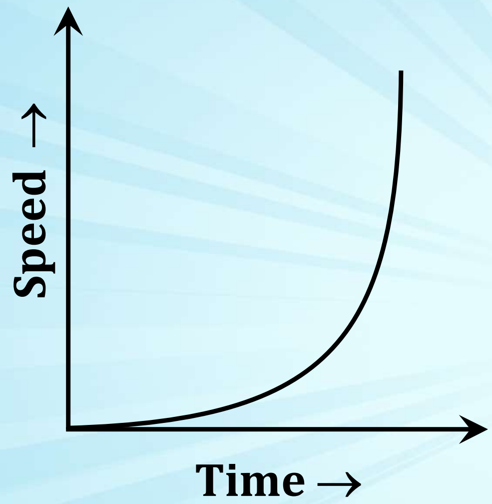
Draw the velocity-time graph of an object moving with uniform velocity.

Ans.



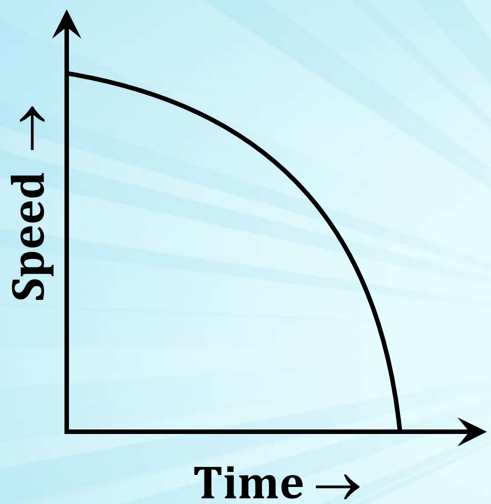
Plot a speed-time graph when the body is under non-uniform acceleration?

Ans.



Plot a speed-time graph when the body is under non-uniform retardation?

Ans.



Draw a velocity-time graph when the speed changes alternatively.

Ans.

Plot the velocity-time graph when the velocity increases in a stepwise manner.

Ans.