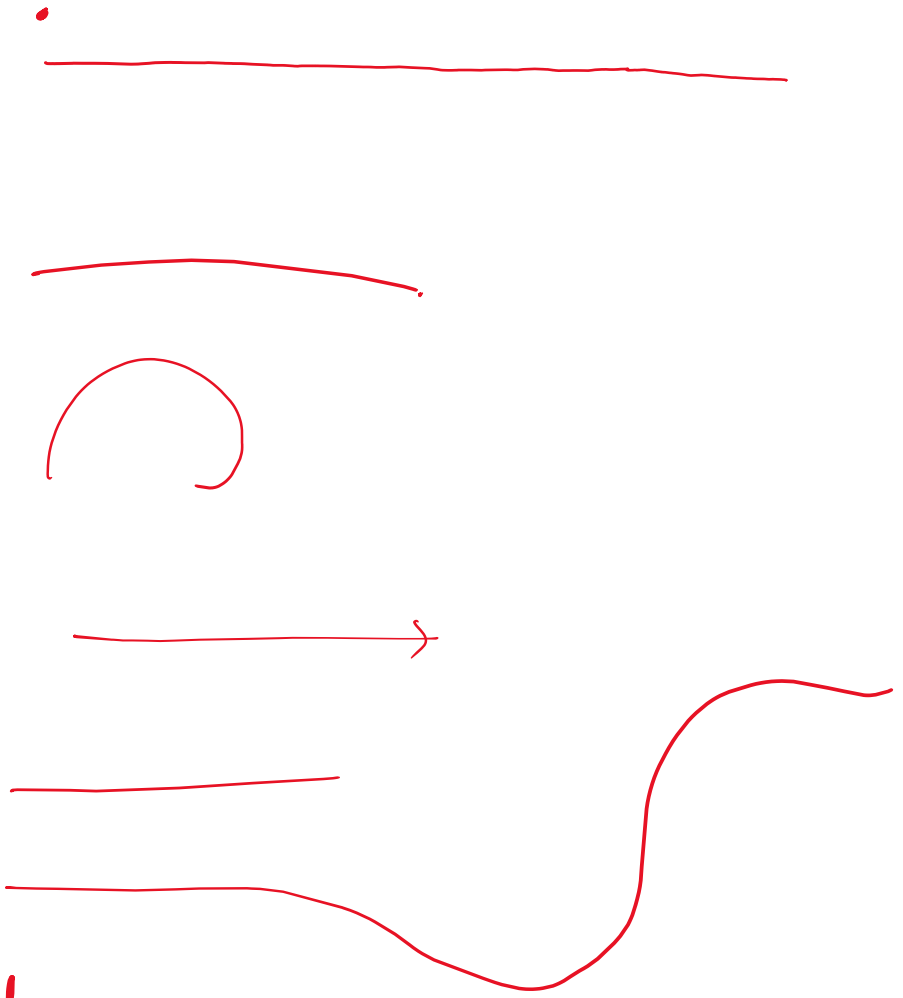
Motion

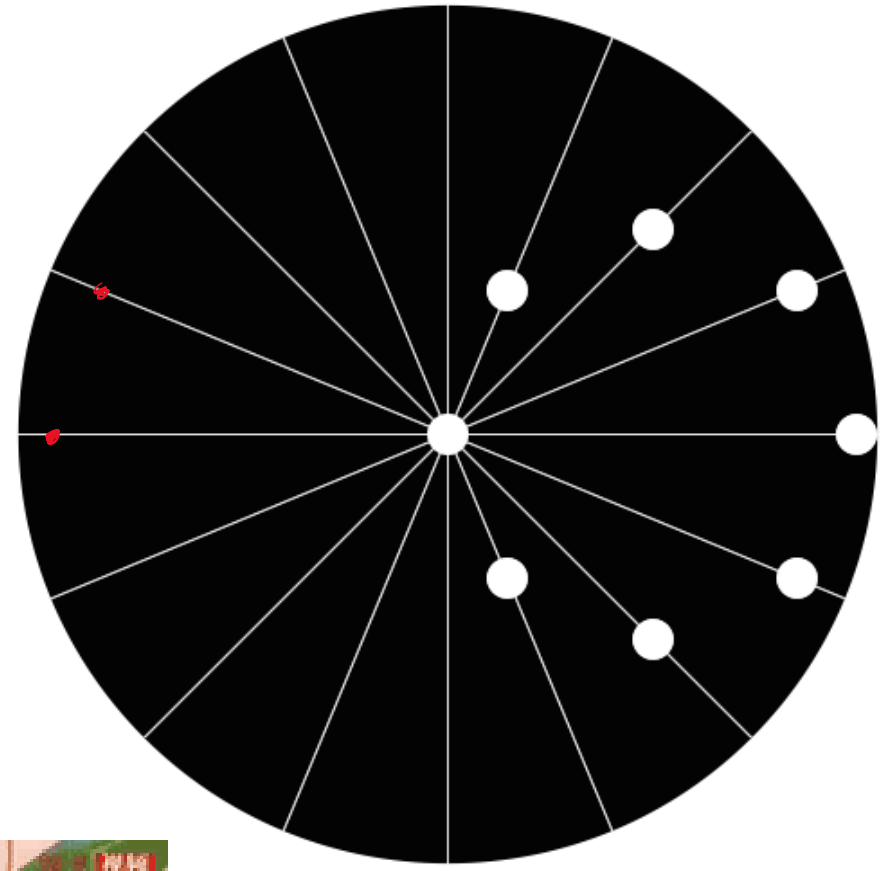
Introduction

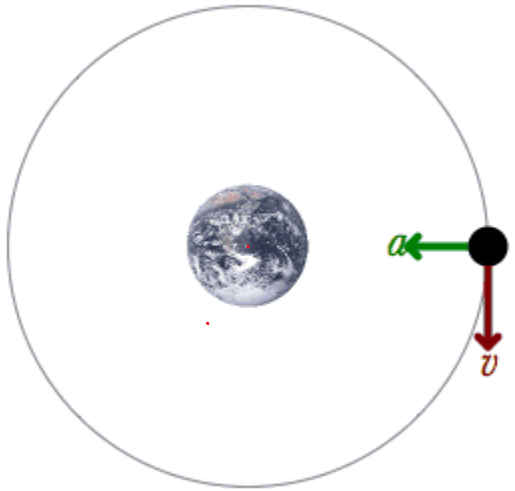
- Some objects are at rest, and some are in motion.
- Atoms, molecules, planets, stars, galaxies are all in motion.
- Some motions can be perceived and some cannot be perceived.
- Day and night; change in season, etc. is because of motion of earth.
- An object may appear to be moving for one person and stationary for some other person.
- Most motions are complex:
  - Linear motion, circular motion
  - Rotational motion, vibrational motion.
  - Combination of above motions.
- In this chapter we will be discussing about linear motion and circular motion.

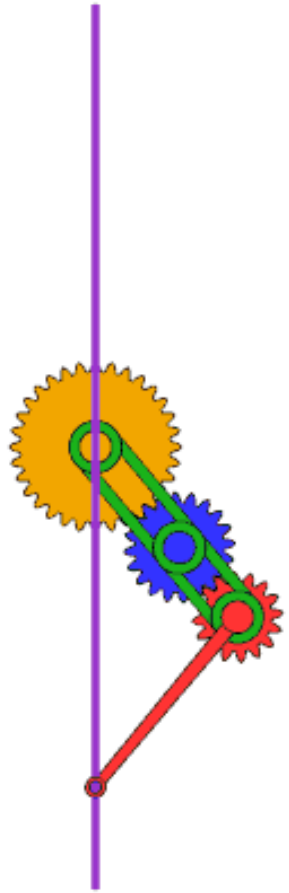


Introduction

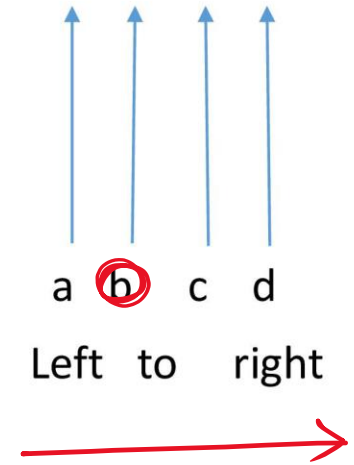
detailed study







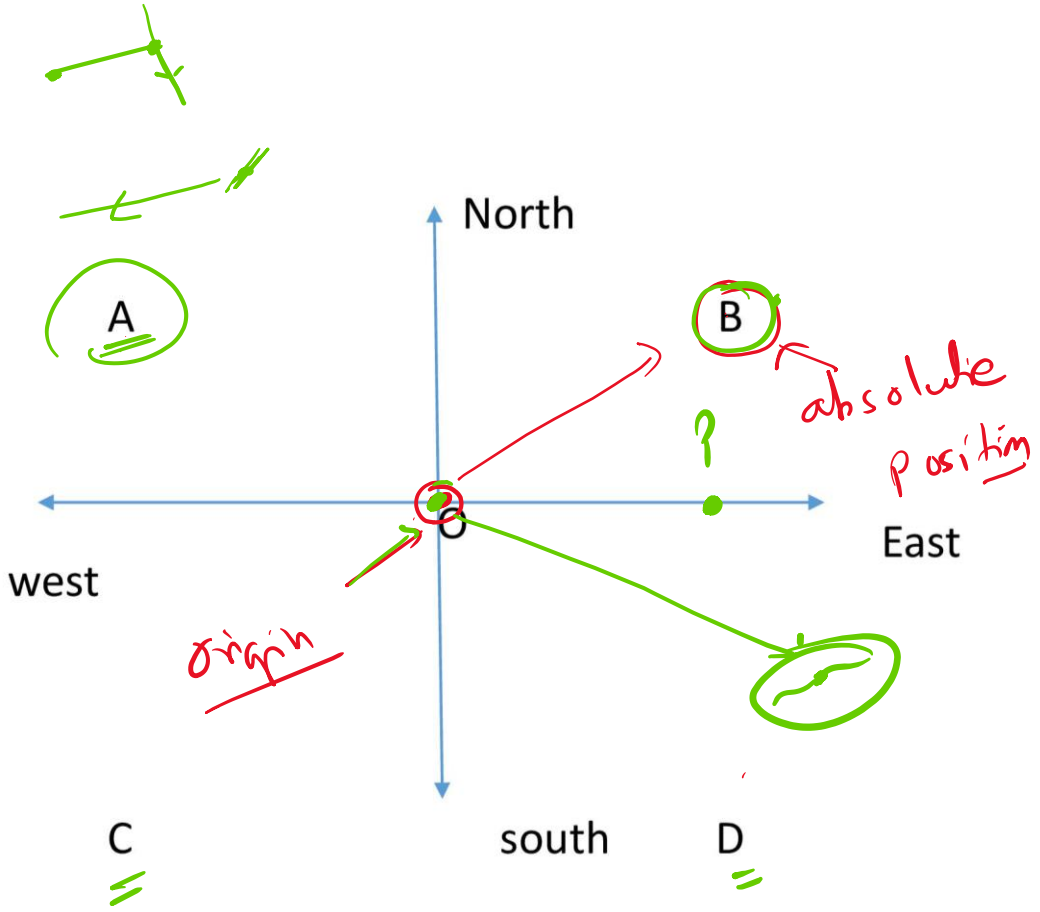
POSITION



- Suppose four a,b,c,d are seating in a row equidistant from their neighbors from left to right as shown
- Position of b with respect to
- a is immediate right
- c is immediate left
- d is second to the left
- Thus position is relative which varies according to the reference point.

Relative and Absolute Position

reference point referral point.



In the figure position of B with respect to A is AB in East

Respect to C is CB North East.

- Thus position of a particular point can vary with different points
- This is known as *Relative Position* .
- But in order to consider all points in one frame we need to consider one point as a absolute referral point an position of all other points with respect to that point will be their

Absolute Position.

For example consider O as a absolute point then position of all other points with respect to O will be their absolute position for B is OB in North East. Similarly A is OA North West and So On.

Note :- 1. We Can take any point as absolute according to our convenience.
2. Direction as well as distance both is required to know ones position.

Reference Point

- **A Reference Point** is used to describe the location of an object. An object can be referred through many reference points.

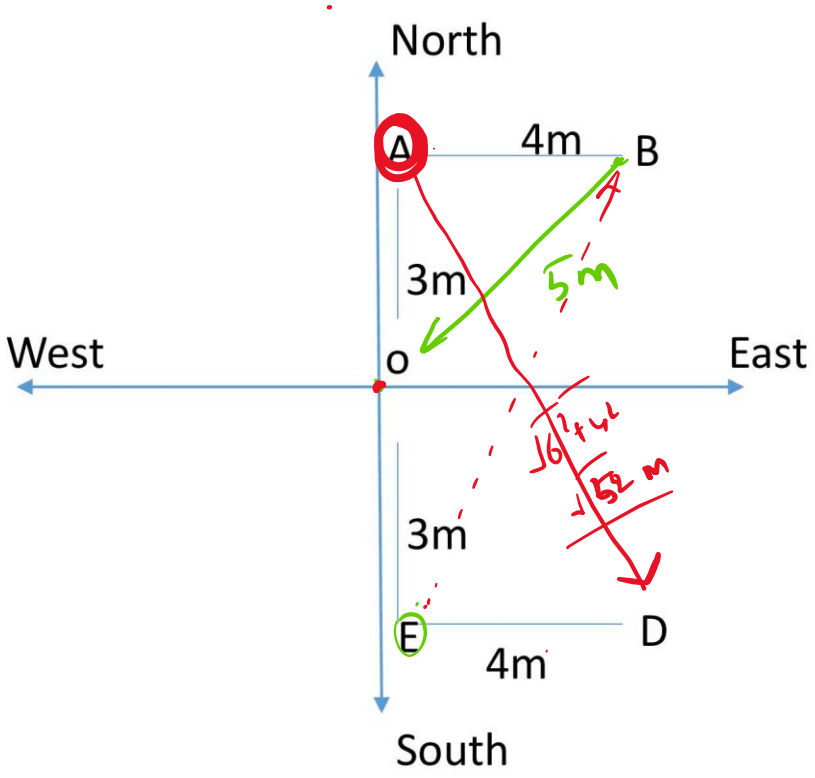
Origin

- The reference point that is used to describe the absolute position of an object is called **Origin**.

Example

- a new restaurant is opening shortly at a distance of 5 km north from my house. Here, the house is the reference point that is used for describing where the restaurant is located.

Illustrative Problem

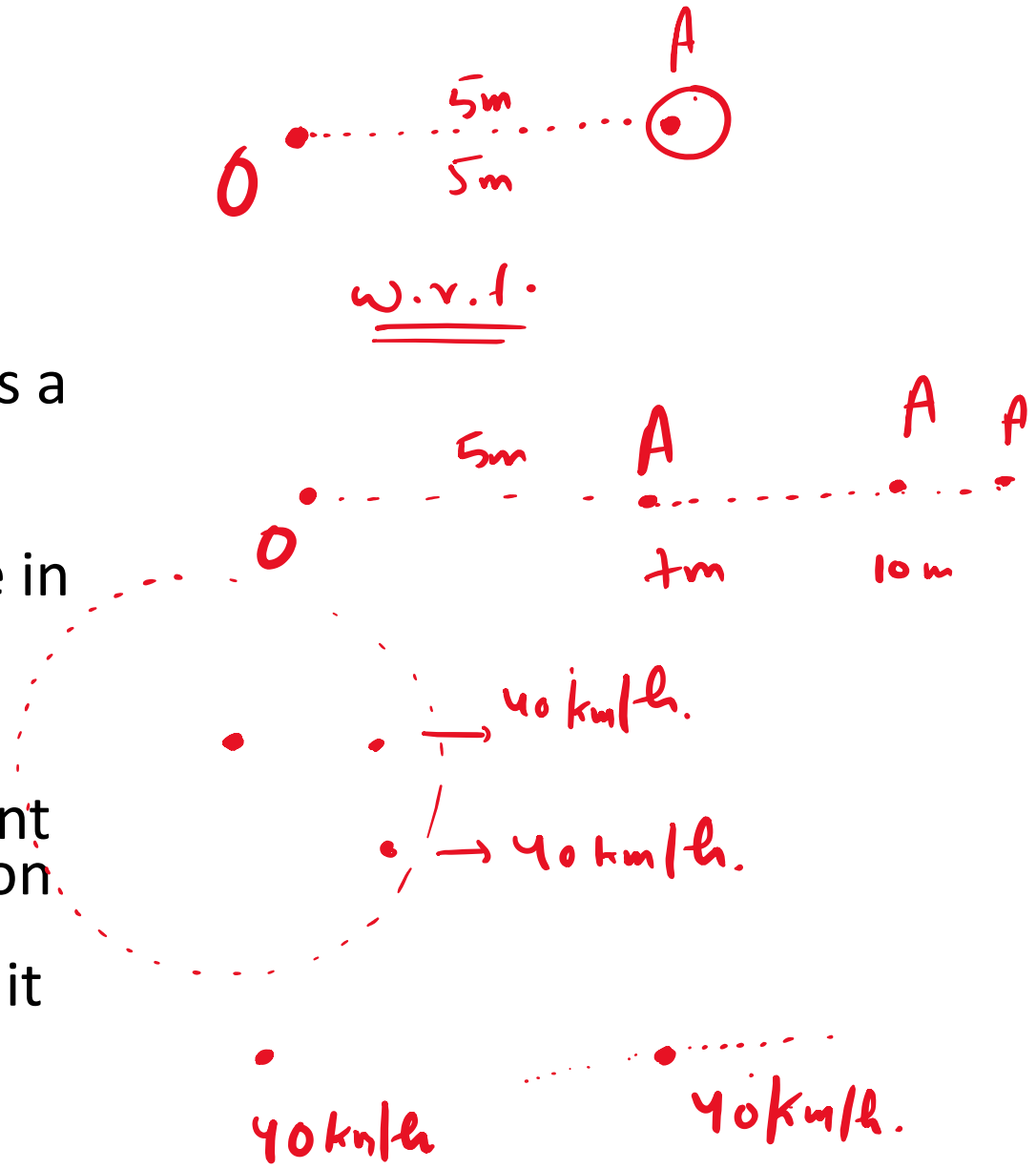


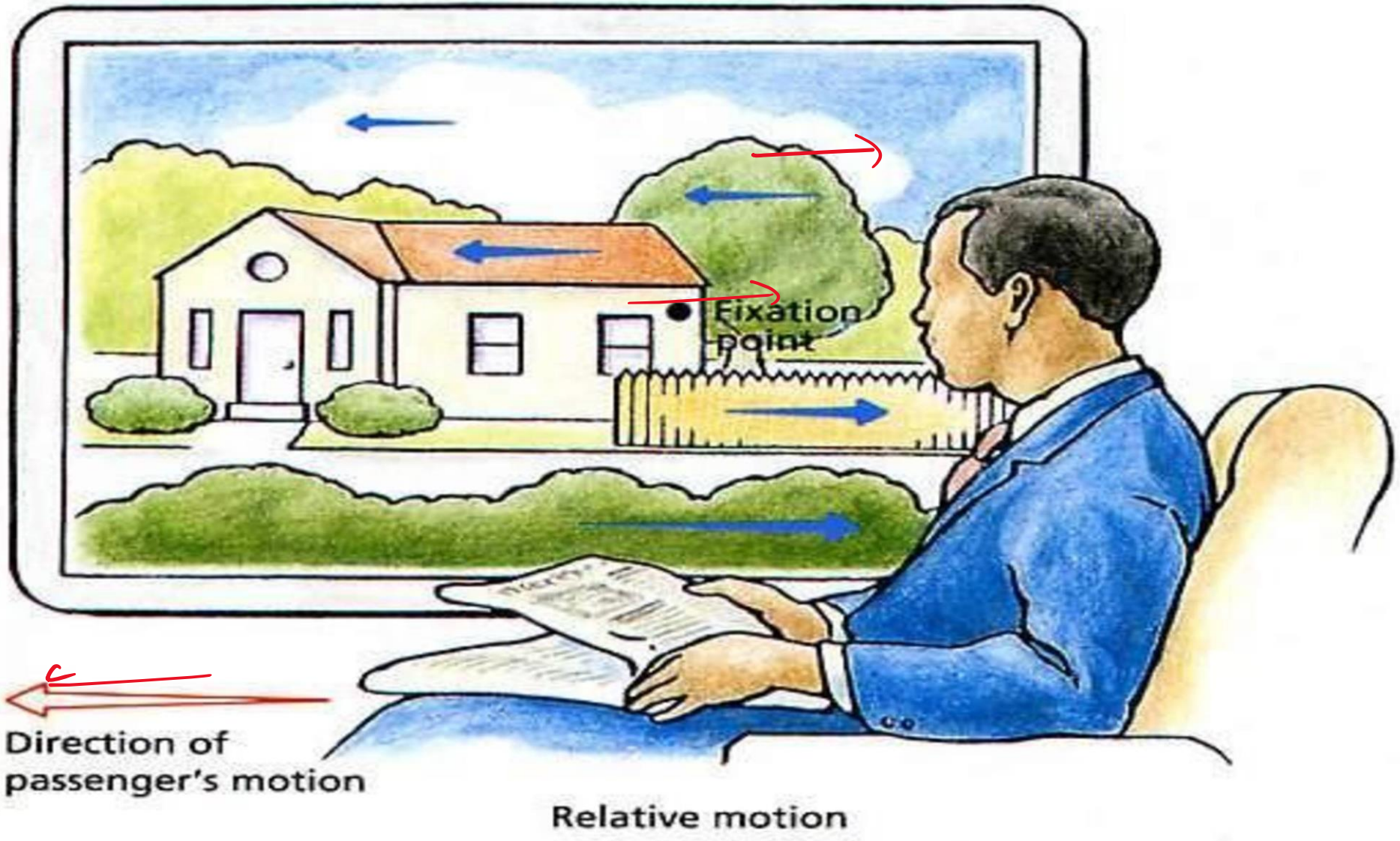
- Questions:

1. What is the position of E with respect to D?
2. What is the position of O with respect to B?
3. What is the position of B with respect to E?
4. Find the absolute position of all points Considering O as absolute point? (Origin)
5. Find the absolute position of all points considering A as absolute Point?

Concept of Rest and Motion

- Rest: A body is said to be in rest if its position does not vary wrt a given referral point as time passes.
- Motion: A body is said to be in motion if there is a continuous change in its position wrt a given referral point as time passes.
- Concept of rest and motion is related to change in position wrt reference point.
  - So, a single object can be at rest or motion at same time wrt different referral points.
- If we consider a single object as a reference point and consider it at rest. Any object whose position is not changing with time wrt to that referral object is at rest and if position is changing then it is in motion.
- To describe most of the motion on earth we consider earth as at rest.





Relative motion

Scalers and Vectors

numerical value.

A scalar quantity has only magnitude.

- Distance (1cm / 20km) — length
- Speed
- Mass (matter)

electric current

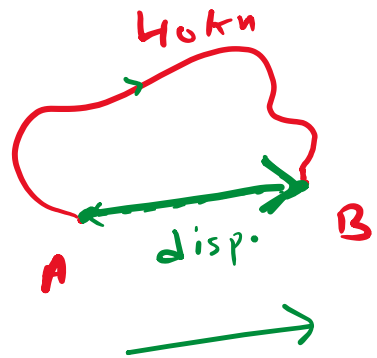
100 km/h

A vector quantity has magnitude and direction.

- Displacement
- Velocity
- Weight
- Acceleration

Force

→ attraction of earth.



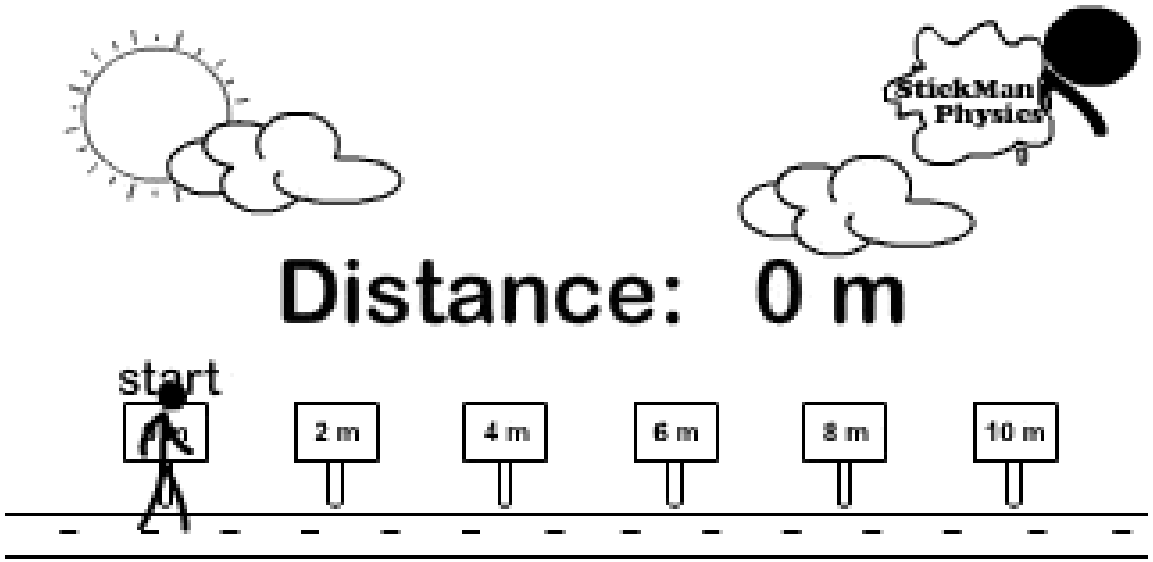
Motion along a Straight Line

Distance (d) (Scalar)

The total path length covered by an object between two endpoints.

Distance is a numerical quantity

We do not mention the direction in which an object is travelling while mentioning about the distance covered by that object.



SI unit : meter (m)

length

⇒ Km

Cm

mm

6m

4m

Distance 10m

Displacement

Vector

The shortest possible distance between the initial and final position of an object is called **Displacement**

Displacement depends upon the direction in which the object is travelling

Displacement is denoted by Δx.

$\Delta x = x_f - x_i$

Where,

x_f = Final position on the object

x_i = Initial position of the object

Initial position

not

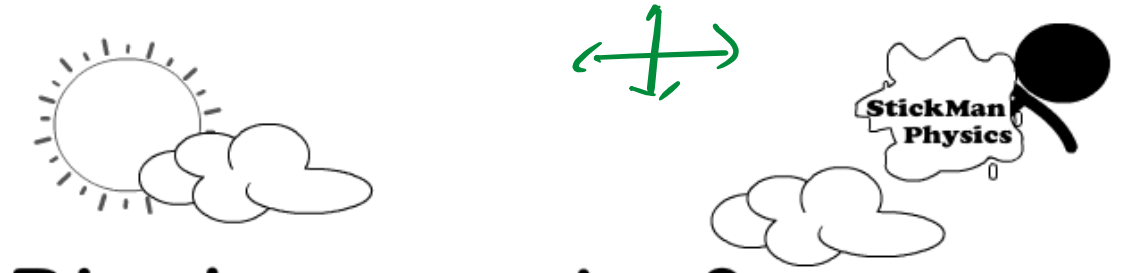
Δ → delta

change

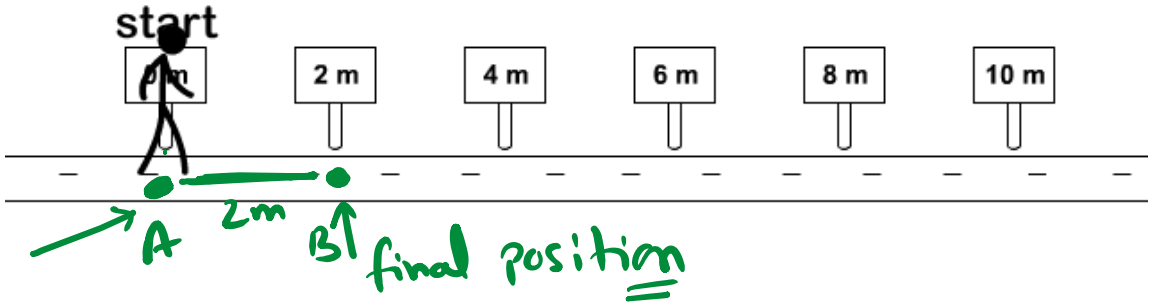
Int

2km

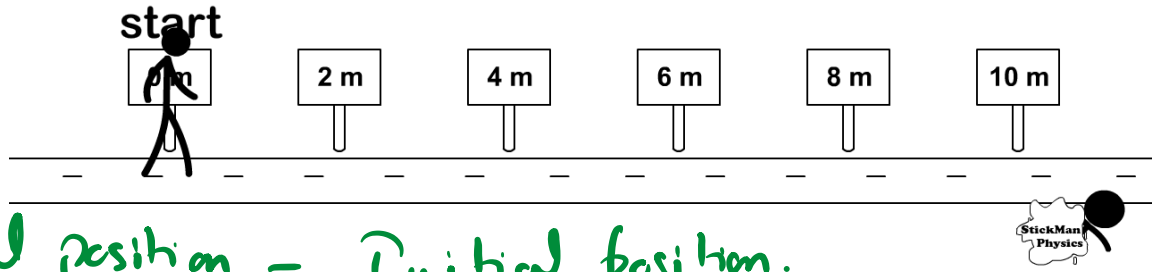
IS = 2 km



Displacement: 0 m



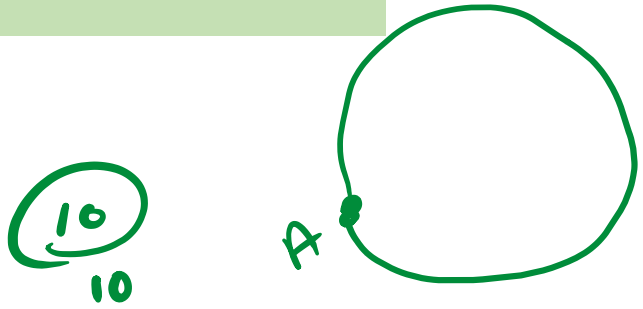
Total Displacement = Final Position - Initial Position

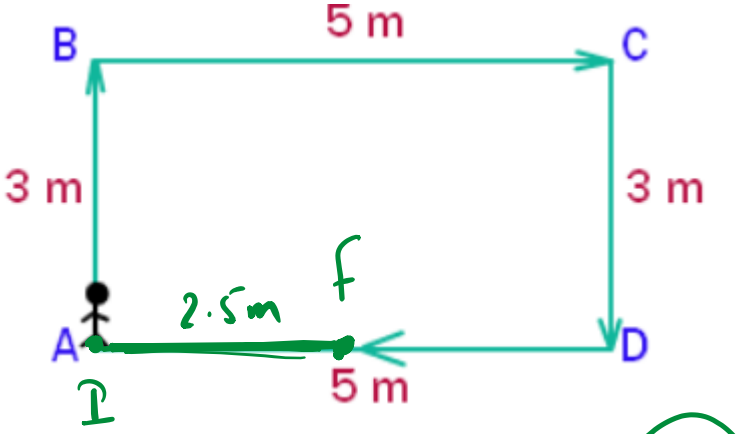


Displacement = final position − Initial position.

Zero Displacement

When the first and last positions of an object are same, the displacement is zero.



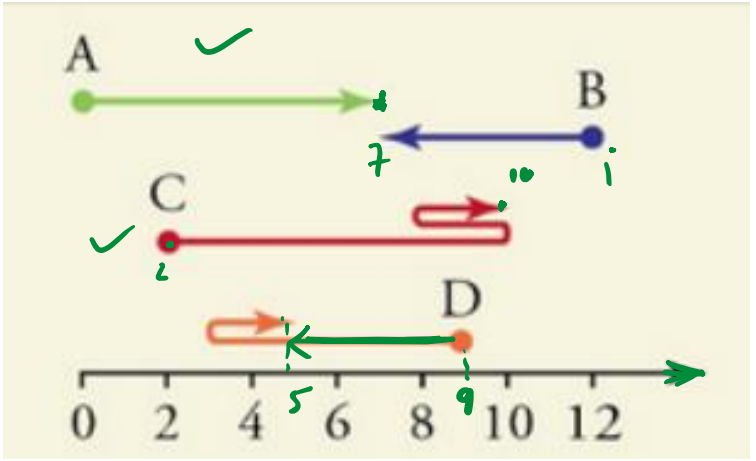


7 − 12 = −5

Negative and Positive Displacement

Here, displacement of object B is negative
$\Delta B = B_f - B_0 = 7 - 12 = -5$
A negative sign indicates opposite direction here.

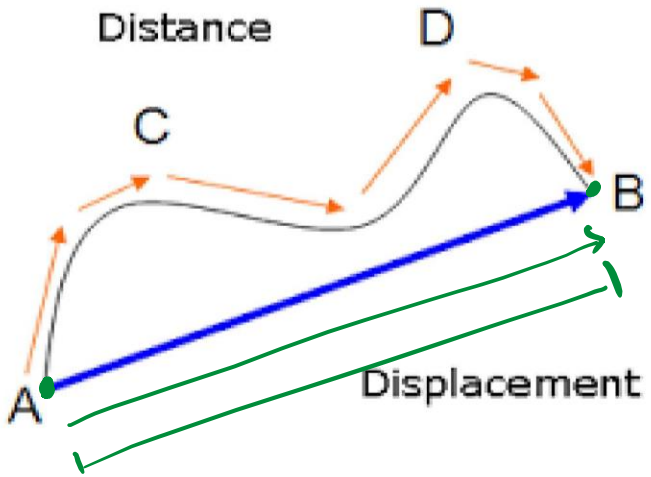
Also, displacement of object A is positive
$\Delta A = A_f - A_0 = 7 - 0 = 7$

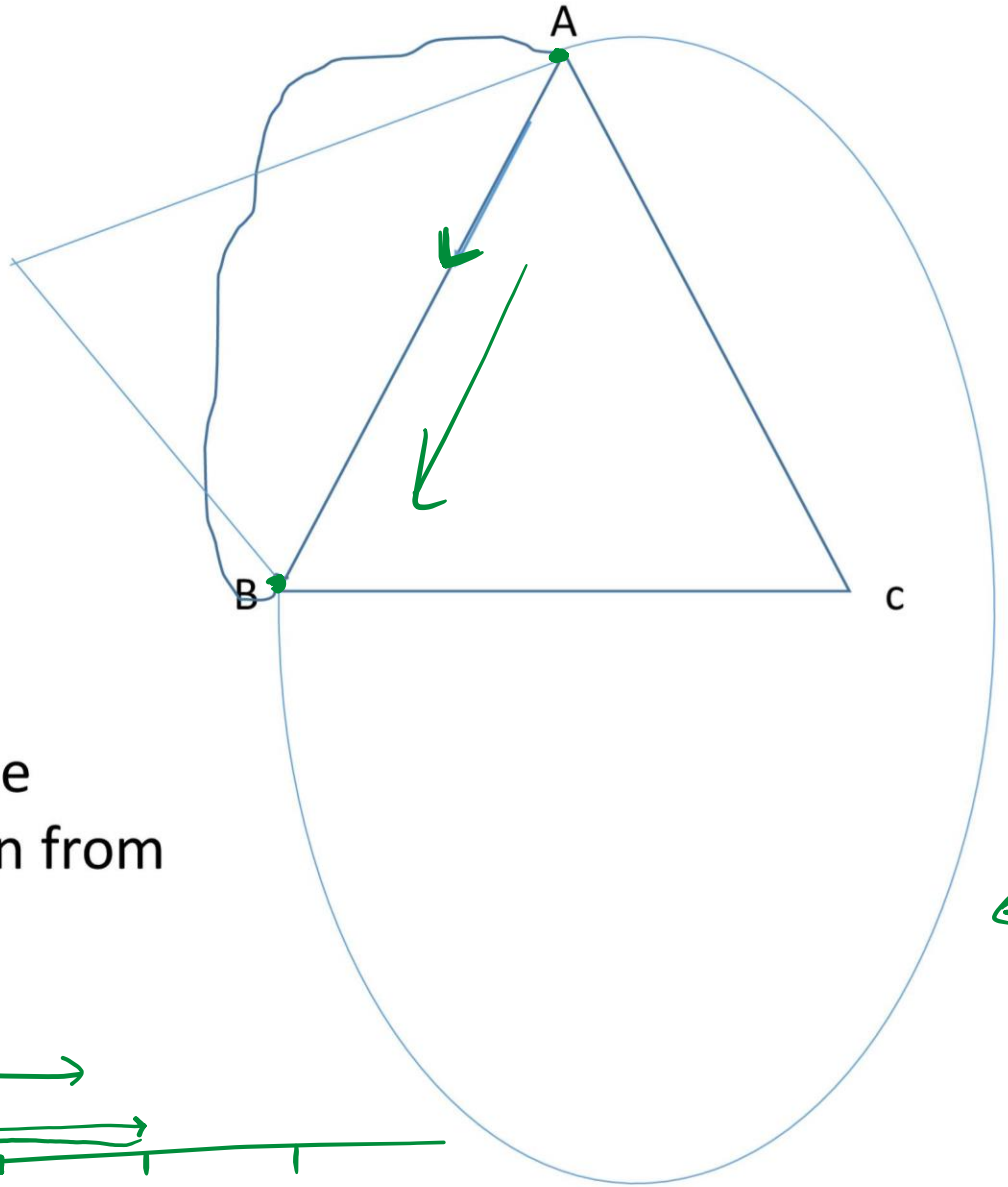


5 − 9 = −4

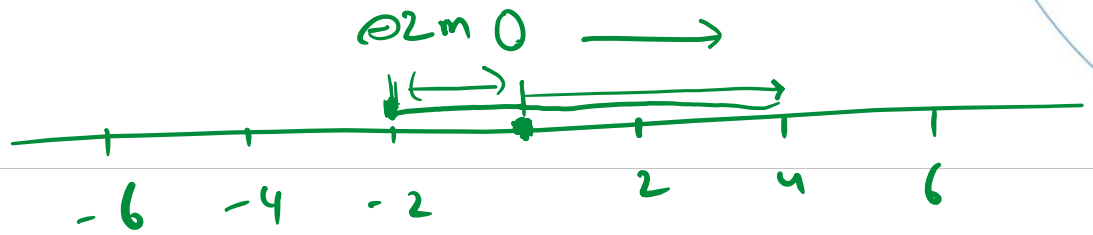
Distance : Zero, the.

Illustrative Examples:





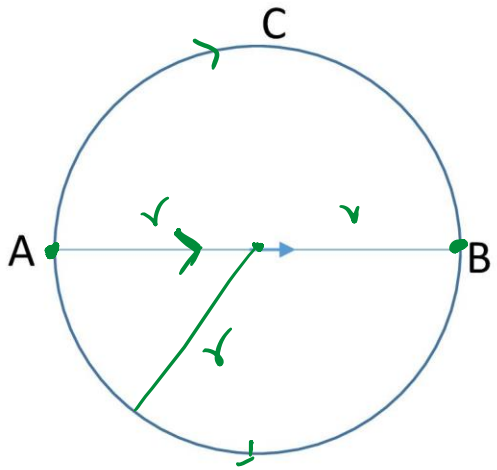
In the figure there can be various paths, but the shortest path denotes actual change in position from Initial point A to final point B which we call as displacement.



Illustrative Example:

If path taken between A and B is through arc it is

$x = \pi r$



Displacement is

$d = 2r$

Suppose a boy running on the track , he starts from A and after completing one round his distance is $2\pi r$

But his position remains same thus displacement is zero.

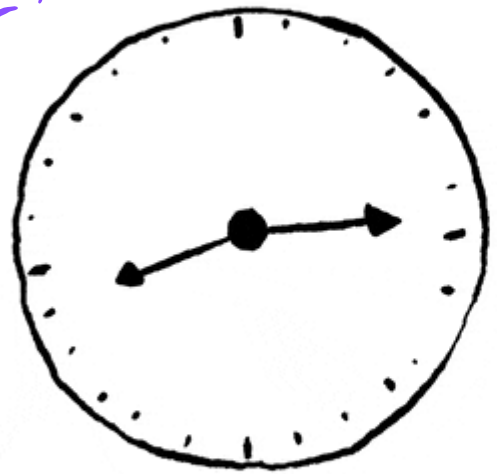
Distance vs Displacement

Distance	Displacement
Distance provides the complete details of the path taken by the object	Displacement does not provide the complete details of the path taken by the object
Distance is always positive	Displacement can be positive, negative or zero
It is a scalar quantity	It is a vector quantity
The distance between two points may not be unique	Displacement between two points is always unique

Time

minutes, hours, day, week, month, Years.

- Duration of an event
- Expressed in seconds (SI unit)
- Most physical phenomenon occurs w.r.t. time.
- It is a scalar quantity



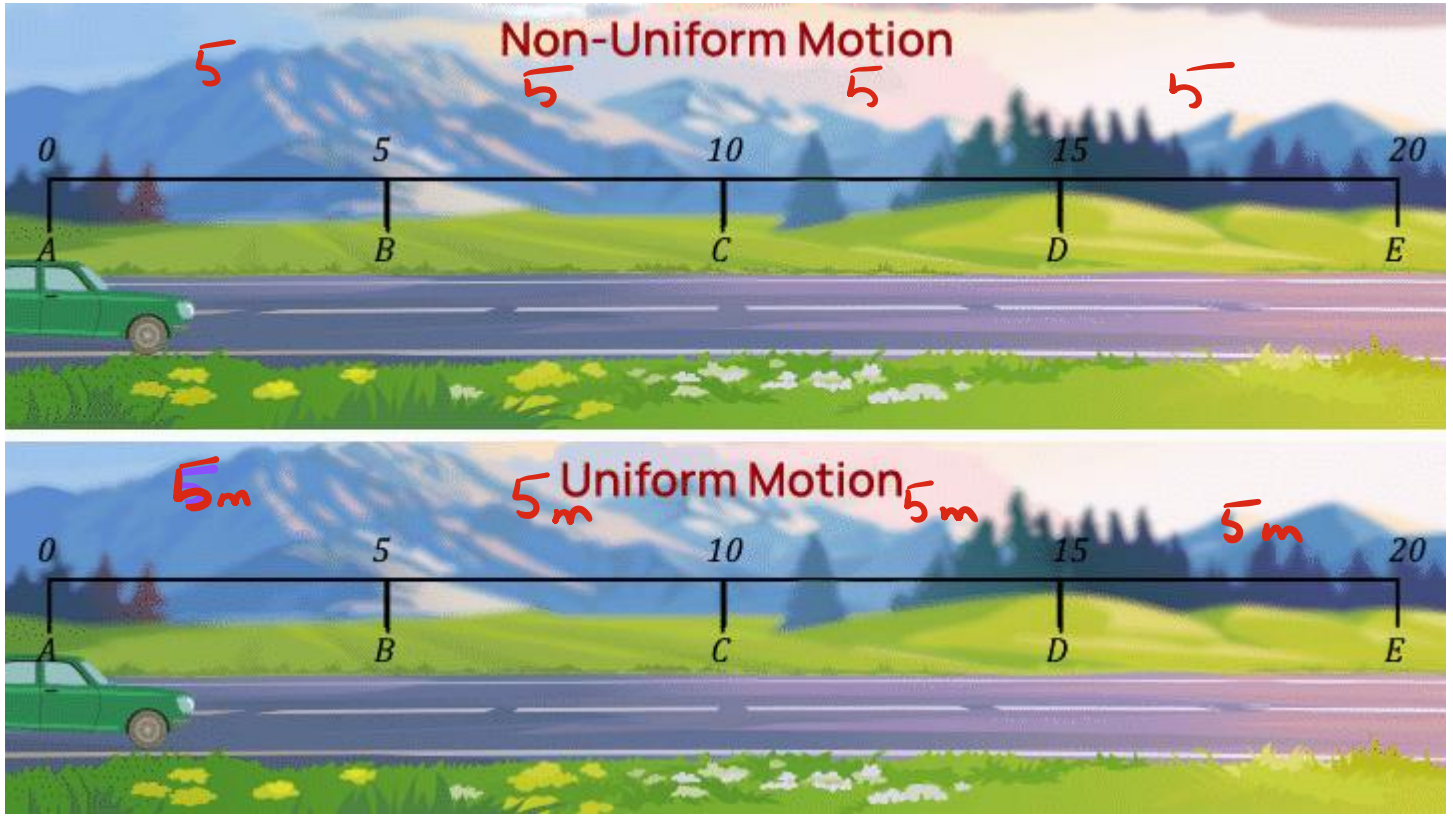
60 x 60 = 3600 sec 1h

24 x 3600 se 1 day

365 x 24 x 3600 sec | 365 day

Uniform and Non-uniform Motion

- When an object travels equal distances in equal intervals of time the object is said to have a uniform motion.
- When an object covers unequal distances in equal intervals of time it is said to be in non-uniform motion.
- To describe rate of motion word speed is used.
- To describe rate of motion in a particular direction word velocity is used.



2s 2s 2s
5m 10m 1m

t

Speed

- It is Rate of change of distance.
- Distance travelled by object per unit time.

$S = \frac{\text{Distance}}{\text{Time}}$ $\frac{+ve}{t}$ $\frac{0}{t}$ $\frac{-ve}{t}$

$\frac{4m}{2s} = \frac{2m}{1s}$

$\frac{\text{Dis}}{\text{time}} = \frac{4}{2} = 2\ ms^{-1}$ m/s

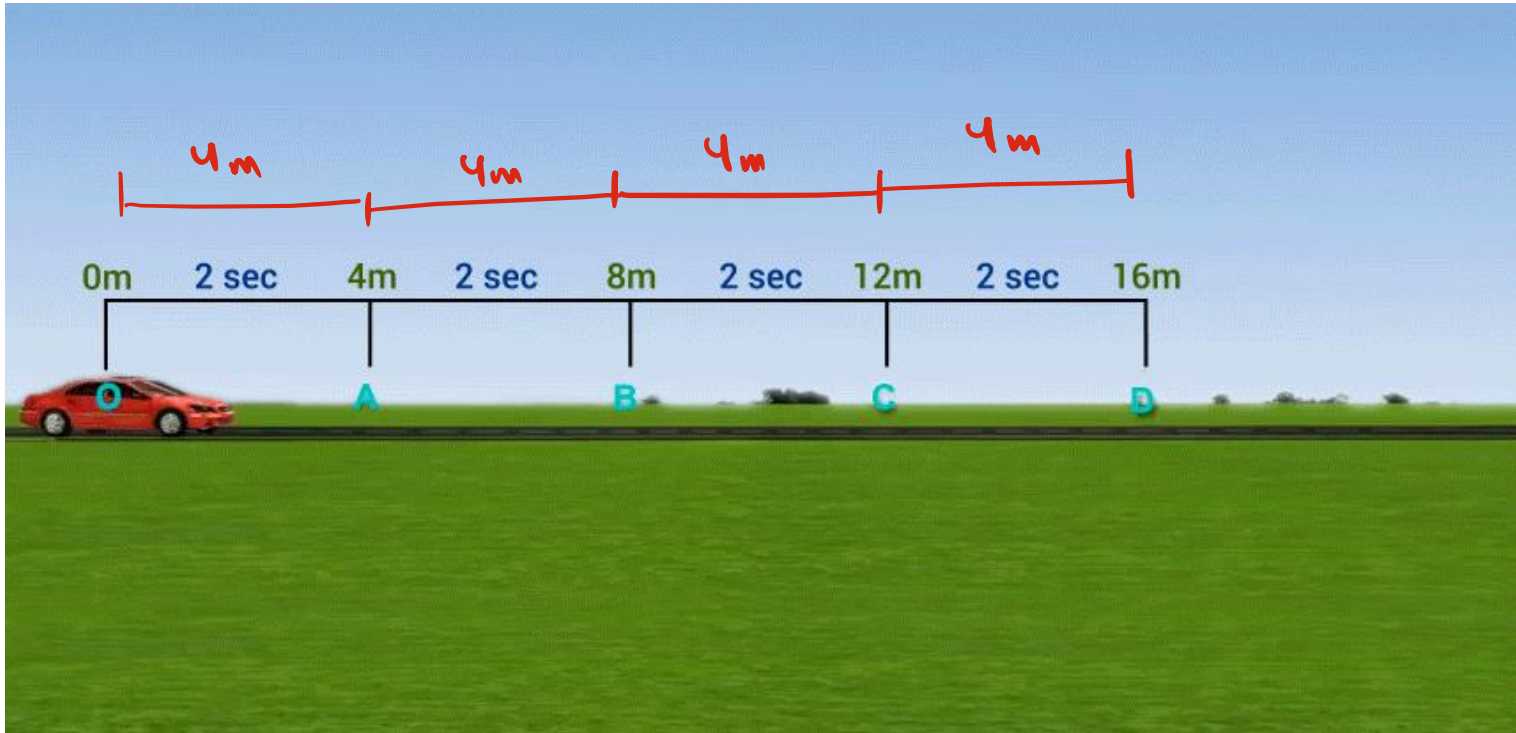
2s → 4m

1s → 2m

$2\ ms^{-1}$

SI unit: ms^{-1}

$m\ \frac{1}{s}$ $\left(\frac{m}{s}\right)$



Average Speed

ms^{-1} | km/h

If the motion of the object is non-uniform then we calculate the average speed to signify the rate of motion of that object.

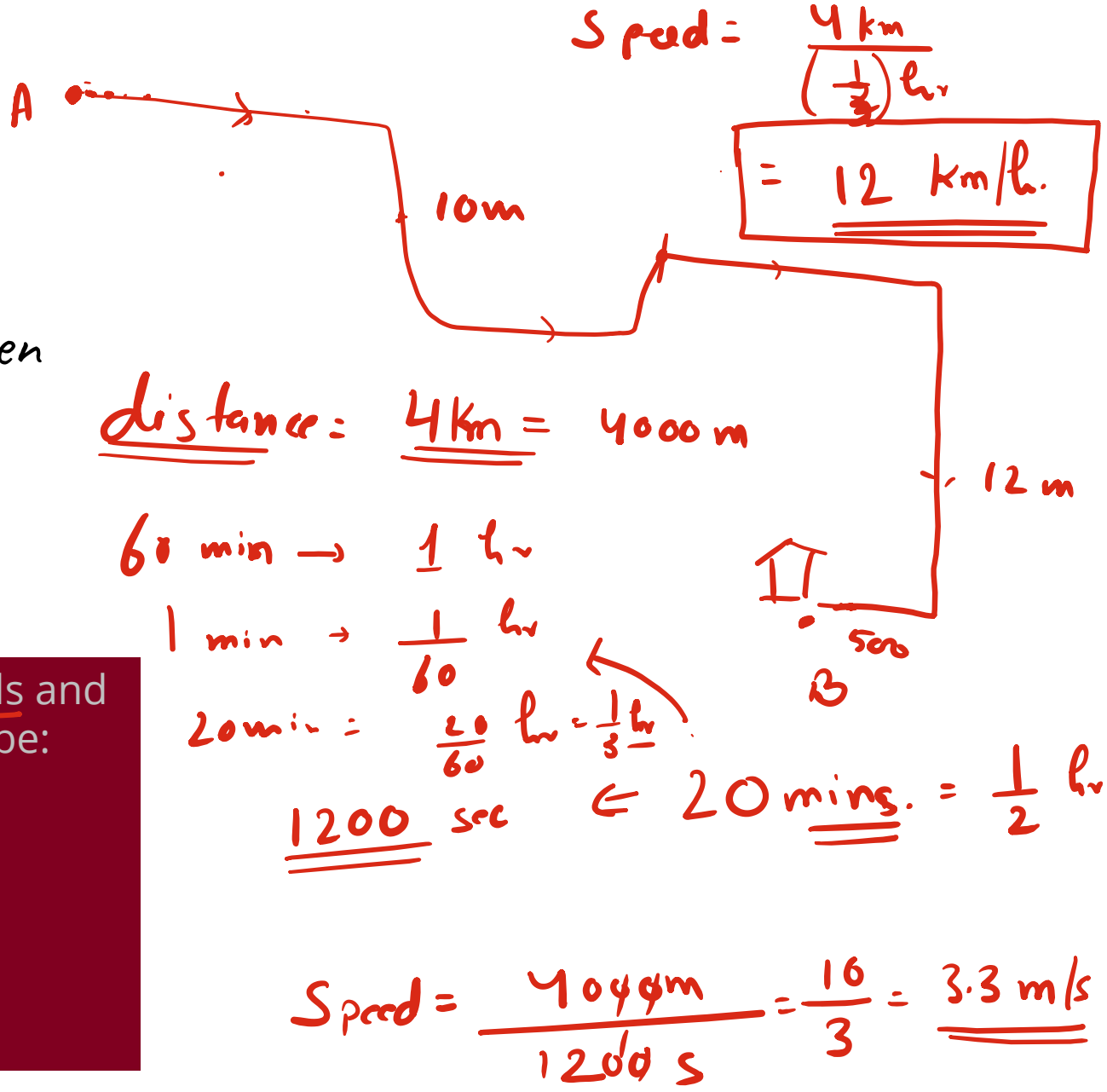
$$\text{Average Speed} = \frac{\text{Total Distance Travelled}}{\text{Total Time taken}}$$

For Example, If an object travels 10m in 3 seconds and 12m in 7 seconds. Then its average speed would be:

Total distance travelled = 10 m + 12 m = 22m

Total Time taken = 3s + 7s = 10s

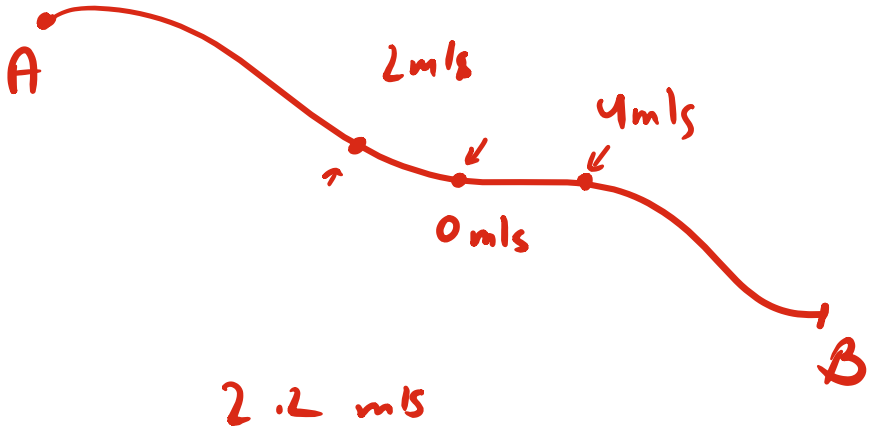
Average speed = 22/10 = 2.2 m/s



Instantaneous Speed

time

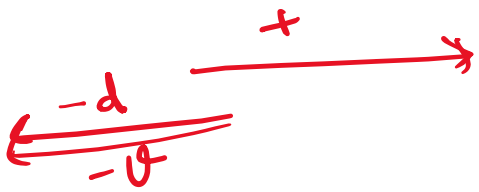
- Speed at a particular instance of time is called instantaneous speed.



Odometer

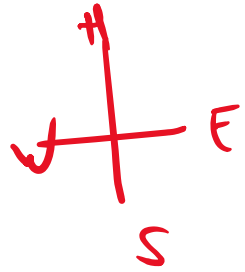
instantaneous.

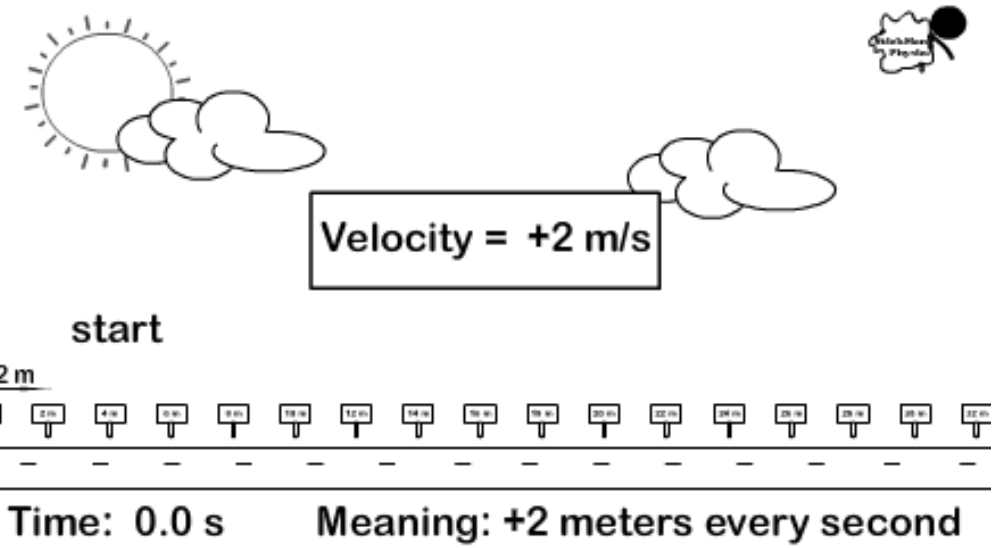
Velocity

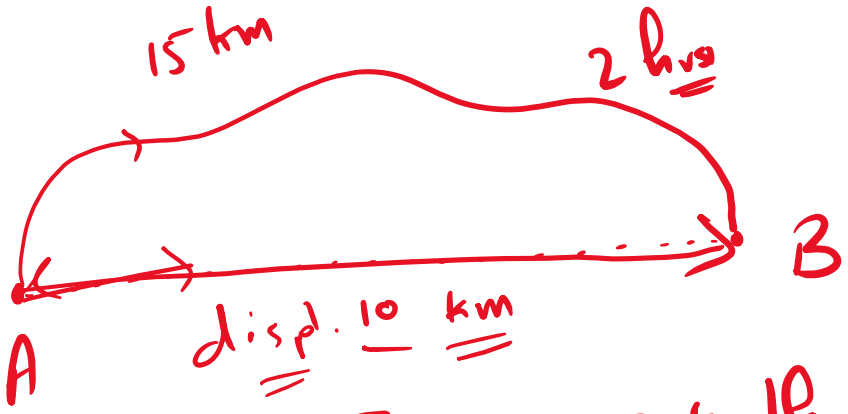


- Rate of change of displacement is velocity.
- It is a vector quantity.
- Here the direction of motion is specified.
- Velocity can be positive or negative.

Velocity = $\frac{\text{displacement}}{\text{time}}$.







Speed = $\frac{15}{2}$ = 7.5 km/h.

✓ Velocity = $\frac{10}{2}$ = 5 km/h in the direction of displacement from A to B

Average Velocity

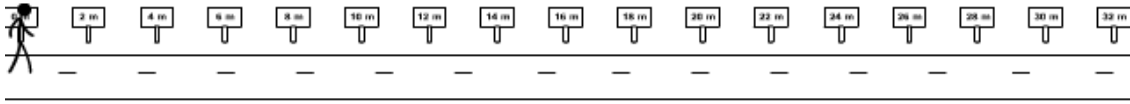
$$v = \frac{\Delta x}{t}$$

Entire Trip

Average Velocity = 3.5 m/s Right

Now

Instantaneous Velocity = 0.0 m/s



Time: 0.0 s

- *For non-uniform motion in a given line, average velocity will be calculated in the same way as done in average speed.*

  Average velocity = Total displacement/Total time

- *For uniformly changing velocity, the average velocity can be calculated as follows :*

  Average velocity = (Initial velocity + Final velocity)/2

  $V_{average} = (u + v)/2$

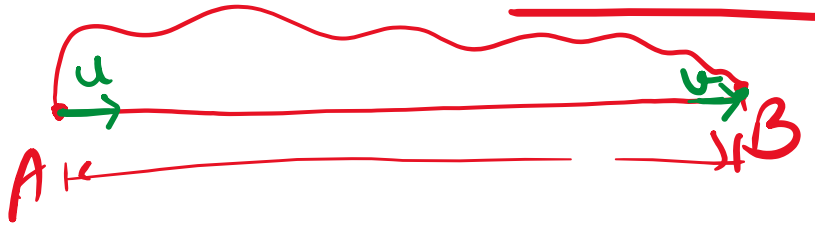
final Position - Initial Position
total time taken.

general formula

initial velocity = u

final velocity = v ✓

$$v = \frac{u + v}{2}$$



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

Speed

$d = 40\ km$

$t = 5\ hrs.$

$$\text{Speed} = \frac{40\ km}{5\ hr} = 8\ km/h = 8\ km\,h^{-1}$$

$$\text{Speed} = \frac{8\ km}{1\ h.} = \frac{8 \times \left(\frac{1000}{1}\right)^{5}\ m}{\left(\frac{3600}{18}\right)^{1}\ s} = 8 \times \left(\frac{5}{18}\right)$$

$$\frac{8^{4} \times 5}{18_{9}}\ m/s$$

$8\ km/h.$

$\frac{20}{9}\ ms^{-1}$

km/h → m/s ($\times \frac{5}{18}$)

m/s → km/h ($\times \frac{18}{5}$)

Q. During an experiment, a signal from a spaceship reached the ground station in 5 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.

$t = 5 \text{ min} = 5 \times 60 = 300 \text{ s}$

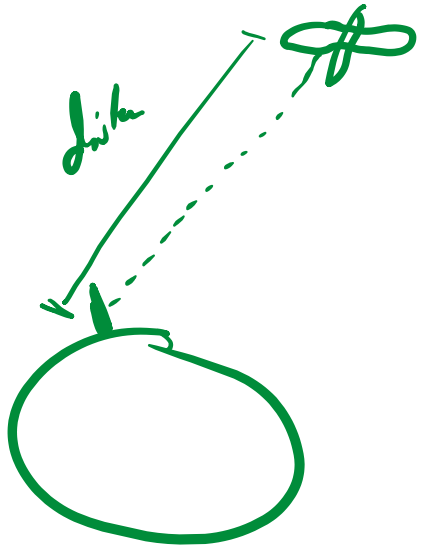
Speed: $\frac{D}{T}$

$D = S \times T$

$= 3 \times 10^8 \frac{\text{m}}{\text{s}} \times 300 \text{ s}$

$= 3 \times 10^8 \times 3 \times 10^2$

$D = 9 \times 10^{10} \text{ m}$



$= \frac{9 \times 10^{10}}{10^3} = 9 \times 10^7 \text{ km}$

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

$v = 45$ m/s

$s = 4.5$ m/s

30 m/s

90 m.

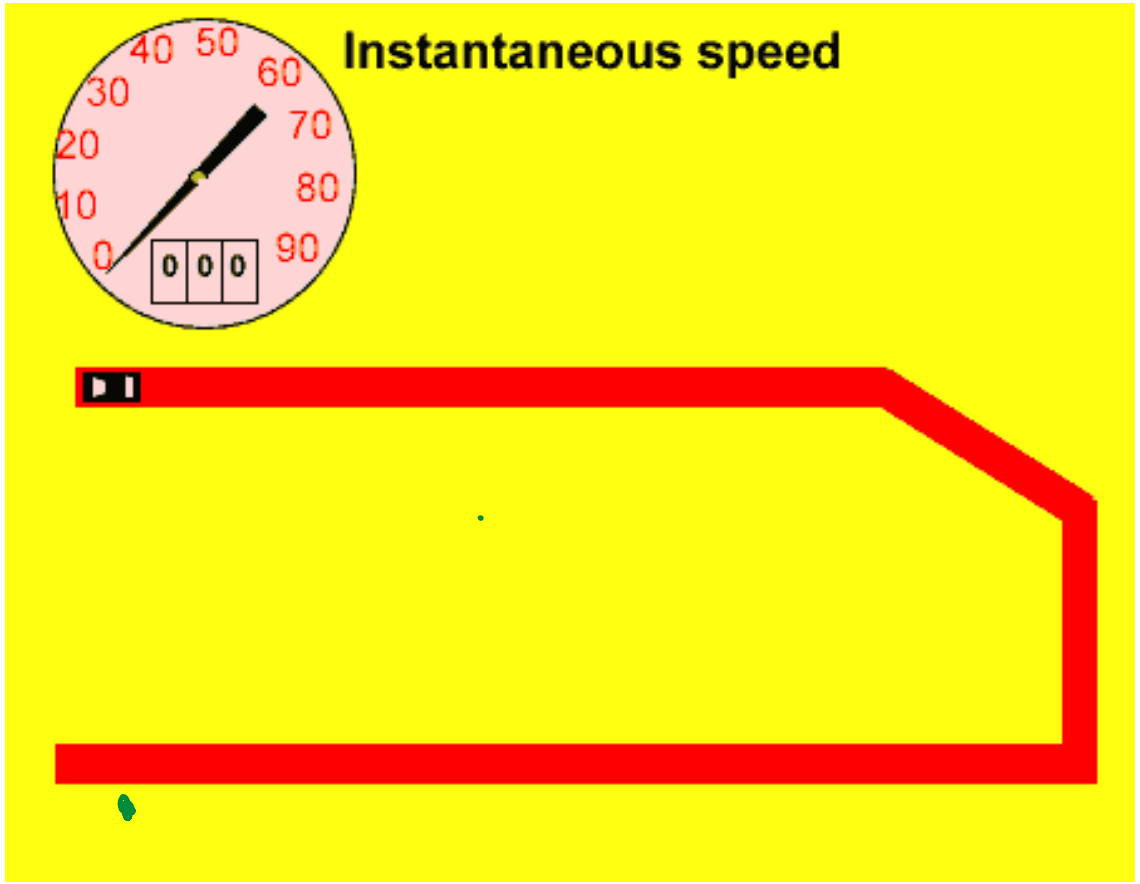
$d = 180$ m

$t = 60$ s.

$$s = \frac{180}{60} = 3 \text{ m/s.}$$

$$\text{Avg velocity} = \frac{\text{total displacement}}{\text{total time}}$$

$$= \frac{0}{60} = 0 \text{ m/s}$$



Take the example of a racing car as pictured in the animation above. It takes the vehicle 10 minutes(0.17 hours) to travel 23km, from start to finish.

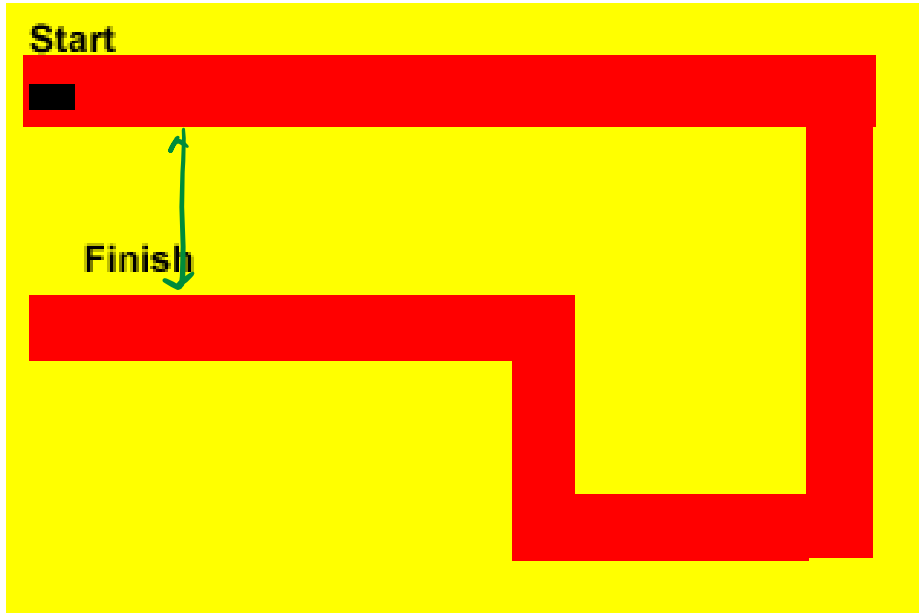
$$\text{average speed} = \frac{\text{distance travelled}}{\text{time taken}}$$

Average speed

$$\text{average velocity} = \frac{\text{displacement}}{\text{time taken}}$$

Average velocity = 4km / 0.17hrs = 23.53km/hr

The average speed is 135.29km/hr but the velocity is only 23.53km/hr. The reason that velocity is lower, is that it can be positive and negative. Since the velocity has negative and positive values some will cancel each other out, hence the lower value. Speed, however, can only be positive.



An ant crawls around a pathway in search of food. Its movement is traced out on the image on the left.

a) Calculate the total distance covered by the ant. = 300 m

b) Calculate the displacement of the ant. ⇒ 30m

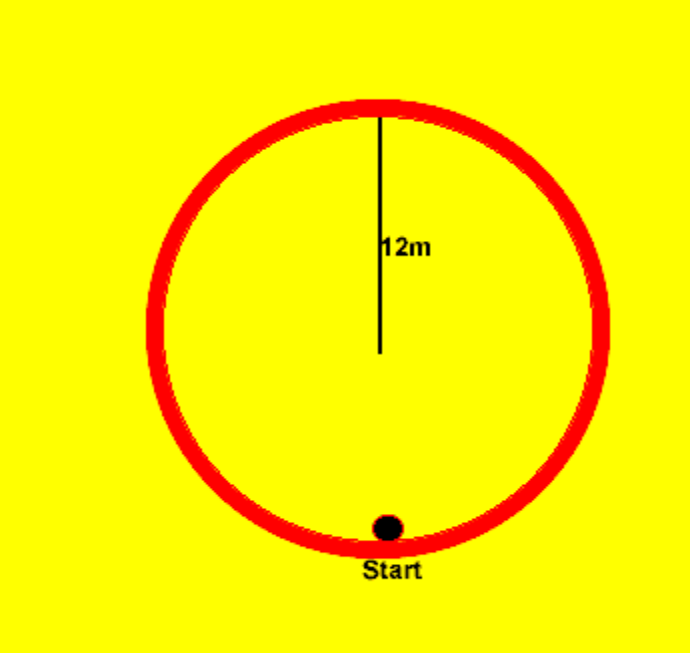
The ant takes 30 minutes to complete its journey

c) Calculate the average speed of the ant. ⇒ $\frac{300\text{m}}{1800\text{s}}$ $\frac{1}{6}$ m/s

d) Calculate the average velocity of the ant.

$t = 30\text{m} = 30 \times 60 = 1800\text{s}$

$\frac{30}{1800} = \frac{1}{60}$ m/s



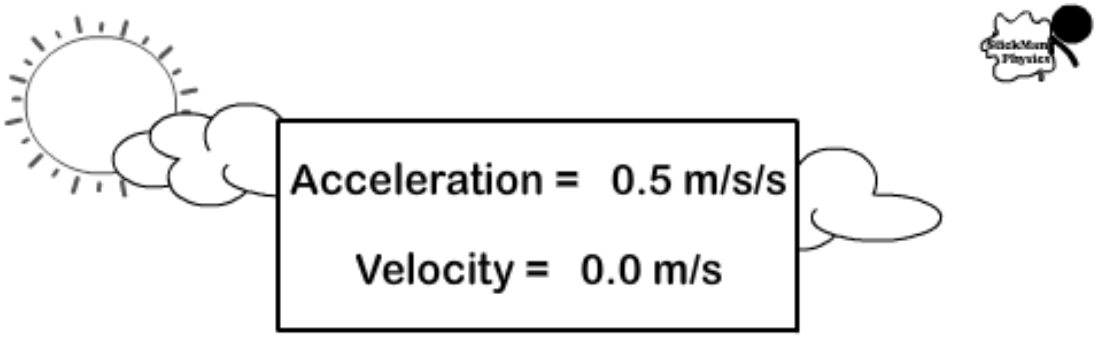
A ball circles inside a cylinder of radius 12m as shown in the animation on the left.
a) Calculate the total distance the ball travels
b) Calculate the displacement of the ball.

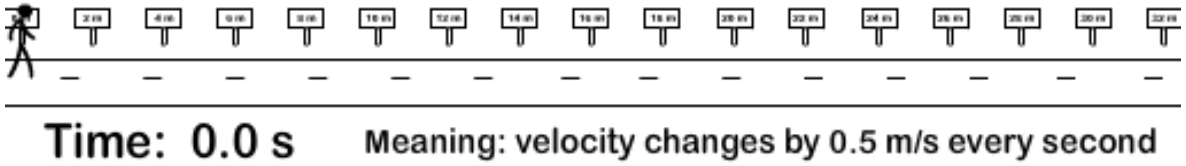
The ball takes 30 minutes to complete one revolution
c) Calculate the average speed of the ball.
d) Calculate the average velocity of the ball.

Acceleration

- *In uniform motion velocity of object remains constant.*
  - *No change in velocity.*
- *In Non-uniform motion, velocity changes.*
  - *Rate of change of velocity per unit time is called acceleration.*

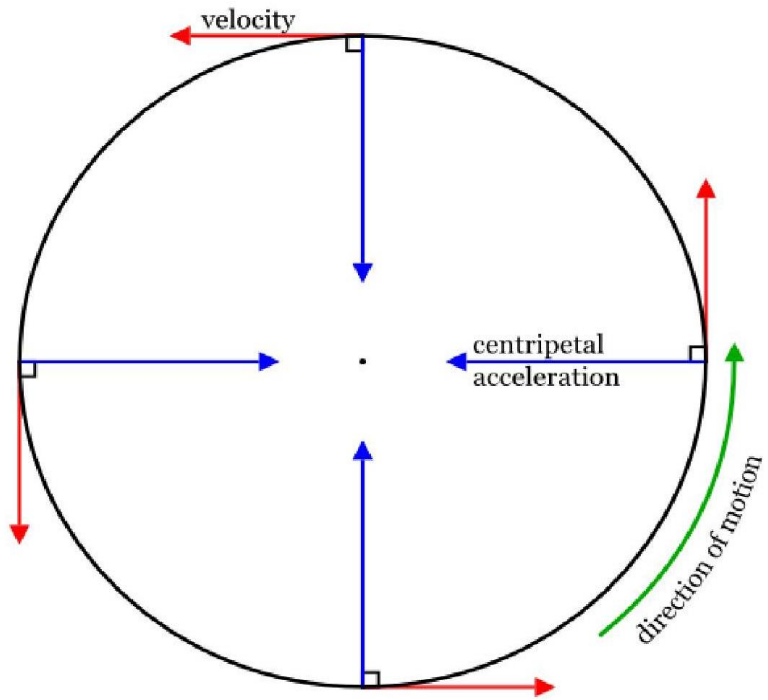
Acceleration = Change in velocity/ Time taken
SI Unit: m/s^2





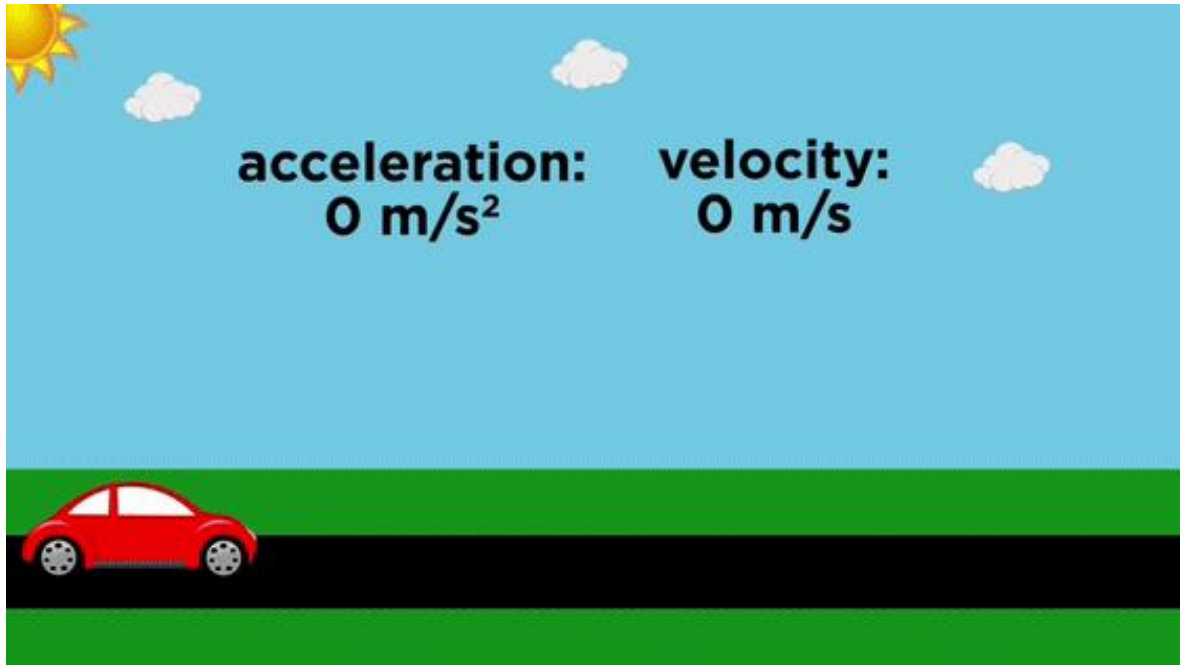
Acceleration

- Acceleration is related with change in velocity.
- Change in velocity in terms of magnitude or direction or both regarded as accelerated motion.
- In the below example (circular motion), the direction of velocity keep on changing but its magnitude is constant. Such kind of motion is also an example of accelerated motion.



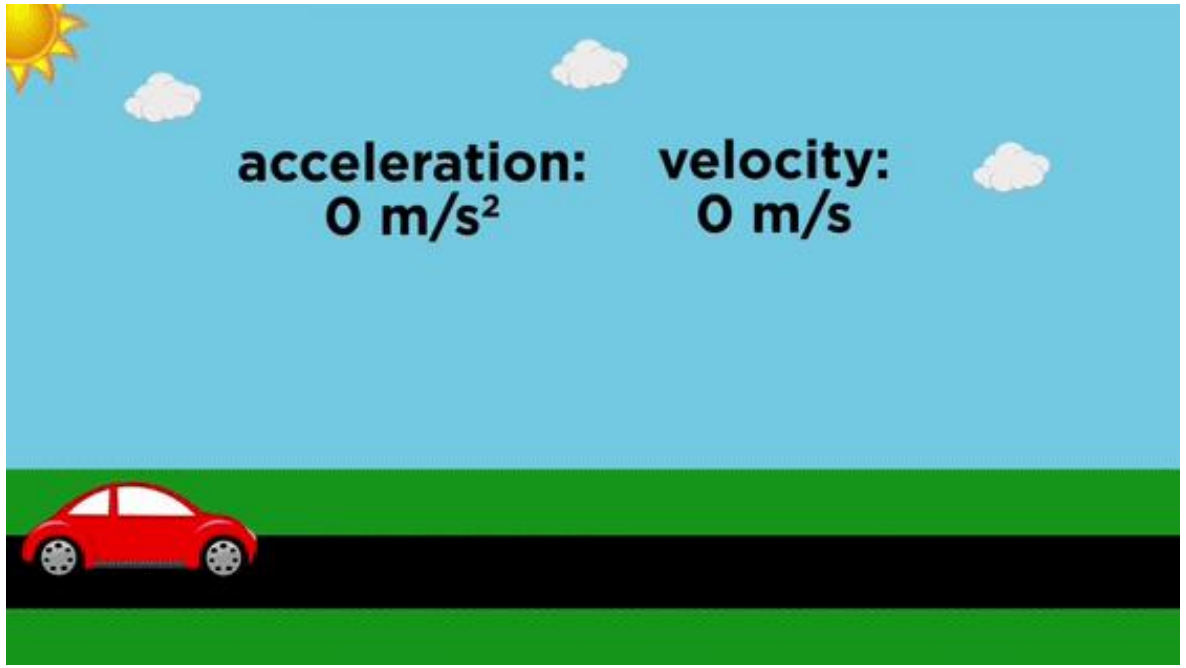
Uniform Acceleration

- *An object is said to be in uniform acceleration if:*
  - *Its velocity changes (increases or decreases) by equal amounts in equal interval for time.*



Uniform Acceleration

- An object is said to be in uniform acceleration if:
  - Its velocity changes (increases or decreases) by equal amounts in equal interval for time.
  - Motion of freely falling object is example of uniformly accelerated motion.



Non-uniform acceleration

- *An object is said to have non-uniform acceleration if:*
  - *Its velocity changes (increases or decreases) by unequal amounts in equal time intervals.*

Positive and negative acceleration

- If velocity of object increases with time:
  - Then direction of acceleration is same as the direction of velocity.
  - This is called **positive acceleration**.

- If velocity of object decreases with time (on applying breaks):
  - Then the direction of acceleration is opposite to the direction of velocity.
  - This is called **negative acceleration** or **Retardation**.

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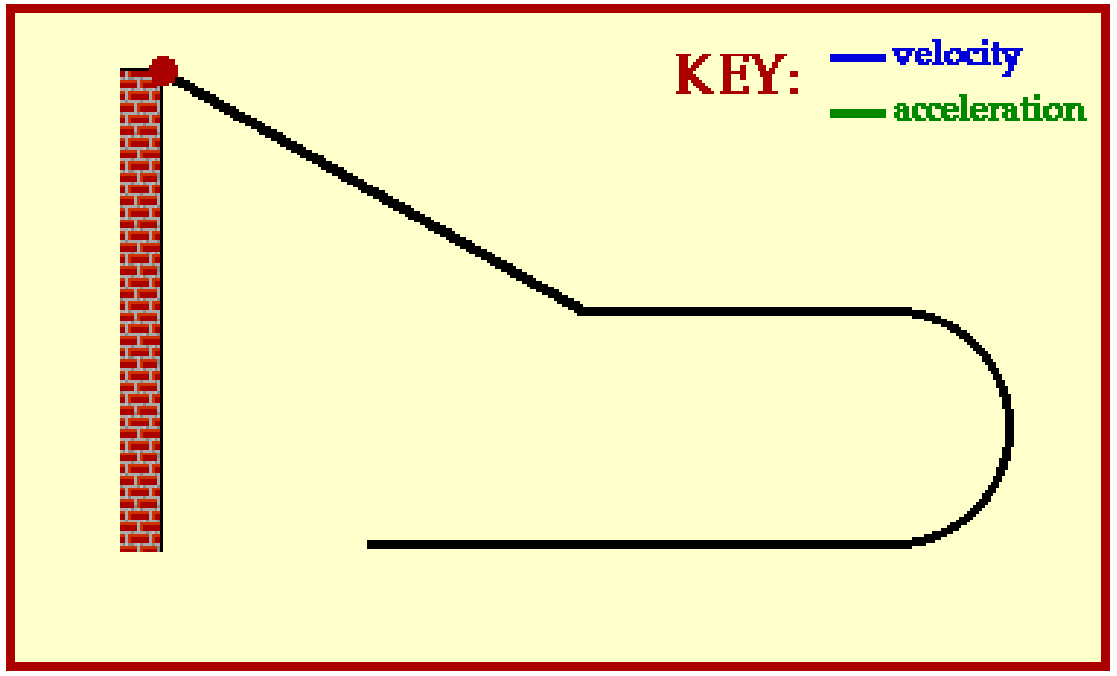

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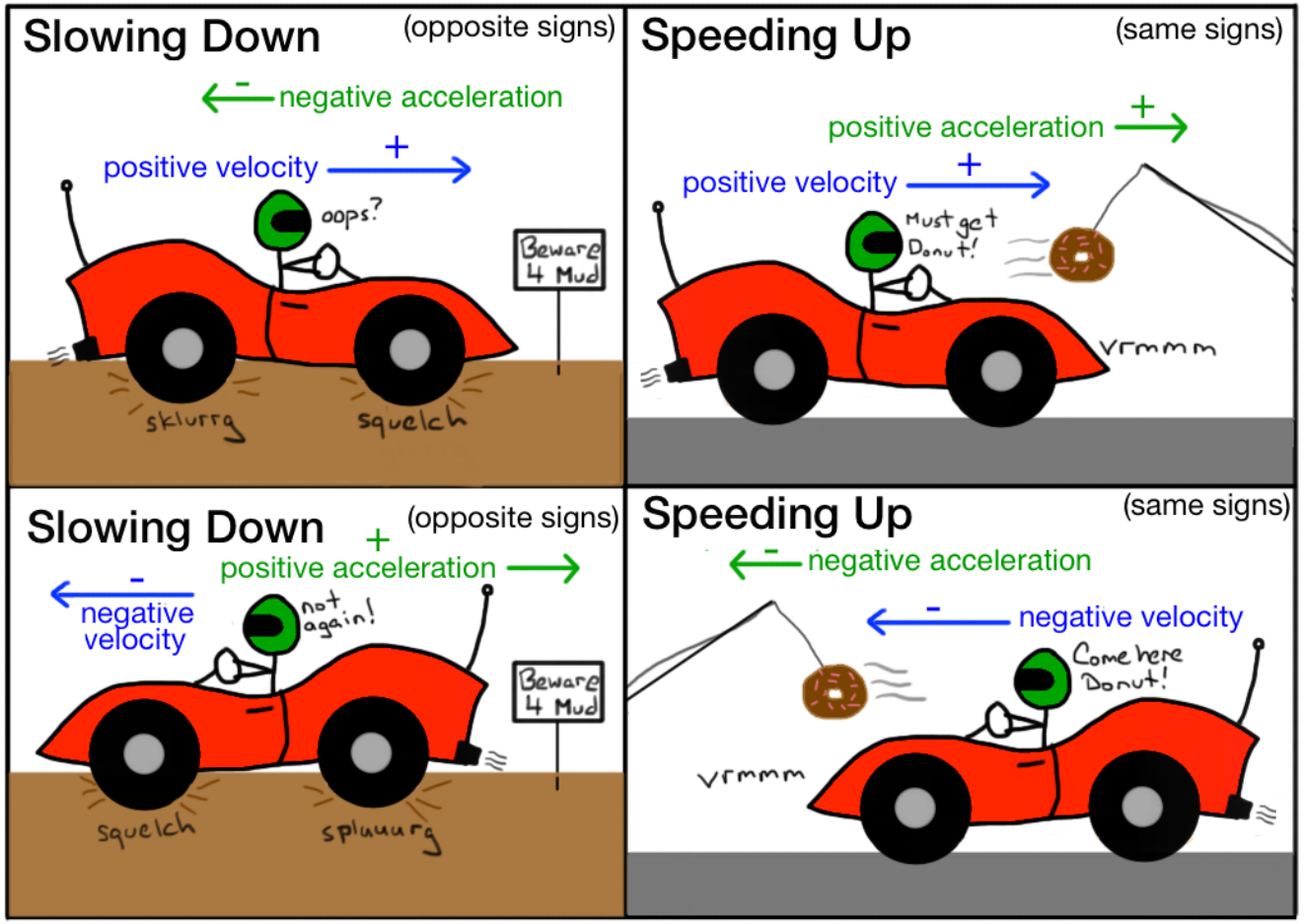

Questions on acceleration

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.

Questions on acceleration

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.