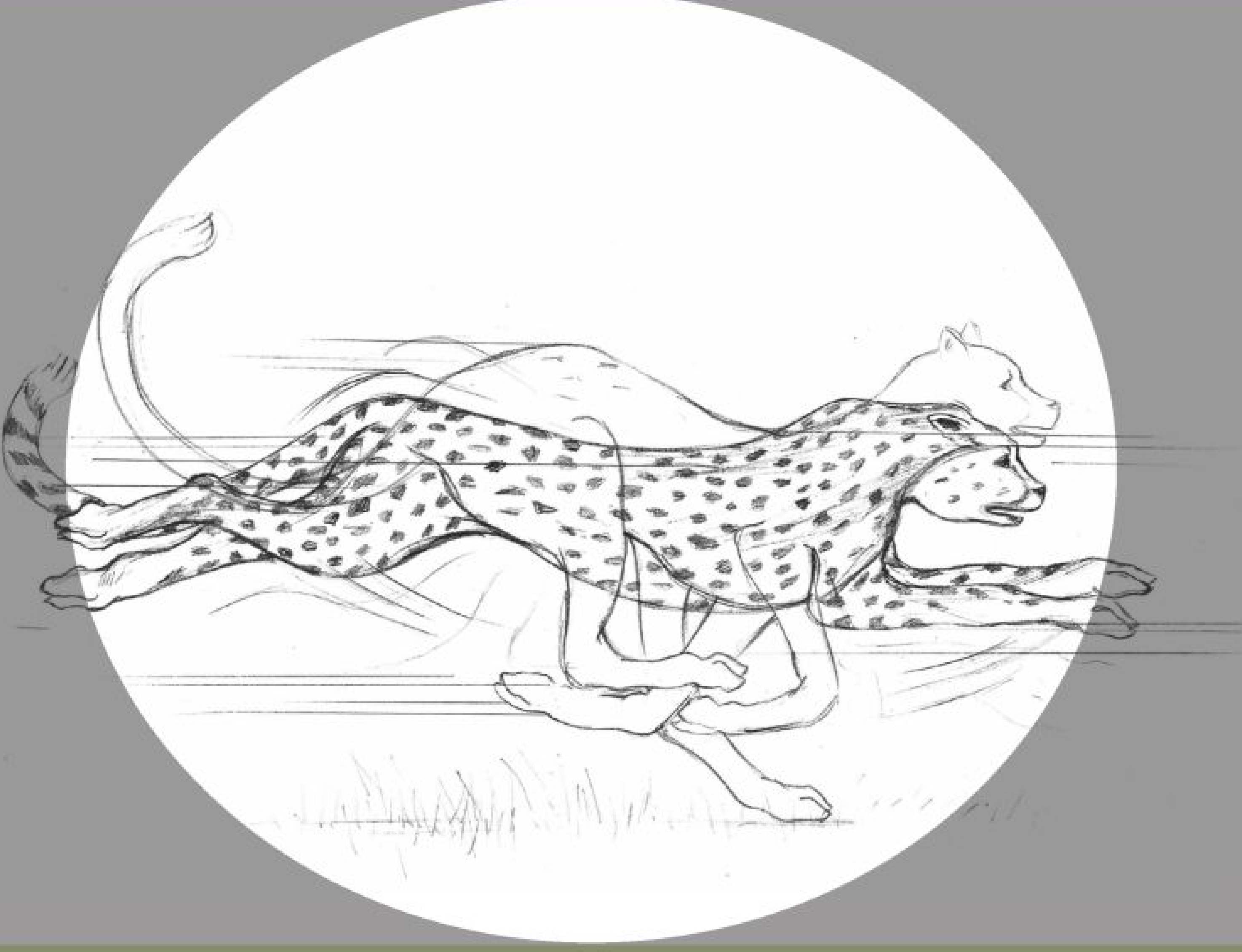
High School Science Series

Motion and Force

Part 1 - Motion



an eklavya publication

Simple and Complex Motion

Types of Motion

What is Motion?

Recognising Motion

Quantifying Motion

Motion and Force

Part I - Motion

Acceleration in One-Dimensional Motion

Average and Instantaneous Speed

Speed

Predicting Motion

eklavya

Uniform and Non-Uniform Motion

Motion and Force
Part 1 - Motion

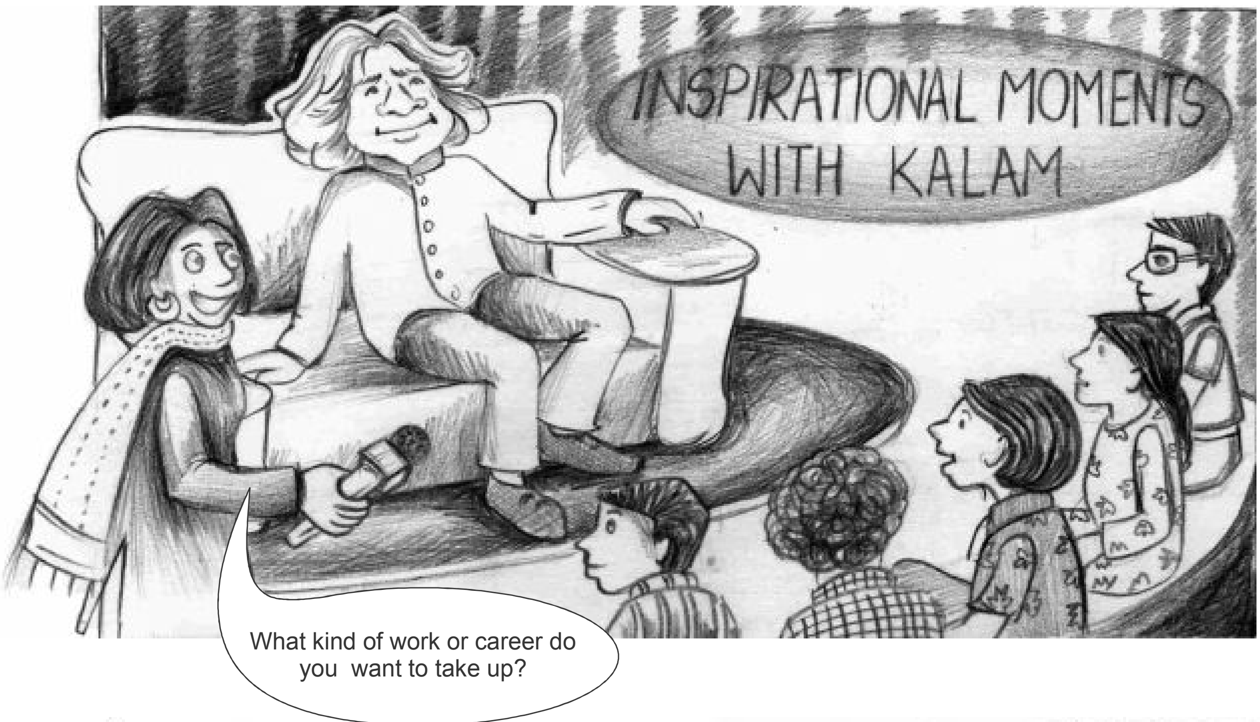
Text: Rama Chari, Himanshu Srivastava, Pragya Shrivastava
Illustrations: Shweta Raina
Design and layout: Jitendra Thakur

March 2013 / 2000 copies
Paper: 100 gsm maplitho and 220 gsm paper board (cover)
ISBN: 978-93-81300-50-3
Price: ₹ 135.00

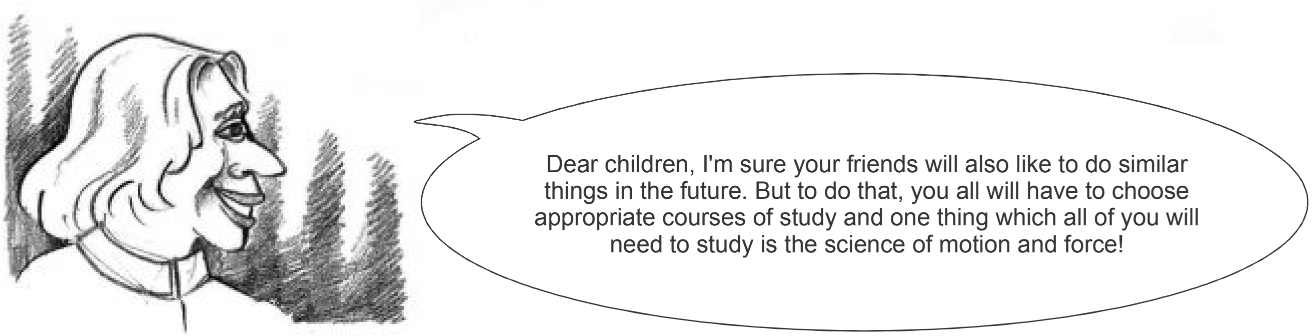
Developed with financial assistance from the Sir Dorabji Tata Trust and the 'Parag initiative' of Sir Ratan Tata Trust and Navajbai Ratan Tata Trust.

Published by
Eklavya
E-10, BDA Colony Shankar Nagar,
Shivaji Nagar, Bhopal - 462 016 (M.P.)
www.eklavya.in

Printed at: Aadarsh Pvt. Ltd. Bhopal, Phone 0755 255 5442


INSPIRATIONAL MOMENTS WITH KALAM
What kind of work or career do you want to take up?


I want to design a rocket which will go to the sun.
I want to drive racing cars.
I want to make artificial wings which can help us fly.
I want to make a cricket bat which will make hitting a sixer easy.


Dear children, I'm sure your friends will also like to do similar things in the future. But to do that, you all will have to choose appropriate courses of study and one thing which all of you will need to study is the science of motion and force!

High School Science Series

For many years now, Eklavya and its Academic Resource Group have been deliberating upon high school science curricula. Science is currently taught in schools as general science till class X, and the prescribed textbooks focus on introducing students to a large variety of topics in a cursory manner. We therefore felt that there was a strong need to develop resource materials for teachers and students in line with the philosophy of the Hoshangabad Science Teaching Programme (a pioneering educational initiative that spanned three decades, in over a thousand schools of some districts of Madhya Pradesh). Members of Eklavya, science teachers, scientists, educationists and others interested in education, all put their heads together to develop a series of modules. These books are each the outcome of extensive collaborations—workshops, discussions, field trials and testing. They are designed to convey a broader understanding of some concepts and topics covered in school syllabi.

This module 'Motion' is the first of a two part series on motion and force. The result of several teacher training sessions and classroom trials conducted by Eklavya, it is meant as a resource material for teachers. Each section has pedagogical notes (text in grey background). They explain the rationale of the treatment used in developing that particular topic. At places, alternative approaches have been suggested. The main text develops the subject with the help of real life examples, hands-on activities and problems for students to think about and try solve. The activities are also a tool to introduce students to the various aspects of experiments and data analysis.

Contents

About the Module

We live in a world that is constantly moving. Motion or movement of objects and people is something we come across every day. Understanding motion is a basic requirement for almost all branches of the natural sciences (including physics, chemistry and the life sciences) and engineering. Most properties of matter can be traced to the motion of the fundamental particles within it. The motions of electrons and other sub-atomic particles govern the physical and chemical properties of the elements. In biology, the movements of cells and sub-cellular units govern the interactions leading to metabolic processes. Even economics is the study of how money moves.

However, the question which confuses us sometimes is whether things are actually moving the way we perceive them or not. Think of watching trees from the window of a moving train. Are you moving forward, or are the trees moving backward? Similarly, we see the Sun move across the sky from east to west but current wisdom says that the Sun appears to move because of the Earth rotating from west to east on its axis. As these examples show, our intuitive ideas of motion based on visual observation do not always give the real picture. Then, how can we find out what is actually happening? Science looks for answers by using a combination of observations made under controlled conditions (experiments) and logical analysis. The understanding of any natural process can be used to make accurate predictions about it and to also develop new technology. For example, knowledge of the laws of motion and force allows for the times of eclipses to be predicted well in advance. The same knowledge has also led to the development of rockets which travel to the moon and back.

This module is an attempt to get you thinking about some of these issues. We will develop the basic concepts necessary to analyse motion and the effects of force on motion. The module is in two parts: the first part deals with describing motion (kinematics), and the second part deals with the relationship between force and motion (dynamics). Motion is relatively easier to grasp because it is a phenomenon we all can see. Also, the measurement of quantities like speed and acceleration can be demonstrated and understood more easily. Force is a more abstract concept and is experienced only by the effect it has on motion. Therefore, we start with motion—its definition, measurement and mathematical treatment. Further, to keep things simple we stick to linear motion. Once the basic concepts are understood, more complex motions (e.g. motion along a curve, oscillatory motion, rolling motion or a combination of several types of motion) can be analysed using these concepts or by building upon them.

We presume that anyone reading this module has a basic understanding of measurement and graphs. If that is not the case, we suggest that you first go through the two appendices on graphs and measurement, as well as the relevant chapters in the *Bal Vaigyanik* textbooks published by Eklavya.

The text of the module is interspersed with various examples and activities. They are designed to make the reader pause and think about what is being discussed. Detailed discussions of some topics, e.g. the scientific method, limitations and errors in any measurement, etc. have been moved to the appendices so that the main text reads smoothly.

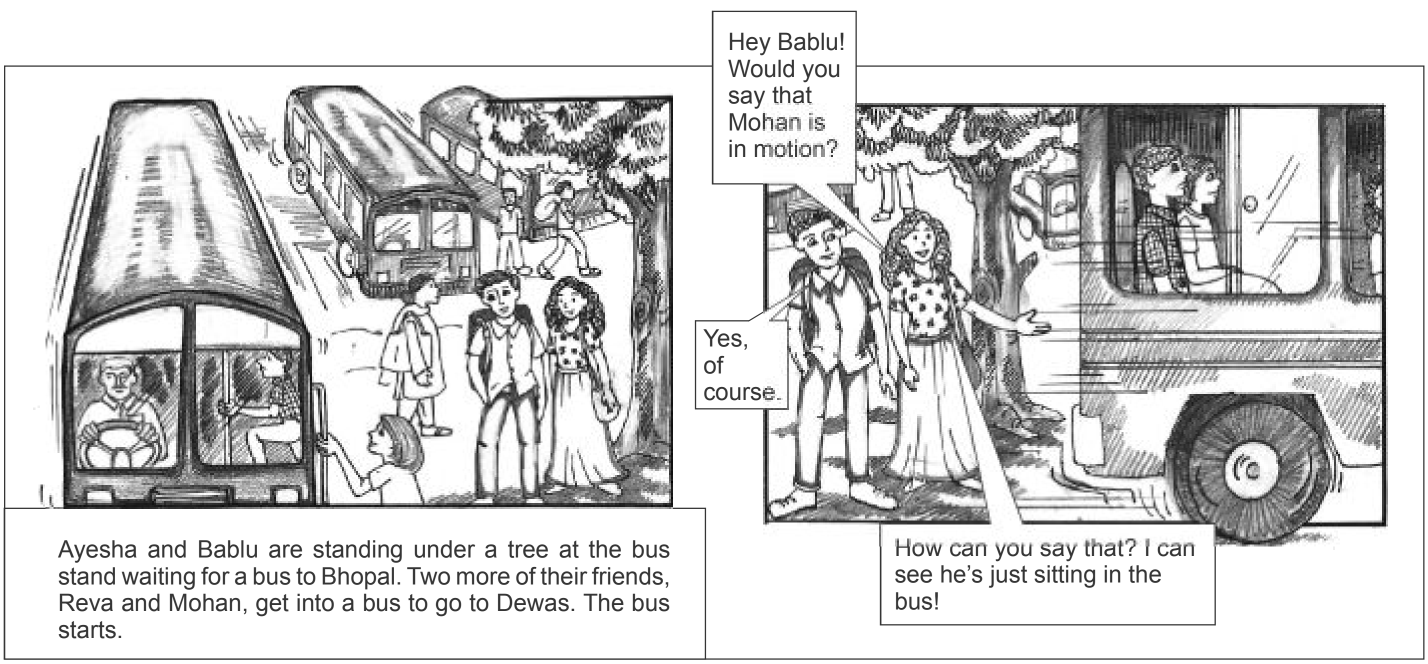
The problems given at the end have been chosen to test whether the concepts discussed in the text have been properly understood. Therefore, do attempt them all to get the most out of this module.

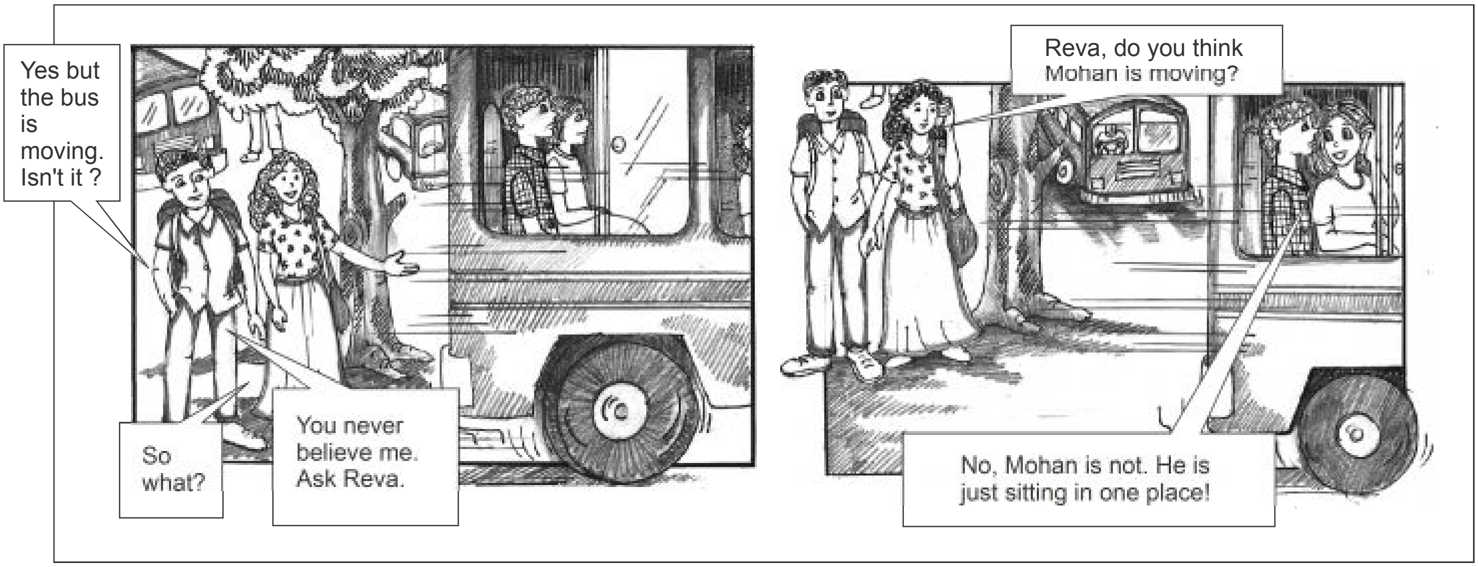
And lastly, but most importantly, this module is only a beginning. If it helps stimulate students (this includes all of us reading this module) to read more, learn more, question more and do more experiments, we would have achieved our aim.

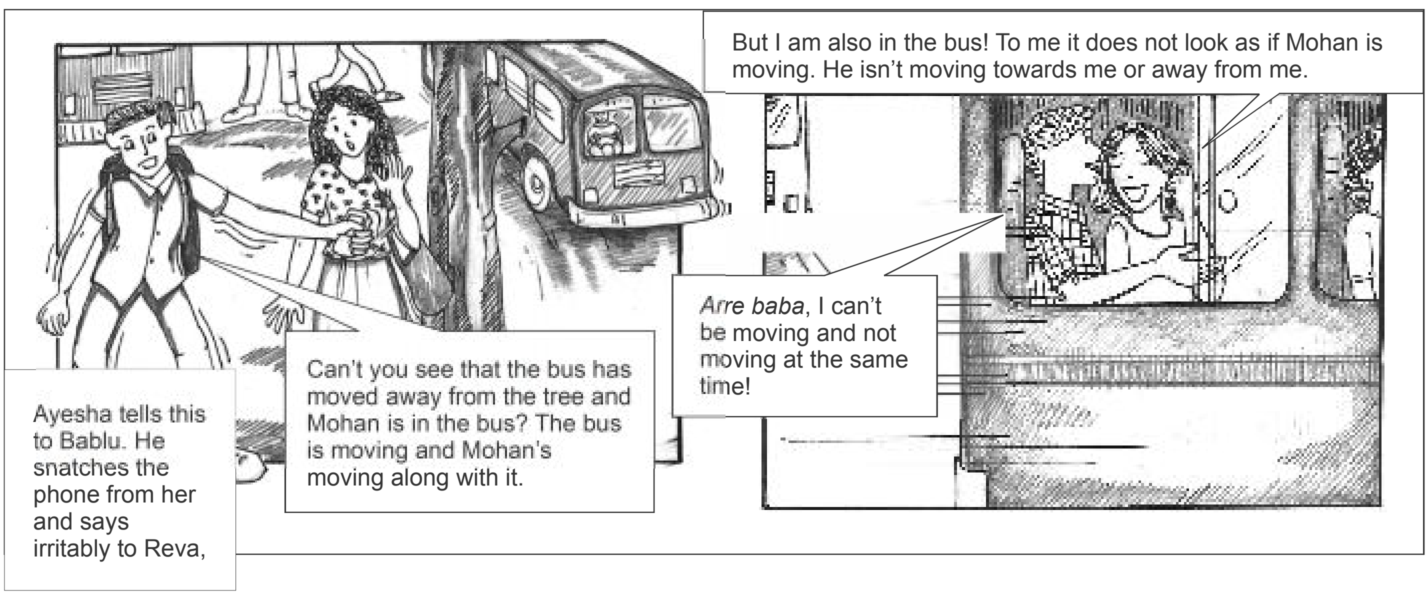
What is Motion ?

A good starting point is to find out what students already know. So you can start by putting questions like these to the class: “What is motion?” or “How can you know if something is in motion?” Most students would have studied something about motion by the 8th standard and will come up with some answers. However, their descriptions may not be complete. Any missing components can be brought out by discussing suitable examples.

For example, the children may feel that motion is a 'change in position' with 'time'. Though correct, this answer is not complete. What is missing is the explicit phrase that the change in position is with respect to a **point of reference**. To bring this out, you can use the conversation shown in the cartoon strip below. You can have four children enact it. A discussion should follow so that the children understand what the point of reference in any given motion is, and the role of the observer in understanding motion. You can use some more examples like the ones given next.







What do you think is happening? How do we decide whether something is moving or not?

Example 1. Observe the moon on a windy night with a fair bit of cloud cover in the sky. As a cloud passes in front of the moon you sometimes think it is the moon which is moving behind the cloud. What would you think if you were to observe a tree at the same time? (Fig. 1)

Fig.1 'Hide-and-seek' with the clouds

Example 2. This is the classic example of watching the scenery from the window of a moving train. When the train is passing through open countryside, we feel that the bushes or lampposts near the train are moving in the opposite direction, but the trees further away seem to be moving in the direction of the train. We do know that both the lampposts and the trees are fixed to the ground; so, why this illusion? (Fig. 2)

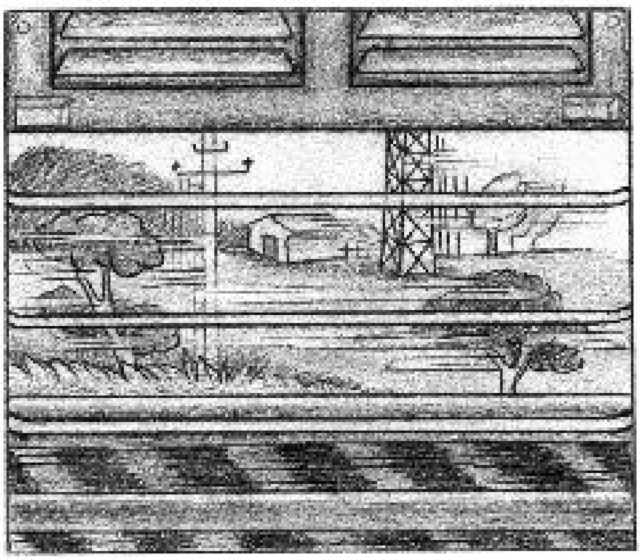


Fig. 2 Scenery flashing past a moving train

The motion of an object is its relative movement with respect to a point of reference as measured by an observer. The point of reference may be the person making the observation or some other point or object visible to the observer. For example, when trying to catch a ball thrown at us, we judge the movement of the ball by its position with respect to ourselves. When writing, we judge the position of the pen with respect to a line on the page or the page edge. Imagine writing something while sitting in a moving train. We, along with the paper we are writing on, are moving with the train. But we write (if the train is moving smoothly) as though we are sitting on a chair in a classroom. The common feature in both the examples is that the point of reference is assumed to be stationary and the movement is observed with respect to it. Thus, we don't bother whether our seat is moving or not. As long as we hold the paper fixed with respect to ourselves, we can write.

What happens when we try to play 'catch' in a moving train?

What is P.T. Usha Doing?

Look at the photograph of the famous athlete P. T. Usha in Fig. 3. What do you see in it?

Did you answer ''P. T. Usha is running on the beach''? The photograph only shows that she has one foot on the ground and the other off it. You can lift one foot off the ground even while standing still. Try now!

From a still photograph we cannot be certain whether she is running (moving) or standing still. For that we need to observe her at different points in time.

Similarly, in the case of the Sun, Moon or a constellation, they look still when we look at them. But if we observe them after half an hour, or sometimes after a few hours, only then can we see that they have moved.

We often use statements like, ''I am walking now'' or ''You are driving very fast now''. It is difficult to understand that when we say 'now', we are actually talking about a small interval of time during which our positions have changed. This will be clearer later when instantaneous and average speeds are discussed.

Time and motion are irretrievably connected to each other. We need to know time to deduce motion, and motion to measure time. All clocks depend on some motion which is considered the standard. In a sand-clock, all the sand flows down a hole in a fixed period of time, in a sundial the shadow moves from one marked position to another every minute or hour, in a modern day watch a crystal vibrates with a fixed frequency, and in an atomic clock it is the fixed time of the electron orbiting in an atom that makes it possible for us to measure time.

Studies have shown that many misconceptions regarding motion arise from the fact that the passage of time is not given the same importance as the change in position. This is possibly because we see the moving object changing its position and the pictures of the object in different positions are stored in our mind. However, time is not sensed directly, and many times we are not even aware of the passage of time.

Fig. 3 P.T. Usha on a beach

P. T. Usha, also nicknamed the Payyoli Express, came from a small village in Kerala and is one of the most successful women athletes in recent times. Between 1983-89, Usha garnered 13 golds at the Asian Track and Field meets. In the 1984 Los Angeles Olympics, Usha became the first Indian woman (and the fifth Indian) to reach the finals of an Olympic event by winning her 400 m hurdles semi-finals. In the finals, she lost the bronze by 1/100th of a second. Usha has won 101 international medals, so far. Her six medals, including five golds, at the 6th Asian Track and Field Championship at Jakarta in 1985 is a record for a single athlete in a single international meet.

Discuss whether the following statements can be correct:

a. I walked for an hour yesterday.

b. I am always running.

c. You are standing still.

d. Mohan is standing still and waving his hand.

Some of these statements have been deliberately chosen to be ambiguous. Discussing these or similar statements in detail will reinforce the concepts of time and the points of reference for the students.

Types of Motion

Ask everyone in the class to remain in their places, to look around and identify objects that are moving. The replies could list: the teacher walking in the classroom, a ceiling fan running in the room, leaves fluttering on trees outside, birds flying in the sky, people walking in the corridor outside, ants or flies in the room, etc. Some may also come up with: the heads of other people looking around, blinking eyes, moving fingers, etc.

How many different kinds of motions can you think of? We use different words like walking, running, jumping, waving, vibrating, shaking, rotating, falling, etc. to describe different kinds of motions.

Depending on the path that a moving object takes, the motion can be called:

a. Linear—moving in a straight line, like a person walking on a straight path, free fall.

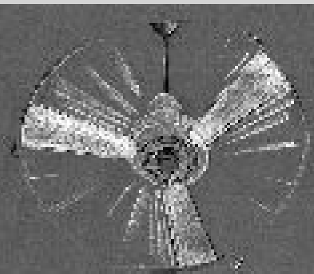
b. Curvilinear—moving ahead but changing direction, like a snake.

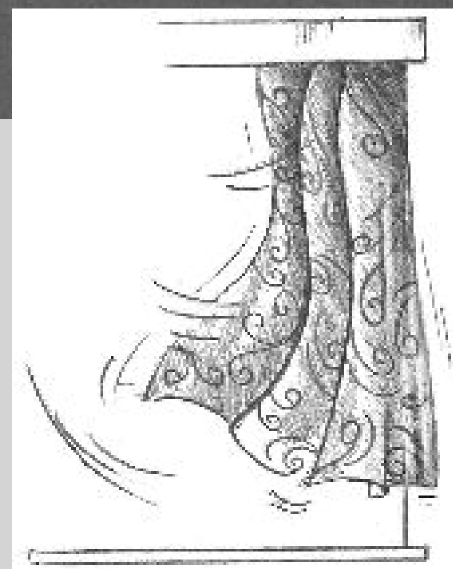
c. Circular—moving in a circle, like a fan.

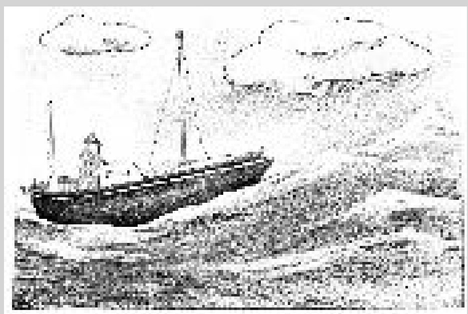
d. Periodic—coming back to the same position after a fixed time interval, like a pendulum.

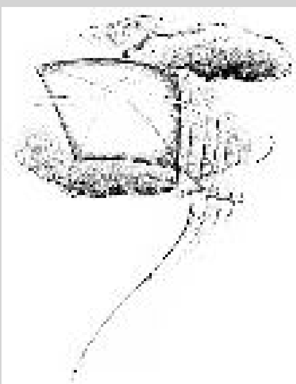
Make a table of the different types of motions you can see. Into which of the above four categories do they fall?

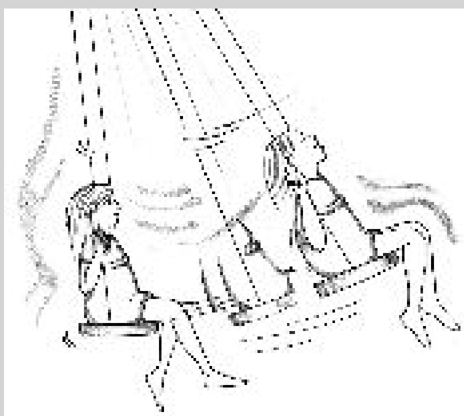
Various Motions from Everyday Life

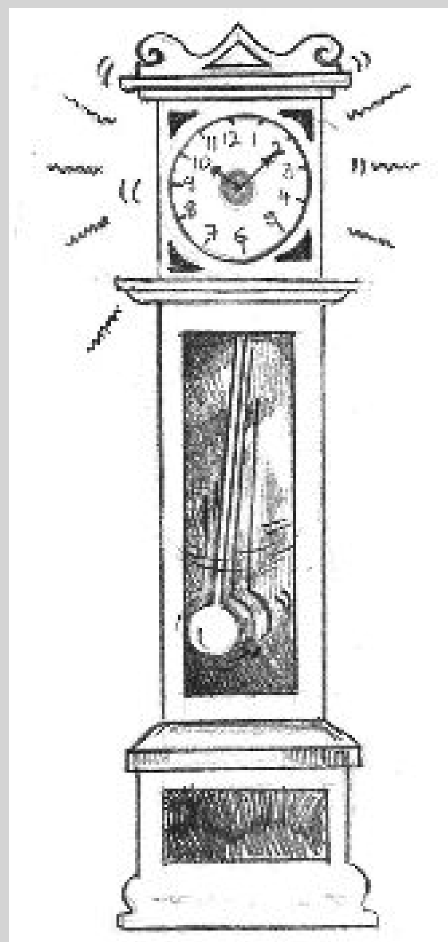


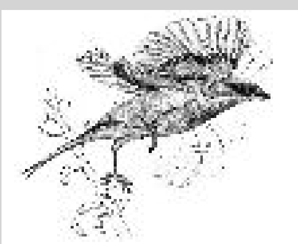


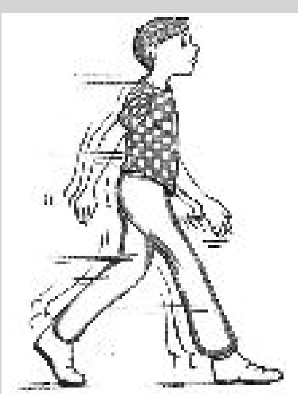












Complex Motion

Example 3. While playing with a top as a child, you may have noticed that it rotates around its axis (the pin) while moving around on the floor (Fig. 4).

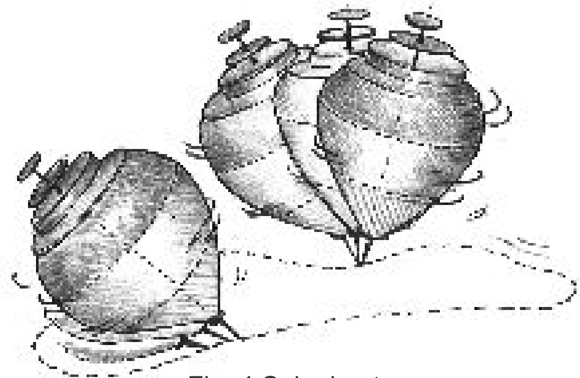


Fig. 4 Spinning top

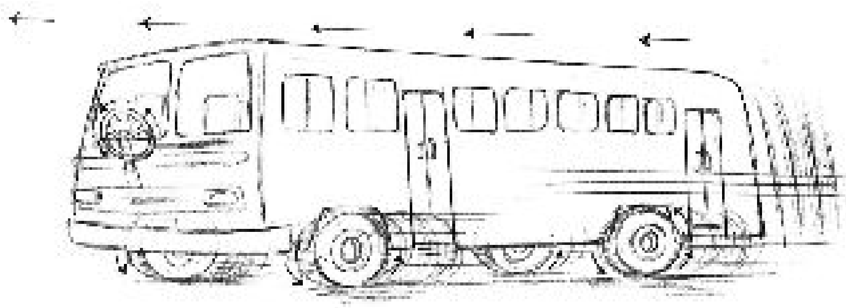


Fig. 5 Motions of different parts of a moving bus

Example 4. In the case of a moving bus, tyres rotate about their axles and move forward, too. The steering wheel rotates about a different axis while moving ahead with the bus (Fig. 5).

Example 5. Similarly, the forward motion of a cycle is also a combination of different motions of its various parts. Look at the photograph of a boy cycling down the road. The boy and the cycle together are moving in a certain direction, while the boy's feet and the cycle's pedals are moving in a circle. The wheels of the cycle are, simultaneously, revolving around their respective axes as well as moving ahead (Fig.6).

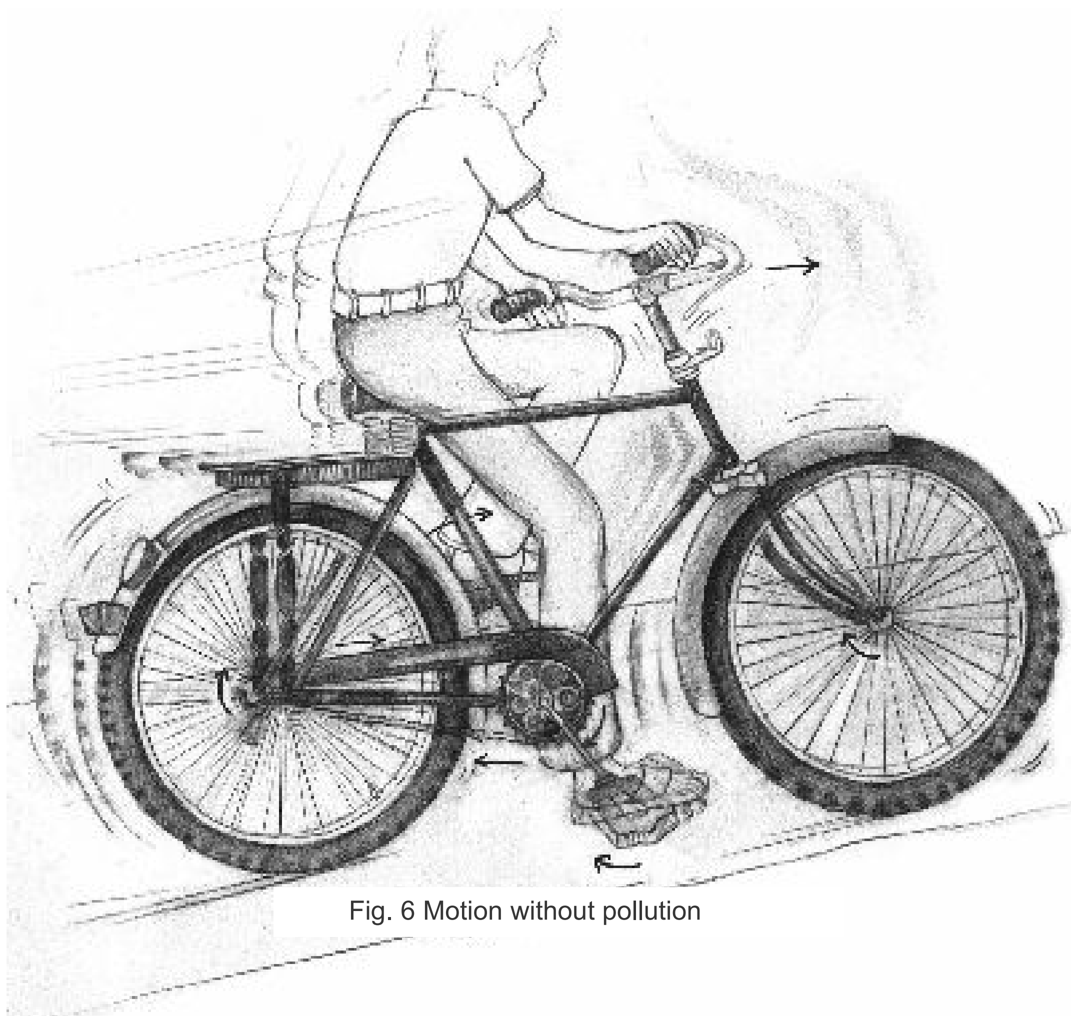


Fig. 6 Motion without pollution

Look around you at moving things and see how many of the motions are complex (a combination of more than one type of motion). Try to identify the different motions that combine to make up an observed complex motion.

For now, we will restrict our discussion to motion in a straight line. We will see that the quantitative description of this linear motion is relatively simple. Therefore, it is easier to understand the basic concepts involved in this kind of motion without getting lost in any numerical complexity. Complex motions can be understood by breaking them into simpler parts, analysing each part independently and then summing them all up again. This is one of the ways in which we learn. When learning to sew, we start with the running stitch, and then go on to hemming and the back stitch. Or, in language, when faced with a complicated text full of new words and terms we refer to a dictionary, which (often) uses simpler words to explain the meaning of a word we find difficult to understand. We will be following this approach to understand motion. We will begin with the simplest scenario, and by trying to understand it we will build a theory of motion. This theory will then be expanded to cover more complicated motions. Working this way, we will move towards a better understanding of real-life motions.

Most real life motions are complex, that is, a combination of more than one type of motion. A ball rolling on the floor will have forward linear motion and simultaneously be rotating around its axis. One approach for studying a complex phenomenon is to break it into simple components, formulate a theory to explain the simple components and then add up the components to get a theory to explain the complex phenomenon. This is called the reductionist approach in science (see box).

The Reductionist Approach

This is a basic approach used in science to explain any phenomenon. As you have seen in the examples discussed in the text, most of the motions that we observe around us are complex processes, whether it is a child riding past on a cycle or a moving railway engine. In order to understand this complexity, a common method used is to try and figure out what factors affect the observed processes. The next step is to study the effect of each of the factors. In order to do this, we vary the factors one by one. That is, in one experiment, we first change one factor while keeping all the others constant as far as possible. In another experiment, we vary the next factor, and so on, till we have studied how the change in each factor independently affects a process. Then, the results of these experiments are put together to try and explain the complex process.

Here, we are making a huge assumption—that the whole phenomenon is merely the sum of its parts, of the factors that influence it. This means that we are assuming that when all the factors that influence a phenomenon interact with each other, we get only the observed phenomenon. This is called ‘the reductionist approach’, since we reduce the problem into its components, analyse the components and try to arrive at an explanation. Is the assumption we make in the reductionist approach valid? All our successes in understanding various physical and chemical processes have come from applying this approach.

Quantifying Motion

To recapitulate, the motion of an object is its **change in position** with **time**. This change of position is measured with respect to a **point of reference** by an **observer**. To quantify motion, we need to measure the change in position with respect to a point of reference as well as the elapsed time. However, very often, we don't explicitly specify the point of reference but assume that the measurements are taken with respect to a convenient point of reference.

The point of reference and the observer, together make the **frame of reference**.

Let us first look at the change in position of an object in motion. This can be found out by measuring the distance covered by a moving object.

What instruments can you use to measure distances?

Example 6. Take two identical, long objects like two dusters or two pencils. You will also need a ruler to measure distance. Keep the two pencils side by side on a table and mark their positions with a piece of chalk. Move the second pencil some distance ahead, keeping it aligned with the first pencil (Fig. 7). Mark the position of the second pencil. Now, measure by how much distance the second pencil has been moved. Ask your friends to do the same exercise. Did you all get the same result? If not, why not?

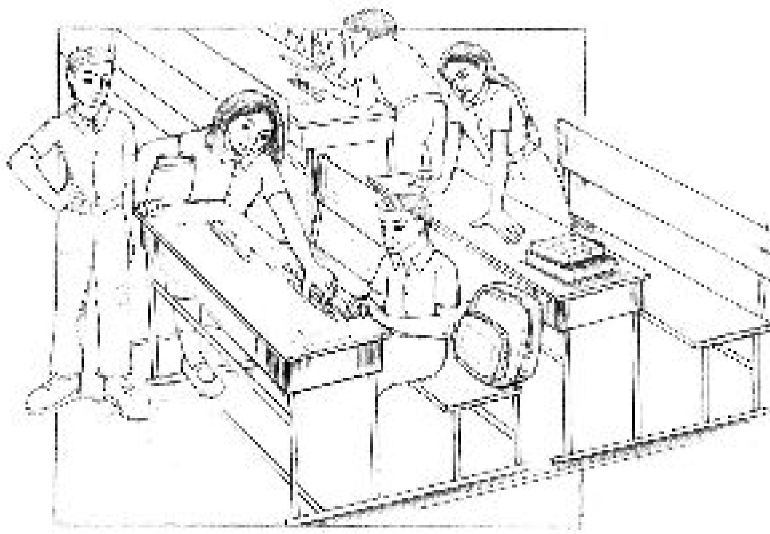


Fig. 7 How far did the pencil move?

Example 7. I have a small ball with a face on it (Fig 8). I roll the ball on the floor from one corner of the room to the other. If the room size is 10’x10’,

a. What is the net distance moved by the ball?

b. Is the net distance moved by one of the eyes the same as the distance moved by the ball?

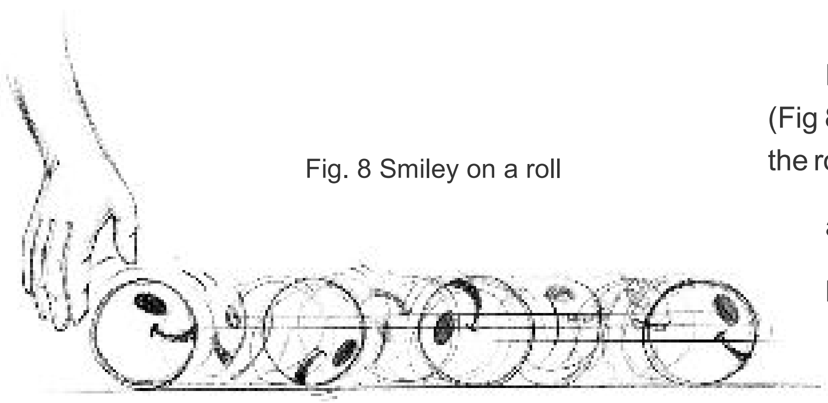


Fig. 8 Smiley on a roll

These questions can lead to a discussion on the following points. The answer to (a) will depend on which corners are chosen–adjacent or diagonal. Also, each point on the ball makes a compound motion, as it is rotating around the centre of the ball which itself is moving in one particular direction on the floor. Generally, we call the motion of the centre of the ball the 'motion of the ball'. In looking at the forward linear motion, the rotation of the ball around its axis is ignored. We also ignore the inaccuracies in distance measurement arising from the finite size of the ball. A discussion can be held on the conditions under which these assumptions are valid.

Example 8. In the picture below, the bus has moved from right to left (Fig. 9). Can any of the marked distances be taken as the distance covered by the bus between the two positions? If yes, which one would you choose and why? If no, then what is the appropriate distance?

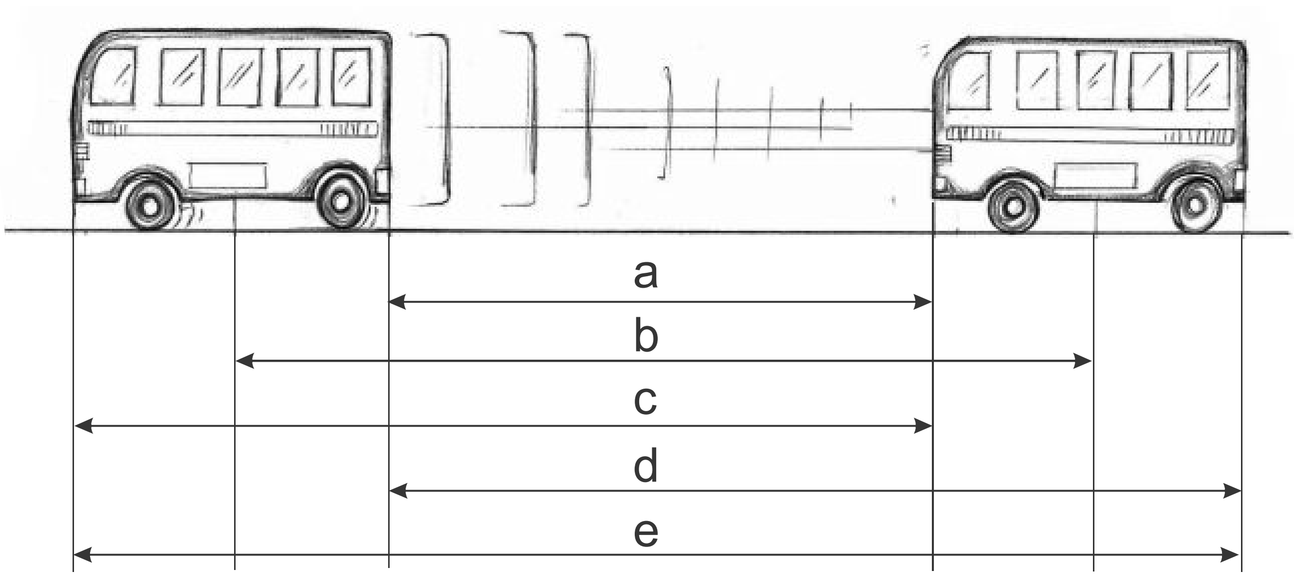


Fig. 9 Front end / back end—which points to measure between?

In measuring the distance covered by a moving object, there are two issues to consider. First, real objects have a finite size and second, different parts of the moving objects can execute different motions. The examples given here are meant to illustrate these two points. The second point can be illustrated best by the example of a bicycle or a bus, both of which are familiar to students. Here, we have discussed the bus, the cycle can be given as a problem to the students. What are the assumptions underlying this estimation of the change in the position of the bus? We selected one point on the bus, measured its change in position and assumed that the whole bus has moved by that much distance ignoring the movements of things like the wheels and the people sitting inside. We also assumed that the shape and size of the bus remains the same at both positions. In effect, we assumed the bus to be a single rigid body. This kind of idealisation is used many times in science so that universal principles underlying observed phenomena can be deduced without getting lost in complicated calculations.

Let us now look at time measurement. That is, we want to measure how much time elapses during a certain motion. How would you measure the time taken to go home from school? Can you use the same method to measure the time taken to throw a ball from one end of a room to the other? Try it.

In some of the activities described later in this module, we suggest the use of a stopwatch (Fig. 10). Good stopwatches, which show upto a 100th of a second will be very useful for your experiments. The figure shows such a stopwatch available in Indore markets. Generally, easily available, commercial digital stopwatches are multi-functional. So, you might need to change the mode of the one you buy to the 'timer' setting. You may refer to its manual to learn how to switch between the different modes, and to learn how to start, stop and reset the stopwatch. The other option is to use the 'stopwatch' function in your mobile phone.

Fig. 10 A typical electronic timer/ stopwatch

All Together

Ask the students to start their stopwatches when you clap/whistle and to stop them with the sound of your second clap/whistle. To start with, keep a sufficient gap between two consecutive claps/whistles. As the students get more and more familiar with the functions of the stopwatch keys, reduce the time between the two claps/whistles. It is necessary that they learn to use the stopwatch as accurately as possible to achieve good experimental results in the activities suggested later in the module.

Click-Click, Quick-Quick

Another interesting activity to help familiarise students with stopwatches is one in which they are asked to check their reaction times. To do this, students are asked to start and stop their stopwatches as fast as they can. The recorded time interval is the smallest that each one can measure. Repeat this activity 20-25 times. The arithmetic mean of all the readings taken by a student will give the 'average reaction time' of that person. In a classroom experiment, the data can be considered to be reliable if the number of readings taken is much larger than the average reaction time (at least 3 to 5 times). You can verify this in the 'All Together' activity. Try to find the shortest time between two claps/whistles that can be measured accurately.

Speed

Now that we have learnt something about measuring distance and time, let us see if we can go further and measure motion. One of the first things we notice about a moving object is how fast it moves. Fastness or slowness is decided by speed. For example, you are getting late for school. One neighbour offers to drop you on his bicycle. Another neighbour offers to take you on his motorbike. Which one would you choose if you want to get to school quickly, and why?

> Students at the high school level (13-15 years) already have some concept of speed in the context of fastness or slowness of motion. Hence, examples similar to the one above can be used to start a discussion on the quantitative measurement of speed.

A motorbike can go at a higher speed than a bicycle, and you can reach your school faster on your neighbour's motorbike. However, speed is not a quantity that can be directly measured. It is calculated by dividing the distance covered by a moving object, by the time taken to do so, or

$$\text{Average Speed} = \frac{\text{Total distance moved}}{\text{The time taken to cover this distance}}$$

Notice, that we have qualified speed by adding 'average' to it. This distinction will be discussed in detail a little later. First, let us have some fun measuring speed.

> The activities on the following pages are designed to break the monotony of the classroom and to get the students moving. They can be done by rolling a ball, moving a chalk or stone by hand, or by observing the ants moving on the floor—by observing anything that moves in a straight line and slowly enough so that the time taken for the activity can be measured using a stopwatch. Students can also be asked to make similar measurements at home and discuss the results in class. If a stopwatch is not available, time can alternatively be measured by the seconds hand of a clock or watch, or the clock in a mobile phone. A ruler or measuring tape will do for measuring distance. Students should be encouraged to discuss the problems they face in making distance or time measurements for something moving very fast, the errors in measuring the distances moved by different objects, measuring distance or time for objects that do not move in a straight line, etc.

The Racing Ants

We have all seen ants scurrying around. Can their motion be described as straight-line motion? Observe their motion and try to measure their speeds. Did you face any problem in determining their speeds? The following activity may help.

Collect some ants (Fig. 12), preferably of different varieties (make sure they do not bite you). Tie a coarse thread between two points such that the thread is stretched taut in the air at some height above the ground. One person with a stopwatch acts as a timekeeper. Place the ants, one at a time, on one end of the thread and note the time an ant takes to move along the thread, as well as the distance it covers (Fig. 13). For this, you can make a mark on the thread where you place the ant and start the stopwatch. Make another mark on the other end of the thread, and stop the stopwatch when the ant reaches this mark. Note the time each ant has taken to cover the distance between the two marks. Then, you can measure the length of the thread between the two marks. The ants may drop down from the thread midway! Can keeping some sugar at some distance help them stay on the thread? Try it and prepare a table of your observations. You can use Table 1 given below as a guide.

Fig. 12 Searching for ants

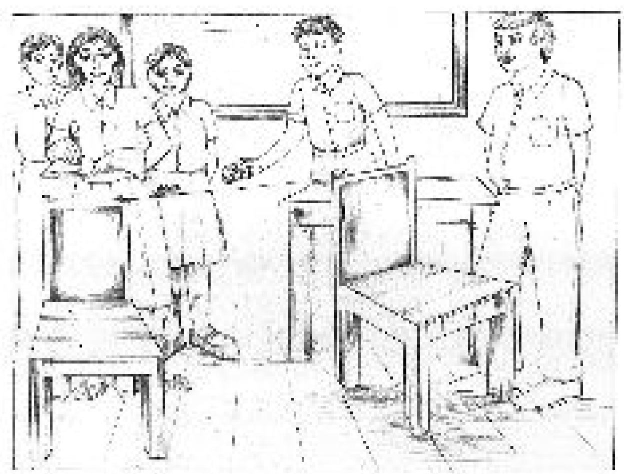


Fig. 13 Ants on a tight rope

Table 1

S. No.	Name	Distance	Time taken	Average Speed
1	Black ant	10 cm	2 s	5 cm/s
2	Red ant	16 cm	4 s	4 cm/s
3				

Which ant was the fastest? (After the experiment, do return the ants to where you took them from). Do you think there was some possibility of error in the measurements? Discuss how you can reduce such errors.

Block Walk

The following example is designed to ease the students into visualising imaginary motion. It clarifies the relation and difference between speed and position. Students often get confused between them.

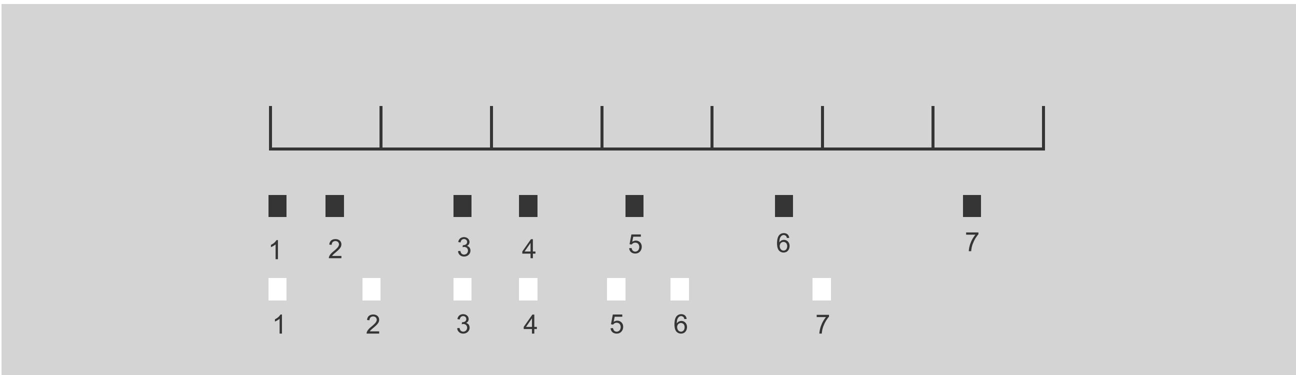


Fig. 14 The positions at each second of two blocks moving in parallel for 7 s. The lines above the blocks mark the distance moved by the blocks.

Two blocks, one white and the other black in colour, are being moved in straight lines parallel to each other. Their positions after every second are shown by the numbered squares in Fig. 14. The numbers show the time in seconds. The blocks are moving from left to right.

1. Which block has a higher average speed?

2. At what time were the two blocks at the same position?

3. When did the blocks have the same speed?

    a. Between 2 s and 3 s

    b. Between 3 s and 4 s

    c. Between 5 s and 6 s

    d. Never

4. When does the black block first overtake the white block?

    a. Between 1 s and 2 s

    b. Between 2 s and 3 s

    c. Between 3 s and 4 s

5. When does the white block first overtake the black block?

Units of Speed

This is a good place to explore the concept of units in some detail by taking speed as an example. The questions we aim to answer here are, (a) why are different units required in different situations, and (b) how to convert values from one unit to another.

In training sessions, we observed something curious. Many students, and even some teachers have a deep conviction that the only possible units of speed are m/s and km/h. Also, they found that conversion between the units of speed (which is a ratio of two quantities—distance and time) is slightly more complicated than that of, say, weight (e.g. converting between kg and g).

A vegetable seller weighs the vegetables in units like 250 g, 1 kg etc., but the trucks carrying vegetables coming into the *mandi* are weighed in tons. Just like there are different units for weight, there can be several units of speed. Some common examples are km/h (used for measuring vehicle speeds) and m/s (used in laboratory measurements). However, other combinations are also possible, like miles/h, inch/s etc., as long as a unit of distance is divided by a unit of time to get the unit of speed.

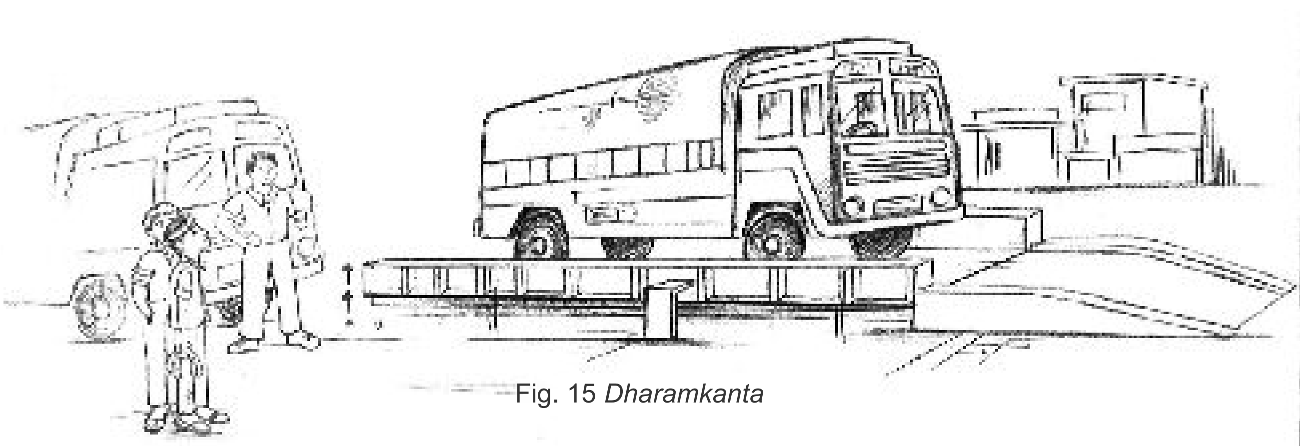


Fig. 15 *Dharamkanta*

Fig. 16 *Sabji mandi*

In the earlier activity on racing ants, can you use some other units for speed? (Hint: Measure distance in inches instead of cm).

Conversion between units

The average speed of a bus is 36 km/h. How much would it be in cm/s?

We know 1 km = 1000 m = 1000 X 100 cm = 1,00,000 cm

And 1 h = 60 min = 60 X 60 s = 3600 s

So 1 km/ h = 100,000 $\div$ 3600 cm/s

Therefore 36 km/h = 36 X 100,000 $\div$ 3600 cm/s = 1000 cm/s

Does this tell you why different units are required in different situations?

What units you would use for the speed of

a. A tortoise

b. A jet plane

One bus travels 4 km in 6 minutes. Another bus travels 3 miles in 10 minutes. Which one was faster? (1 mile = 1.6 km, approximately).

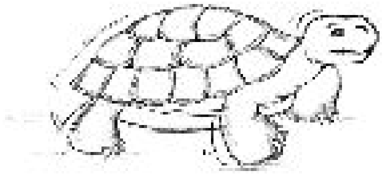
The famous Pakistani fast bowler, Shoaib Akhtar (also known as the 'Rawalpindi Express') was trying to set a bowling speed record of 100 miles/h. However, the stadium speedometer measured the speed in km/h. In one over, the values recorded were 158.3 km/h, 155 km/h, 142 km/h, 157.3 km/h, 148 km/h and 159.2 km/h. Do you think he reached his target in this over? Find out the record for the fastest bowling in international cricket.

Example 9. You can practice some more conversions between units by doing the following exercise:

Table 2

S.No.	**Convert**	**to**	**Using**
1	cm/s	m/s	1 m = 100 cm
2	inch/s	cm/s	1 inch = 2.54 cm
3	km/h	m/s	1 km = 1000 m and 1 h = 3600 s

Typical Speeds

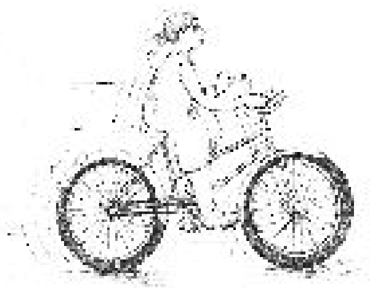


tortoise: 0.1 m/s

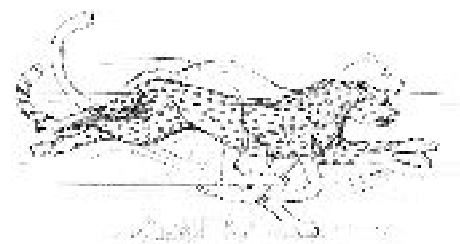
person walking: 1.4 m/s

falling raindrop: 9-10 m/s

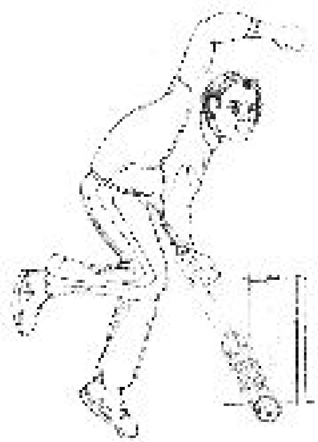
cat running: 14 m/s



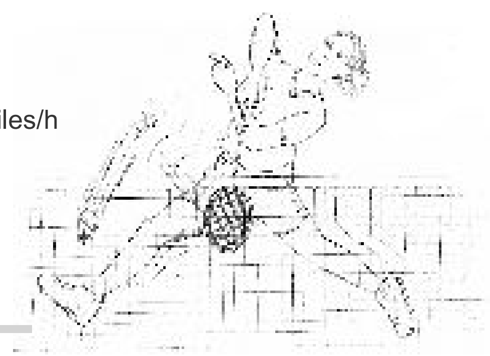
cycling: 20-25 km/h



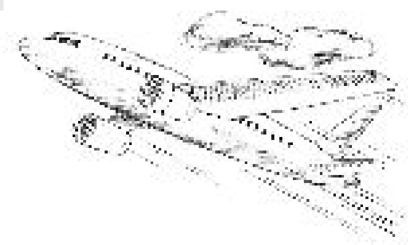
cheetah running: 31 m/s



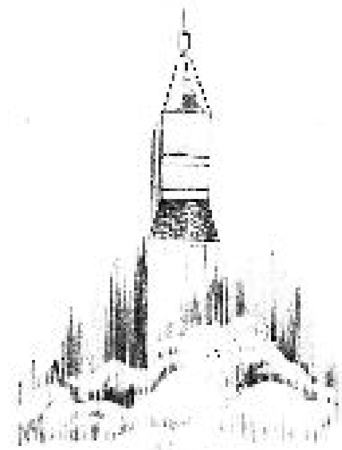
bowling speed of fast bowlers: 90-100 miles/h



badminton smash: 80-90 m/s



passenger jet: 180 m/s



space craft: 5200 m/s

At this point it is worth getting a feel of the speeds we encounter in our world. The table on the left gives the typical speeds of some motions. Ask the students to add more items to the list and to guess their speeds. To get a feel of the magnitude of speed, take the walking speed as a reference and then compare how much faster or slower the other motions are. For example, a domestic cat can run at ten times a human being's normal walking speed, while a cheetah can run twenty times faster. Ask the students to find out how fast people can run to see if we can outrun a cat or a cheetah chasing us!

Which is faster—the bowling speed of a fast bowler or a badminton smash?

Projects

1. Choose a motion for speed measurements. It could be your baby brother's crawling speed, the running speed of your pet dog, the speed at which your friend cycles, the speed of water flowing in a canal, the speed at which a leaf falls from a tree etc. Make several measurements of the speed of the motion you have chosen, noting down the conditions under which you make the measurements. Now analyse (with some help from your teacher) the measurements to see if you can arrive at a figure for the typical speed of the motion under study.

2. Try to find the typical speeds of more animals. Make a chart listing animals (including humans) in the increasing order of their speeds. If you are good at drawing you can draw their pictures along the list. Now see if the predators are always faster than their prey!