MOTION

If you were to drive or design a scooter, a car, a truck, a train or an airplane you need to know about speed, velocity, acceleration etc. These terms helps you describe and analyze motion. You can also use these terms to analyze a cycle ride, a walk, an animal's motion, a shooting star etc. This chapter will help you to learn the scientific

way to investigate and analyze the motion in a straight line.

Content

Measurement

1.1 Importance of measurement

In our day to day life we use many different measurement units like kilogram, meter, kilometer, liter etc in different contexts. There are different equipment such as scale, weighing balance, beaker etc.to measure these physical quantities.

In the scientific world, there are standardized units for all the physical quantities. For example kilogram is the unit of mass, meter is the unit of length.

Standardization of measurement units is important for uniformity. For example, 1 meter length in India will be equal to 1 meter in U.S.A. too.

To reduce error one should:

1. Repeat the measurement activity number of times.
2. Take care of the least count of the scale.
3. Take care of other parameters that may affect the activity.

1.2 Make your own measuring tape

Making a paper tape of at least two-meter length

Make your own paper tape

Material Required:

1. Three A-4 size paper sheets (one side used paper will do)

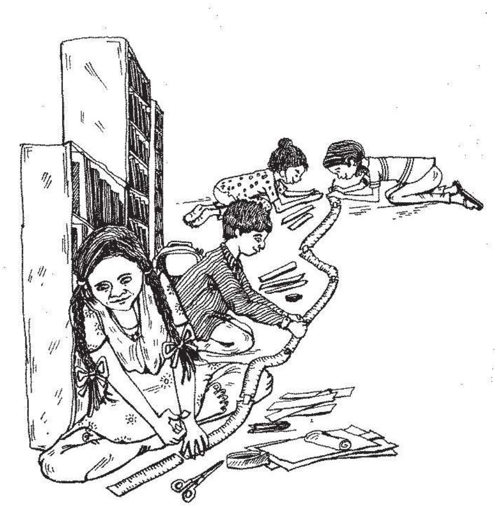
2. A sketch pen

3. Scissors

4. A scale

Process to do the activity:

1. Use a scale to draw some lines on paper, draw them one centimetre apart from each other.



2. Cut the paper strips along the drawn lines.

3. Join the paper strips together, lengthwise, using gum/tape on any one end

4. Choose any side of the strip as the starting point. Start marking the lines from 0, 1, 2…..200.

Your centimetre tape is ready to use now. You can coil it to keep it in your pocket.

1.3 Measurement of steps

Estimation of length and its standardization

Let's measure the length of your steps:

Can you estimate the distance between the two walls of your classroom?

Can you estimate the distance between the front door of your classroom and the door of your principal's room?

Can you estimate the distance between your home and the school?

Let's work out for the distance between your home and the school :

You have made a measuring tape. For shorter distance, you may use it but as the distance becomes larger, measuring the entire length using only 2-meter long tape becomes tedious.

There is another way to work out the approximate length to the school from home or vice versa.

You can use your step to measure these long distances. You just have to count the numbers of steps that you take to reach the school from your home.

1.4 Standardization Of Scale

<u>Make Your Step Your Scale</u>

Material required:

1. Empty space to walk

2. A paper tape

3. Chalk/Marker

Process to do the activity:

1. Find an empty space near your classroom, it could be a corridor or any other empty space. The only condition is that you should be able to walk and take at least 20 steps naturally.
2. Mark a starting point to begin your walk.
3. Measure 10 meters from this point. That will be the end point of the walk.
4. Walk on it a couple of times.

Is your step count always the same?

Now walk on the path 10 times and make a table to record the data. Every time count your steps and fill in the data in the table given.

Has your step count been varying a lot?

Is there a range within which these numbers fall?

You have done an important finding -"The range". The range helps you to predict that if you walk the distance 11th time, the number of steps you will take to cover the same distance will be within the range.

Walk another 5 times on the path to test if your prediction was right or wrong.

Table 1.4: Step Count table

1	2	3	4	5	6	7	8	9	10

1.5 Average Length Of A Step

What is the average length of your step?

One more discovery to be made

You have walked on the 10 meter path 10 times, now please work out the average of all 10 numbers in your notebook.

Divide the distance you walked with "the average" to find out the average length of your step.

So, the average length of your one step = 10 meter/average number of steps

What is the average length of a step?

This number is the average number of steps you take to cover the distance of 10 meters.

Look at this number and compare it with the numbers in the table.

Are all the numbers of the table close to this number?

Now you have two predictive powers in your hands: one is "the range" and second is "the average".

<u>Test your predictive power:</u>

Walk a much longer distance that you can measure with *your paper tape. Now count your steps while you walk. Multiply it with the average length of your step to get the length of the distance.*

Verify your finding:

Now use your paper tape to measure the same length that you just measured using your steps. ***Compare these two numbers. Are they close enough?***

Distance from your home to the school:

To know the distance from your home to the school, count your steps to the school from home every day.

Please make the following table in your notebook to keep a record of these numbers.

Table 1.5: Number of steps

Number of days	Number of steps

Average Number of Steps = ...

The distance between your home and the school

*= Average number of steps * the average length of your step*

Hurrah!

Riddles of Motion

Do you now realise that motion is a riddle in itself? Are you interested to explore it further?

Let us summarize what we have understood about motion in this unit

You feel something is in motion if it changes its position or speed with respect to you or with respect to some other object in your view.

When we say that a boat is in motion, we consider stationary objects such as trees, land etc. as our reference point and see the change in position of the boat with respect to these objects. Also, we consider the change in time that takes place when a moving object reaches from one point to another.

If two objects, say our two boats, move at the same speed in the same direction, then by sitting in one boat and observing the other boat alone, you would not be able to say if that boat is in motion or not. Because, as far as its motion with respect to your boat is concerned, it is not moving.

That is why we don't feel the motion of the earth's rotation and its revolution around the sun because we are moving with it at the same speed.

We have also noticed that the observer plays an important role in describing a motion. The path a moving object covers varies according to the position of the observer. For example, as you saw in the video of the ball and the moving car, from front view it appeared that the ball is not coming back at the same position from which it was bounced. Whereas, from the top view of the observer moving with the ball, it appeared that the ball returns to the same position from where it was bounced.

All motions are relative!

Let us now explore some other concepts used to describe and analyse motion such as Speed, Average Speed, Instantaneous Speed, and Constant Speed.

Speed

You watched the scooter video and worked out average, instantaneous and constant speed.

In real life, it is difficult to maintain constant speed as there are so many hurdles on the way in the form of vehicles and bumps on the road, etc. You can get constant speed but for short time intervals only.

That is why the speed that we commonly encounter or talk about in our daily life is average speed. Average speed of an object is the total distance covered by the object divided by the total time taken to cover this distance.

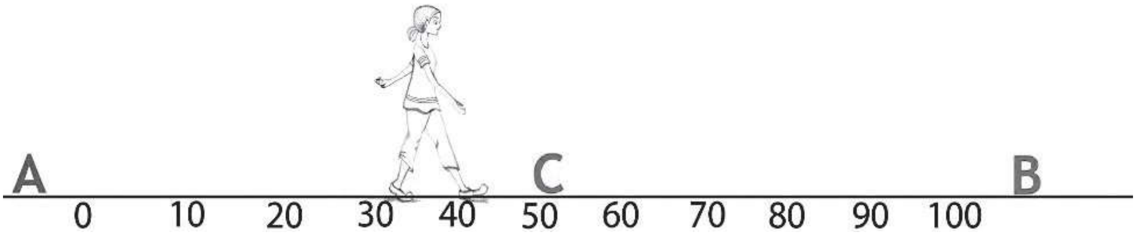
To find the instantaneous speed at any moment, you just need to look at the speedometer of the running vehicle.

However, for an object moving with constant speed, the instantaneous speed and the average speed will be the same.

In the next lesson we will learn what is displacement and what is its relation to velocity?

$$\text{Average Speed } (v_{avg}) = \frac{\text{Total Distance } (\Delta d)}{\text{Total Time } (\Delta t)}$$

Displacement and Velocity



There is a subtle difference between distance and displacement.

The distance between two points could be anything depending on whether it is measured straight or long and winding, but displacement will always be the shortest distance. Which means the straight

line from the initial point to the direction of terminal point of a journey is displacement.

These ideas were explained using the example of Lily's journey on a straight path. Further, speed and velocity were also elaborated using the same example.

Now you know that to calculate speed you use total distance covered in the total time spent whereas to find out velocity you consider total displacementcovered in the total time.

You noticed that distance and speed do not have information of direction and they could be zero or positive, but never negative. While displacement and velocity have an extra information of direction and they could be positive, negative or zero.

So, we need distance and displacement covered by an object in a time period to know its speed and velocity respectively.

In the next chapter, you will get to know how speed or velocity can be represented visually.

Graphs of Motion

5.1 Introduction to graph

Graph is also a way to represent motion

In earlier classes you have used graph for various exercises. In case you want to refresh your memory, there is a video on the clix platform explaining how a Graph paper looks like and what does horizontal and vertical line mean?

In motion you deal with distance-time graph, displacement-time graph, speed-time graph, velocity-time graph and acceleration-time graph.

On the graph, time is always represented on the X axis and distance, speed or velocity is represented on the Y axis in context of motion.

The relationship between these two helps you to discover the nature of motion.

5.2 Let's Check

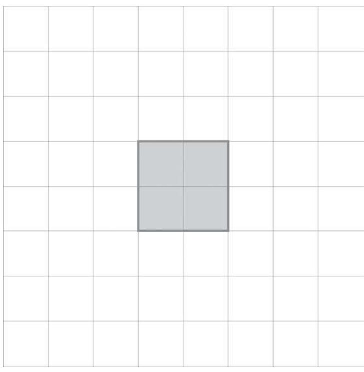
How much do we know about graph?

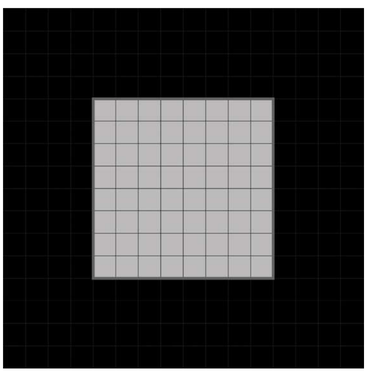
1. In the two adjoining images, the area covered by the shaded part is:

   a. not equal

   b. cannot say anything

   c. equal



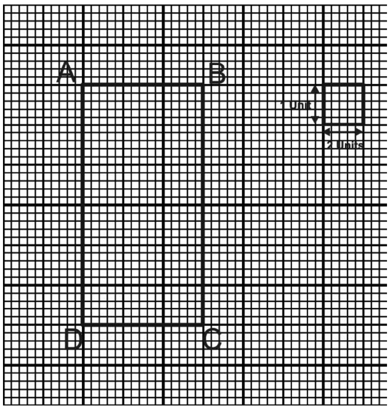


2. Shape ABCD covers 18 squares. Suppose the height of the square is 1 unit and width is 2 units, then the height and the width of the shape ABCD will be:

   a. Height = 3 units, Width = 6 units

   b. Height = 6 units, Width = 6 units

   c. Height = 6 units, Width = 3 units

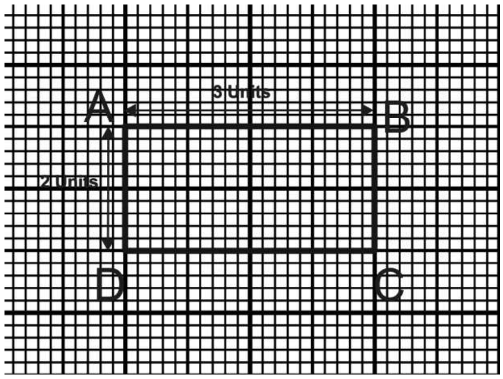


3. Shape ABCD has height 2 units and width 3 units. Area covered by the shape is:

   a. 6 unit

   b. 6 $unit^2$

   c. 10 $unit^2$



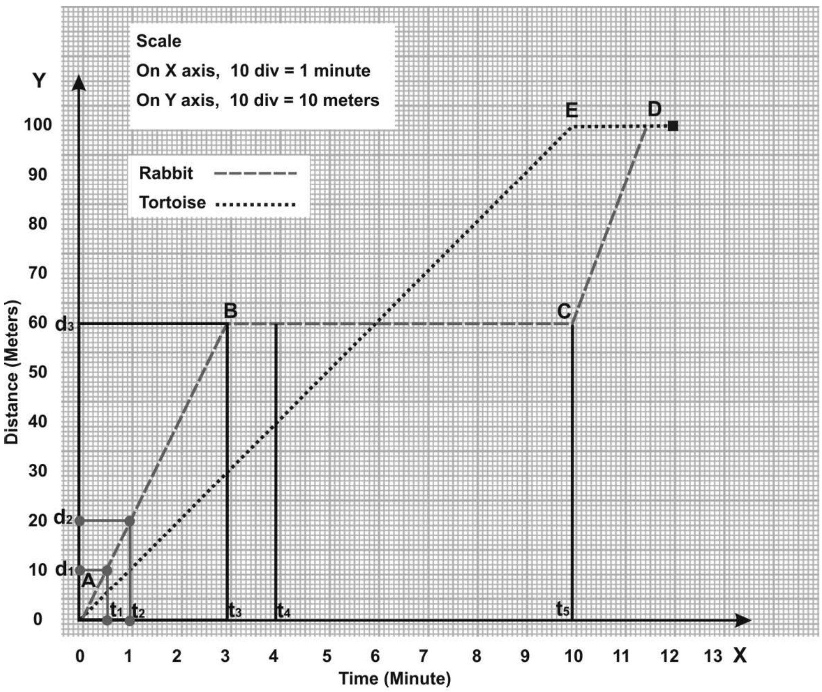
5.3 INTERPRETATION OF GRAPH

Tortoise and rabbit's race

Let's begin with a famous story of the race between a tortoise and a rabbit that you might have heard.

In the story, the rabbit runs faster and rest on the way while the tortoise runs with slower speed but moves continuously till the end point. Finally slow and steady runner wins the race.

The graph below depicts the story of the race between a tortoise and a rabbit.



To tell your friends how both rabbit and tortoise were moving over time compared to each other, you need to know how to interpret the graph.

On the line segment AB in the graph, distances d_1 and d_2 corresponds to times t_1 and t_2, which shows position is changing with respect to time. That means line segment AB in graph represents motion.

Similarly, line segments CD and AE also represent motion. Now, you can see on the line segment BC, distance from origin d_3 corresponds to time t_3. Further, distance d_3 also corresponds to time t_4. For two different times we have same distance from the origin. So for this segment of graph, position is not changing with time and this represents the state of rest.

Can you figure out which curve (ABCD or AED) corresponds to rabbit's motion and why?

5.4 Position time graph

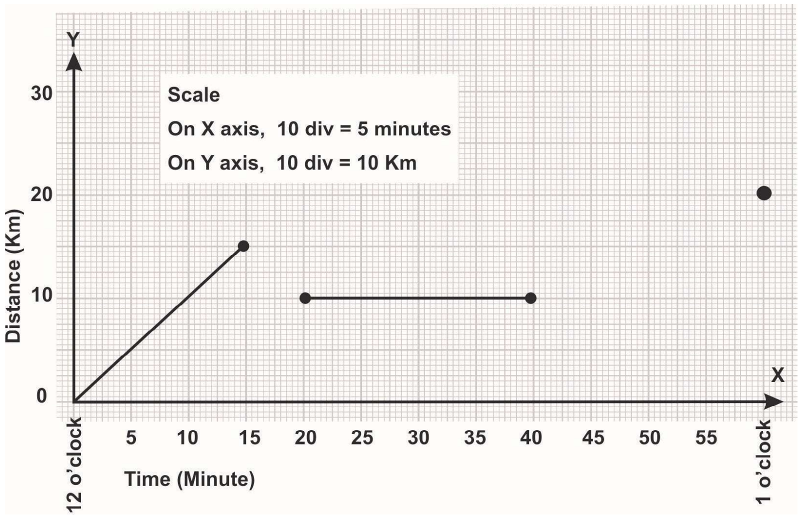
LET'S DO EXERCISES

1. Use the table given to make another graph of the race between the tortoise and rabbit.

Time (min)	0	1	2	3	4	5	6	7	8	9	10	11	11.5
Rabbit (meter)	1	20	40	60	60	60	60	60	60	60	60	87	100
Tortoise (meter)	0	10	20	30	40	50	60	70	80	90	100	100	100

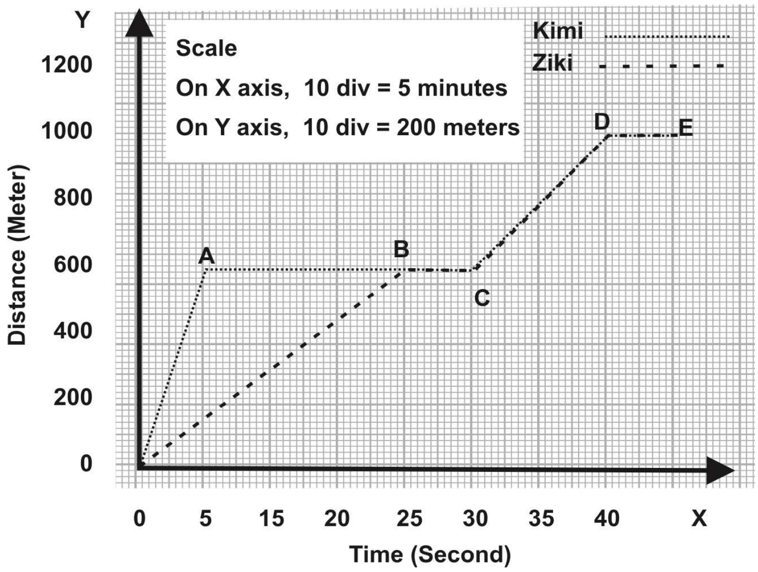
2. *A goods train is going from Itarsi station to Bhopal station. At 12:00 PM it leaves Hoshangabad and after 15 minutes at an upward track, its engine and brakes fail and the train rolls backward for 5 km and stops on a plane track. The driver and the train guard inform the controller. A new engine takes 20 minutes to arrive there. The new engine pulls the train and helps it to cross the valley in next 20 minutes. The graph and table given below is based on this story but are left incomplete. Can you draw the remaining portion of the graph and fill in the table as well?*

Time (min)	12.00	12.15		12.40	
Distance (km)	0.0		10		20



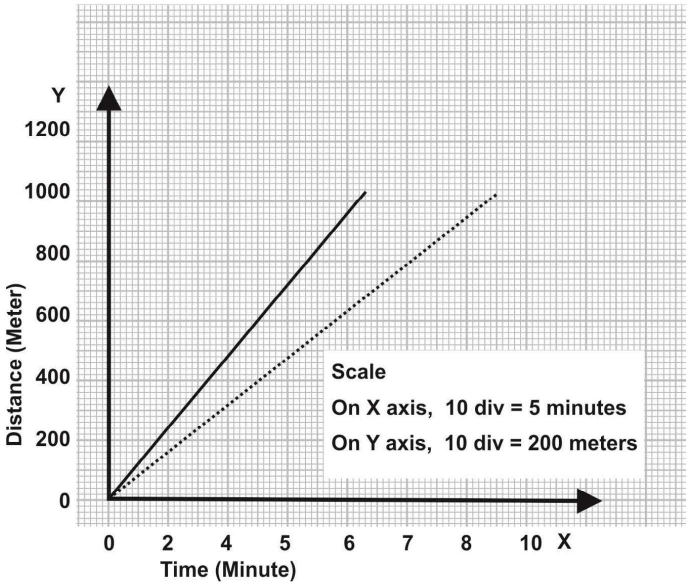
3. *The graph given below shows the journey of two sisters Kimi and Ziki from their home to the school. Kimi takes a stop at a book shop. After a while Ziki also joins her. Then from the shop they go to the school together. Fill up the table given using the information given in the graph.*

Who takes less time to reach the shop?	
For how long did Kimi stay at the shop?	
Can you identify the part of the line depicting Kimi's stay at the shop?	
What was the distance between the school and the shop, between the home	



Time (sec)	Kimi (m)	Ziki (m)
0		
5		
15		
20		
25		
30		
35		
40		

4. *Vimal and Abid participate in 1000 meter race. The slope of the graph shows their run. Who ran faster, Abid or Vimal? Why do you think so?*



5. *A school bus with kids leaves the village at 10 AM. At 11 AM when it reaches the bridge, the river is flooded and flowing over the bridge. The bus has to stop there for two hours. At 1 PM, when the river flow goes down and the water level is lower than the bridge, the bus crosses it. It takes the bus another hour to reach the school. By that time the school is already over. The bus begins its return journey right away. In just one hour it drops the kids at the village. Depict this story on a graph.*

5.5 Speed time graph

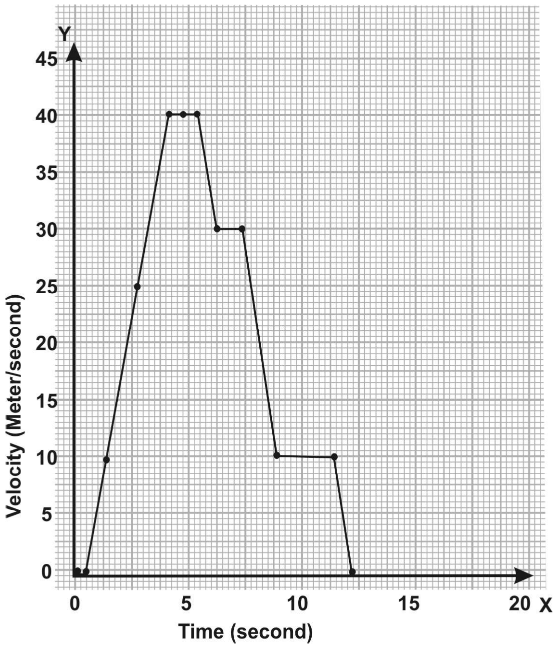
Let's do exercises

1. The graph represents a motorcycle ride.

(i) Mark the point(s) on the graph that shows the motorcycle is at rest.

(ii) Mark the point(s) on the graph that shows motorcycle with constant velocity.

(iii) Complete the given table based on the graph.

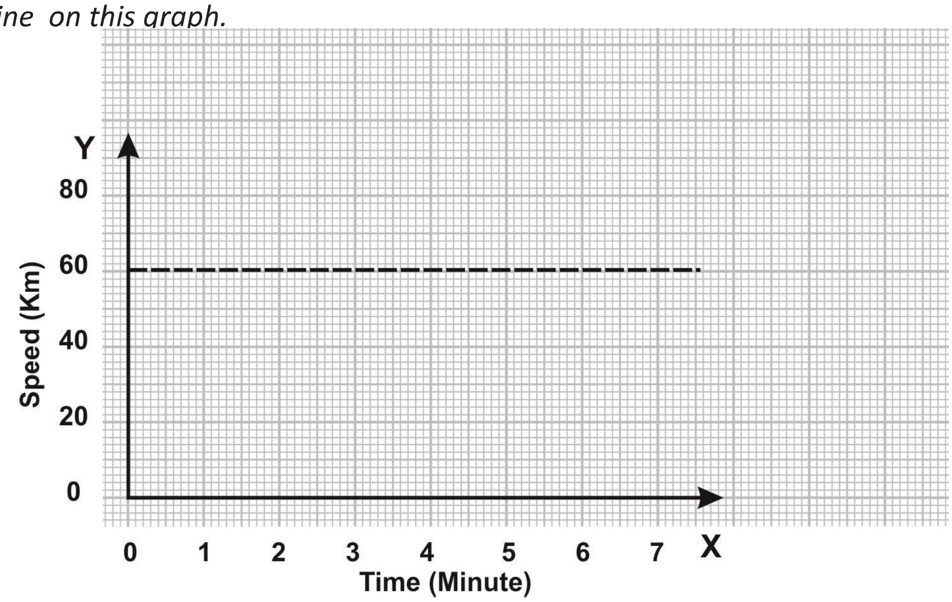


(sec)	Speed (m/s)
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	

2. *Police control room receives an information that a black suspicious car is going to pass, please stop it and check it. At 12'o clock the car moves past the front of the station. The police start their patrolling jeep exactly at 12'o clock but for 2 minutes they could not move the jeep due to some engine issues. Please answer:*

(i) If the car is moving still why the line is running parallel to the x axis horizontally?

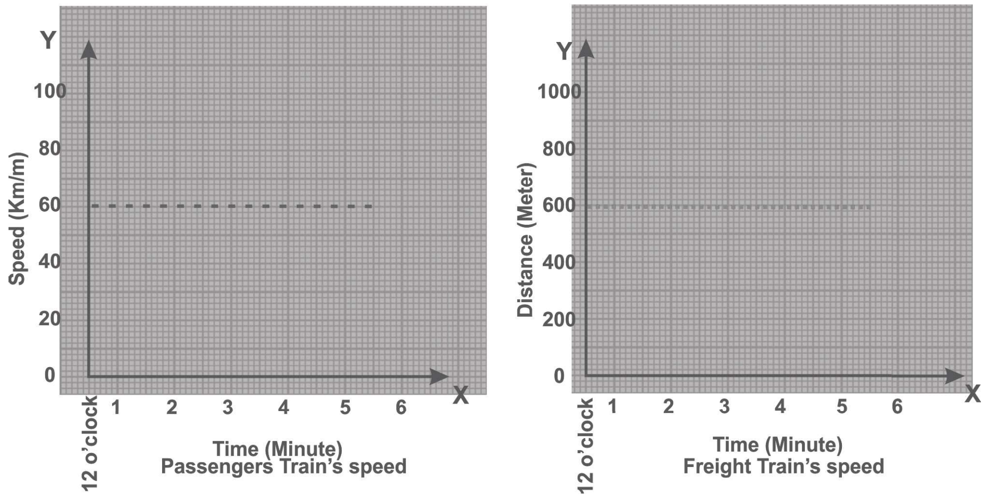
(ii) Please draw the first 2 minutes of the police jeep when it was not able to move. Draw the line on this graph.



3. *Look at the graph and answer the following:*

   (i) Please identify which train is in motion and which is at rest.

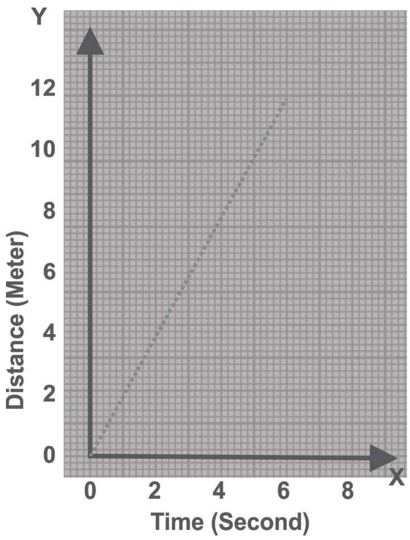
   (ii) Tell us how these graphs are different.

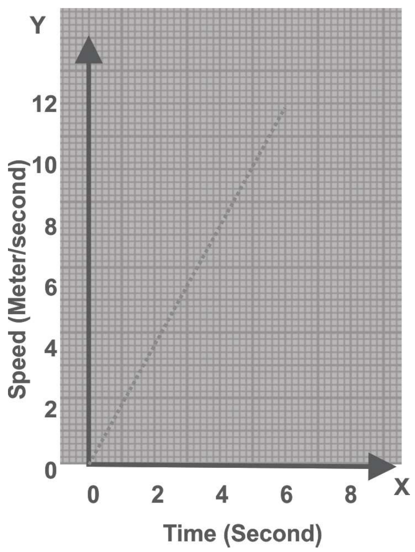


4. *Use the data given in the table below to plot the graph of two objects moving with different velocities.*

Time (sec)	0	1	2	3	4	5	6
Object 1 speed (m/s)	0	2	4	6	8	10	12
Object 2 speed (m/s)	0	1	2	3	4	5	6

5. *Look at these graphs – Do they represent same kind of motion? How do they defer from each other?*





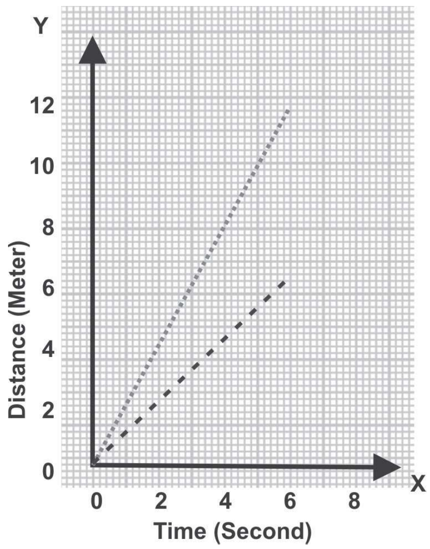
Look at the velocity-time graph of a moving object. The area enclosed by the velocity-time curve and time axis gives you the total distance covered by the moving object. You will learn this in the equation of motion. Please fill up the blanks to get the distance for the graph given below.

Area of a triangle = ½ x a x b

= ½ x......x.......

= 36 unit

You will use this method to find the distance in section on equation of motion, where you will learn how to relate four quantities to get equations to work out complex problems of motion.



5.6 Let's check

Here are the few questions based on what you have learnt, let's check and try to answer them:

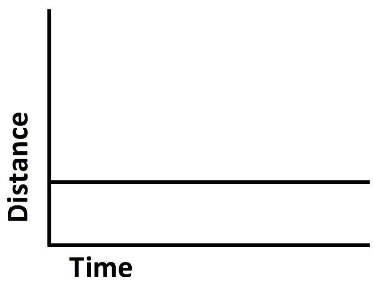
1. What does the graph explain about the state of the object?

   a. Object is at rest

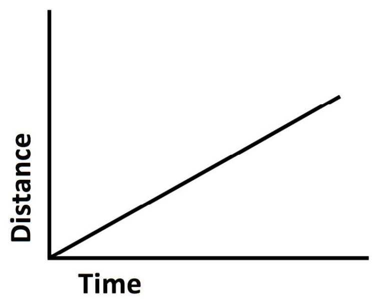
   b. Object is accelerating

   c. Object is moving with a fixed speed

   d. None of the above

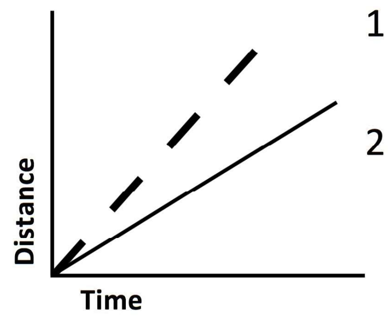


2. Now, what do you think this graph explains about the state of the object?
   a. Object is at rest
   b. Object is accelerating
   c. Object is moving with a fixed speed
   d. Both (B) and (C)

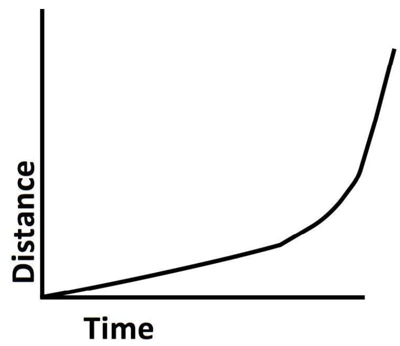


3. Compare the slopes and choose the correct option:

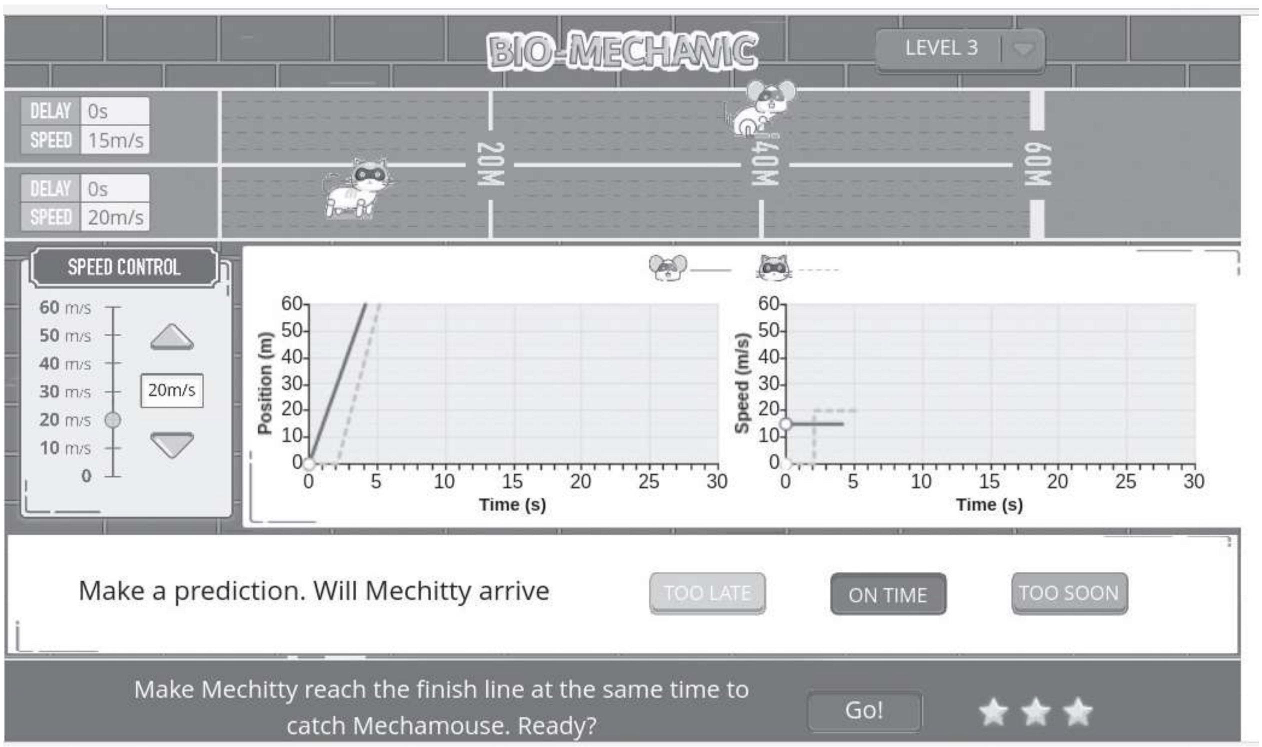
a. (1) is accelerating at a faster rate
   (2) is accelerating at a slower rate
b. (1) is accelerating at a slower rate
   (2) is accelerating at a faster rate
c. (1) is moving at a slower speed
   (2) is moving at a faster speed
d. (1) is moving at a faster speed
   (2) is moving at a slower speed



4. Now, come on... how do you interpret this curve?
   a. None of the above
   b. The object is accelerating for the whole time
   c. The object is stationary for some time then accelerating
   d. The object is moving at a constant speed



Run Kitty Run Game



In the game you had various tools – time (delay), speed and graph to work out the speed of your cat to match the speed of the mouse which was being controlled by the computer itself.

You also got an opportunity in the game to link the motion on the track with the position-time graph.

At some level you also change the slope on the track to change the speed of your kitty.

The game also helped you to check your estimations about the speed or time that the cat would take to catch the mouse.

Hope you enjoyed the game.

How to figure out change in velocity

7.1 A way to investigate motion

Is the cycle moving with the same speed between the two points or is the speed varying?

If the speed of a moving object does not change with time, we call it to be in uniform motion.

Say, if an ant covers 1 cm distance in one second and continues to cover same 1 cm distance in every second we can say it is in uniform motion.

If the speed of a moving object changes with time, we call it to be in non-uniform motion.

Say, if another ant covers 1 cm in first second, 2 cm in the next second, 1.5 cm in the third second we can say it is in non-uniform motion.

Non-uniform motion is quite common, everyday examples including a bus traveling on the road, birds flying, breeze blowing, water flowing. It is difficult to find the examples of uniform motion around us.

To be precise, we need to get some data to prove our point in science. Simply saying something does not work in science.

So how do you prove if a motion is Uniform or Non-Uniform?

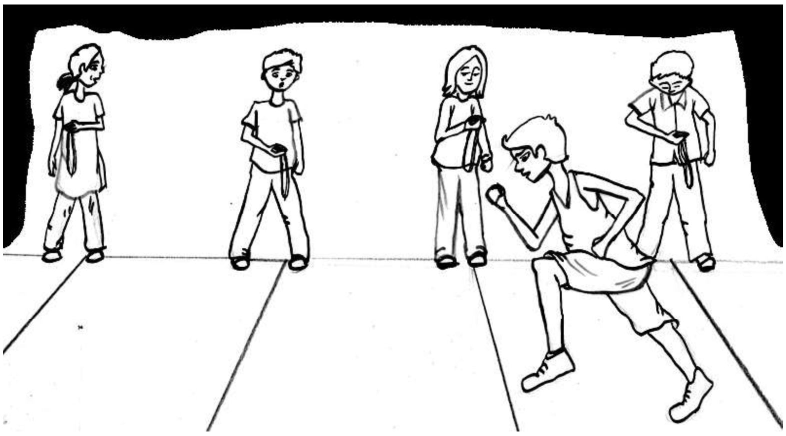
Before we learn a method to investigate motion, let us try to answer the following questions:

Suppose you run a 50-meter race. Could you estimate whether you will run from start to finish at the same speed or whether your speed will vary?

You may have also ridden a bicycle down a slope without pedalling. Did its speed increase as it rolled downhill? Did the speed keep on increasing?

7.2 Discover your own motion

A running race activity



Investigating motion of a runner in a race and analysing whether the motion of a runner is uniform or non-uniform.

You need to organize a running race event. The entire class will participate in it in groups of six members each.

Following are the details of the activity to be conducted.

Material required to perform the activity:

1. Measuring tape or meter scale; to measure the track
2. Four stopwatches per group; to record the time
3. Paper and pen; to note down the data

Process to do the activity:

1. Find a track at least 40 meter long and divide it into four equal segments. For example a 40 meter track could be marked at the intervals of 10, 20, 30 and 40 meters.
2. Place one of the group members as a timekeeper with a stopwatch at each segment to record the time.
3. Set a starting point and ask one of the group members to run till the end point.
4. Note down the data for the run.

With a loud sound "Start" the person starts the race. All timekeepers keep their stopwatches to zero. Once the runner passes the first segment, the first timekeeper standing there stops his stopwatch. The same process is observed for each segment till the runner crosses the end segment point.

7.3 Workout change in speed of runner

Change in speed: running race activity

Collate data of the running race activity and calculate the average speed of the runner. This will give you an insight whether the speed of runner is uniform or non-uniform throughout the race and if there is any variation of speed through the various segments.

Hope all of you have looked at your data. Now let us reflect on the following questions before moving ahead.

Table 7.3 (a): Time Taken **Note: You may also choose a track of different length and change the table accordingly.**

Username of the participant	Time taken (sec) for Segment 1 (0-10 meter)	Time taken (sec) for Segment 2 (10-20 meter)	Time taken (sec) for Segment 3 (20-30 meter)	Time taken (sec) for Segment 4 (30-40 meter)

Table 7.3 (b): Average Speed

Username of the participant	Average Speed for Segment 1	Average Speed for Segment 2	Average Speed for Segment 3	Average Speed for Segment 4

Did you take same time to run each segment? Was your run uniform or non-uniform?

You can use the following equation to calculate the average speed. Do not forget to write the unit of speed.

$$\Delta V = d_1 - d_0 / t_1 - t_0$$

7.4 Discussion time

You have done the activity and collected the data. You may have experienced something that you might not have thought of. Here are few questions for you to analyse what you have done.

Do you have same average speed in the different segments of the track? If no, then what could be the reason(s).

If you had only initial and end points, would your average speed give you any indication of the way your speed varied while you were running?

Is the speed maximum at the end point of the race? Did you run so that your speed kept increasing from the beginning to end?

Did you take the same time to run each segment? In the race, did you run with constant speed?

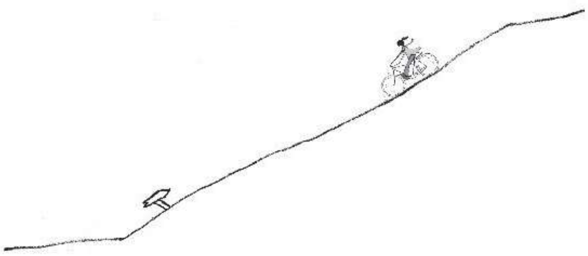
If the motion for a particular time interval is uniform, what is the possibility of the motion becoming non-uniform if the time interval is shortened?

In principle, we can make the time interval shorter and shorter. But in reality, there is a limit to what we can measure. So the time interval should always be clearly specified.

If we analyse the data of all the runners in your class, we can find out who the fastest runner is and who is fastest in each segment. The running example gives you an idea about one kind of non-uniform motion where the change in velocity is irregular.

7.5 Motion in inclined plane

How do you run on a slope



Suppose you are riding a bicycle on a hilly road. From the running race activity, you know that to predict the nature of motion we need to record the distance covered by an object in shorter and equal time intervals.

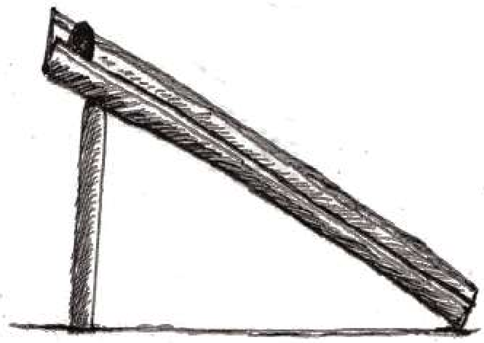
For a cycle on a real road, it will be difficult to record data – there will be other people and vehicles on the road, it will be difficult to find the right place to sit and spot the cycle etc.

In that case, there is a need of designing an experiment that recreates the same event in your classroom. Using this you can observe some parameters of the event and make a close guess about the real life event.

This in general is called a control experiment or a model of a real life situation.

7.6 Rolling ball experiment

Control experiments help scientists study a system in great detail



Now, let us design a control experiment that will be similar to the bicycle ride on the slope. It will help you to record data with better accuracy. Here we are replacing road with an aluminium or wooden plate and cycle with a steel ball or a marble. We are calling it as “Inclined Plane Experiment”.

Material required to perform the experiment:

1. *An aluminium angle of length 160 cm*
2. *A marble or a steel ball of diameter 1 inch*
3. *Stopwatches*

Setting up the experiment:

Place one end side of the aluminium angle at a higher point to give it an inclined slope. If the ball is moving too fast, then it will be difficult to take precise measurements. For this, you need to figure out just the right height for the ball to roll down smoothly from the beginning to end.

Process to do the experiment:

1. *Choose any one end of the angle and mark a line across its width at 1 or 2 cm. This is your starting point or zero point at 0 cm mark.*
2. *Now measure the rest of the angle’s length and divide it such that each segment is of length 30 cm. (You will get around 5 segments).*
3. *Raise one side just enough so that if you leave the steel ball from top, it smoothly rolls down till the end.*

4. Use stopwatches to record the time it takes to cover each segment.

Note: Please coordinate in your group so that everyone gets a chance to record the time.

7.7 Work out the change in speed of ball

Change in speed: rolling ball experiment

Here is the table to record the data of the experiment. Repeat the experiment as many times as needed to be able to record the time for each segment of 30 cm for at least four different runs.

Let us reflect on what we have done in order to analyse the speed of the ball:

Was it easy to record the time?

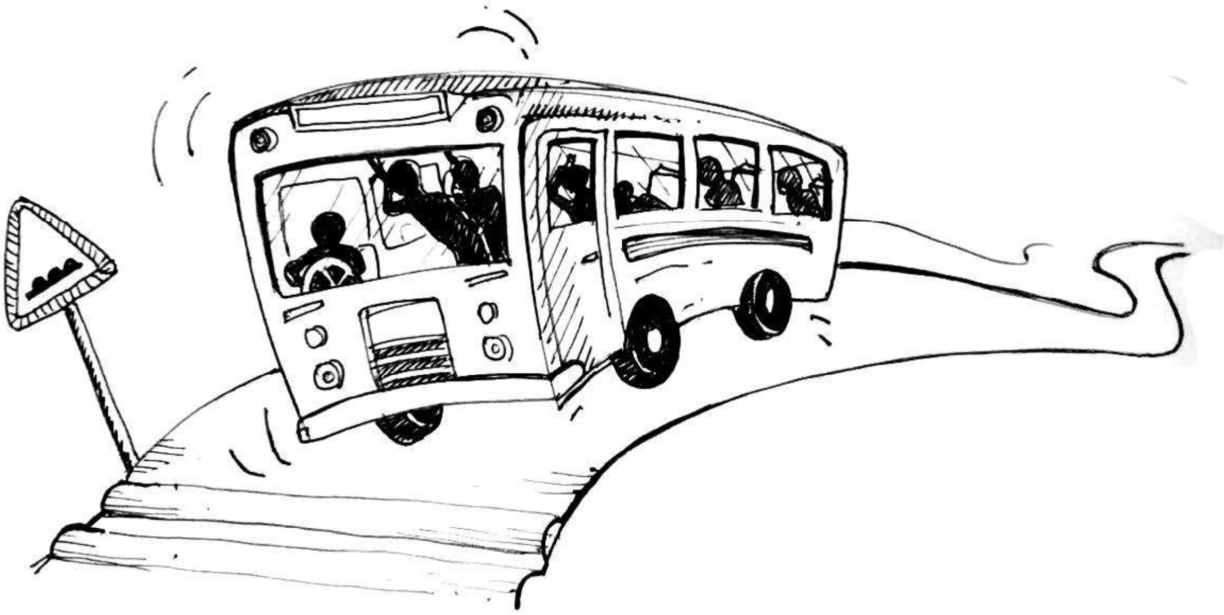
Was the error manageable or high?

Does the speed of the ball change with time?

Table 7.7: Rolling Ball Experiment

Segment	Time t for 1st run (s)	Time t for 2nd run (s)	Time t for 3rd run (s)	Time t for4th run (s)	Average time (s)	Average Speed (m/s)
0-30 cm						
30-60 cm						
60-90 cm						
90-120 cm						
120-150 cm						

Acceleration



In the previous lesson you have done the running race activity and rolling ball experiment. You observed that the speed of ball was not constant over the different length segments of the angular channel. To verify, you may refer the data you have collected. You worked out the change in speed in one second by analysing the data you recorded.

In this lesson, you went through a video analysis tool which allowed you to record the position of the ball at every 30th part of a second and further analyse its motion. It also generated position time curve for every set of data. In this way you analysed acceleration of the runner and the ball rolling down on a channel.

Further, the story of a bus was depicted on a velocity-time graph. The graph showed the accelerated, unaccelerated and decelerated motion of the bus.

At the end, you have also gone through an example of the train whose speed decreases to zero on applying the brake. It showed retardation.