Science

MOTION

Student Handbook

CONNECTED LEARNING INITIATIVE

An initiative seeded by

TATA TRUSTS

CLIx (2018)

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The **Connected Learning Initiative (CLIx)** is a technology enabled initiative at scale for high school students. The initiative was seeded by Tata Trusts, Mumbai and is led by Tata Institute of Social Sciences, Mumbai and Massachusetts Institute of Technology, Cambridge, MA USA. CLIx offers a scalable and sustainable model of open education, to meet the educational needs of students and teachers. The initiative has won UNESCO's prestigious 2017 King Hamad Bin Isa Al-Khalifa Prize, for the Use of Information and Communication Technology (ICT) in the field of Education.

CLIx incorporates thoughtful pedagogical design and leverages contemporary technology and online capabilities. Resources for students are in the areas of Mathematics, Sciences, Communicative English and Digital Literacy, designed to be interactive, foster collaboration and integrate values and 21st century skills. These are being offered to students of government secondary schools in Chhattisgarh, Mizoram, Rajasthan and Telangana in their regional languages and also released as Open Educational Resources (OERs).

Teacher Professional Development is available through professional communities of practice and the blended Post Graduate Certificate in Reflective Teaching with ICT. Through research and collaborations, CLIx seeks to nurture a vibrant ecosystem of partnerships and innovation to improve schooling for underserved communities.

Collaborators:
Centre for Education Research & Practice – Jaipur, Department of Education, Mizoram University – Aizawl, Eklavya – Bhopal, Homi Bhabha Centre for Science Education, TIFR – Mumbai, National Institute of Advanced Studies – Bengaluru, State Council of Educational Research and Training (SCERT) of Telangana – Hyderabad, Tata Class Edge – Mumbai, Inter-University Centre for Astronomy and Astrophysics – Pune, Govt. of Chhattisgarh, Govt. of Mizoram, Govt. of Rajasthan and Govt. of Telangana.

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MOTION

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CLIx/Eklavya Team
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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 this lesson we shall look at the importance of measurement in our daily lives as well as in the scientific world . In our daily lives, we use different measurement units like kilogram, meter, kilometre, litre, etc. There are different equipments such as a scale, the 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.K. too.

There might be possibilities of errors also. To reduce error, one should -

1. Repeat the measurement activity a number of times.

2. Take into account the least count of the scale.

3. Take care of other parameters that may affect the measurement.

1.2 Make your own measuring tape

Making a paper tape of at least two-meter length

Make your own paper tape

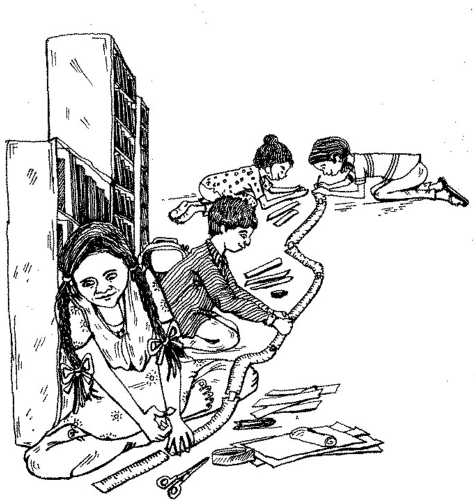
Materials Required:

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 into strips along the drawn lines.

3. Join the shorter ends of the paper strips to each other using gum or sticking tape.

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 roll it to fit it in your pocket.

1.3 Measurement of steps
1.3.1. Let's measure the length of your steps

Estimation of length and its standardization

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?

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

You have made a measuring tape. You may use it to measure short lengths. But as the distance becomes longer, using a 2-meter long tape will make the job tedious, tiring.

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

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

1.4 Standardization Of Scale

Make your step your scale

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 requirement is that you should be able to walk at least 50 steps comfortably.
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 the distance a couple of times, counting steps each time.

Is your step count always the same?

Make a Step Count table as shown below to record your data. Walk on the path 10 times. Count the number of steps you take each time and fill in the data in the table.

Table 1.4: Step Count table

1	2	3	4	5	6	7	8	9	10

Has your step count been varying a lot?

Is there a range within which these numbers fall?

You have made 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.

1.5 Average length of a step

1.5.1. What is the average length of your step?

You have walked on the 10 meter path 10 times. You have recorded the number of steps each time. Now please work out the average of all 10 numbers in your notebook.

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**".

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

1.5.2 Measure again and again!

You measured a 10 meter distance on the ground walked on it ten times, didn't you?

Now do the following three exercises also -

Please measure the distance on the ground again with the paper tape - 3 to 5 times.

Did the distance turn out to be slightly long or short each time?

Please use a scale from your geometry set and use it to compare the centimeter marks drawn on the paper tape?

Do you notice any difference?

Please measure your scale with someone else's scale? It will provide a good comparison if it is a different brand.

Sometimes, the scales may show a difference in the centimetre measure.

You have now discovered one of the most important aspects of measurement - Measurement carries the possibilities of errors also.

You can reduce them but you cannot get rid of the errors completely.

We need to be aware of errors in measurement and take steps to reduce them.

That is why -

1. We repeat the measurement activity
2. Take care of the least count of the scale
3. Take care of other parameters that may affect the measurement activity.

1.5.3 Test your predictive power

Walk a distance that you can comfortably 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.

1.5.4 Verify your findings

Now use your paper tape to measure the same distance that you just measured using your steps.

Compare these two numbers. Are they close enough?

1.5.5 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 in exploring it further?

Let us summarize what we have understood about motion in this unit. You feel that 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 point of reference and notice 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.

Also, if you and another person or an object are moving in the same direction at the same speed, then you would not be able to say if that person or object is moving. Let us look at the movement of the two boats that we saw in the video. If you were in one of the boats and observing the other boat, you would not be able to say whether that boat is in motion.

We don’t feel the motion of the earth because we are moving with it at the same speed.

We have also noticed that the observer plays an important role in describing motion. The path a moving object covers varies according to the position of the observer.

Let’s discuss this with the video of the ball and the two observers watching it. To the man who was at the same level as the man throwiing the ball, it appeared that the ball is not returning to its position. The observer having the top view will think that the ball returns to its position.

Motion is 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. You may maintain constant speed for some time but not all the time because there are so many hurdles on the way such as vehicular traffic, bad roads, etc.

That is why the speed that we commonly encounter or talk about in our daily life is an 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.

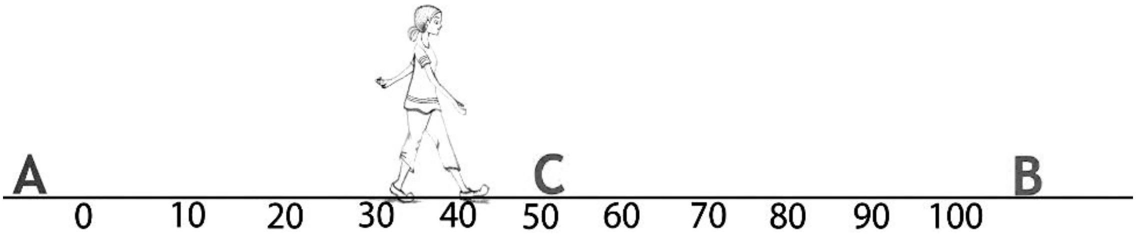
You find instantaneous speed as speedometer reading. The speed shown on the speedometer at a particular time is instantaneous speed.

If you travel at constant speed, then your average speed will be equal to instantaneous speed.

In the next lesson, we shall learn about displacement and its relation to velocity.

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

Displacement and Velocity



The concepts of distance and displacement 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 whereas to find out velocity you consider total displacement covered in the total time.

You noticed that distance and speed do not have information of direction and these values 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.

Now it is understood that 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 Graphs

A graph is also a means to represent motion.

Watch the folllowing video for a glimpse of a graph. You show two variables on these two axes (singular – axis) .

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

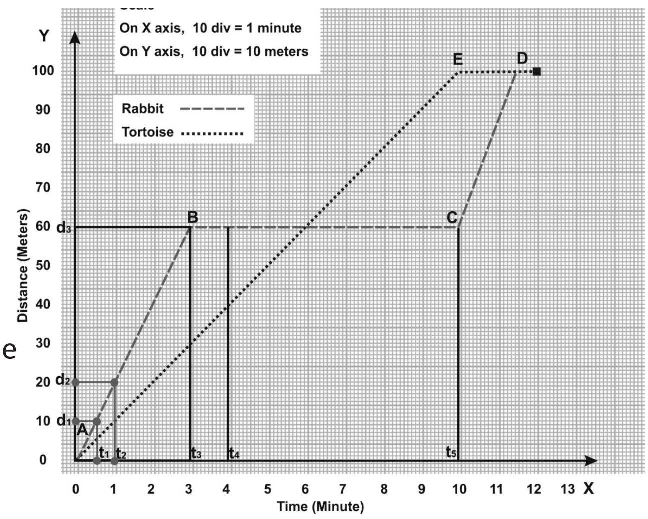
On the graph, time is always represented on the X axis and distance, speed or velocity is represented on the Y axis in context of motion.

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

5.2 Interpretation of graph

Tortoise and rabbit's race

Let's begin with the famous story of the race between a tortoise and a rabbit. In the story, the rabbit runs faster and rests on the way while the tortoise runs with slower speed but moves continuously till it reaches the finishing point. Finally the 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 the rabbit and the tortoise compared over time when they were running, you need to know how to interpret the graph.

On the line segment AB in the graph, distances d1 and d2 correspond to times t1 and t2, which shows that 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 d3 corresponds to time t3. Further, distance d3 also corresponds to time t4. For two different values of time, we have same value in distance. 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? How did you figure this?

5.3 Position time graph

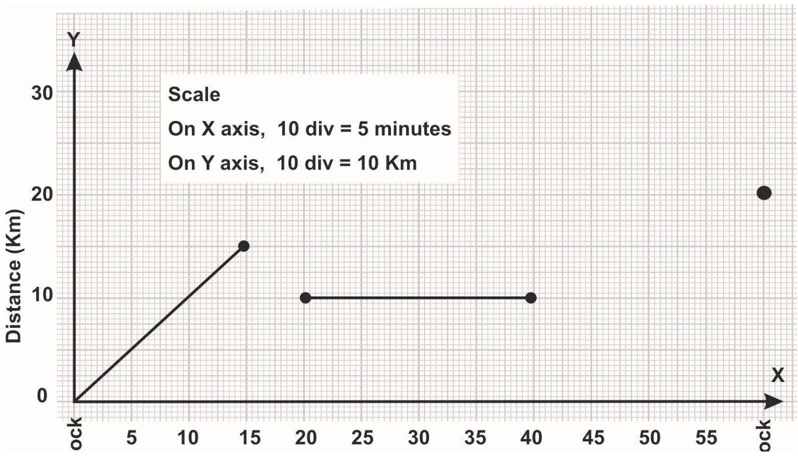
LET'S DO EXERCISES

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

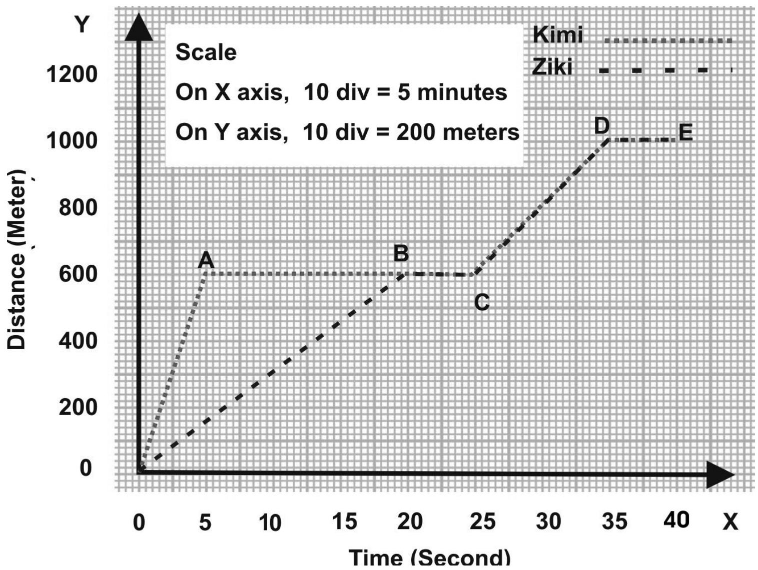
2. A goods train is going from Itarsi station to Bhopal station. At 12:00 p.m., it leaves Hoshangabad and after 15 minutes at an upward track, its engine and brakes fail and the train rolls backward for 5 km and stops on a plane track. The driver and the train guard inform the controller. A new engine takes 20 minutes to arrive there. The new engine pulls the train and helps it to cross the valley in the 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



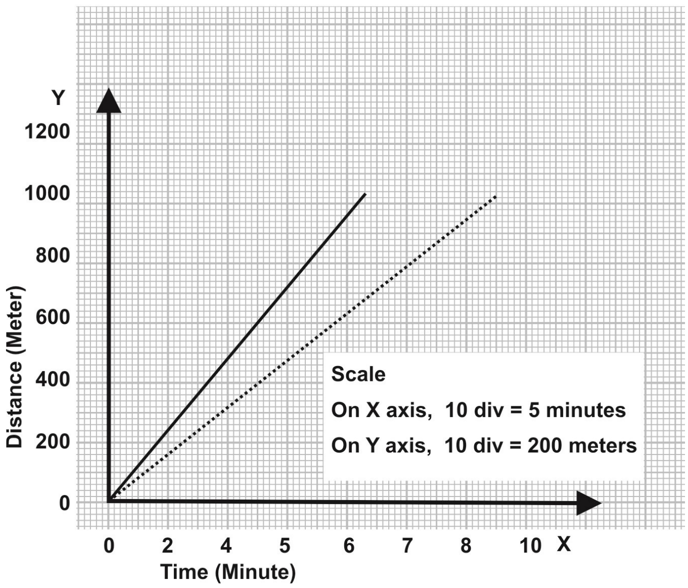
3 The graph given below shows the journey of two sisters Kimi and Ziki from their home to the school. Kimi takes a stop at a book shop. After a while Ziki joins her. Then from the shop they go to the school together. Fill up the table given below using the information given in the graph

(i) Who takes less time to reach the shop?	
(ii) For how long did Kimi stay at the shop?	
(iii) Can you identify the part of the line depicting Kimi's stay at the shop?	
(iv) What was the distance between the school and th e shopbetween the home and the shop?	
(iv) What was the distance between the school and th e shopbetween the home and the shop?	



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

4. *Vimal and Abid participate in a 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 a.m.. At 11 a.m., 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 p.m., when the water level goes down and is lower than the bridge, the bus crosses over to the other side. 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

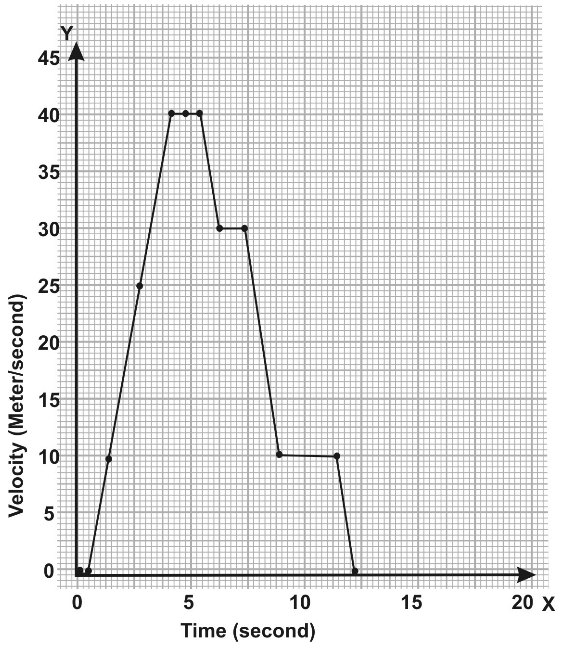
Let's do exercises

1. The graph represents a motorcycle ride.

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

(ii) Mark the point(s) on the graph that show(s) that the motorcycle is moving with constant velocity.

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

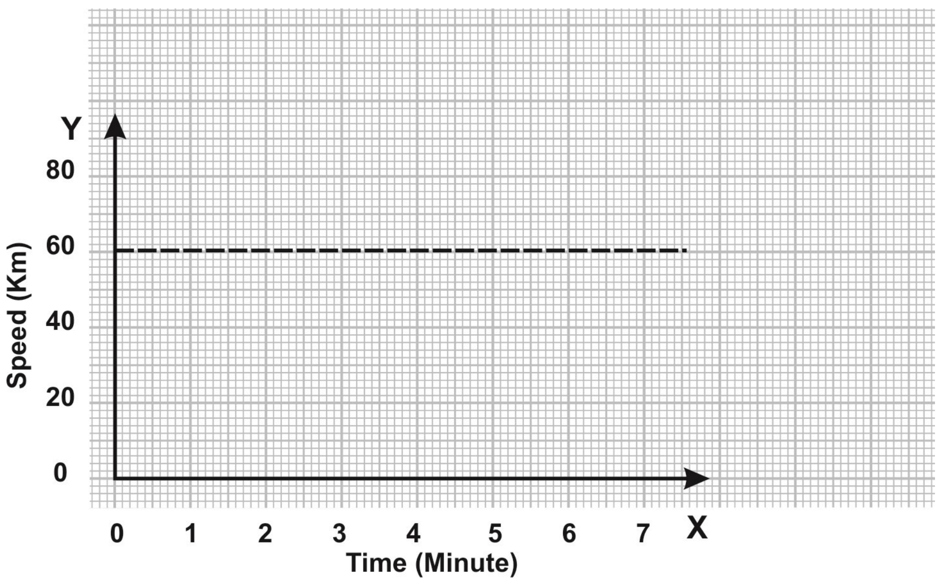


(sec)	Speed (m/s)
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	

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

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

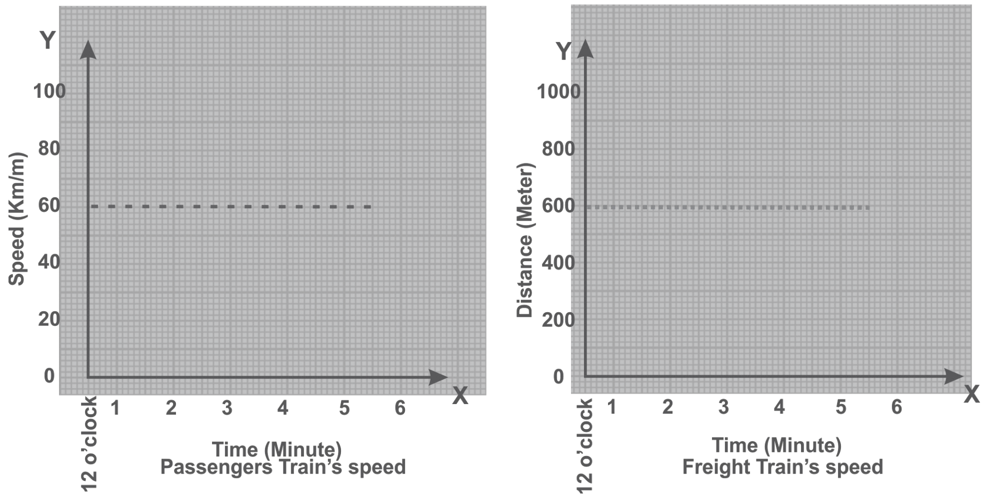
(ii) Please draw the first 2 minutes of the police jeep when it was not able to move. Draw the line on this graph.



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

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

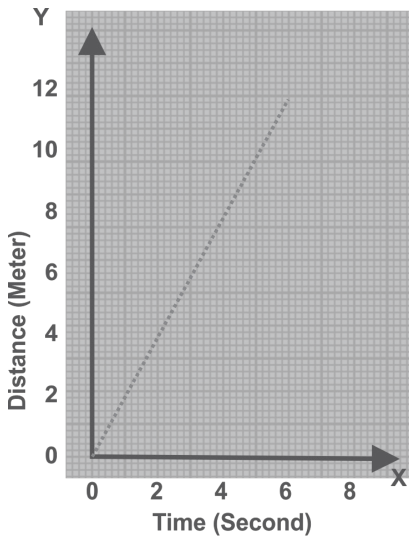
   (ii) Tell us how these graphs are different.

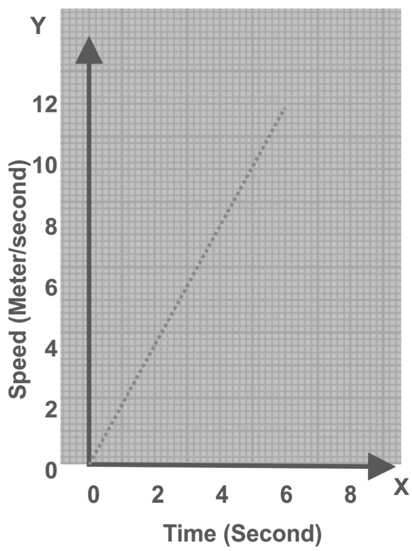


4. *Use the data given in the table below to plot the graph of two objects moving with different velocities.*

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?*





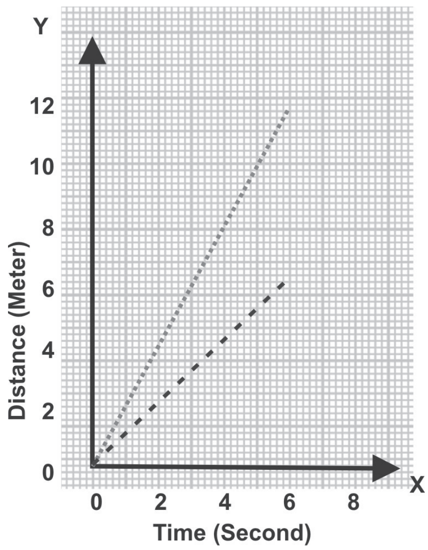
Look at the velocity-time graph of a moving object. The area enclosed by the velocity-time curve and time axis gives you the total distance covered by the moving object. You will learn this in the equation of motion. Please fill up the blanks to get the distance for the graph given below.

Area of a triangle = ½ x a x b

= ½ x......x.......

= 36 unit's

You will use this method to find the distance in section on equation of motion, where you will learn how to relate four quantities in 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?

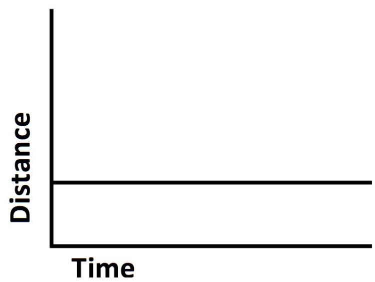
   a. Object is at rest

   b. Object is accelerating

   c. Object is moving with a fixed speed

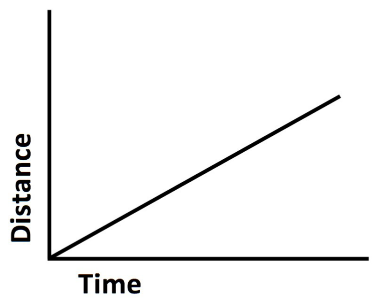
   d. None of the above

   (accelerating – beginnning to move quickly,



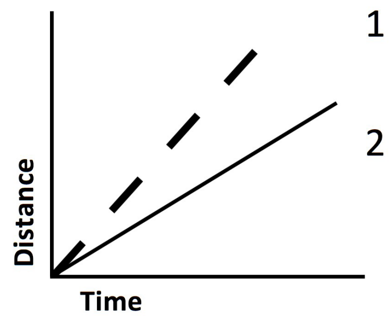
moving at a faster rate)

2. Now, what do you think this graph explains about the state of the object?



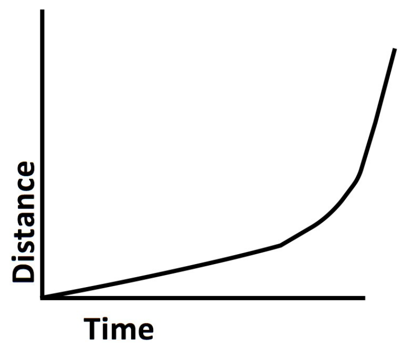
   a. Object is at rest
   b. Object is accelerating
   c. Object is moving with a fixed speed
   d. Both (B) and (C)

3. Compare the slopes and choose the correct option:



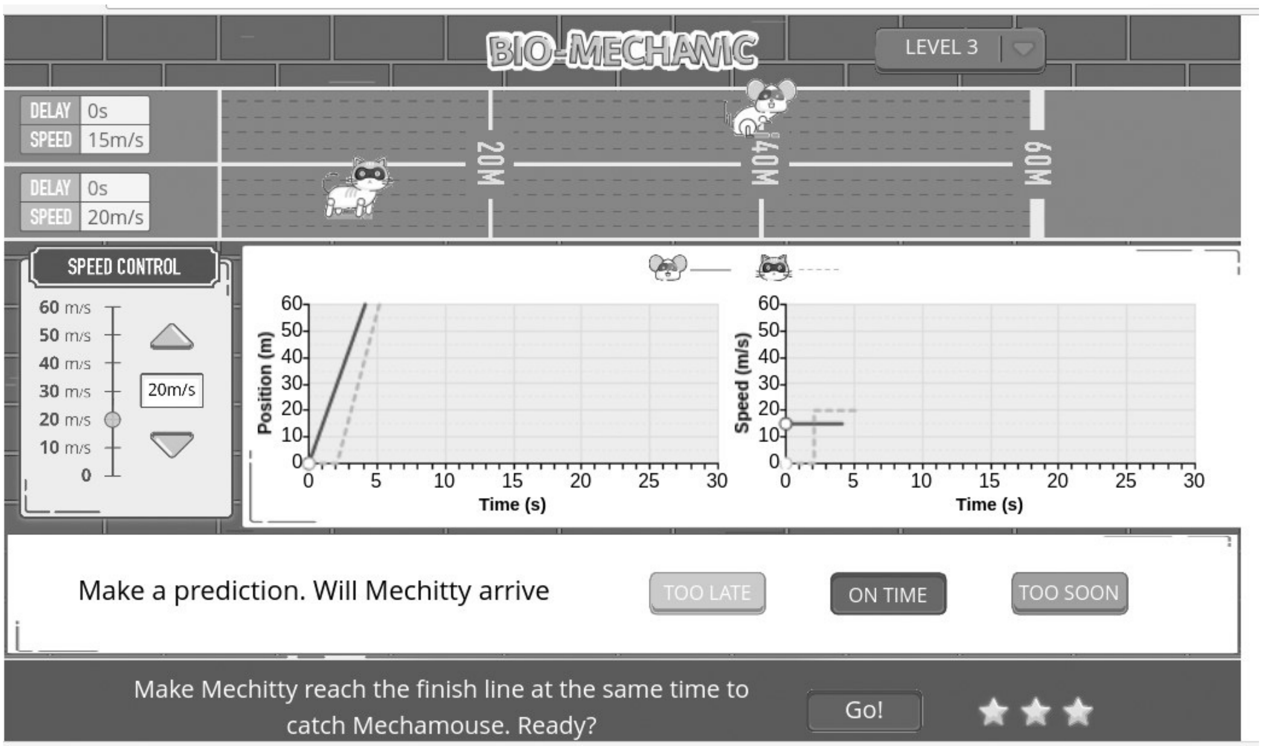
a. (1) is accelerating at a faster rate
   (2) is accelerating at a slower rate
b. (1) is accelerating at a slower rate
   (2) is accelerating at a faster rate
c. (1) is moving at a slower speed
   (2) is moving at a faster speed
d. (1) is moving at a faster speed
   (2) is moving at a slower speed

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 and then accelerating
   d. The object is moving at a constant speed

Run Kitty Run Game



Run Kitty Run

In the game, you had various tools – time, delay, speed - to work out the speed of your cat to match the speed of the mouse that 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. And at some level, you could 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 kitty will 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 bicycle 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 say that the object is in uniform motion.

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

If the speed of a moving object changes with time, we say that the object is in non-uniform motion.

For example, 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 include a bus travelling on the road, birds flying, breeze blowing, water flowing. It is difficult to find examples of uniform motion around us.

In order to be precise, we need to get some data to prove our point in Science. Merely saying something does not work in science.

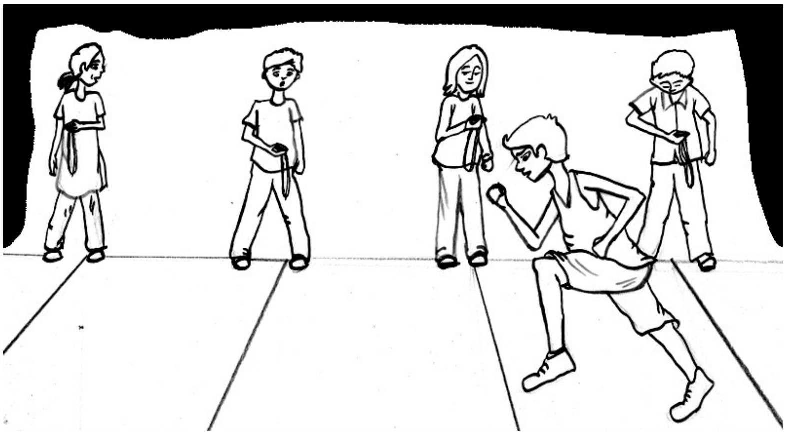
So how do you prove if a motion is Uniform or Non-Uniform?

We shall learn the method that will help us investigate, get data and describe uniform and non-uniform motion in the following sections.

7.2 Discover your own motion

A running race activity

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



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:

1. Suppose you had to 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?

2. If you are riding a bicycle down the slope, without pedalling, will its speed increase as it rolls downhill? Will the speed keep on increasing?

Activity 1 – Race

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 the data

Process to do the activity:

1. 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 “Start”, the person starts the race. All timekeepers keep their stopwatches at 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

<u>Change in speed: running race activity</u>

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

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)

Note: You may also choose a track of different length and change the table

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

You can use the following equation to calculate the average speed,

$$\Delta V = d1 - d0 / t1 - t0$$

Do not forget to write the unit of speed.

questions before moving ahead.
Did you take the same time to run each segment?

Was your run uniform or non-uniform?

7.4 Discussion time

You have done the activity and collected the data. You may have experienced something that you did not expect. 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).

1. Do you have same average speed in the different segments of the track? If no, then what could be the reason(s).
2. 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?
3. Is the speed maximum at the end point of the race?
4. Did you run so that your speed kept increasing from the beginning to end?
5. Did you take the same time to run each segment?
6. In the race, did you run with constant speed?

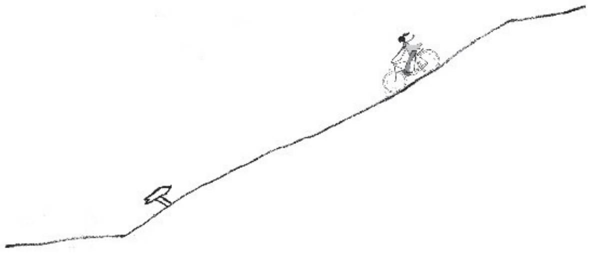
If the motion for a particular time interval is uniform, what is the possibility of the motion becoming non-uniform if the time interval is shortened?

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

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 bicycle 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 to design 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. In this experiment, an aluminium or wooden plate will act as the road and a steel ball or a marble will be the bicycle. We call this an "Inclined Plane Experiment".

Material required to perform the experiment:

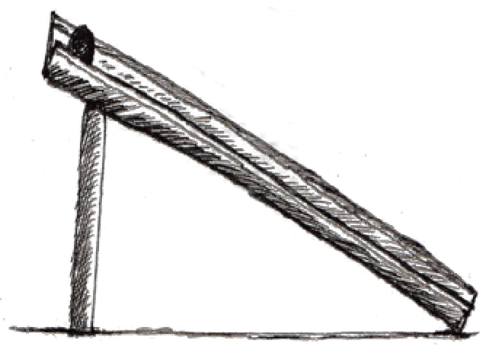
1. *An aluminium angle of length 160 cm*
2. *A marble or a steel ball of diameter 1 inch*
3. *Stopwatches*

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 upto 5 segments).*
3. *Raise one side just enough so that if you place the steel ball on the top end and let it go, it will roll down smoothly 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 for the experiment. Repeat the experiment as many times as needed so that you have recorded the time for each segment of 30 cm in at least four different runs.

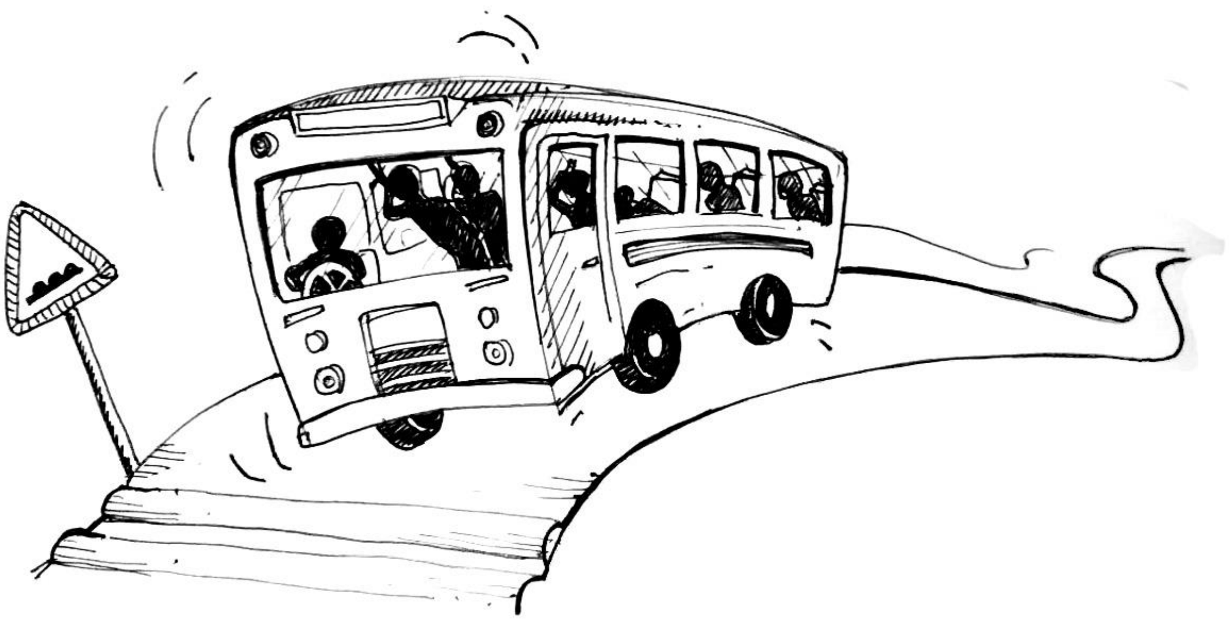
Table 7.7: Rolling Ball Experiment

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						

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

1. Was it easy to record the time?
2. Was the error manageable or high?
3. Does the speed of the ball change with time?

Acceleration



In the previous lessons, you conducted the running race activity and the rolling ball experiment. You observed that the speed of ball was not constant over the different length segments. To verify, you may refer to the data you have collected.

You worked out the change in speed in one second by analysing the data you have recorded.

In this lesson, you went through a video analysis tool which allowed you to record the position of the ball at every 30th 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/ aluminium strip.

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

Towards the end, you have also gone through an example of the train whose spee¬d decreases to zero on applying the brake. You learnt about retardation or deceleration.

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