PHYSICS

For Middle Schools

Text 1

EXPERIMENTAL EDITION

NATIONAL COUNCIL OF EDUCATIONAL RESEARCH AND TRAINING

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Preface

The Education Commission while discussing the structure of education in our schools and colleges recommended that teaching of science should commence at Class V with Physics and Biology as separate disciplines. It was also suggested that teaching of Chemistry should commence a year later. In response to this recommendation, the Chairman, University Grants Commission, New Delhi, appealed to men of science in Universities to get together to prepare curricular material for the middle school with a view to improve teaching of Physics in schools. The response to this appeal was immediate and enthusiastic. Four study groups were constituted, each comprising of research scientists, university professors and school teachers to develop curricular materials. Dr. B.D. Nag Chaudhuri was the convener of the Physics group until he joined the Planning Commission.

The Physics study group, after long deliberations, considered it necessary to initiate a new approach to the study of Physics at the school level. This approach is essentially based on the active participation of students in the learning process through experimentation, supplemented by demonstration by teacher and discussion leading to the understanding of the basic concepts in Physics. The efforts of the group have been to relate, as far as possible, the teaching of Physics to what a student sees and does in everyday life. In addition, it is intended to transmit in some measure, the thrill and excitement of doing experiments which would help students to understand Physics and find something new for himself. Thus the main emphasis is on the process of science rather than on the product of science.

In order to enable the students to perform experiments, the group has developed simple and inexpensive kits which form an integral part of the instruction material. Experiments to be demonstrated by the teachers have also been indicated.

The Directors and members of the study group are conscious of the shortcomings and limitations of the material. The practical difficulties in implementing the course will become clear after full scale trial. Teachers in both urban and rural schools are our primary concern and we look forward to a meaningful appraisal of the material. We also look forward to the reaction of the young students to whom it is addressed. We look up to the senior physicists in universities and other institutions for their mature criticism of the material presented here from the standpoint of the contents as well as of the way of presentation. For these reasons the present edition is being brought out as an experimental edition which will undergo revision after the feedback from various sources.

All my colleagues join me in offering our grateful thanks to Professor D.S. Kothari, Chairman, University Grants Commission, who conceived this idea, for guidance and stimulation; Shri L.S. Chandrakant, Joint Educational Adviser, Ministry of Education; Dr. S. K. Mitra, Joint Director, NCERT; Dr. R. N. Rai, the then Head of the Department of Science Education; Dr. M.C. Pant, Shri Rajendra Prasad and Mrs. N. Mitra in the NCERT who helped in this endeavour in many ways.

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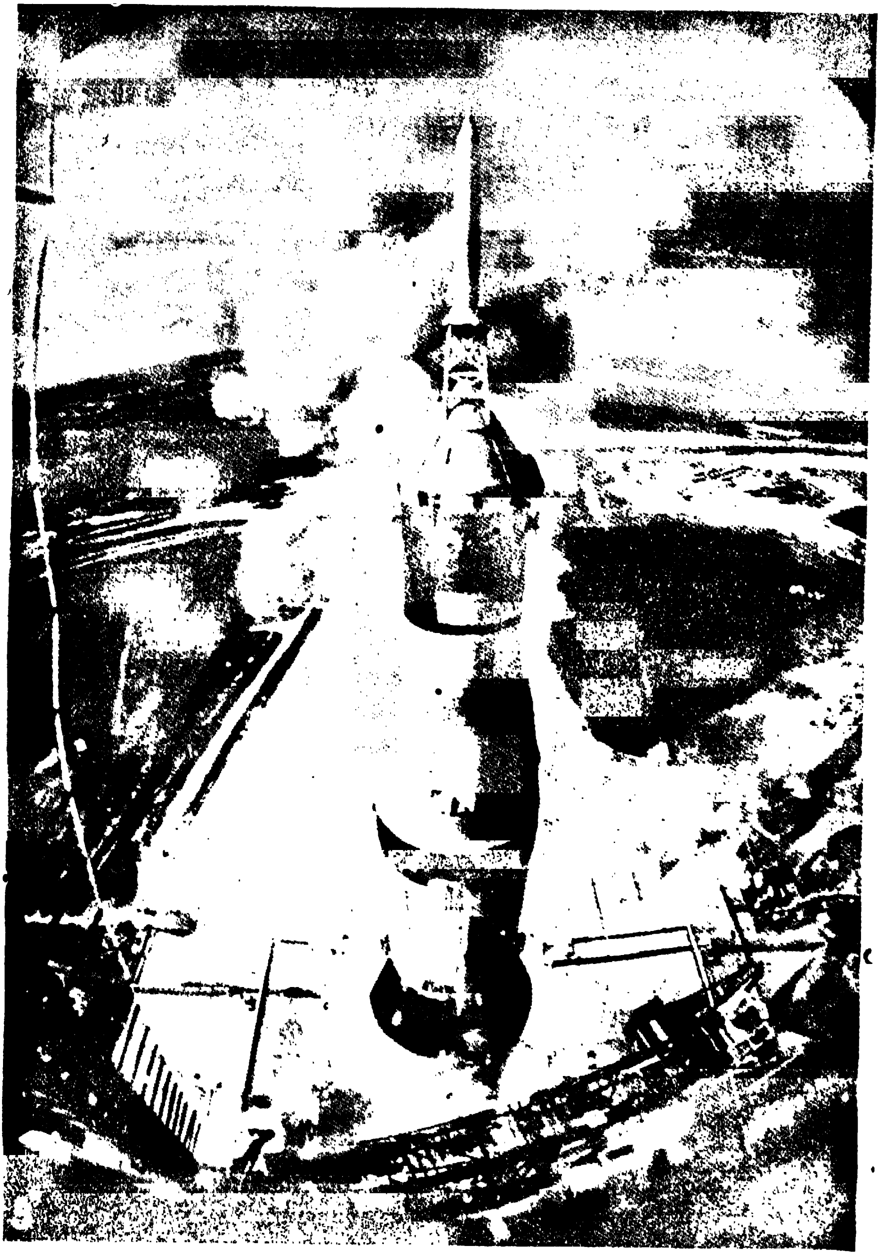
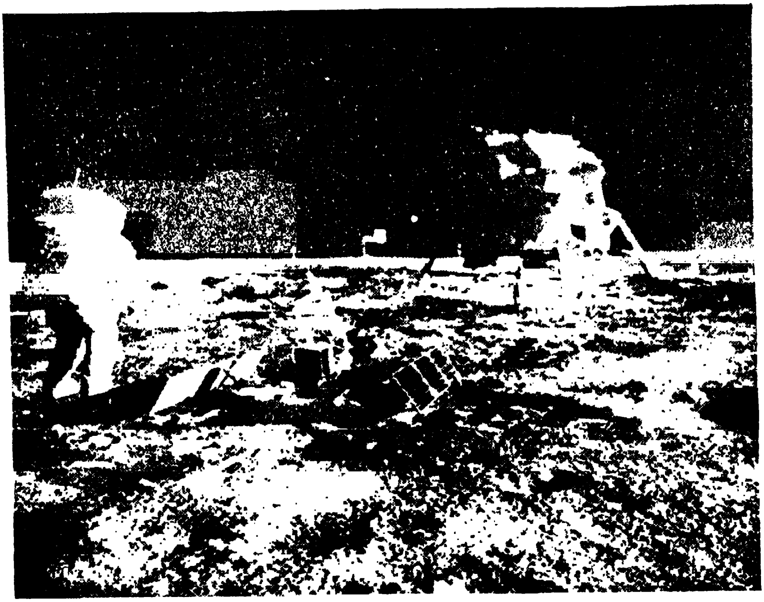
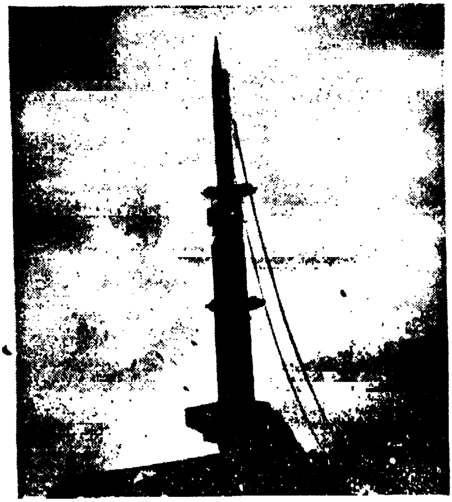


Apollo-11, atop its giant saturn rocket, rises from the launch pad at Cape Kennedy, Florida (USA) on July 16, 1969 to begin its historic flight to land men on the Moon.



Men on the Moon—Astronaut Aldrin walks on the Moon's surface while astronaut Niel Armstrong took the photo on July 21, 1969.



Thumba Rocket Base near Trivendrum (India)

Introduction

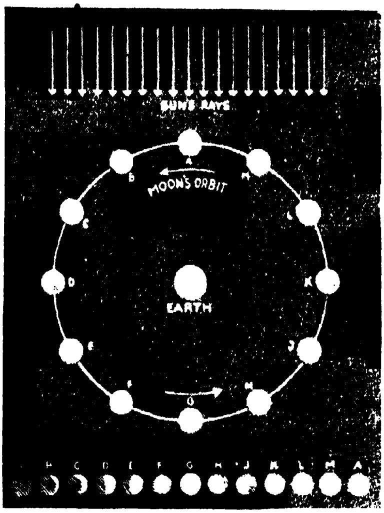
Physics is the fundamental science of the world in which we live and the variety of phenomena that occur around us every moment. It tells us what we know about the world, how men and women from various countries found it over the ages and how they are finding out even today.

When you take a rod of iron and heat it, before heating it looks greyish. As you heat it, you find that its colour changes. It glows with red heat at about 500°C, you cannot hold it any more. Then with yellowish colour and then it appears white. If you heat it further you will find that this rod is converted into liquid which flows. The liquid when heated still further gradually disappears and in the process small particles of iron are shot out. This very iron rod when brought near a compass needle affects it. Similarly, if you strike this rod you hear sound coming out of it. These phenomena might have raised several questions in your mind. Some of the questions that may be asked are : Why iron appears grey and why is it converted into liquid at high temperatures ? Why does it affect a compass needle ? The study of Physics will help you to answer these questions.

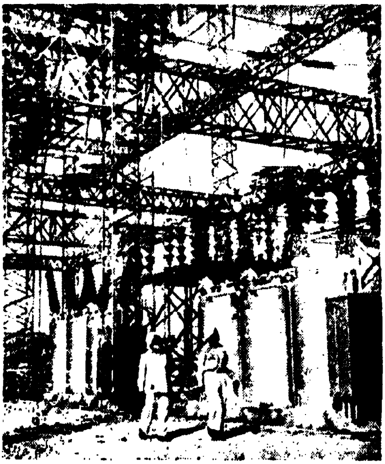
You see everyday in the morning sun rising in the east and setting in the west. It is dazzling in the afternoon and you can look at it only at the time of sunrise or sunset. At these times it appears red. Then we have the moon. It is full on Poornima day. Then as days advance, the moon appears smaller, half, crescent and then on Amavasya day we do not see the moon at all and it is all dark in the night. We also see some heavenly bodies, say Bhudha, Shukra, Shani, etc. They occupy certain positions in the sky on a particular day. Their positions change as days advance. On a rainy day you may have observed a rainbow with its fascinating colours. The same colours you may have observed when a drop of oil spreads over the surface of water. Perhaps you have played with soap bubbles. They also exhibit variety of colours. These series of phenomena which you observe everyday must have roused your curiosity to understand why they occur. Your study of Physics will help you to understand them. Indeed the correct understanding of the causes of the phases of the moon, the motion of the earth round the sun, etc., enabled man to set foot on the moon.

You use electricity everyday. You use it to light your houses, heat your electric iron and kettle, broadcast your voice on the AIR and receive it on your radio set. You can even see a person talking on your television set even though the person may be thousands of kilometers away. So far electricity was generated by burning coal and oil. Then man utilized the waterfall to generate electricity. We now have several power stations. You may perhaps, have heard that recently electricity was generated by using the energy stored in the atoms at the power station built at Tarapore in Maharashtra. We are building two more such power stations. Physicists have through their study of the atom and its nucleus been able to understand the secrets of the atomic nucleus and utilize its inexhaustible store of energy for useful purposes.

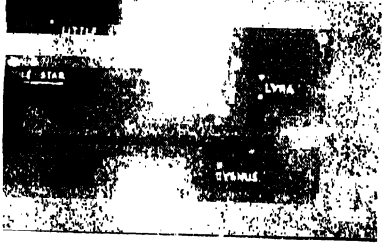
The developments in Physics have had considerable influence on the developments in several other disciplines such as Chemistry, Geology, Meteorelogy, etc. and in turn Physics has also benefited from these disciplines. The study of nature through these disciplines is ever so fascinating. This study requirs tools tools of every kind. The most important amongst these is of course your mind. Next you need to observe phenomena with some instruments and appliances. You have your eyes to see, ears to hear, hands to feel and touch, tongue to taste, nose to smell. These are our first instruments to collect information about events in the world. You may have by now experienced that our senses have limitations and in certain cases they convey wrong information and are subject to error. Take three beakers, containing hot, warm and cold water. Put your finger in hot water first and then in warm water. You will say that warm water is cold. Now do it the other way. First put your



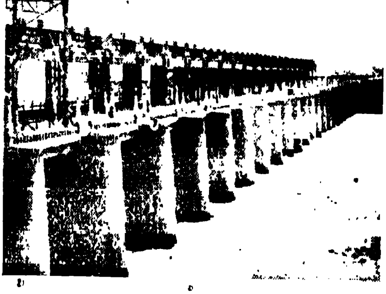
The Moon's phases



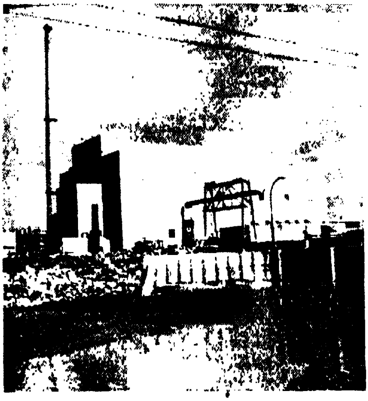
Power station at Bhakra-Nangal Project



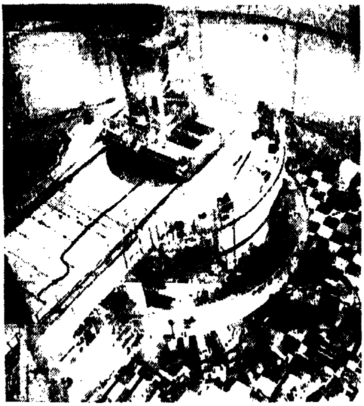
A few well-known stars in the night-sky



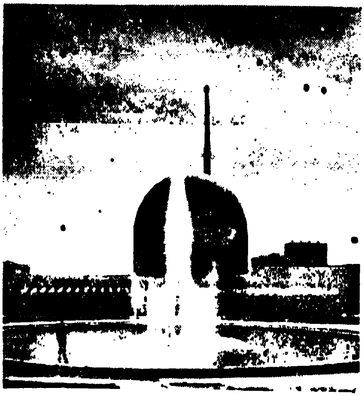
Nangal Water Barrage



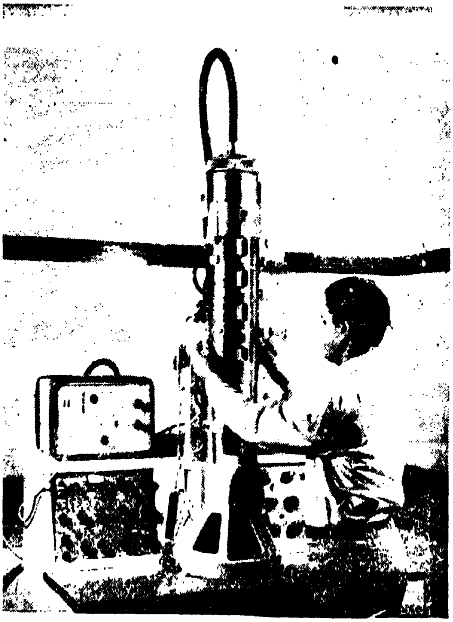
Atomic power plant at Tarapore • Maharashtra



Interior view of Canada-India Atomic Reactor, 'Cirus' at Trombay near Bombay.

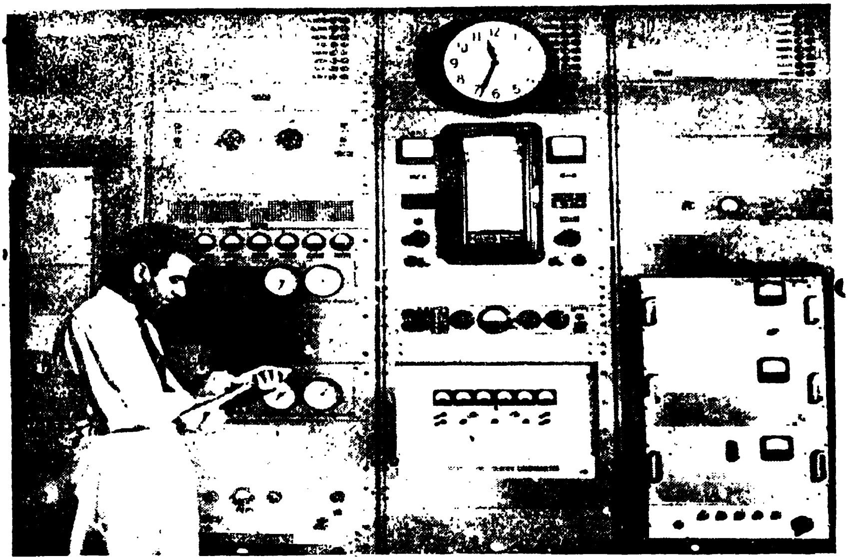


External view of the Reactor, 'cirus'.

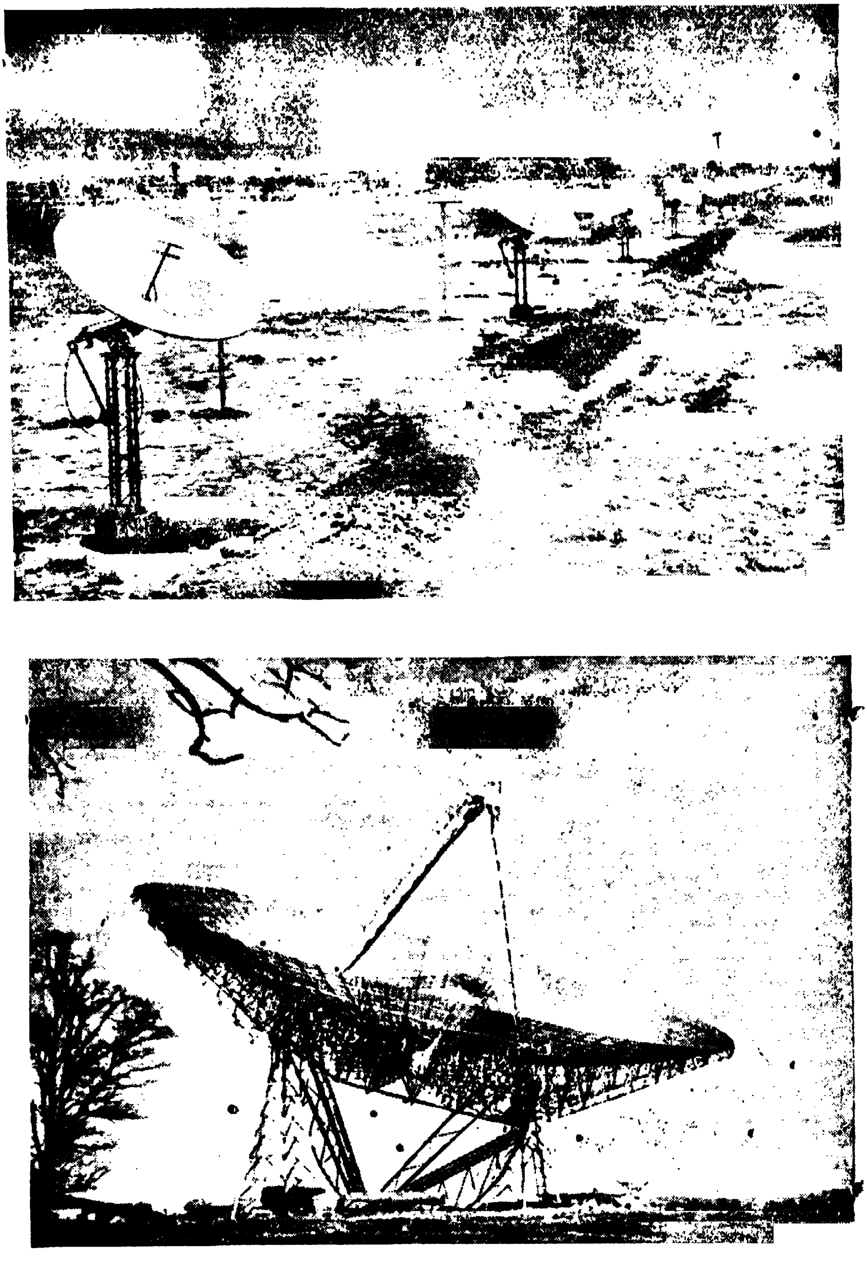


Electron Microscope at The National Physical Laboratory, New Delhi.

Telescope at Mt. Palomer in California with its 200'' reflector.



Time and Frequency standards at National Physical Laboratory, New-Delhi, which measures time to an accuracy of 1 part to 10^8 sec.



Array of Radio Telescope near Bombay and a giant Radio Telescope.

finger in the cold water and then in warm water. You will then say that the water is hot. Your senses have a subjective feeling.

Then, you have an estimate of time. If you have gone to play and are deeply engrossed in it, you feel that you have spent a few minutes although you may have played for an hour. Conversely, when you are doing uninteresting work or waiting eagerly for your friend, you feel minutes equivalent to hours. Similar is the story with all other senses. Realising these limitations physicists try to collect information with the help of 'senses' which are out of them. That is, he uses his instruments and appliances. They have developed thermometers which would read temperature faithfully. They have invented clocks which will mark time honestly. Similarly they have made microscopes which can make tiny atoms visible. They have made telescopes with which one can see heavenly bodies. It is through these and such other instruments, appliances and machines that we try to observe our world and the phenomena that occur around us.

It is important to remember that progress in science is a continuing process. As you start to answer one question, ten questions crop up and in answering them, hundred questions arise. As our knowledge of the universe increases, new horizons open up presenting us with fresh problems and newer opportunities. It will be your privilege to answer some of these questions and contribute to this mighty book of knowledge. It is our endeavour to put you on the road and prepare you to face some of the challenging and fascinating questions. Come on, let us start with this most absorbing game.

We shall first try to understand something about measurement without which we cannot get any quantitative information about either the world or the phenomena that occur around us. Measurement is thus basic to acquiring knowledge. This book will help you in answering questions such as how far, how fast, how heavy and the like. Indeed, these are the very questions you are asked on the first day by your teacher when you go to school. Your teacher must have asked you your name, your height, your weight, how far is your home, how much time you take to come to school, etc. You may have answered these questions intuitively, but in the following pages we will try to see the underlying principles.

CHAPTER I

Measurement of Length

1—1. The need for measurement of length

In everyday life, we often feel a need to measure length. It may be when you want to get your clothes stitched at the tailor's or when you want to prepare the ground for playing football, hockey or kabaddi, or when you want a chair to be made by a carpenter (Figure 1-1). Perhaps you can give a few more examples.

1 2. Meaning of measurement

When you go to a shop to buy a piece of cloth for your shirt, you ask the shopkeeper to give you two-metre length of cloth. You know how he measures the cloth with a metre rod and then cuts it. You have perhaps seen at home that the cloth is sometimes measured by using arm's length. If you do that, you may find that the cloth is five arm-lengths. You could also measure the cloth using your

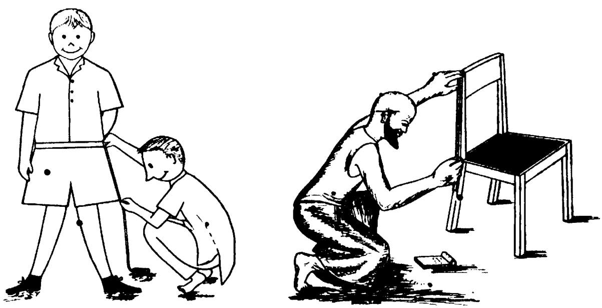


Fig. 1—1

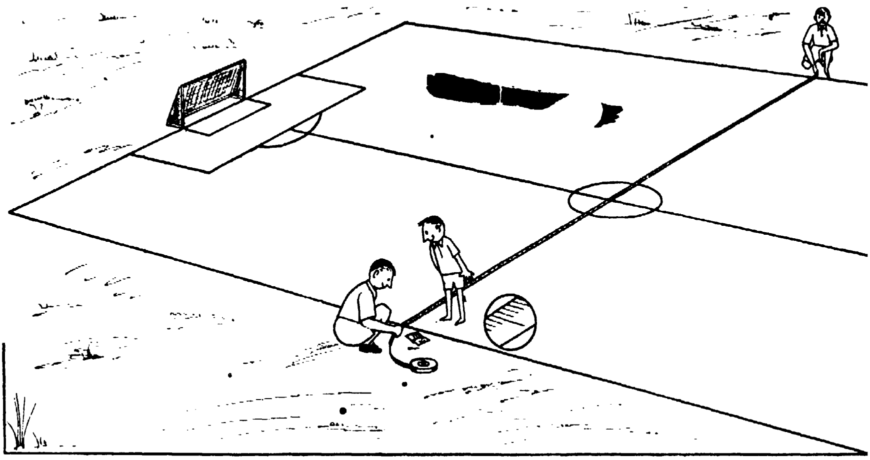


Fig. 1—1

palm stretched out from thumb to little finger. Using your palm, you may find that the same cloth is ten 'palm-lengths'. In all these ways of measuring we have compared the length of the cloth with a known length such as a metre, an arm-length or a palm-length. Indeed any *measurement means the comparison of the unknown length* (i.e., the length you want to measure, such as a piece of cloth) *with the 'known' length* such as a metre, an arm-length or a palm-length. In the above expressions, 2 metre-lengths, 5 arm-lengths, 10 palm-lengths, etc., we have two quantities, namely, (1) *a measure* and (2) *a unit.* When we say that the cloth is 2 metre* long, 2 is the measure and metre is the unit.

Activity

Measure the length of a table using a metre scale and your palm. From these two measurements find out the length of your palm in terms of a metre. Now, measure your palm-length directly with a scale and compare the two results.

* Note that, even when we have to say '2 metre' we do not use the plural of metre, i.e., we do not say 2 metres.

From the above experiment, we get an idea of how many palm-lengths are equal to one metre. We see from this example that smaller the unit, larger is the measure.

Question

Which are the measures and the units in the following : 5 arm-lengths, 10 palm-lengths, 2 kilometres, 10 centimetres.

1-3 The need for a standard unit of length

We have seen that we can express the length of a table as 5 palm-lengths, 3 arm-lengths, etc. Now, if your friend measured the same table with his palm or with his arm, would the measurements be exactly the same ?

Activity

Measure along the wall a distance of 10 arm-lengths and mark it. Ask your friend to measure this distance with his arm. Does he measure exactly 10 arm-lengths ?

Let us consider another example. Suppose your uncle at Bombay writes to you that he needs 10 palm-lengths for his shirt and asks you to buy the cloth for him. You go to the shop and ask the shopkeeper to give you 10 palm-lengths of cloth. The shopkeeper will immediately ask you, "Whose palm-length" ? If you buy according to your palm-length, the cloth would be insufficient. Would it not have been better if your uncle had written that he needed 3 metre length of cloth ? Then there would have been no difficulty, for a metre is of the same length everywhere and for everyone. *Such a unit that remains the same, no matter when and by whom it is used is called a standard.*

This standard can be any length, say the distance between two marks on a stick or the length of a rod, if all the persons in all the countries accepted it. As a matter of fact, the distance between two marks on a platinum-irridium bar (Figure 1-2) kept at the International Bureau of Weights and Measures in the French town of Sevres

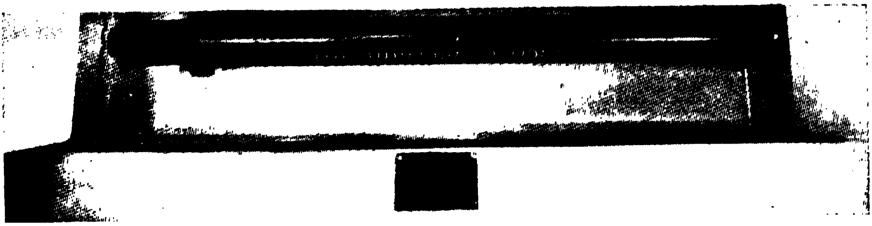


Fig. 1—2

The International Standard platinum-irridium metal bar kept at International Bureau of wieghts and measures at Sevres, Paris

near Paris has been accepted as a standard of length. *The distance between two marks on this rod is defined as the 'metre'.* A similar bar which is a copy of this International Standard (Figure 1-3) is kept at the National Physical Laboratory, New Delhi. The distance between the two marks on this bar serves as the National standard of length and all the scales manufactured in the country can be checked against this standard. Ask your teacher to tell you the the story of how the metre at Sevres came to be accepted as a standard.

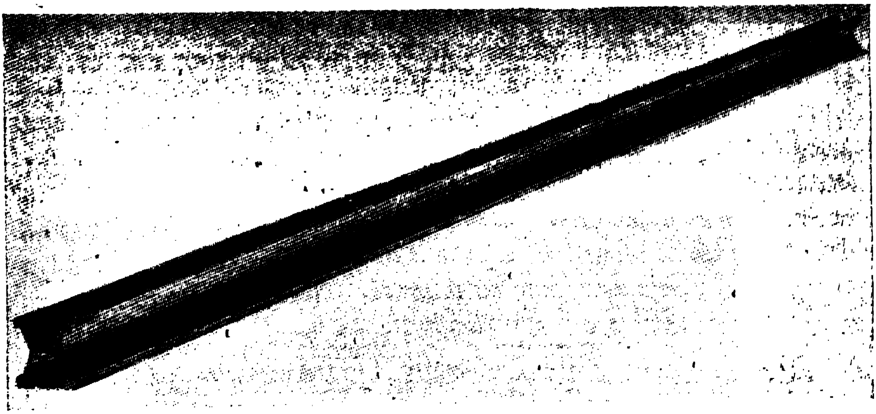


Fig 1—3

The Prototype of the International Standard Metre bar kept at the National Physical Laboratory, New Delhi

Question

Can palm-length, arm-length or a foot-length be used as a standard unit of measurement ? if not, Why ?

In everyday life we come across distances which are much longer than a metre and also distances which are much smaller than a metre. Thus, for example, the distance between Delhi and Agra is 192,000 metres. To express this distance as 192,000 metre is a little inconvenient. Indeed, this distance can be expressed as 192,000 metre$=192\times1000$m. Now, if we can define 1,000 metre as another unit—a kilometre (km.), then the distance between Delhi and Agra could be expressed as 192 km. A kilometre is, therefore, a unit derived from the metre$=$1,000 m. Similarly, to express a small distance such as the diameter of a wire which is 0·0005 of a metre, one could say that this distance 0·0005 of a metre is$=\frac{0\cdot5\times\text{metre}}{1000}$. We define $\frac{\text{metre}}{1000}$ as a millimetre. Thus millimetre (mm) is another derived unit and is$=\frac{1 \text{ metre}}{1000}$. Such larger as well as smaller derived units* have been defined as follows :

* In the metric system of units in which a metre is taken as a unit of length, we have seen that the derived units are obtained by multiplying the metre by either 10, 10^2, 10^3 and so on, as well as by 10^{-1} 10^{-2}, 10^{-3} etc. There is also another unit for measuring distances. This is a yard. This unit was adopted by England and is defined as the distance between two line marks on a bronze bar maintained at a temperature of 62°F and kept in the custody of the Standards Department of the Board of Trade, London. The distances smaller than a yard can be measured in terms of the foot or the inch. Note the following relationships.

12 inches$=$1 foot
3 feet $=$1 yard
1 inch $=$2·54 cm,
1 metre $=$39.37 inches.

However, in the system of units in which a yard is the unit of length, the derived units are obtained as you have seen above by either multiplying or dividing by a number which is not a power of 10. Thus one mile$=$1760 yards (yds) ; 1 foot$=$1/3 yard and so on. This is rather inconvenient and hence metre has been accepted as an International Standard unit of length and the yard has been redefined in terms of metre as 1 yard$=$0·9144 metre,

1 kilometre (km) = 1,000 metre = 1,000 m = 10^3m**
1 hectometer (hm) = 100 metre = 100 m = 10^2m
1 decameter (Dm) = 10 metre = 10 m = 10^1m
1 decimetre (dm) = 1/10 metre = 0.1 m = 10^{-1}m
1 centimetre (cm) = 1/100 metre = 0.01 m = 10^{-2}m
1 millimetre(mm) = 1/1,000 metre = 0 001m = 10^{-3}m

Questions

1. The height of the Qutab Minar is 72 m. What will be its height in km and mm? Which is the most convenient unit to express the height?

2. The diameter of a human hair is 0·005 mm. Express this in cm.

1-4 The use of a scale

Looking at a metre scale, we find that the metre length is divided into 100 equal spacings, marked : 1, 2, 3...100. The distance between any two consecutive marks is one centimetre. Each centimetre is further divided into 10 equal parts. Each part is a millimetre. This is the smallest distance we can measure with the scale. This distance is called the 'least count' of the scale.

Fig. 1—4
Measurement of the length of a pencil with a metre scale.

** Note that figures on the extreme right are easier and shorter, forms for writing large numbers. Thus one can express 1000 metre in shorter form as 10^3 metre. This implies that $1000=10\times10\times10$, i.e. 10 multiplied by 10 three times, which is expressed as 10^3. Similarly, 100 metre is $=10\times10$ metre. This can be expressed as 10^2 metre meaning that 10 is multiplied by 10 two times. Similarly, 1/1000th of a metre is $\frac{1}{10\times10\times10}=\frac{1}{10^3}$ which is expressed as 10^{-3} m. It is easy to see that 1/100th of a metre would be $1/100=1/10\times10=1/10^2=10^{-2}$ m.

Express 100,000, one million, one crore in powers of 10, Let us measure the length of a pencil with this scale. Place the scale with its edge along the pencil as shown in (Figure 1-4). Slide the scale along the pencil till any convenient centimetre mark (say 1) coincides with one end of the pencil, say A. Read the division on the scale, coinciding with the other end B. The end B lies between the 18th and the 19th centimetre mark. It is easy to see that the length AB is more than 17 cm and less than 18 cm. Further we find that B lies between the 4th and the 5th mm mark after the 18th cm mark. This shows that the length AB is between 18.4 cm and 17.5 cm. It is, however, not possible to say whether it is 17.45 cm or 17.46 cm etc. This is because millimetre is the least count of the scale. You may note that while measuring, it is not advisable to use the ends of the scale as they are usually worn out.

1-5 Errors in measurement

To measure length correctly, we have to be very careful in taking readings. However, we come across various difficulties. Let us examine them.

Activity

Take a postcard and measure its length using different scales. Repeat the observations 10 times. Do you get exactly the same answer everytime?

You will find that all the scales do not give the same measurement. This is because all scales are not equally accurate, although each one of them is sold as a metre scale. If you want all the scales to be equally accurate, each one of them will have to be checked against the National Standard and corrected suitably.

The next important thing is to take readings properly. It is necessary to place the scale along the length you want to measure. Figure 1-5 shows the correct and the incorrect positions of the scale to measure the length of an edge of the book. The accuracy of measurement also depends on the position of the eye while taking readings. Figure 1-6 illustrates this. From the figure, can you tell which of the positions a, b or c will give correct readings ?

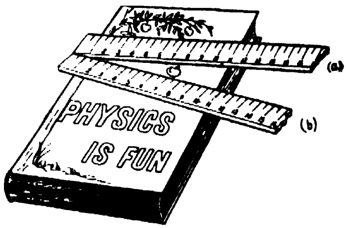


Fig. 1—5

Measurement of the width of a book.

(a) The correct way of placing the scale

(b) The incorrect way of placing the scale.

We can therefore, say that while taking readings on the scale, the eye must be placed at the same level.

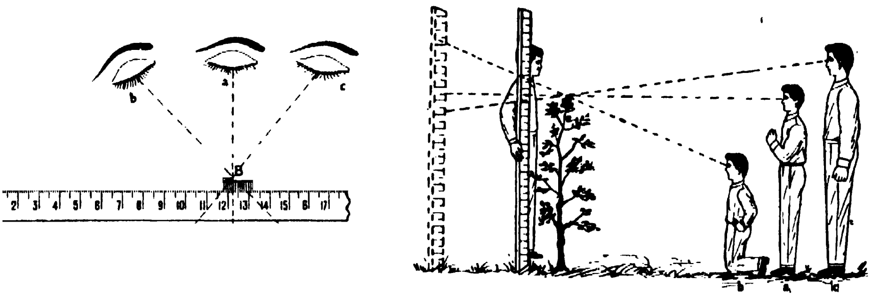


Fig. 1—6

(a) The correct position of the eye while taking readings.

(b) and (c) The incorrect position of the eye.

Because of the possibility of errors in any measurement, it is necessary to repeat the observations a number of times. All these measurements may or may not give the same value. In an experiment to measure the length of a rupee note using a metre scale, following readings were obtained :

No. of observations	*Reading of the scale at one end*	*Reading of the scale at the other end*	*Length of the rupee note*
1	9.0 cm	18.7 cm	9.7 cm
2	8.0 ,,	17.8 ,,	9.8 ,,
3	5.0 ,,	14.8 ,,	9.8 ,,
4	3.0 ,,	12.7 ,,	9.7 ,,
5	6.0 ,,	15.6 ,,	9.6 ,,
6	7.0 ,,	16.7 ,,	9.7 ,,
7	8.0 ,,	17.7 ,,	9.7 ,,
8	9.0 ,,	18.7 ,,	9.7 ,,
9	5.0 ,,	14.8 ,,	9.8 ,,
			87.5 cm
			Average = 87.5/9 cm = 9.7222 cm

We find that all these measurements are not exactly the same. Where different measurements give slightly different values, we take the average of all the values, In the above example,

Total of 9 measurements $= 87.5$ cm.

Therefore the average length $= \frac{87.5}{9}$

$= 9.7222$ cm.

Since the least count of the scale is 0.1 cm, we cannot be accurate in recording observations beyond the first decimal place. Thus, in the first observation, it is not known whether the length of the rupee note is 9.71 cm or 9.72 cm and so on. All that can be said is that the length is greater than 9.7 cm and less than 9.8 cm. In taking the average also, it is better to state the result upto the first decimal place. Thus, although the mathematical average is 9.7222 cm, we round it off to the first decimal place. In doing so, look at the number in the second decimal place. If it is greater than or equal to 5, we increase the first decimal digit by 1. If, however, the number in the second decimal place is less than 5, we ignore it. In the above case we round off the average length of the rupee note to 9.7 cm.

Activitiy

(1) Measure carefully the following distances 5 times and determine the average in each case :

   (*a*) length, breadth and height of a rectangular block of wood.

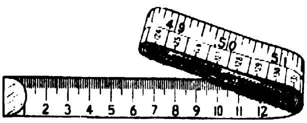
   (*b*) length and breadth of your physics text-book

   (*c*) length and breadth of an eraser.

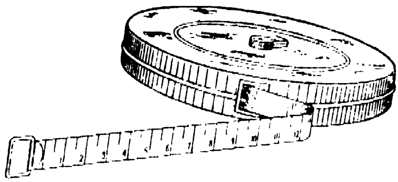
   (*d*) length of your pencil.

(2) Measure the thickness of your physics text-book (excluding the cover). Count the number of pages in it. Can you get the average thickness of a page?

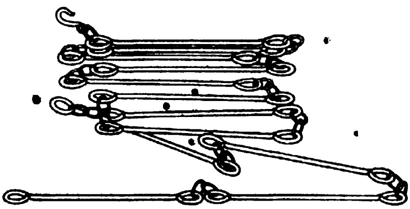
(3) Measure the length and breadth of your classroom. Have you seen the tailor's tape and the surveyor's tape (Figure 1-7 (a) (b) and (c)). Will these tapes be better than a metre scale in measuring the length and breadth of the classroom ?



(a) Tailor's tape



(b) Surveyor's tape



(c) Surveyor's chain

Fig. 1-7

(4) Measure the length and breadth of a *duree* on which you sleep.

(5) Try to estimate the following distances :

(*a*) Length and breadth of the door of your classroom.

(*b*) The height of your friend.

(*c*) Length and breadth of your geometry box.

Check your estimates by actual measurement.

(6) Look at the two lines AB and CD (Fig. 1-8.). Are these two

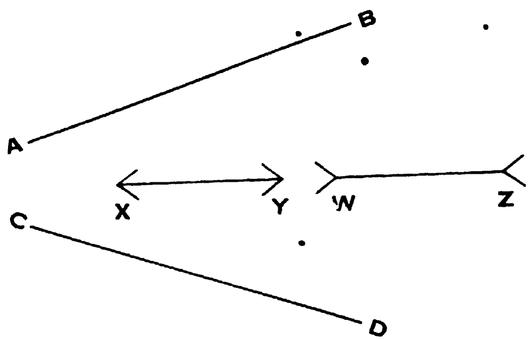


Fig. 1-8

straight lines equal in length or one is larger than the other? Use the scale to measure the lengths AB and CD. What do you find ? Look at the two lines XY, WZ. Which of them is longer ? Estimate and check your answer by actual measurement.

(7) In the diagram you find blocks of wood marked A, B, C, D and E arranged in order (Fig. 1-9). Another block X is also shown in the diagram. Will you put this block between C and D or between D and E? Will the measurement of lengths of X and D help you in your decision?

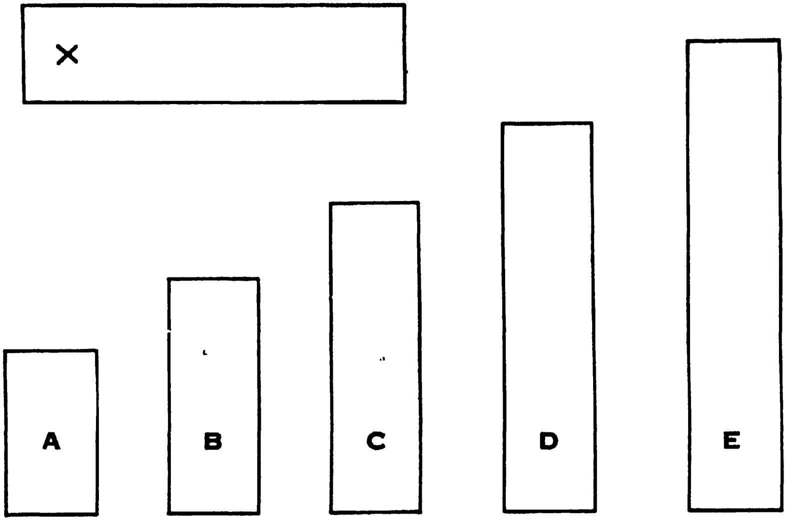


Fig. 1—9

1—6 Measurement of length along a curve

So far we have measured distances along a straight line. However, there are many distances which do not lie along a straight line and which we may want to measure. Suppose you want to measure the outline of a leaf or the circumference of the rim of the tumbler in which you drink milk and such other distances. Can you use the scale for these measurements as you did in the measurement of distances along a straight line? Perhaps you cannot do that. Let us first consider measuring a distance between two points which cannot be drawn on a paper, such as the diameter of a ball. Let us see how one can measure the diameter of a ball. Draw a straight line on the floor and place a metre scale along the straight line. Now place the ball close to the scale as shown in figure 1-10, and bring two rectangular blocks of wood on either side of the ball, with one edge of each of the blocks sliding along the scale. Bring them close to the ball so that they just touch the ball. Do not press the ball in between the blocks as the ball will get deformed. Take readings of the edges of the blocks touching the ball. Do these readings give the diameter of the ball?

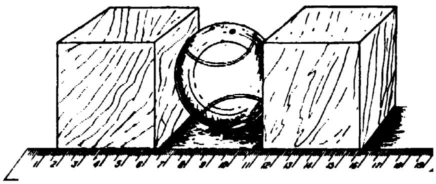


Fig. 1—10

Measurement of the diameter of a ball with the help of wooden blocks and a metre scale.

Questions

(1) Are such big wooden blocks necessary when the portions touching the ball are small (see Figure 1-10) ?

(2) Is it necessary that the faces touching the ball be vertical?

(3) Are there any sources of error ?

Activity

Find out the diameter of a football, a measuring cylinder and a round bottle.

Let us now consider the measurement of a distance along a curve, such as the outline of a leaf, as shown in fig. 1-11. If we can think of a method for measuring this, we can measure distance along any irregular curve. Obviously, you cannot measure this distance with a scale alone. For this we use an instrument called a divider as shown in Figure 1-12. The distance between the two pin-points of a divider can be changed by pulling out or pushing in the arms of the divider. Open out the divider so that the two pin-points are separated by some distance. Start from the point A by fixing on it one of the pointed ends of the divider. Keep the other end of the divider on the curve and make an impression at it; call it point B. Lift the divider and now place it so that one of its pointed ends is at B. Put

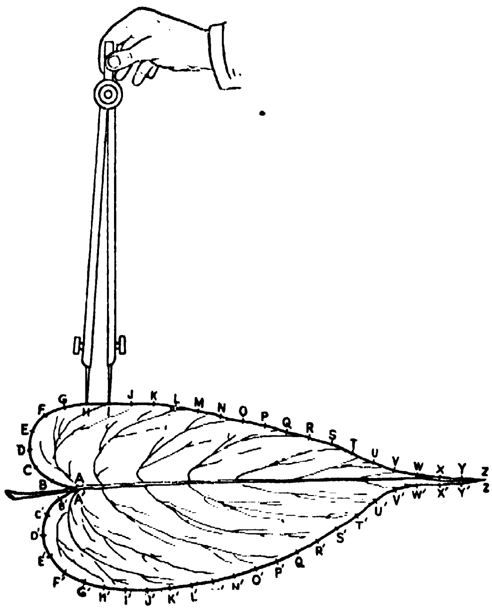


Fig. 1—11
Measurement of the outline of a leaf with the help of a pair of dividers.

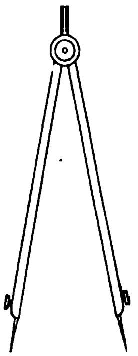
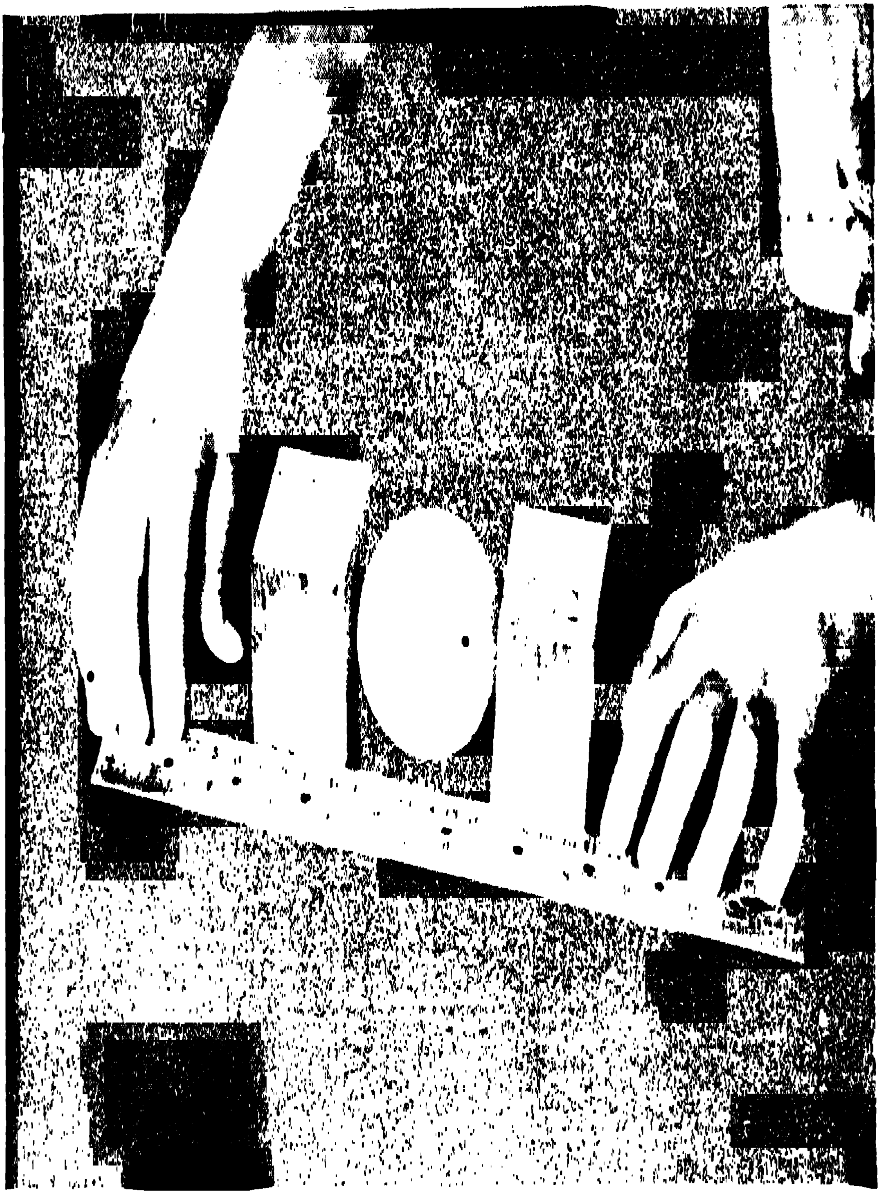


Fig. 1—12
Divider

the other end on the curve, say at C, and repeat this process till you reach the last end of the curve A′. Keep a count of the number of times you have repeated the process. Next, with a scale measure the distance between the two points of the divider. Can you now get the length of the curve in Figure 1-11 ? You will agree that the distance between the two pin-points should not be changed during measurement. Can you use a piece of thread to measure the distance along the curve ?



Activity

(1) Take three different spacings of the divider say, 2 cm, 1 cm and 5 mm and measure the same curve AA′ (Figure 1-11). What do you find? If the curve AA′ is not an exact multiple of a divider spacing how will you measure the length? In measuring the distance along the straight line, will the spacing between the pin-points of the divider matter? From the above measurements do you get an idea as to what should be the distance between the pin-points of a divider in order to measure AA′ as accurately as possible?

(2) Use a divider to measure the veins of the leaf as shown in Figure 1-11.

(3) Measure the circumference of the circle shown in Figure 1-13 Measure the lengths along the figures ABCDEF and OPQRSTUVWXYZ by opening the divider equal to AB and OP respectively. Can you draw any conclusions from these measurements?

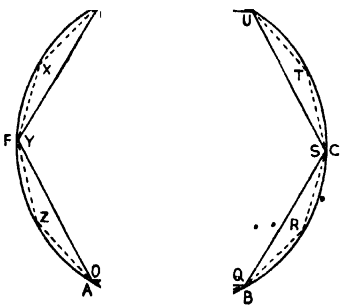


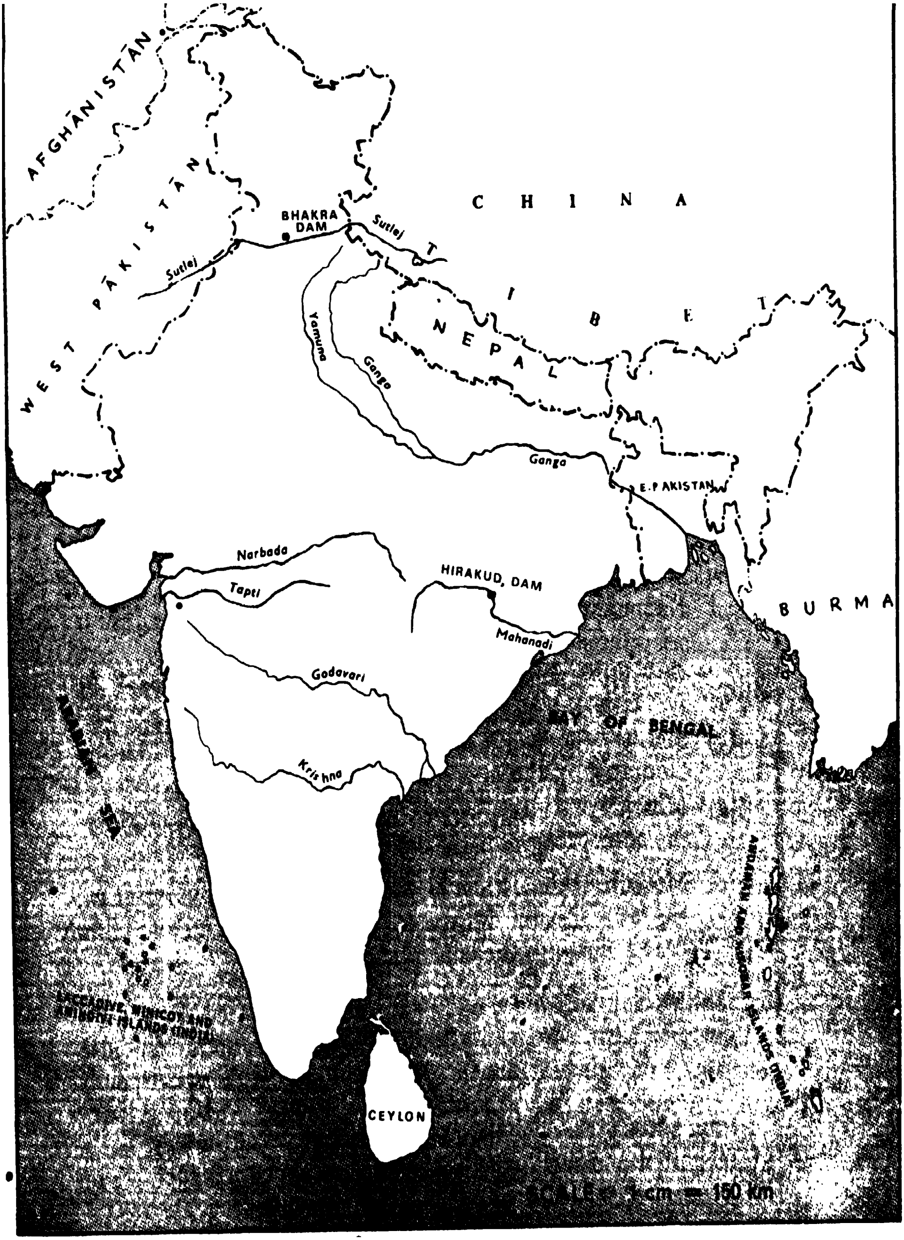
Fig. 1—13

(4) Draw circles of various radii and determine the ratio of the circumference and the diameter in each case. Is it not surprising that in each case the ratio is the same?

(5) Use a piece of thread and measure the circumference of the handle of a cricket bat and a pencil. Should you use a thick


AFGHANISTAN
WEST PAKISTAN
JAMMU AND KASHMIR
Srinagar
CHINA
TIBET
HIMACHAL PRADESH
Simla
Chandigarh
PUNJAB
HARIYANA
DELHI
UTTAR PRADESH
NEPAL
Gangtok
Thimphu
BHUTAN
NEFA
ASSAM
Kohima
Shillong
MANIPUR
Imphal
E. PAKISTAN
Agartala
TRIPURA
RAJASTHAN
Jaipur
Lucknow
Allahabad
Patna
BIHAR
Ahmadabad
GUJRAT
Bhopal
MADHYA PRADESH
WEST BENGAL
Howrah
Calcutta
BURMA
Nagpur
ORISSA
MAHARASHTRA
Hyderabad
ANDHRA PRADESH
MYSORE
KERALA
TAMILNADU
CEYLON

Fig. 1—14 (a)


AFGHĀNISTĀN
WEST PĀKISTĀN
CHINA
TIBET
NEPAL
BHAKRA DAM
Sutlej
Sutlej
Yamuna
Ganga
Ganga
E. PAKISTAN
BURMA
Narbada
Tapti
HIRAKUD DAM
Mahanadi
Godavari
Krishna
BAY OF BENGAL
SEA
CEYLON
SCALE 1 cm = 150 km

or a thin thread? If instead of a thread you use a rubber-band, will it matter?

(6) Use a piece of thread and measure the distance AA′ along the curve (Figure 1-11).

(7) Look at the map of India. (Figure 1-14 (a) and 1-14 (b). At the bottom of the map is written 1 cm = 150 km. This means that if the distance between two cities is 5 cm on the map, then the actual distance is 750 km. We have, in fact, reduced distances in proportion so that the whole of India could be mapped on a piece of paper such as the one you have before you. On this map now do the following :

   (*a*) Measure the distance along a straight line between Bombay and Delhi, Delhi and Madras, Nagpur and Calcutta, Allahabad and Hydrabad and between other important cities and determine the actual distances.

   (*b*) On the map, railway lines are also shown. They are irregular curves. Find out the distance between Bombay and Delhi, between Delhi and Madras, and between Nagpur and Calcutta by rail. Compare your results with the distance given in a railway time-table and also with those determined along a straight line between the two cities.

   (*c*) Measure the length of the Ganges, Yamuna, Krishna and Godavari on the map and determine their actual lengths.

   (*d*) Measure the coastline of India on the map and determine the actual length of the coastline.

   (*e*) Measure the coastline of various countries say, America, England, Ceylon, Burma etc., on a world map and compare them with the coastline of India.

(8) On the map a distance of 150 km is represented by a distance of 1 cm. Instead of reducing distances you can also draw a magnified figure in which distances are proportionally increased. Look at the ant (Figure 1-15 (a)). Ant is very tiny and it is difficult to see its legs. Take a lens, i.e., a magnifier and see through it. The ant appears bigger. You

can take a magnified picture of the ant. Figure 1-15 (b) is one such picture. At its bottom we see a figure ($\times 5$). This means that the figure has been scaled up by 5. This implies that if the distance on the figure is 1 cm then the actual distance is 1/5 cm.

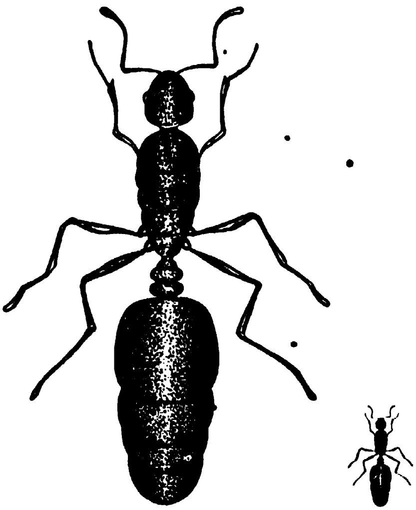
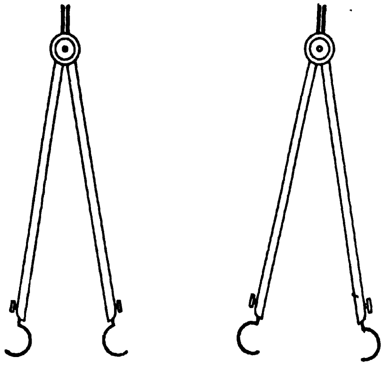


Fig. 1—15
(a) An ant (b) The same ant appears bigger when looked through a lens.

Measure the distance between the two hind legs of the ant.

In some dividers, there is an arrangement to fix either pointed needles or attachments as shown in figure 1-16. The instruments in figure 1-16 (a) and 1-16 (b) are called calipers. To what use can calipers be put? For measuring the diameter of a sphere or a tennis ball, will you use a divider or a caliper? Which of these instruments will you choose to measure the 'internal' diameter of a cylinder ?



(a) (b)

Calipers

Fig. 1—16

Activity

(1) Measure the internal as well as the external diameters of a bangle and determine the thickness of the glass used for the bangle.

(2) Measure the internal diameter of the tumbler in which you drink water at the rim and the diameter of a cup at the rim.

(3) Measure the diameter of a *thali*

1—7 Measurement of large distances

Suppose you want to measure long distances say the distance you walk from your home to the school, or say the perimeter of the football ground : Can you think of any method to measure such large distances? Obviously you will not use a metre scale to measure such a large distance. Perhaps you can use a surveyor's tape. If, however, the surveyor's tape is not available, can you think of any other method ? Perhaps you can try the following :

Walk 100 steps and measure the distance walked with a metre scale. Repeat this several times and tabulate your results as shown below :

	1	2	3	4	5	Average value
Distance for 100 steps						

Having measured the average distance you walk in 100 steps, you can now estimate the distance you walk from home to school.

Activity

Try and obtain an estimate of the distance between your home and that of your friend's.

As you grow older, you would perhaps like to measure even longer distances, say the distance of a distant mountain from your house. You may perhaps like to measure the breadth of a river or the distance between you and a ship far away. May be you would like to know the distance of the moon from the earth or even far away planets and so on. All these distances can be measured accurately and you will learn the methods for measuring these distances later. On the other hand you may like to find out the diameter of a very thin wire or the thickness of a leaf or the diameter

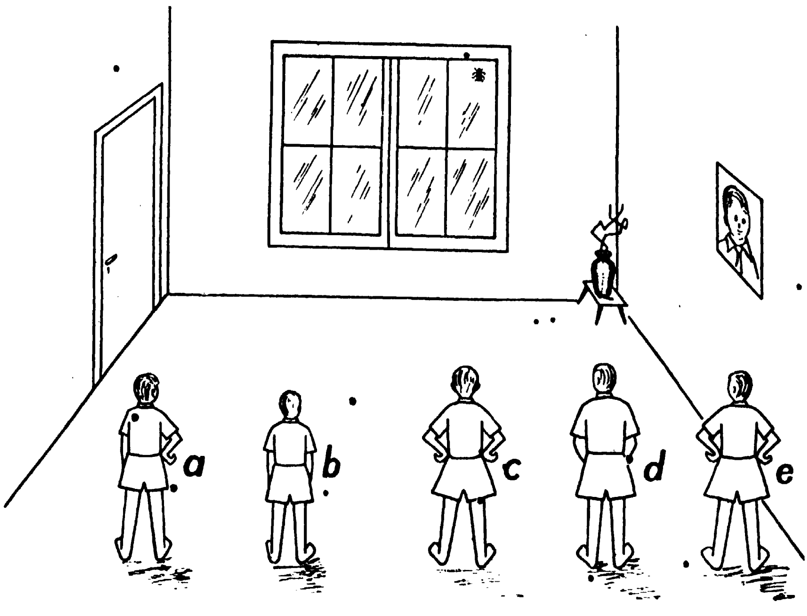


Fig. 1—17

of a speck of dust and so on. These small distances can also be measured accurately. The methods for measuring such small distances will be described later.

1—8 The idea of a graph

Look at figure 1-17 There is a spider on the window. Suppose 5 of your friends see the spider from the positions shown in the figure. Which of the following statements given by your friends helps you most in locating the spider although you have not seen the spider at all ?

(a) The spider is on the window.

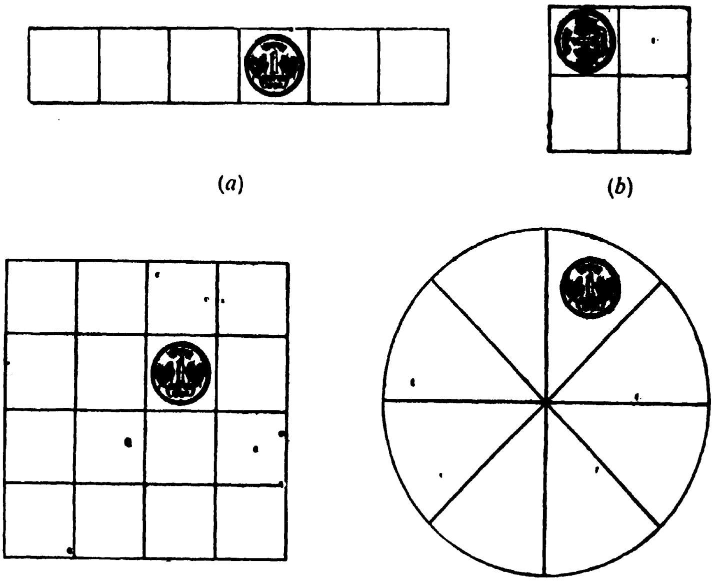
(b) The spider is in the right hand top corner of the window.

(c) The spider is in front of me.

(d) The spider is at the top corner towards my left.

(e) The spider is at the top edge towards my left.

A coin is placed in various positions shown by fiigures 1-18 (a),



(a) (b) (c) (d)

Fig. 1—18

(*b*), (*c*) and (*d*). Write down statements which will most correctly describe to your friend the position of the coin in these figures ?

Figure 1-19 shows a football match in progress. F is the position of the football and R that of the referee. G_1 and G_2 are the two

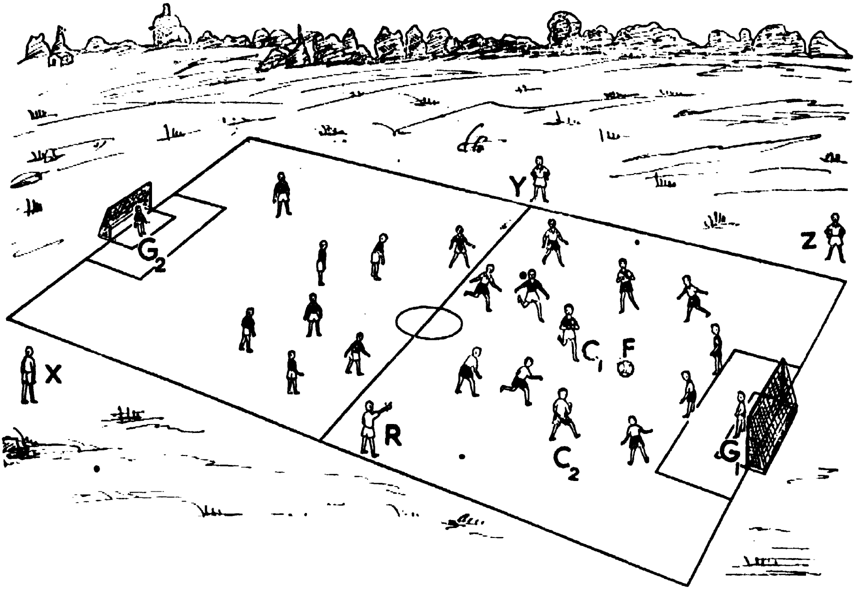


Fig. 1—19

A game of football in progress X, Y and Z are the three observers.

goalkeepers and C_1 and C_2 are the positions of the two centre forwards. Suppose three of your friends X, Y and Z are witnessing the match from the positions shown in the figure. How will they describe clearly the positions of the football and the players on the field ? Is it possible for another person who has not watched the match to draw a diagram and locate the position of the football and the players on the basis of the description given by X, Y and Z? You will find that the description for the same position given by different persons X, Y and Z changes because they describe distances and directions from their own positions. Let us try to understand this in detail.

Look at figure 1-20. You see a teacher standing in the middle of the classroom. Can you think of a way of describing the location

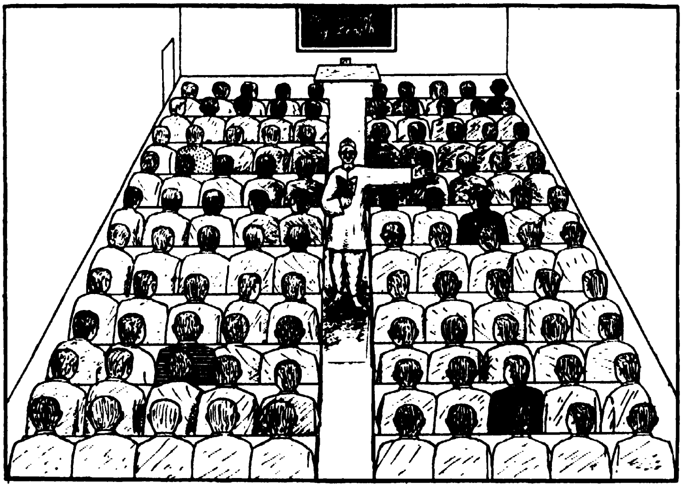


Fig. 1—20

of every student with respect to the teacher? How will you locate the boy wearing the dark shirt with respect to the teacher? If you go past three students to the left of the teacher and one student up, you can reach the student wearing the dark shirt. Following this procedure, you can describe the location of every student with respect to the teacher. Now it might strike you that while describing location in this manner, you have fixed certain directions such as the right or the left of the teacher and the front and back. The point from which these directions originate (in this case, the position of the teacher) is called the 'origin' and the right-left and front-back directions are called the axes of reference. Suppose we represent each student by a point and mark it appropriately, we can then represent this very picture in a different way. Let us see how we can do it. Let us take a graph paper. A graph paper is crossed over by two sets of lines which are perpendicular to each other. This is also called a squared paper. Let us take a point O in the centre of the paper and call it the origin; in our example O will represent the position of the teacher. Let OX′ be the direction to the right and OX the direction to the left of the teacher. Similarly, OY′ be the front and OY the back directions (Figure 1-21). You will

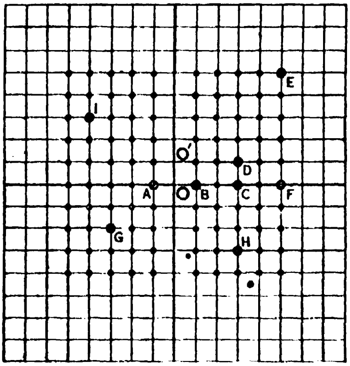


Fig. 1—21
Representing a class on a graph

see that we are now representing the class with respect to the axes XOX′ and YOY′, with the teacher at O. The boy to the immediate right of the teacher is represented by the point A on the graph and the boy to the immediate left will be represented by the point B. Note that there are no boys along the line YOY′. The boy wearing the dark shirt is reached by going three students on the left of the teacher and one student to his back. On the graph paper now we will go three divisions on the right, i.e., along OX and one division along a line parallel to OY, i.e., along D. Similarly, we can plot the position of every student on the graph paper.

Activity

Plot the position of the boy wearing the shirt with black spots and the boy wearing the shirt with black stripes on the graph.

On the graph paper, you notice various points like E, F, G, H and I. Can you describe the location of these points with respect to your axes and the origin? Perhaps you will say that to reach F, one has to go 5 divisions along OX and 5 divisions along a line parallel to OY, such as FE. The distance of 5 divisions along OX is called the "X coordinate" of E and the distance of 5 divisions along a line parallel to OY is called the "Y coordinate". Thus the X coordinate of E is 5 and the Y coordinate is 5. This is usually written as (5,5) in which the first number refers to the X coordinate and the second number to the Y coordinate.

Activity

(1) Describe in the manner given above the location of G, H, and I.

(2) If the teacher moves to the place represented by the point O′ along YOY′ in figure 1-21, will the coordinates of the boy wearing dark shirt change ?
Determine the coordinates of boys wearing the shirt with black spots, and the shirt with black stripes, with respect to the teacher standing at O′.

Look at figure 1-22. A pole in the centre of the figure is the

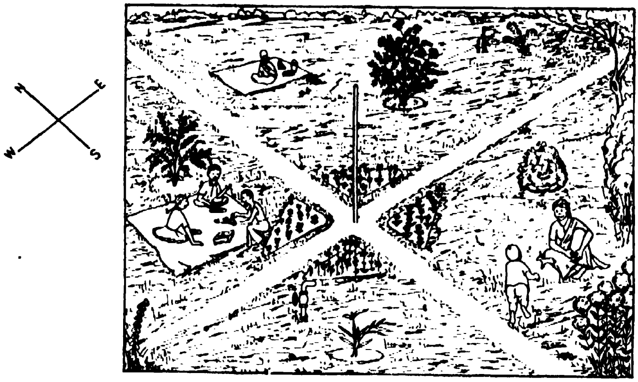


Fig. 1—22

origin with respect to which we will describe the location of all bodies. We have the east-west and north-south directions marked on the figure. There is a rose bush, 5 m along east and 3 m along north;

a tap, 5 m along west and 2 m along south; and a jasmine tree 3 m along west and 5 m along north. All the trees can correspondingly be described on a graph. Take a graph paper. Perhaps you may think of taking a graph paper several metre long and several metre broad so that you can plot the graph. But, if you think again, you will yourself see that this is not practicable. Can you think of any method? Perhaps you will say : let the distance between any two neighbouring parallel lines or one small division represent 1 m. If you do this, you can plot the graph of the garden in the picture on a small graph paper.

We have seen in the above examples that one can locate the position of the object with reference to the origin O and the two axes of reference. In addition to the use of a graph to locate the position of the object, it can be used to describe the relation between quantities such as the weight of potatoes and the price of potatoes, distance travelled and the time taken to travel it, etc. It is this aspect of the graph that Physicists are more concerned with. Let us see by taking one simple example as to how this can be done.

One kilogram of potatoes costs 1 rupee, two kilos would cost 2 rupees, three kilos would cost 3 rupees and so on. Let us represent the relationship between the weight of potatoes and the price by a graph. Here we fix the origin O and two axes of reference OX and OY. Let us take one big division on the OX axis to represent 1 kilo of potatoes and let one big division on the OY axis represent one rupee. In the above example one kilo of potatoes costs one rupee. To express this on the graph, we go a distance equal to 1 big division from O. (This corresponds to 1 kilo as stated above). Two kilos would mean two big divisions on the OX-axis. Three kilos would mean three divisions on the OX-axis. Similarly, one big division on the OY axis will represent one rupee, two big divisions two rupees, three big divisions three rupees and so on. The statement that one kilo of potatoes cost 1 rupee would be represented on the graph by a point whose coordinate on the weight of potato axis would be one and on the rupee axis will also be one. Thus the statement one kilo potatoes costs one rupee would be represented by a point P whose coordinates are (1,1) (Fig. 1-23). Similarly, the statement that

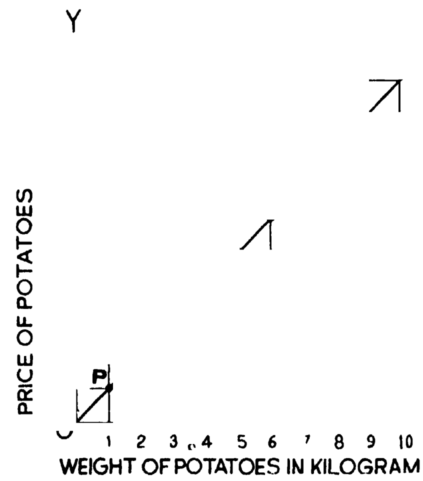


Fig. 1—23

the two kilo of potatoes cost two rupees would be represented by a point Q on the graph whose coordinates are (2,2). The statement that three kilos of potatoes cost three rupees would thus be represented by a point whose coordinates are (3,3). Can you represent the statement that 8 kilos of potatoes cost 8 rupees by a point on the graph? What would be the coordinates of such a point? You will see that we have represented all these statements by a series of points P, Q, R etc.

Question

If the points P, Q, R etc. are joined, they form a straight line. What relation does this line show between the weight of the potatoes and the price of the potatoes?

Let us take another example. The price of one notebook is 50 paise. This means that the price of two notebooks would be one rupee and so on. As in the previous example, let us take a graph paper, fix the origin O and the two axes OX and OY. Let one big division on the OX axis represent one notebook, two divisions would mean two books, three divisions would mean three books, tec.

Similarly one big division on the Y-axis represents 50 paise. Two divisions would be equivalent to 1 rupee. With this scale can you represent the following statements by corresponding points on the graph paper? Write out the coordinates of the correspondig points. 4 notebooks cost 2 rupees ; 6 notebooks cost 3 rupees.

You may still take another example of a graph representing a relation between two quantities. A motor car moves a distance of 40 kilometres per hour. It means in the first hour it goes a distance of 40 km. In two hours it goes a distance of 80 km. In three hours it would go a distance of 120 km. Represent these statements by points on the graph.

Activity

1. On graph paper, plot the following points : A(3,5) ; B(2 – 7) ; C(–3, 4) ; D(10, 5) ; E(–5, –7) ; F(0, – 6) ; G(5, 0).

2. Plot the following points and join them in the given order : (1, 2) ; (2, 4) ; (3, 6) ; (4, 8) ; (–1, –2) ; (–2, 4).

3. Plot the following points and join the successive points by a straight line :

   (–2, –3) ; (2, 4) ; (3, 8) ; (4, 10) ; (5, 9).

4. Ten thin plates are kept one above the other and the total thickness of the stack is 3 cm. Ten other similar plates are placed over them making the thickness 6 cm. Another 10 plates make the total thickness 9 cm. Plot the graph between the number of plates and the thickness. (Here you want to describe the relation between two quantities ; the number of plates and thickness). Plot the number of plates along OX and thickness along OY.

   (*a*) What sort of curve do you get by joining the points you have plotted ?

   (*b*) Find out the thickness of 50 plates.

   (*c*) Find out the thickness of a single plate.

1—9 Scaling

Take a sheet of graph paper. Take 0 as the origin and draw a straight line joining the following points :

X	0	2	4	6	8	10	12
Y	0	4	8	12	16	20	24

Now multiply all the coordinates given in the table by 3. You get the new points :

X	0	6	12	18	24	30	36
Y	0	12	24	36	48	60	72

Plot these points on the graph paper. What do you find ? Similarly, dividing the earlier coordinates by 2, we get the following points :

X	0	1	2	3	4	5	6
Y	0	2	4	6	8	10	12

Plot these points. What do you get ?

We see that the same straight line represents the relation between X and Y coordinates in all the three cases. This magnification or contraction of a graph is called scaling or change of scale of the graph.

Activity

1. The length and breadth of a book are 20 cm and 12 cm respectively. If you magnify the size of the book five times what will be its new length and breadth ?
2. You are given the following points :

X	3	5	11	19	27	13	13	11	11	9
Y	18	16	17	6	20	22	27	23	29	22

Plot them on a graph paper and join the points in the given order. Look at the figure. What do you get ? Multiply the X coordinates by 2 and keep the Y coordinates unchanged. You are, therefore, changing the X scale without changing Y scale. Plot these points on the graph :

X	6	10	22	38	54	26	26	22	22	18
Y	18	16	17	6	20	22	27	23	29	22

How does the figure look now ?

Now keep X coordinate the same but double Y coordinates and plot the points and join the consecutive points by a straight line :

X	3	5	11	19	27	13	13	11	11	9
Y	36	32	34	12	40	44	54	46	58	44

The figure now appears elongated vertically.

Now double both the X and the Y coordinates.

X	6	10	22	38	54	26	26	22	22	18
Y	36	32	34	12	40	44	54	46	58	44

Join the consecutive points by a straight line. What do you observe ?

Can you draw any inference from this exercise ?

CHAPTER 2

Measurement of Area

2—1 Meaning of Area

When you buy new books and notebooks at the beginning of the year, you probably cover them with a brown paper or some-other decorative paper. Let us take an atlas, a notebook and a pocket book and put covers on them (Figure 2-1). You can perhaps answer the

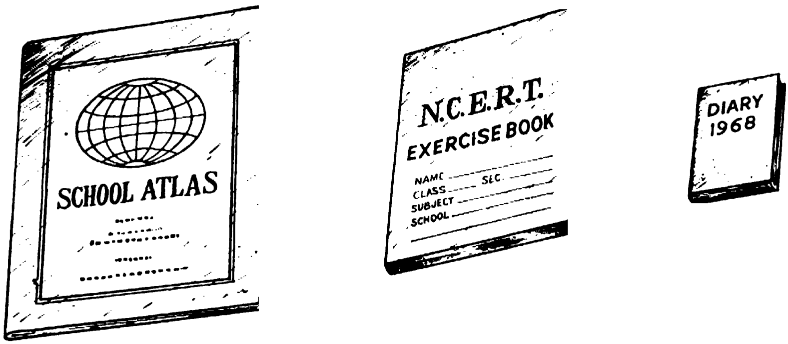


Fig. 2—1

following question. Will the paper required to cover the atlas be more than that required to cover the notebook? If the answer is yes, think for yourself as to why you require more paper to cover the atlas than that required to cover the notebook which, in turn, is more than that required to cover a pocket book although the pocket book is thicker than the note book and the atlas.

Take a sheet of white paper and place it on the table. Place on the paper a match box and mark its outline on the paper with a pencil. Replace the match box by a geometry box and again mark the outline. Repeat the process, first with a notebook and then with the atlas. You will see that the outline of the atlas contains the outline of the notebook which, in turn, contains the outlines of the geometry box and the match box. This means that the portion of the paper occupied by the match box is the least. The portion of the paper contained by the outline of each of these bodies is the area of those faces of these bodies which were in contact with the paper. You see thus that the area of the face of a match box is less than the area of the face of a geometry box etc.

Questions

1. *If you want to paint your room in such a way that the roof is painted cream-yellow and the walls light-green, will you require the same amount of yellow and green paint* ?
2. *Is the area of the face of an atlas greater than the area of the face of a notebook* ?

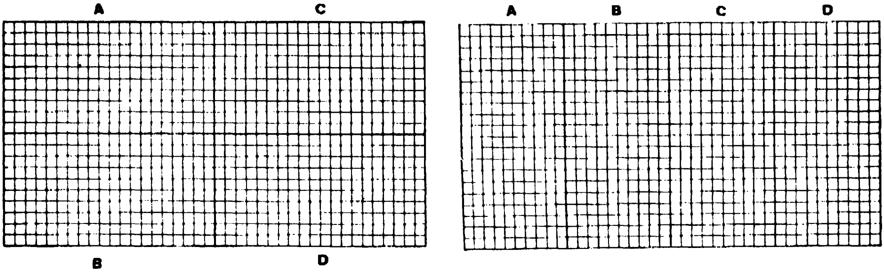
So far we have merely compared areas. We shall now see how they can be measured. The need to measure area is felt in everyday life. If a farmer buys a field, he says 'I want 5 hectres of land'. If you want to build a house, you may need a plot of land measuring 1,000 sq m. These terms 5 hectres*, 1,000 sq m, etc. are the area of the land. If you want to buy a piece of plywood or a sheet of glass, the price of the materials required is quoted in terms of a square metre which is one of the units of area. Similarly if you want to tile the floor or paint the walls of your house, the charges are quoted per sq. metre.

2—2 Unit of area

You have seen in the earlier example that the portion of the paper contained by an outline of a note-book gives the area of the face of the notebook in contact with the paper. Take a graph paper and place a notebook on the graph paper and mark its outline. Cut the graph paper along the outline. The area of the graph paper is the area of the face of the note-book. Measure the

Note that 1 hectre = 10,000 sq. m.

length and breadth of the graph paper and enter the readings in the following table. Cut the graph paper into four equal parts along the thick lines as shown in figure 2—2 (a). Arrange these four



(*a*) (*b*)

(*c*)
Fig. 2—2

pieces in the shapes as shown in figure 2—2 (b) and 2—2 (c). Since the same paper is arranged in these patterns, the area of Figure 2—2 (b) is equal to the area of figure 2—2 (c) which is equal to the area of the face of the note-book. Measure the length and breadth of the Figures 2—2 (b) and 2—2(c). Tabulate the readings.

	Figure 2-2 (a)	*Figure 2-2 (b)*	*Figure 2-2(c)*
Length			
Breadth			
(length + breadth)			
(Length × breadth)			

From these observations you will see that although the length and breadth change as you go from Figures 2-2 (a) to 2-2 (b) and to 2-2 (c), the product of length and breadth remains the same. We have also seen that the area of figure 2-2 (a) = area of figure 2-2 (b) = area of figure 2-2 (c). Thus the area of a rectangular figure is equal to the product of its length and its breadth.

Activity

Cut out a graph paper of the same size as that of the face of your physics book. Cut the graph paper into 16 equal rectangular parts. Arrange them into various rectangular shapes. Measure the length and breadth in each case. Does the product of length and breadth change or does it remain the same ?

Just as we measured length by comparing the unknown length with some known length, we measure area by comparing the unknown area with a known area. You can, for example, express the area of the top face of a rectangular table in terms of the area of one of the faces of a match box or in terms of the area of one of the faces of the book or in terms of the area of a post card. We then say that the area of the top face of the table is so many 'match boxes' or so many 'books' or so many 'post cards'. You may as well take an old 10-paise stamp and measure the area of the table in terms of the area of the stamp. It is also possible to measure the area of the table in terms of a square cardboard sheet of side 10 cm and then say that the area of the table is so many times the area of the square whose side is 10 cm. You will see that in all these measurements, we are trying to compare the area of the top face of the table, which is unknown, with the area of say, the face of a match box, a post card, a square cardboard sheet of length 10 cm etc. We may, however, find that the unknown area may not contain a whole number of 'match box', 'post card' or 'square cardboard sheet'. The method of determining area in such a case is explained in section 2—4.

Questions

The area of a table is 840 times the area of a match box surface; 70 times the area of a geometry box surface; 80 times the area of a post card; 2016 times the area of a stamp; 100 times that of a square cardboard sheet of length 10 cm.

In these expressions, which are the measures and which are the units ?

We can use various units to measure the area of the top of a table. However we must select a unit which would be acceptable as a standard unit of area. Of these units, which will be acceptable as a standard unit of area? Since the area of a rectangle is defined as the product of its length and its breadth, the unit of area could be defined in terms of the unit of length and the unit of breadth. Thus a convenient and accepted unit of area is the area of a square whose length is 1 m and breadth 1 m. This area is 1 m $\times$ 1 m and is expressed as 1 sq m. or 1m^2.

Question

Is it necessary to preserve this unit as the International Standard, as was done in the case of the unit of length ?

As in the case of length, to express bigger and smaller areas, multiples and submultiples of this unit are used. These are* :

1 sq km	=	1 km $\times$ 1 km = 1 km^2
1 sq cm	=	1 cm $\times$ 1 cm = 1 cm^2
1 sq mm	=	1 mm $\times$ 1 mm = 1 mm^2

Questions

Express (a) 1 sq m in terms of sq cm; sq mm; sq dm,
(b) 1 sq km in terms of sq m; sq cm .

Activity

Take a graph paper. Cut out a square of side 1 cm from the graph paper. This, as you will see, is one of the big squares on the graph paper. Each small division on the graph is 1 mm. Count the number of small squares in the bigger square. What is the area of one small

*Note that other units of area are square yards (sq yd), square feet (sq ft), or square inches (sq in). Note the following relationships :

1 sq yd	=	3 ft $\times$ 3 ft	=	9 sq ft
1 sq ft	=	12 in $\times$ 12 in	=	144 sq in.

square? How many small squares make up a big square ? Is 1 sq cm = 100 sq. mm?

2. Draw a square with the side equal to the length of your pencil and measure its area by measuring its length and breadth.

2-3 Measurement of the area of a rectangular (or square) figure

Draw a rectangular figure ABCD on a piece of paper. In this figure, AB = CD and AD = BC. Measure the length AB taking all the precautions mentioned in the earlier chapter. Take ten observations for the length AB and breadth AD and find the average values of AB and AD. Can you determine the area of the figure ABCD ?

Area of ABCD = length AB $\times$ breadth AD.

Record your observations as shown in the table below.

No. of observations	*Length AB (cm)*	*Breadth AD (cm)*	*Average value AB*	*Average value AD*
1	5.2	4.9		
2	5.3	4.8		
3	5.3	4.8		
4	5.2	4.7		
5	5.1	4.7	5.22 cm	4.81 cm
6	5.2	4.8		
7	5.2	4.8		
8	5.2	4.8		
9	5.3	4.9		
10	5.2	4.9		

The average length AB comes to 5.2 cm. This average has been rounded off to the first place of decimal because the least count of our scale is 1 mm. Similarly, the average breadth AD is 4.8 cm.

Area ABCD = 5.2 cm $\times$ 4.8 cm. = 24.96 sq cm.

Are we justified in expressing the area ABCD to the second decimal place?*

Activity

1. Draw the outline of your book, note-book, atlas and geometry box on a paper and measure the areas of their faces in contact with the paper.
2. Are the areas of all the faces of a match box the same ?
3. Measure the area of a post card and a stamp.
4. Measure the area of the table and the daree.
5. Measure the area of a football ground.
6. Estimate the area of the floor of your room, the top of your table and the window pane, and check your answer by actual measurement. What could be the use of such a measurement ?

2—4 Measurement of the area of a rectangular or a square figure using a graph paper

Take a centimetre graph paper. Put a post card on the graph paper and draw its outline. It would be convenient to put the two edges of the post card along the two perpendicular prominent lines of the graph as shown in figure 2—3. Draw the outline of the post card on the graph paper. The area contained in the outline is equal to the area of the post card. Count the number of small squares in this outline. In an experiment, this number was found to be 12,600. Then the area of the post card is 12,600 sq mm. What will this area be in sq cm and sq m? Measure the length and breadth of a post card and determine the area as a product of its length and breadth and compare this with the area determined using a graph paper.

*The minimum distance we can measure with a scale is 0.1 cm (1 mm). Therefore, the smallest square we can draw is a millimetre square whose area will be $0.1 \times 0.1 = 0.01$ sq cm. Hence, with a scale capable of measuring distance with an accuracy of 1 mm, we can measure areas of rectangular bodies with an accuracy of 0.01 cm^2. Hence we are justified in expressing the area of figure ABCD to the second decimal place.

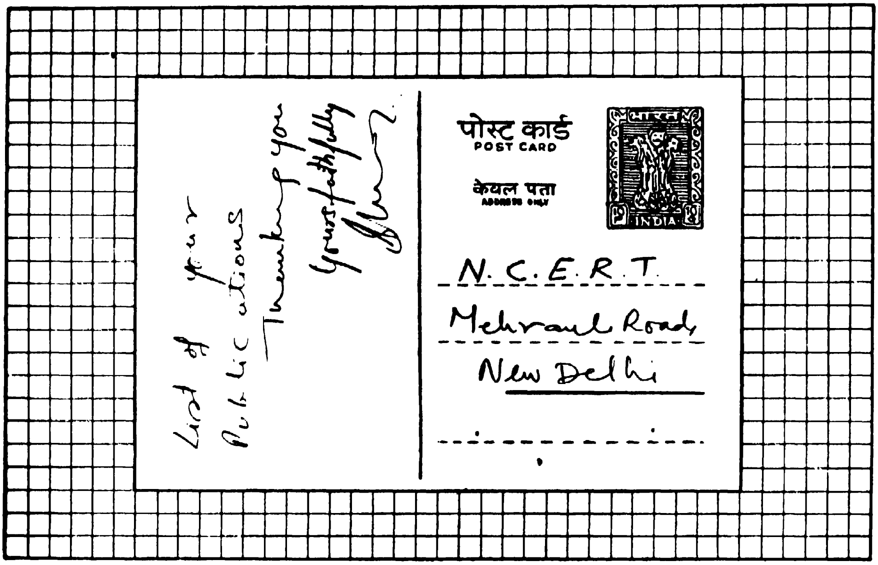


Fig. 2—3
Measuring the area of a postcard with the help of a graph paper.

We see that the graph paper can be used to measure the area of a postcard.

Activity

Find out the area of the top surface of a match box by measuring the length and the breadth. Next measure this area using a graph paper and compare the results.

While using a graph paper to measure the area, you will find that the outline of the figure encloses not only full squares but also some half or even less than half squares. If the figure includes more than half the square, we count it as one; in case it includes less than half, we ignore it. Can you reason out why we do this ?

Question

Will the measurement of area by a graph paper be more accurate than the measurement of area by measuring length and breadth ?

2—5 Measurement of the area of an irregular figure

Take a leaf and place it on a centimetre graph paper. Mark its outline (Figure2-4). The outline is neither rectangular nor square.

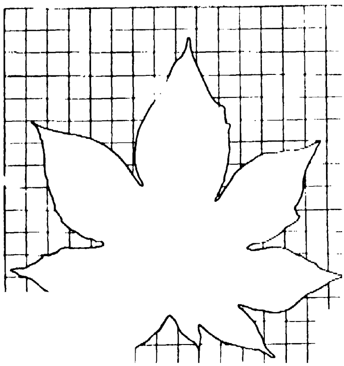


Fig. 2—4

Measuring the area of a leaf with the help of a graph paper

Can you think of any method to measure the area of this leaf? Perhaps you can measure the area by counting the number of small squares contained in the outline. If the number of squares contained in the outline is 1,000, then the area of the leaf is 1,000 sq. mm.

Activity

Take three different graph papers so that in the first the smallest square is of length 1 cm ; in the second the length of the smallest square is $\frac{1}{2}$ cm. and in the third the length of the smallest square is 1 mm. Measure the area of the same leaf using these three graph papers. Which of these three graph papers will give more accurate measurements ?

2—6 Use of Scaling

In chapter 1, we used the concept of scaling to magnify or contract distances. We can use the same concept to represent a given area on a magnified or a contracted scale. Let us take a used post card. Measure its length and its breadth. What is its area ? In one typical experiment, following, readings were obtained :

The Length of the post card = 14.0 cm.
The Breadth of the post card = 9.0 cm.
The area of the post card = $14.0 \times 9.0 = 126{\cdot}0$ sq. cm.

If we now magnify the size of the post card by 2 we get :

Magnified length = 28.0 cm.
Magnified breadth = 18.0 cm.
The magnified area of the post card = $28{\cdot}0 \times 18{\cdot}0 = 504{\cdot}0$ sq. cm.

Is there any relation between the actual area of the post card and the magnified area of the post card ? Is the ratio of the two areas 1 : 4 ? Explain why this is so ?

Again, if we contract the size of the post card by 2 we get :

Contracted length = 7·0 cm.
Contracted breadth = 4·5 cm.
The contracted area of the post card = $7{\cdot}0 \times 4{\cdot}5$
$= 31{\cdot}5$ sq. cm.

Is there any relationship between the actual area of the post card and the contracted area of the post card ? Explain this result.

Activity

1. Draw four squares with sides of 1.0, 2.0, 3.0 and 4.0 cm respectively. The side of the second square is twice that of the first and the side of the third square is three times that of the first. Look at the areas of these squares (may be after colouring them). How do these areas compare ?
2. Take a stamp. Measure its length and breadth and determine its area. If you look at the stamp through a magnifying glass, the stamp appears bigger. If the magnification is 3 what will be its length and breadth as seen through the magnifying glass ? What will be the area of magnified stamp ? What is

the ratio of the area of the magnified stamp and the actual stamp ?

3. Take rectangular cardboard sheet of size 4 cm $\times$ 5 cm. Measure its length and breadth. Calculate its area. Keep this sheet under a lamp or a torch at a distance of 5 cm and observe its shadow as shown in figure 2-5. Mark the outline of the shadow. Measure the length and breadth of this shadow. Calculate the area of the shadow. What is the ratio of the area of the shadow and the area of the cardboard sheet? Lower the cardboard sheet and keep it at the distance of 10 cm from the lamp. Mark the outline of the new shadow. Measure the length and breadth of the new shadow. What is the ratio of the area of the new shadow and the area of the cardboard sheet ?

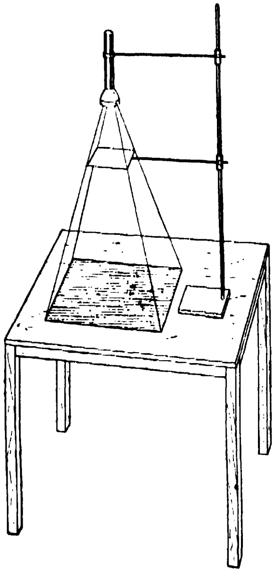


Fig. 2—5

4. A slide projector projects a slide of 24 mm $\times$ 24 mm. on a screen of the size 24 cm$\times$24 cm. Calculate the area of the slide and its magnified picture. What is the relation between magnification in length and magnification in area ?

5. Take a graph paper. The smallest square has a length 1 mm and its area is 1 sq. mm. On this graph paper mark the outlines of squares of length 2,3,4,5,6,7,8,9,10 mm. Measure the areas of these squares and enter your observations in the table :

From the above table you may observe that if we magnify the size of the square by 2' the area of the square is

Side of a square (mm)	*Area (sq mm)*
1 mm	
2 mm	
3 mm	
4 mm	
5 mm	
6 mm	
7 mm	
8 mm	
9 mm	
10 mm	

magnified by 4 (or 2 × 2); if we magnify the size by 3 the area is magnified by 9 (or 3×3) and so on. What will be the ratio of the areas of the squares of edges 1 cm and 10 cm respectively?

6. On a map of India we have a scale reading 1 cm = 150 km. On this map mark a square of edge 1 cm. Its area is 1 sq. cm. Now, 1 cm on the map is equal to 150 km. The area of 1 sq. cm on the map will, therefore, be equivalent to 150 km × 150 km. or 22500 sq. km. What will be the area of a rectangle of length 2 cm and breadth 3 cm? What will be the actual area of the region enclosed in rectangle of length 3 cm. and breadth 2 cm on the map?
7. You are given a map of India. Trace the map on the graph paper and determine the area of India. Measure the areas of Uttar Pradesh, Maharashtra, West Bengal, Tamil Nadu and Madhya Pradesh. It will be interesting to find out how densely populated are the above states. The population of these states, according to 1961 census, is 7,37,46,401; 3,95,55,718; 3,49,26,279; 3,36,86,953; 3,23,72,408, respectively. Calculate the population, per sq. km. for these states.
8. Measure the area of your palm and your foot.
9. Draw circles of radius 2.0, 3.0, 4.0 cm and the squares of

length 2.0, 3.0, 4.0 cm. Compare the areas of the circles and the corresponding squares.

10. Draw circles of radius 2.0, 3.0, 4.0 cm. Measure their areas. Find the ratio of the area of a circle and the square of its radius in each case. Do you find the same ratio in each case ?

11. Draw a rectangle, 2 cm. by 3 cm. Cut a card-board piece of 1 sq. cm. and find out the area of the rectangle with the help of the piece of cardboard.

12. You are given a parallelogram. How can you calculate its area ?
    Can you draw a rectangle of the same area ?

13. You are given a cylinder. of 5 cm. length with a circular base of 1 cm diameter. Find out the total surface area of the cylinder.

(*Hint* : Take a strip of graph paper of width equal to the length of the cylinder. Wrap it round the cylinder to cover the surface. Unroll the strip and find its area).

CHAPTER 3

Measurement of Volume

3·1 Meaning of volume

In everyday life we come across expressions such as 'a cup of milk', 'a tin of kerosene', 'a bucket of water', 'a bottle of ink', etc. What do we understand by these expressions ? You will, perhaps, say that a cup of milk means the milk which fills a given cup. Similarly, a tin of kerosene would mean a tin full of kerosene. You will agree that the kerosene filled in a tin is much more than the milk filled in a cup. Thus each of the above containers such as a cup, a bottle, a tin, a bucket, etc. have different capacities for holding liquids. The capacity of a container is called its internal volume or simply the volume. Thus the volume of kerosene oil contained in a tin is many times more than the volume of milk contained in a cup.

We now ask ourselves the question : 'On what factors does volume depend ?' To answer this question let us perform the following experiment.

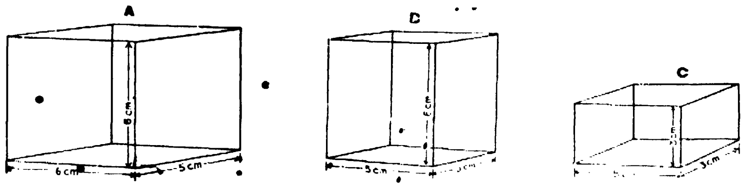


Fig. 3—1

Take three different containers A, B, C, from your kit (Figure 3-1). The length, breadth and height of these containers are shown in Table 3-1. Check these dimensions by actually measuring length,

TABLE 3—1

Container	*Length* (*cm*)	*Breadth* (*cm*)	*Height* (*cm*)
A	6	5	6
B	5	3	6
C	5	3	3

breadth and height of these containers with the help of a scale. Containers C and B have bases of same surface area but their heights are different. On the other hand, containers B and A have the same height but have bases of different surface area. Find out which container has the largest volume and which one has the smallest volume ? [Hint : Fill the container A with water and then pour this water into containers B and C]. Can you find out the relation between the volumes of these containers ? Is there any relation between the volumes of these containers and the areas of their bases and their heights ?

Let us now consider cylindrical vessels. Take three cylindrical vessels as shown in figure 3-2 and supplied in the kit. Measure their

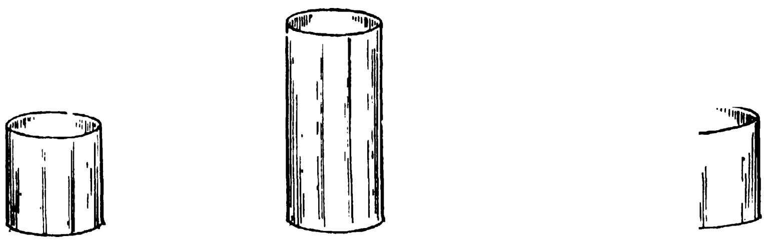


Fig. 3—2

heights and find out the areas of their bases with the help of a graph paper. Record your observations as under. Find the relation

TABLE 3—2

Vessel	*Area of base*	*Height*
A		
B		
C		

between the volumes of these vessels. Is the volume of B twice the volume of A and the volume of C four times the volume of A ? Find the relation between the volumes of these vessels, the areas of their bases and their heights.

3–2 Volume of Solids

Just as liquids have volume and vessels have internal volume, solids also have volume. Take a glass tumbler half-filled with water and mark the level of water. Drop a small stone in it. You will find that the level of water inside the glass tumbler rises. Why does the level of water inside the tumbler rise ? A story of a thirsty crow is often told. The crow saw a pitcher which contained only a small quantity of water. The crow tried to reach the water but was helpless. The crow, however, was clever. He put small pebbles inside the pitcher and raised the level of water inside the pitcher and quenched his thirst (see Figure 3-3). You will see that when you drop a stone inside the tumbler, the level of water inside the glass tumbler rises because the stone falls to the bottom of the tumbler and displaces a volume of water equal to its own volume. Take the stone out. Does the level of water fall back to its original mark ? How do you explain this ? Now pour some water in the tumbler to make the level of water rise by an amount equal to that when the stone was dropped in the tumbler. Is this amount of water equal in volume to that of the stone ? If you now take different solid bodies—a marble, a piece of metal and a stone and drop them one by one in the tumbler, you will find that the level of water rises in each case. Is this rise the same in each case ? If not, why is this so ? Estimate which one has the largest volume and which one has the smallest volume.

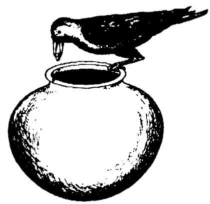


Fig. 3—3 Thirsty crow

Activity

Take a glass tumbler. Pour some water in the tumbler. Mark the level of water by fixing a wire round the tumbler. Drop a stone. The level of water rises. Mark this new level by another wire. Empty the tumbler without disturbing the two wires. Now put kerosene to the same mark up to which water was filled. Put the same stone in kerosene. To what level does the kerosene rise ? Is it the same as was in the case of water ? Repeat this experiment with various liquids and observe the rise in level of liquid in each case on dropping the stone. What do you infer from these observations ?

Let us now consider a solid whose faces are rectangular as shown in the figure 3-4. In case of vessels you have found that their volume is related to their heights and the area of their bases. How is the volume of a solid, as shown in Figure 3-4, related to its length, breadth and height ? To understand this let us do the following experiment.

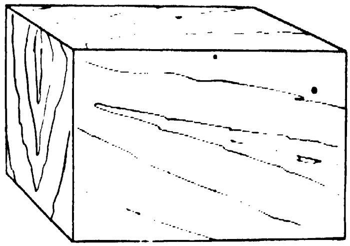
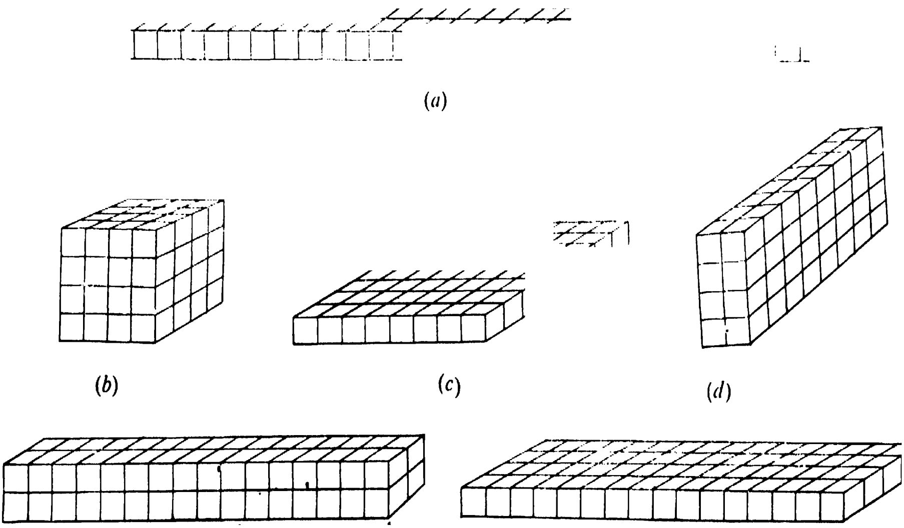


Fig. 3–4



(a)

(b) (c) (d)

(e) (f)

Fig. 3—5 Different arrangements of 64 cubes

Take 64 identical cubes. Arrange these cubes into different geometrical shapes as shown in figure 3-5 (*a*), (*b*), (*c*), (*d*), (*e*) and (*f*). Since each cube has identical dimensions, the volume of each one of the cubes should be the same. How will you verify this? Now the total volume of 64 cubes will remain unaltered even though they are arranged in six different ways as shown in figure 3-5. Measure the length, breadth and height of each arrangement that you have made and record the observations, as follows.

TABLE 3–3

Figure	*Length*	*Breadth*	*Height*	*Area of base* × *height*	*Length* × *breadth* × *height*
3—5 (*a*)					
3—5 (*b*)					
3—5 (*c*)					
3—5 (*d*)					
3—5 (*e*)					
3—5 (*f*)					

From these observations we conclude that although the length, breadth and height change from one arrangement to another, that is, from *a* to *b*, *b* to *c*, *c* to *d*, and so on, the product, length × breadth × height remains the same. Is this product length × breadth × height equal to the volume of geometrical shapes as shown in the figure 3-5? We also see from the above observations that the product of area of base × height remains the same in all the arrangements as shown in figure 3-5. Now measure the area of all the faces of the geometrical shapes arranged as shown in figure 3-5. Also measure the lengths of the edges perpendicular to the respective faces. Determine the product of these areas and the respective lengths of the edges. Is this product the same and equal to the product of the length, breadth and height of these geometrical shapes?

From the above observations we conclude the following:

Volume of a block of rectangular shape = length × breadth × height
= area of the face × length of the edge perpendicular to the face.

Now check your observations for the vessels of rectangular faces (Figure 3-1) and cylindrical vessels (Figure 3-2). Can you say the following ?

The volume of vessel of rectangular faces	= Area of base $\times$ height
The volume of a cylindrical vessel	= Area of base $\times$ height

3-3 Unit of volume

We have seen that the quantity of liquid required to fill a cup, a tin or a bottle gives the volume of the respective containers.

Activity

Take a bucket and find out its volume using a cup and a bottle. How will you express your results ?

Can these containers be used as standards to measure the volume ? Indeed, we could take any other container, such as a spoon-full of water as a unit to measure the volume. However, such units will be entirely arbitrary. Like measurement of length and area we must measure volume in terms of a unit which is generally acceptable as a standard. We have learnt that the volume of a vessel or a solid block of rectangular faces is equal to the product of its length, breadth and height. For measuring distances, we have chosen the metre as a unit. A unit of volume is defined as the volume of a cube which has an edge of 1m length :

Therefore unit volume $= 1\text{m} \times 1\text{m} \times 1\text{m} = 1\text{cu m} = 1\text{m}^3$

The volume of any vessel or a solid body will then be given in terms of the volume of this cube. To express volumes larger as well as smaller than a cu m it is desirable and convenient to use multiples or submultiples of the cubic metre (cu m). These derived units are :

$1 \text{ cu km} = 1 \text{ km} \times 1 \text{ km} \times 1 \text{ km} = 1 \text{ km}^3$
$1 \text{ cu cm} = 1 \text{ cm} \times 1 \text{ cm} \times 1 \text{ cm} = 1 \text{ cm}^3$
$1 \text{ cu mm} = 1 \text{ mm} \times 1 \text{ mm} \times 1 \text{ mm} = 1 \text{ mm}^3$

Activity

Express 1. 1 cu cm in terms of cu mm.
2. 1 cu m in terms of cu cm.
3. 1 cu m in terms of cu mm.

To measure the internal volume of vessels or the volumes of liquids and gases a unit called litre (l) is used. A cubical box with inside dimensions of 10 cm on each side has a volume of 1,000 cu cm.* This volume is called a litre. A thousandth part of a litre is called a millilitre (ml). Millilitre is equal to a cu cm.

3 4 To measure the volume of liquids or containers : The measuring jar

How can we measure the capacity of a cup or the volume of a given liquid ? This is conveniently done with the help of a measuring jar. It is very easy to construct a measuring jar. Take a hollow glass cylinder closed at one end and a hollow unit cube of internal volume equal to 1 ml. On the glass cylinder paste a thin strip of white paper, as shown in figure 3-6. Fill the cube with water and pour it into the hollow cylinder. Mark the level of water on the paper strip as 1 ml. Fill the hollow cube again with water and pour it into the cylinder. Mark the new level of water as 2 ml. Repeat the process several times marking 3 ml, 4 ml. and so on, on the paper strip. Thus a measuring cylinder is ready. Such a measuring cylinder or jar can measure the volume of liquid or the capacity of a vessel.

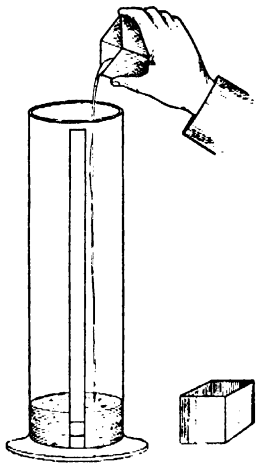


Fig .3—6

Care should be taken while using a measuring cylinder. The level of liquid should be read carefully. Look at figure 3-7. The liquid surface is slightly curved at the walls of a measuring

* According to International Conference which adopted International Units 1 litre = 1000.027 cu cm. However, such a small difference between a litre and 1,000 cu cm is taken into account only when making very accurate scientific measurements. You will learn more about this later.

cylinder while in the middle it is almost flat. Hence readings should be taken at the flat part of the surface. This is conveniently

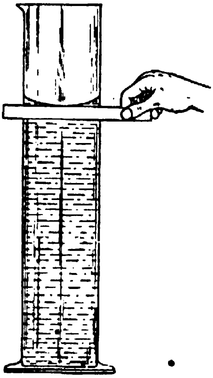


Fig. 3—7

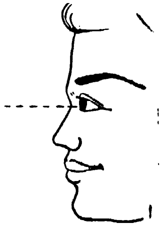


Fig. 3—8

done with the help of paper strip or a thin wire as shown in figure 3-7. The accuracy of measurement also depends on the position of eye as illustrated in figure 3-8. Because of the possibility of errors in any measurement it is necessary to repeat the measurement number of times and take the average value as the correct one.

Activity

1. You are given three test-tubes of different internal diameters. Construct measuring cylinders from them. Are the graduation marks on these three cylinders same ? If not, why ?

2. Take a glass jar of any shape, for example, a tumbler as shown in figure 3-9 (*a*). Pour some water into it. Mark the level of water with a coloured pencil. Call this the zero mark. Put a block of aluminium 2 cm × 2 cm × 2 cm in the water. The level of the water rises. Mark this new level. What volume does this level indicate ? Now remove the block you had dropped in. (A thread tied to the block may help). The level falls to the zero mark. Pour some water to bring the level back to the second mark. What is the volume of water you have poured ? Put the same block again in

water. The level of water will rise further. Put a third mark at the level of water. What volume does this third mark show ? You go on like this and thus make several marks. Are these marks equidistant ? If not, why ?

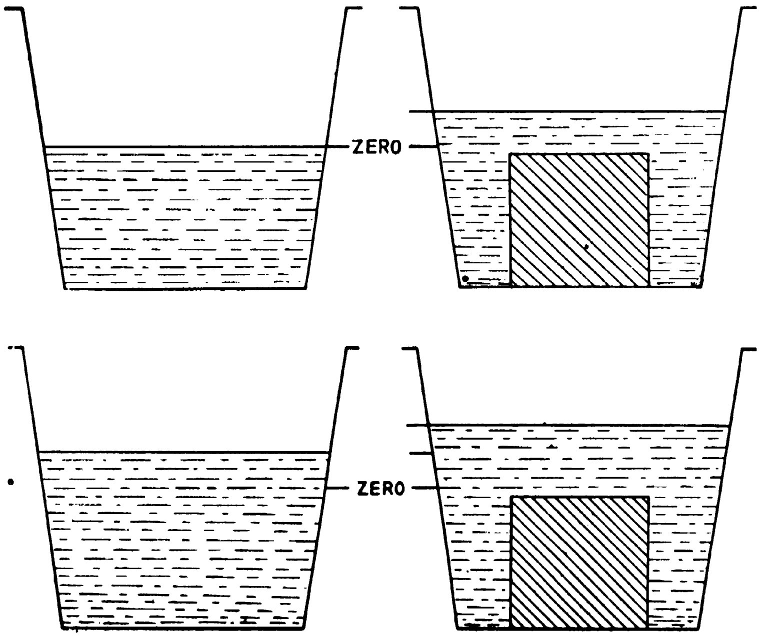


Fig.3—9 (a)

3. Which of the vessels shown in figure 3-9 (*b*) would you prefer for making a measuring jar.

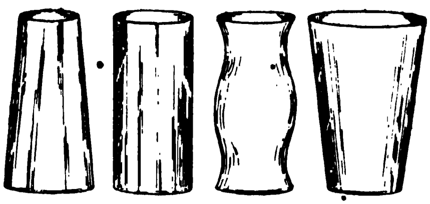


Fig. 3—9 (b)

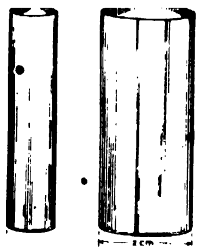


Fig. 3—9 (c)

4. You have two cylindrical measuring jars of different radii as shown in figure 3-9 (c) Which one will you choose to measure small volumes of the order of 1 ml ?

Figure 3-10 shows graduated vessels used in the laboratory. The measuring cylinder is used for measuring or pouring out desired volumes of liquid. The measuring flask and pipette are used for obtaining fixed volumes. The burette delivers any required volume up to its total capacity and is made long and narrow to increase its sensitivity. There is a stopcock at its lower

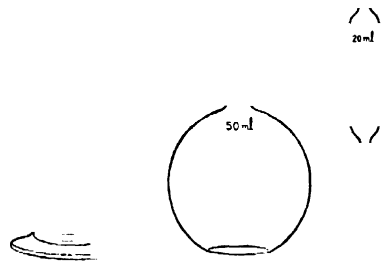


Fig. 3—10 Graduated vessels used commonly in a laboratory

end to adjust the flow of liquid. The liquid is filled from the top and its level is noted. It is taken out from the bottom by opening the stopcock. The level of liquid in the burette falls and is noted again. The difference in the levels of the liquid gives the volume of liquid taken out.

Now let us find out the capacity of a given cup. Fill the cup with water and then pour the water into the measuring cylinder. Suppose the level of water in the cylinder is at the 32 ml mark. Then the volume of water contained in the cylinder and, therefore, the capacity of the cup is 32 ml. If, however, the level of water lies between the 32 and 33 ml marks, find out which mark is nearer the level of water. If it is the 33 ml mark, then the volume of water will be 33 ml.

Activity

1. Find out the volume of a drinking glass, a cup, a mug and a milk bottle.
2. Find the volume of a spoonful of water. (Take a spoonful of water and pour it into a measuring jar. Repeat this process 50 times. Find the total volume. Divide this by 50 to get the volume of one spoonful of water).
3. Find the average volume of a drop of water.
4. Take a lump of plasticine and make a round ball from it. Drop it in a measuring jar. Measure the volume of the sphere of plasticine. Now take it out, make it into any other shape and drop it again in the jar. Measure the volume again. What do you find ?

3—5 Measurement of the volume of regular and irregular solids

The volume of a solid with rectangular faces can be determined by measuring its height and the area of its base.

Let us now find the volume of a given block of wood with rectangular faces. Take ten observations each for the length, breadth and height and record them as shown in the table below.

TABLE 3—4

No.	*Length (cm)*	*Breadth (cm)*	*Height (cm)*
1	5.1	4.9	2.2
2	5.2	4.8	2.2
3	5.3	4.8	2.1
4	5.3	4.7	2.1
5	5.2	4.7	2.0
6	5.2	4.8	2.0
7	5.2	4.8	2.0
8	5.3	4.9	2.0
9	5.2	4.9	2.1
10	5.2	4.9	2.1
Average Value	5.22	4.82	2.08

The average length is 5·2 cm. This average has been rounded off to the first place of decimal as the least count of our scale is 1 mm. Similarly, the average breadth is 4.8 cm and the average height is 2.1 cm.

Then the volume of the block $= 5.2 \times 4.8 \times 2.1$

$= 52.416$ cu cm

Question

Are we justified in expressing the volume of the block to the third decimal place ?

To measure the volume of irregular solids, take a measuring cylinder half-filled with water. Read the level of water. Next drop a solid, say a ball inside it. Find the new level of water. The difference in the two levels, therefore, gives the volume of the solid (Figure 3-11).

When a solid is made up of a material lighter than water it will float. A cork, for instance, will float on the surface of water. Can you think of a method for determining the volume of a piece of cork ?

The method of finding the volume of a solid body with the help of a measuring jar is particularly suitable for bodies of irregular shape. It is not necessary that water should only be used. We can take any other liquid in place of water but we have to be careful to see that there is no chemical reaction between the solid and the liquid.

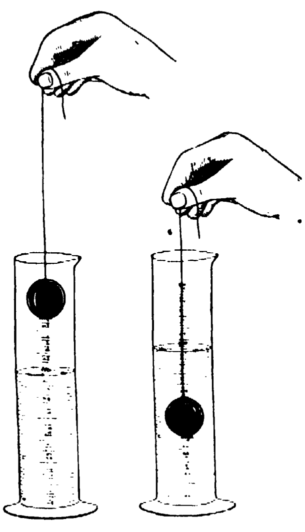


Fig. 3—11
Measuring the volume of a solid

Activity

1. Take a metal cube. Calculate its volume by measuring its length, breadth and height. Find also its volume

with the help of a measuring cylinder. Do you find any difference between the two observations ?

2. Find the capacity of a cup with the help of a measuring cylinder. Put the empty cup in the measuring cylinder half-filled with water and find the rise in the level of water. Is the volume thus obtained equal to the capacity of the cup ? If not, why ?
3. Find the volume of a spoonful of sugar.
   (Hint: the sugar when put into water gets dissolved. It is, however, insoluble in turpentine oil).
4. Estimate the volume of your class room.
5. You are given a rectangular vessel and a solid glass block which fits exactly inside the hollow vessel. Find (*i*) the length, breadth and height of the hollow space with the help of a divider and a scale and calculate the capacity of the vessel, (*ii*) the capacity of this vessel with the help of a measuring cylinder, (*iii*) the volume of the solid block by measuring its length, breadth and height, (*iv*) the volume of the solid block with the help of a measuring cylinder. Do you find any difference between these readings ? If not, why ?
6. Take a measuring jar. Fill it with water to a certain mark. Drop a small stone and find out the volume of the stone. Repeat this taking kerosene instead of water. What do you find ?
7. Take a measuring jar. Fill it with water to a certain mark. Put one spoon full of sugar. Observe the level of water in the jar. Allow it to rest for some time. Observe the level again. Repeat till the level does not change any more. Repeat this using kerosene. Can you explain these observations ?

CHAPTER 4

Time Interval And Its Measurement

4-1 Meaning of a time interval

Most of you have seen a clock or a watch marking the time of the day. From early morning when you get up from bed till late at night when you go to sleep, you are aware of the passage of time. You have a certain time for sleeping and resting and another time for working, playing, and so on. In the following pages we shall try to find out more about time.

Nature itself has given us several ways of measuring time. To begin with, there is our heart beat; about once a second, some times slower, sometimes faster, it beats for our whole life. Then we have the sun. Every morning when we get up we see the sun rising in the sky in the east. The sun slowly moves up and at noon it is almost over head. The sun sets in the west and we call it the evening. This chain of events has continued ever since the sun and the earth came into existence. Then there are four seasons ; summer, rainy season, winter and spring. These repeat every year one after the other.

We have just spoken of the heart beat. You can easily feel the time that it measures, but it is not easy to measure periods of time smaller than that between two heart beats. Similarly, periods of time longer than the life of a man are not easy to measure. Time however, does extend beyond these limits. Thus the blinking of an eye takes a much shorter time than the heart beat. Similarly certain trees, for example, live for hundreds of years which is much larger than the average life of a man. We shall see how we can measure such very large as well as very small time intervals.

Calendar

All of you know that our country became independent in 1947.

History records several such important events. Gandhiji staged his famous Dandi-march in 1931; king Ashoka ruled in 270 B.C. ; and so on. All these events have been recorded on a certain scale. Thus Independence came after the Dandi-March. All the years that have been mentioned, namly, 1947, 1931 and 270 B.C. are on a certain time scale which is called the calendar. The most widely used calendar is the Gregorian Calendar named after Pope Gregory XIII.* It counts time after the birth of Christ. When we say India became independent in 1947 A.D. (Anno Dommini, which means in the year of our lord, after the birth of Christ), we mean that India became independent 1947 years after Christ was born. Similarly, we can say Gandhiji staged his Dandi-march 1931 years after the birth of Christ. Any event occuring before the birth of Christ, such as, say, the rule of Ashoka, can also be recorded on the same calendar. Thus when we say that Ashoka ruled in 270 B.C., we mean that Asoka was ruling in India 270 years before Christ was born. Thus we see that the birth of Christ is merely a point of time with reference to which the occurrence of all other events are recorded. Indeed, any point of time could be taken as the reference point.

In the above examples, we in fact, mentioned time interval between two events. When we refer to the age of a boy on first January 1968, we have two events, namely the date of his birth and the 1st January 1968 in our mind. When we say India became independent in 1947, we are referring to the time interval between the birth of Christ and the year in which India got independence. Similarly, when we say Ashoka ruled in 270 B.C., we mean that the time interval between the birth of Christ and the rule of Ashoka is 270 years.

Question

What do we mean when we say that today is 25th May 1969 ?

We see that the measurement of time really means measure-

* In addition to the widely accepted Gregorian Calendar, there are other calendars too. One such calendar, which is our national calendar, is called Saka era. This era takes for its reference point the beginning of the Saka rule. With reference to the Gregorian calendar it took place in 78 A.D. Other calendars, such as Vikram era, Budha-Nirvana era, etc. are also used.

ment of the time interval between two events. In all the above examples we have considered large time intervals. The time interval could also be much shorter. If we say that Rama takes half an hour to reach school, we mean that the time interval between the event of Rama starting from his house and his reaching school is half an hour. Here again what we measure is the time interval between the two events, namely the instant he starts from his house and the instant he reaches the school. Again we may say that the blades of a fan take one tenth of a second to complete one rotation. This statement similarly means that the time interval between the instant the blade of a fan crosses a particular mark and the instant it crosses the same mark next time is one tenth of a second. We can, indeed multiply such examples. We see that the measurement of time is, indeed, the measurement of the time interval. Further, these time intervals could be thousands and thousands of years or could be small fractions of a second.

4-2 Unit of time interval

We have seen in the earlier chapters on measurement of length, area, and volume that measurement essentially implies comparison of an unknown quantity with a known quantity. In the measurement of the length of a piece of cloth, the length of the cloth was an unknown quantity which we compared with the length of the metre scale which is a known quantity and is taken as the unit. Similarly, in the measurement of the time interval, we compare the unknown time interval which we want to measure, with the known time interval. This we take as unit of time interval. However, the selection of the unit of time interval and also the comparison of any other time interval with a unit interval presents us with a problem. Our unit of time interval should be reproducible and repeatable. In the case of length, one could preserve a standard of length and store it permanently. This is, however, not possible in the case of time; we cannot store any unit of time interval. Since we cannot store any unit of time, we may take any phenomenon that repeats itself regularly after a certain time interval and use the time interval between any two repetitions of the phenomenon as a unit of time interval.

We have already referred to several repetitive phenomena on the first page. We have, for example, a heart beat. Let us find out whether the interval of time between two heart beats could be taken as a unit of time interval and one could compare any unknown time interval with this unit. Take a small bottle with a stop-cock attached to it as shown in figure 4-1. Fill it with water upto a

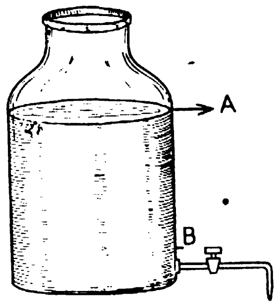


Fig. 4—1

certain level. Open the stopcock and adjust it so that water can be emptied in a few minutes. Make two marks A and B on the bottle as shown in the figure. Fill the bottle with water so that the level of water stands a little above the mark A. Begin counting your heart beat as soon as water level is at A and count the number of heart beats till water reaches mark B. Repeat the experiment three or four times and determine the average number of heart beats for water to flow from A to B. You will find that the number of heart beats measured during the flow of water from A to B is nearly the same. Let your friend do the same experiment. Do you get the same answer in each case ? Now run a distance of hundred metres and back and immediately repeat the same experiment. Do you measure the same number of beats this time ? You can see for yourselves that the time interval between two heart beats is not always constant; sometimes the heart beats fast and sometimes it beats slow. You will, therefore, agree that the time interval between two heart beats is not a good unit of time interval. We shall, therefore have to think of some other unit of time interval which is reproducible.

Activity

Repeat the above experiment using your pulse beat. Let your friend also do the same experiment. Do both of you get the same result each time ? If not, why ?

We know that there are several natural phenomena which repeat periodically, for example, the recurrence of day and night, the phases of the moon and the seasons. These repetitive phenomena can be used to measure time interval. We again note that in all these measurements we will be comparing the unknown time interval with a known time interval such as the interval between two days, the interval between two full moons or the interval between the two longest days of the year. The three repeating events mentioned above have intervals of time which are (1) the day ('day' here means a day and a night); (2) the month --from the end of one full moon to the end of the next full moon; and (3) the year.

Usually a day is regarded as the time interval between one sunrise and the next sunrise or between one sunset and the next sunset. The length of the day, as defined above, is found to be variable*. This you can check by noting the time of sunrise and sunset on a few successive days as reported in the newspapers. In view of this variation in the length of the day, we cannot use this as a unit. However, an average is taken and this average day, known as the '*mean solar day*', is taken as the fundamental unit of time.**

Activity

1. Collect information for sunrise and sunset for one month in summer and one month in winter and plot (a) the time of sunrise and the time of sunset for each day (b) the time

* This variation in the length of the day is due to the fact that except at the equator, the sun does not rise or set at the same time in different seasons of the year.

** The mean solar day is the average interval between the two successive passages of the sun over the meridian at a place, derived from a very large number of observations.

interval between one sunrise and the previous sunrise for each day.

2. The earth takes nearly 24 hours to rotate round its axis and hence the time interval between two sunsets on the earth is nearly 24 hours. Following planets complete one revolution about their axes in the time shown against each of them :

Venus	=	240 hours
Earth	=	23 hours, 56 minutes and 4.09 seconds
Mars	=	24 hours, 37 minutes and 22.67 seconds
Jupiter	=	9 hours and 50 minutes
Saturn	=	10 hours and 14 minutes

What would be the length of a day on Venus, Mars, Jupiter and Saturn?

A year is another natural repetitive time interval. This time interval is obtained from the recurrence of the seasons. Apart from rotating on its axis and thus causing the day to recur at a place, the earth has another motion too. This is its revolution around the sun which causes the change in seasons. The earth takes just under 365.25 days (more accurately 365.2422 days) to complete one rotation. This time interval is called one year.

Questions

Other planets complete one revolution around the sun in the time period shown against each of them :

Mercury	=	*87.96 days*
Venus	=	*224.07 days*
Earth	=	*365.24 days*
Mars	=	*686.95 days*
Jupiter	=	*4332.58 duys*
Saturn	=	*10759.22 days*

What would be the length of a year on Mercury, Venus, Earth, Mars, Jupiter and Saturn ?

The mean solar day is divided into 24 hours; an hour is divided into sixty minutes; and a minute into sixty seconds. Therefore

one mean solar day* $= 24 \times 60 \times 60 = 86{,}400$ seconds

These short time intervals such as seconds, minutes are measured with the help of clocks and watches

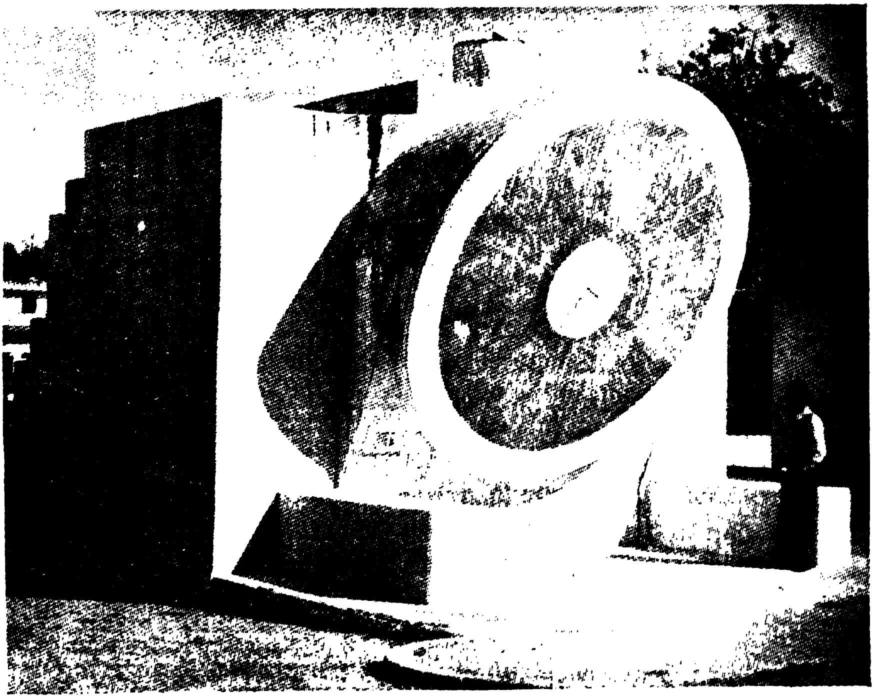


Fig. 4—2 (a) Sun-dial at Jaipur built in 1730

4-3 Measurement of time-interval—Sun-dial

Let us now learn about various devices for measuring time intervals that have been in use from time to time. In olden days when modern clocks and watches were not devised, very simple

* A day in September is shorter than a day in December by about 11 minutes. A day from sunset to sunrise in September is 23 hours, 59 minutes and 39 seconds whereas in December it is 24 hours and 30 second.

devices were used to measure time. Figures 4-2 (a) and (b) show some of these devices.

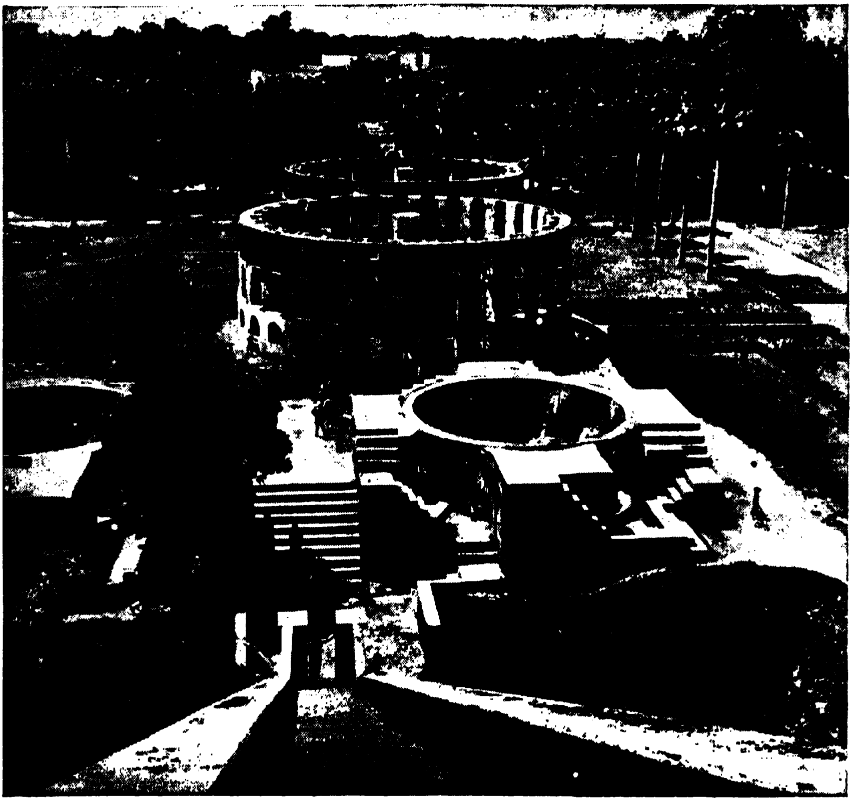


Fig. 4—2 (b) Jantar Mantar at Delhi

The sun-dial was known to have been in use at least as early as 2000 B.C. It was widely used by the Egyptians, Greeks, Romans and Indians. A simple sun-dial is shown in figure 4-3. It consists of a smooth rectangular base placed horizontally. To this base is fixed a piece called a *stylus or gnomon,* whose shadow falls on the board. The edge of the shadow indicates the time. Markings are made on the base to give the hours of the day.

Fig. 4—3 A sun-dial

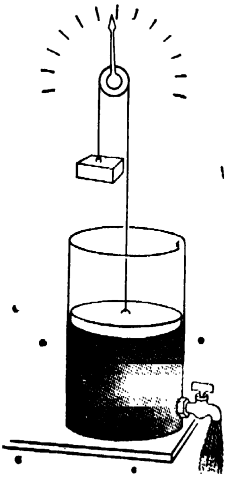


Fig. 4—4 (a) Ancient water clock

Another type of time recorder used in the early days in India, China, Greece and Egypt was the water clock, figure 4-4. (a). In its simplest form, the water clock is a large bowl of glass with sloping sides and with a tiny hole at the bottom as shown in figure 4-4 (b).

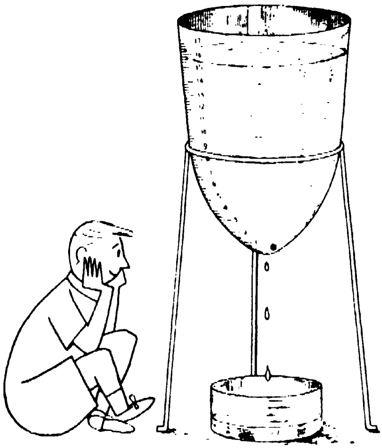


Fig. 4—4 (b) A water clock

The bowl is filled with water up to a certain mark and water is allowed to trickle out of the hole. Every time this bowl empties itself in approximately the same interval of time. The inner surface of the bowl is graduated in minutes and the level of water indicates the time. After the bowl is emptied it is filled again.

Activity

Take a glass bottle having an opening at the lower end. Attach a glass tube provided with a stopcock and a capillary tube as shown an figure 4-5. Adjust the stopcock so that water trickles down drop by drop. Fill the bottle to a certain mark and allow the bottle to empty itself. Mark the level of water every 15 minutes. After the bottle is completely emptied, fill it again to the same mark and allow the water to trickle down as before. Do you find any change in the markings that you made ? If not, do you think this bottle can be used as a clock ?

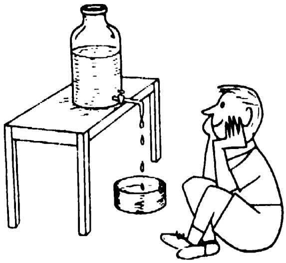


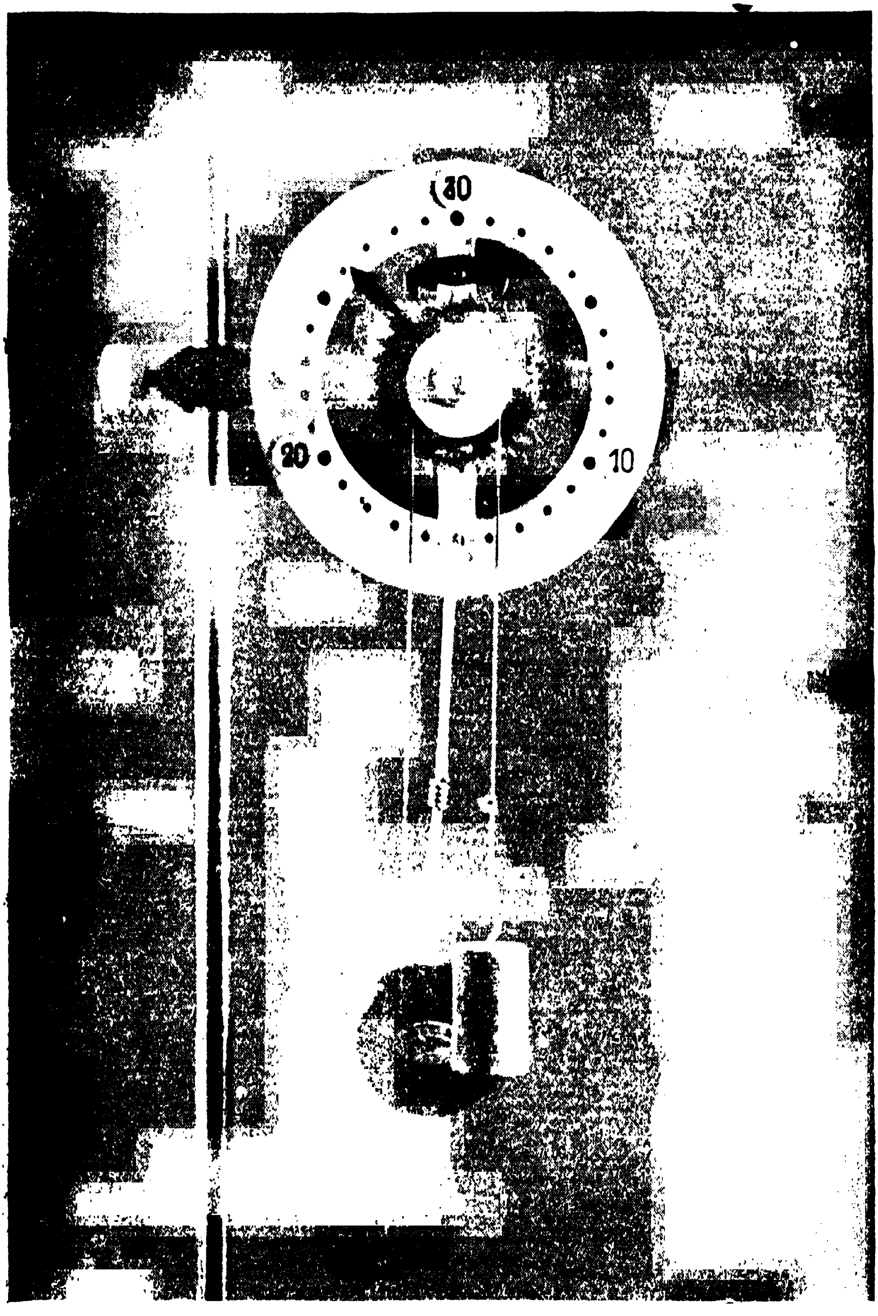
Fig. 4—5

1. Are the markings (15 minutes' interval) on the bottle spaced equally ?
2. What is the smallest time interval you can measure with this clock with a particular stop-cock setting ?
3. If you change the stopcock setting, so that water flows faster than before, do your markings indicate the same time interval ? Are the 15 minutes' markings closer or more widely spaced than you had before ? In this setting what is the smallest time that you can measure ?
4. Can you adjust the stopcock so that it takes exactly 30 minutes for the bottle to empty itself ? Suppose your school clock goes out of order, can you use this water clock to mark the beginning and the end of the periods in your school ?

Instead of water one could make sand flow out of a bottle with a narrow orifice. A sandclock which uses this principle is shown in figure 4.6. Such clocks were used in the olden days.

Activity

Take wax candle of length, say, 5 cm as shown in figure 4-7. Burn the candle; the wax gradually melts. Can you use wax candle to measure time ? Will the candle of a given length always burn in the same interval of time ?


30
20
10

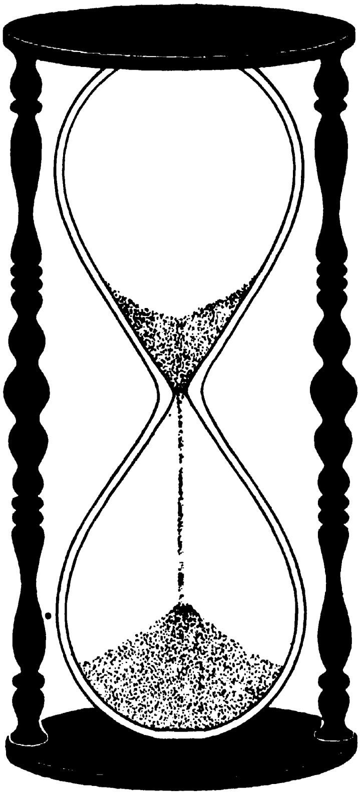


Fig. 4—6 A sand-clock

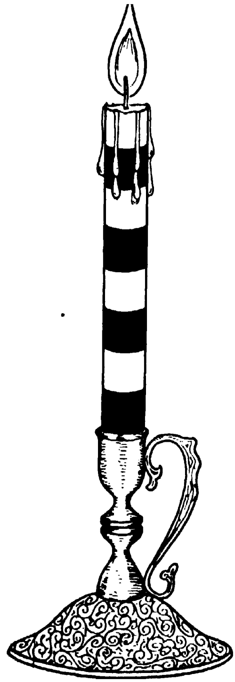


Fig. 4—7 The use of a wax-candle to measure time intervals

Pendulum Clocks

All the clocks mentioned above have their limitations. The real advance in the science of time measurement was made by the great Italian physicist, Galileo. The following story is told of how Galileo came to study and discover the laws of pendulum. In 1581, at the age of 17, while kneeling one day in the cathedral of Pisa, he observed the swinging of the great cathedral lamp which was suspended by a long chord. It occurred to him to find out whether each swing of the lamp took the same time or whether the time varied for each swing. He used his pulse beat to measure the start swinging. But I had never dreamt of learning that each swing would employ the same time in passing". The fact which Galileo noted is that the time for one complete to and fro swing of a pendulum, like the cathedral lamp he saw, is constant. This observation of Galileo led to the idea that if a pendulum could be kept swinging by a spring or a slowly falling weight, it could be used to measure time intervals.

A simple pendulum can be made as follows. A heavy piece of metal is tied to one end of a piece of light string. The other end of the string is fixed to a rigid support and the solid piece of metal, called the bob, is allowed to hang freely as shown in figure 4-8. We

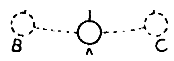


Fig. 4—8 A simple pendulum

may mark this position 'A'. This position is called the 'position of rest' or the 'mean position'. Such a pendulum, when allowed to oscillate (swing) takes the same time to complete one *oscillation* which is defined as the swing of the pendulum from A to B to C and back to A (see figure 4-8). An oscillation can also mean the travel from C to B and back to C. The time for one oscillation is called the 'period' of the pendulum. The distance AB is equal to AC, and is called the 'amplitude of oscillation'. The length of the pendulum is the distance between the point of suspension and the centre of the bob.

Question

Pendulum oscillates between A and E as shown in figure 4-9. What will be one complete oscillation if you were to start timing when the bob crossed B, C, D, and (1) moved towards right (2) moved towards left ?

Activity

1. Find the time for 20 oscillations for a pendulum with the help of a stopclock. Repeat this observation ten times.

   Change the length of the pendulum and repeat the whole set of readings again.

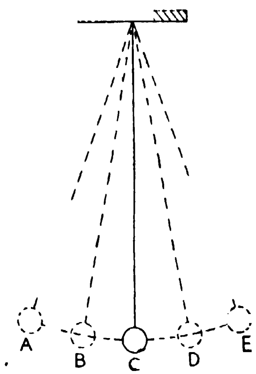


Fig. 4—9

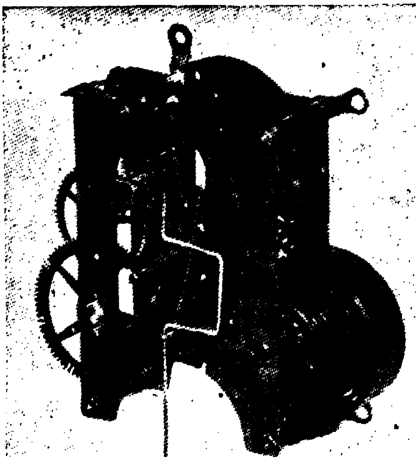
2. Replace the bob by a stone, keeping the length of the thread from the support the same. Find the time for one oscillation. Is it the same as before ?

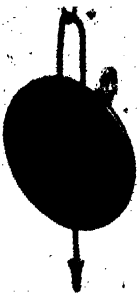
3. Take a simple pendulum and draw its bob on one side, say B, 2 cm from the mean position. Now let the bob go ; the pendulum will oscillate. Find the time for one oscillation. Repeat the experiment by displacing the

bob 4 cm, 6 cm; 8 cm, 10 cm and find out the time for one oscillation for each of these amplitudes. What do you observe ? Will it be correct to say that if the amplitude is small, the time of oscillation is independent of amplitude.

4. Find the time of oscillation for a pendulum of length 50 cm, 100 cm and 150 cm. Which of these take maximum time for one oscillation ? What determines the periodic time of a pendulum ? Is it the weight of the bob or the length of the pendulum ? Varying the length of the pendulum determine the periodic time in each case. Plot a graph between periodic time and the length of the pendulum.

From the above experiments you may realize that if we can make a pendulum of suitable length, such that time of one swing is exactly equal to one second and somehow keep it moving, then such a pendulum can be used to measure time. Thus, with the help of a pendulum, we have an easy and reliable method of measuring time intervals of the order of a second. A simple pendulum of the type described above is unsuitable for making clocks ; this was therefore replaced by a rigid body (Figure 4-10). The pendulum is kept swinging with the help of a coiled spring. The spring, when wound, supplies the energy for swinging of the pendulum by getting unwound. After it is completely unwound, it is wound again. This forms the driving mechanism of the clock. The movement of the pendulum is then given to the hands of the clock. Figure 4-11 shows such a mechanism, which is also called the anchor escapement. As the pedulum swings to the right, a tooth at A escapes but the escape wheel is not free to turn rapidly, as another tooth is caught at B. As the pendulum swings to the left, the tooth at B escapes, but another tooth is caught at A, so that for each swing of pendulum one tooth goes past, first at A and then at B. It is this action of the escape wheel and anchor which causes the familiar 'tick-tock', 'tick-tock' in the clock. As a tooth escapes, it gives a little push to the pendulum, and this keeps it swinging. It is, therefore, not the pendulum, which makes a clock go but it is the clock which keeps the pendulum going.





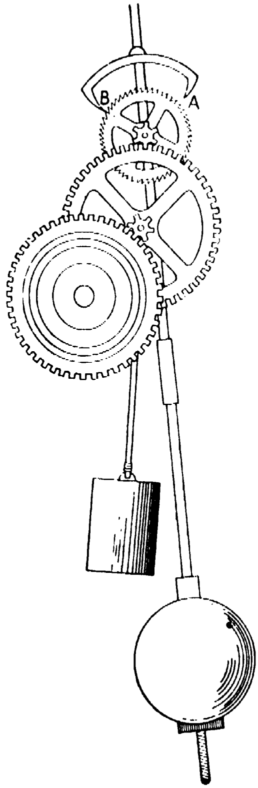


Fig. 4—11 The escapement mechanism in a pendulum clock

Fig. 4—10 A pendulum clock

Activity

Take a wooden disc 8 cm in diameter and 2·5 cm in thickness provided with a hook at its centre and supplied in the kit. Take a thin copper wire of standard gauge (S.W.G.)* No. 25, about a metre long and fix one end of this wire on a clamp. Suspend the disc at the other end. Make a chalk mark on the disc and draw a line on the floor such that the chalk mark on the disc lies exactly on this line. Twist the disc and release it. The disc will oscillate. Find the time for 10, 20, 30, 40 and 50 oscillations. From each of these observations calculate the time for one oscillation. Do you get the same result each time ? Can you use this arrangement for measuring time ?

For watches and all portable clocks, it is not possible to use a pendulum ; so the alternative form of the oscillating system, a balance wheel is used as shown in figure 4-12. The balance wheel

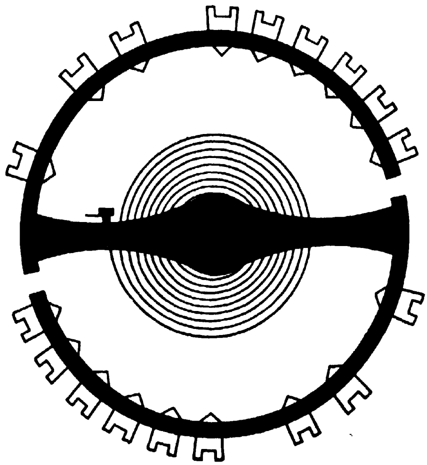


Fig. 4—12 A balance wheel used in a watch

system being very small and delicate, is usually more expensive and needs frequent cleaning and oiling. The balance wheel, instead of turning round and round, swings to and fro. The to and fro

* You will learn about S.W.G. numbers and the corresponding diameters in the Chapter on Electricity,

oscillations of the balance wheel are maintained by a very fine spiral, often called a hair spring. Figure 4-13 shows the balance wheel in a watch.

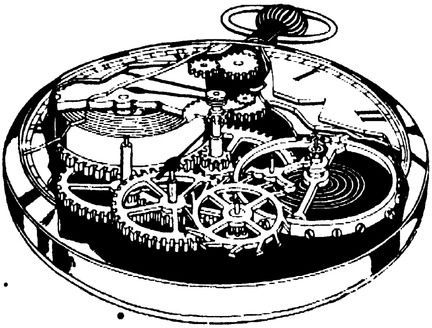


Fig. 4—13 A stop-watch (inside view)

A stop-watch looks like an ordinary watch, fitted with a centre seconds hand and can be stopped or started at will. Pressure on the button starts the hand moving, pressure again stops the hand, so that reading can be taken and the pressure on the button at the third time causes the hand to fly back to the zero position. The stop-watch has a dial graduated only in seconds, with a small inner dial to show the minutes.

Since the pressure on the outside button sets the movement going, and the pressure on the same button also stops it, one can keep one's eye on the experiment or on the final mark in a race and time it accurately. The seconds hand shows a minimum interval of 1/5 or 0.2 seconds. The balance wheel of this watch swings five times a second.

Several other devices have been developed which can measure time intervals of the orders of milli and micro-seconds. You will learn about these in later years. The following table shows a time scale from which yon can get an idea of the magnitude of a millisecond and a microsecond.

1 year	=	364.2422 days
1 day	=	24 hours
1 hour	=	60 minutes

1 minute	=	60 seconds	
1 millisecond	=	1/1000 sec.	$=10^{-3}$ sec.
1 micro-second	=	1/1000000 sec.	$=10^{-6}$ sec.

Activity

1. Speak out the numerals 1, 2, 3......20, as quickly as you can. Press the button of stop-watch the moment you start speaking and press the button again the momont you finish speaking. Find the total time taken for speaking the entire numerals. From this time interval, find the time interval for speaking one numeral, by dividing the above time interval by the total number.
2. Find the time taken to Speak 'ta-ta-ta'........., say 100 times. Hence calculate the time interval between two 'ta-ta's. Similarly, count the numerals 1, 2, 3, 4...100 and find the average time for speaking any one numeral. Can you use any of these methods to determine time intervals shorter then a second? Which of the methods you would prefer ; say 'ta-ta'......or the alphabet or numerals.
3. Find the time for one rotation of a table fan while it is rotating at low speed with a stop-watch by measuring the time interval for 100 revolutions. From this observation, calculate the time of one revolution. Repeat these observations several times and see whether time of one revolution is always the same. Find the number of revolutions a fan would make in half an hour. You, however, cannot find the time of one revolution when the fan is revolving fast. As you grow up, you will learn about other methods to determine such small time intervals.
4. Find the time taken for, say, 100 heart beats or pulse beats. Find the time for one beat. Compare this time with that obtained by other students. Is it the same? Is it approximately equal to a second? Similarly, find the time taken for one blink of the eyelids or the time for one swing of an arm. Compare these times with those obtained by other students.

Fig. 4—14

5. Look at figure 4-14 and at the game in progress as shown. Arrange yourselves in the similar way. Start the clock when the first student touches the student next to him. The second student should in turn touch the third and the third student touch the fourth, and so on. Stop the clock when the last student is touched. Find the total time interval. How much time does it take for one student to touch another?

CHAPTER 5

Motion

5—1 What is Motion

In our daily life we see many objects moving - a man walking along the road, a boy running on the playground beyond, a girl cycling, a speeding car, moving dogs and cows, a flying bird, a football rolling on the ground, and many other things which continually change their positions, some moving slowly and some others moving fast. When you walk from your home to school or when you run on the playground you are in motion. Perhaps you can give a few more examples of motion from your own experience. In all these examples which we have described above and in several others which you come across in everyday life, there is something common to all of them. If you observe them over an interval of time they keep changing their position.

Give a few examples of bodies in motion.

A crawling ant is continually changing its position; so also is a man who is walking. When you are asked to come to the blackboard, you will move from your seat and walk up to the board. In this process you change your position. You will see that in all these cases an object in motion changes its position with respect to other objects. When you walk in a room, you change your position with repect to the other bodies in the room. Thus we can say that motion is characterised by change of position.

5—2 Relative motion

Let us think of a situation. Two friends, Rama and Hari sit in a cart which starts moving while Leela stands by and watches them (figure 5-1). Is Rama changing his position with respect to

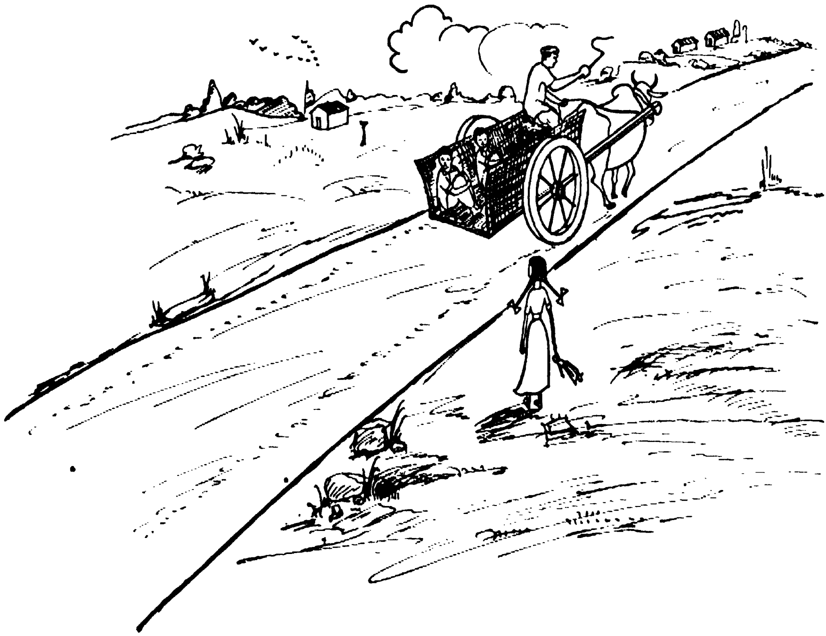


Fig. 5—1

Leela ? Is Hari also changing his position with respect to Leela ? Will Leela say that Rama and Hari are in motion ? Is Rama changing his position with respect to Hari ? Will Rama say that Hari is in motion ?

Let us take another example. You are travelling in a moving train in which you have got several other passengers in your compartment. Is there any change in your position with respect to the other passengars or any other objects in the compartment, although you are moving along with the train ? Look at nearby trees, lamp posts or any other objects outside. What do you observe ? Suppose your train arrives at a station and finds another train waiting on the parallel lines just adjacent to your train. Suppose both the trains start at the same time in the same direction and are equally fast (say, each travels 2 km per minute). If you now look at the passengers in the other train sitting just opposite to you, (figure 5-2), would you find any change of position between you and the passengers ?

NOT TO SCALE

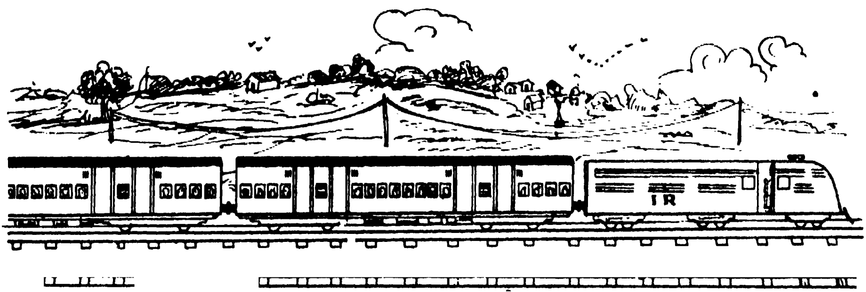


Fig. 5—2

Suppose an ant is sitting stationary on a globe which is rotated about its axis. Is the ant changing its position with respect to the two pins fixed on the globe (figure 5-3) ? Does the ant move with respect to the two pins ?

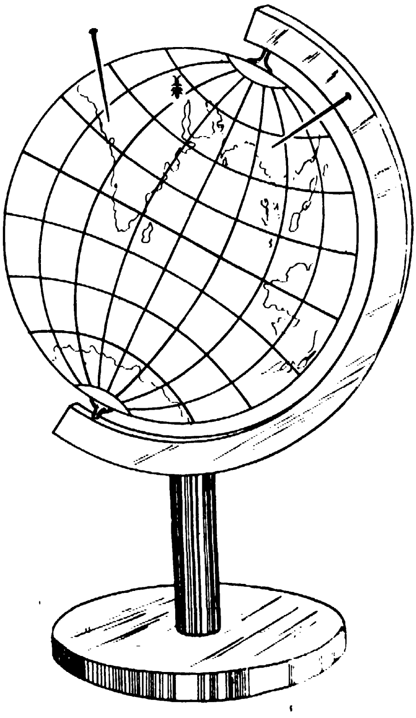


Fig. 5—3

You are perhaps aware that the earth on which we live and walk is nearly spherical. The earth rotates about its axis once in 24 hours and moves round the sun once in a year (figure 5-4). In

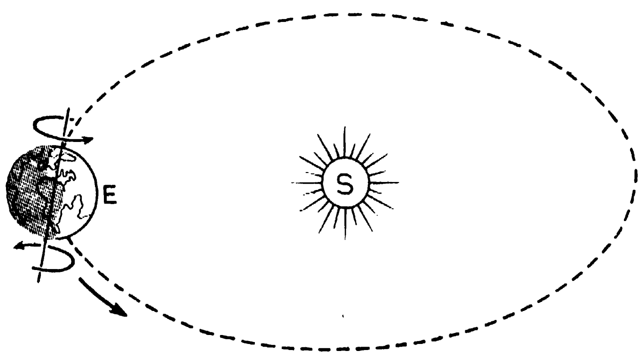


Fig. 5—4
The motion of the earth about its axis and around the sun

a class room we are all sitting. Are you changing your position with respect to your friend sitting close by ? Are you moving with respect to your friend ? Are you changing your position with respect to a lamp post on the road or a tree beyond ? Are you moving with respect to the lamp post ? Do you realise that you as well as your friend, the lamp post and tree are all moving along with the earth, although there is no relative motion between these objects ? An observer outside the earth (as a pilot in a space-ship) will find that you along with trees, lamp posts etc. are moving. Thus, when you say an object is moving, we imply that it is moving with respect to you. In the first example, Rama and Hari are moving with respect to Leela whereas Rama and Hari are at rest with respect to each other, as there is no change in position between them. Similarly, in the second example you are at rest with respect to other passengers, but you are in motion with respect to the lamp posts, trees, stations etc. Thus you will find that all motion is relative and there is nothing like absolute motion.

5—3 Displacement

Let us take an example of an ant crawling on the floor from A to B (figure 5-5). Its position during its motion has changed

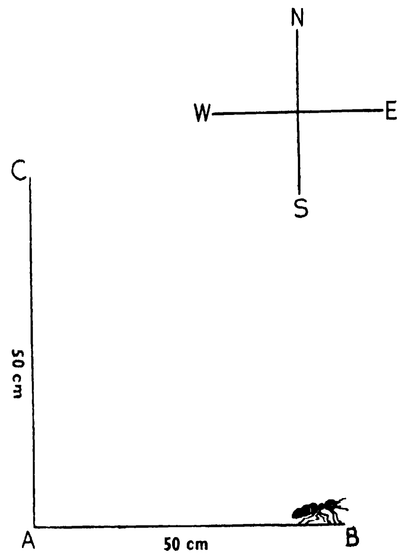


Fig. 5–5

from A to B. It has moved a distance AB. If you are told that the ant has crawled a distance of 50 cm starting from A, will you be able to find out its final position ? May be you will ask in which direction the ant crawled. Indeed, the knowledge of the direction in which the ant crawled is necessary to know its final position. If it crawled east then it would be at B. If it crawled north it would be at C. Thus the direction along which the change of position took place should be known before one can tell the final position. The distance the ant crawled along with the direction in which it crawled is called the *displacement*. Thus, we would say in the first case that the ant had a displacement of 50 cm. towards the east. To know the displacement one should, therefore, not only know the distance from the object's initial position but also the direction in which the motion took place. As in the case of the graph we may indicate the direction of the displacement with reference to any fixed direction such as AO. If a boy walks along AB a distance of 10 m as in figure 5-6, we can say that the boy underwent a displacement of 10 m along

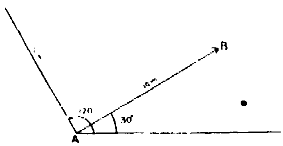


Fig. 5—6

a direction inclined at an angle of 30° with respect to the fixed direction AO. Another boy may start walking from A and go along AC covering again the same distance 10 m. We will then say that this boy has displacement of 10 m along AC, that is, along a direction inclinded at an angle of 120° with respect to the fixed direction AO. If, in order to know a quantity fully, you need to know not only its magnitude but also its direction then such a quantity is called a *vector quantity*. Displacement, as you will now see, is a vector-quantity. The distance travelled irrespective of the direction merely gives the idea of the change of position without letting us know in which direction the change took place. This quantity, *i.e.*, the distance travelled, has merely a magnitude associated with it without any directional property. Such quantities are called *scalar* quantities.

Suppose a boy goes a distance of 500 m along a particular direction which is represented in the figure 5-7 by AO. Let us

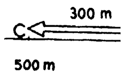


Fig. 5—7 A trip AF followed by a trip FC is equivalent to a single trip AC.

call this trip AF. He then returns along the same path and walks a distance FC equal to 300 m. The result of these two trips is the same as if he had made a single trip from A to C. In other words :

Trip AF + Trip FC = Trip AC

You see that this addition is not a simple addition. If it were so, we would get a distance of 500 m + 300 m = 800 m. We see from figure 5-7 that we can represent Trip FC by a negative number, because its direction is opposite to the direction of AF. Taking into consideration the direction in which the movement takes place, we get the correct answer :

Trip AF + Trip FC = Trip AC
500 m. + (−300 m) = 200 m

If you want to designate trip properly, you have to be careful about the way you write it. Thus, the trip AF means you started from A and went to wards F for a distance of 500 m. Similarly, the trip FC means you started from F and went towards C for a distance of 300 m. The trip FC is not equal to the trip CF. Although the distance travelled in both these trips is the same, their directions are exactly opposite. You will see that to describe the trip properly we have not only to mention the distance travelled but also the direction in which the motion took place. In actual practice, the motion does not take place always in one direction. A cart, for example, goes a certain distance along one direction and then turns and goes a certain distance in the other direction. In this case how do we determine the equivalence of these two trips ? The trips are in different directions and therefore, we cannot do a simple addition. Let us take an example with actual distances. Suppose a cart starts from A and moves a distance of 3 km north towards B. After reaching B the cart turns east and moves another distance of 3 km so as to reach a point C as shown in figure 5-8. In this case the cart started from A and after the two trips AB and BC reached the point C. This is equivalent to a direct trip from A to C. We can, therefore, write that :

Trip AB + Trip BC = Trip AC

We can add trips although they are at an angle to each other. It may, however, be noted that adding trips that are not along the same line

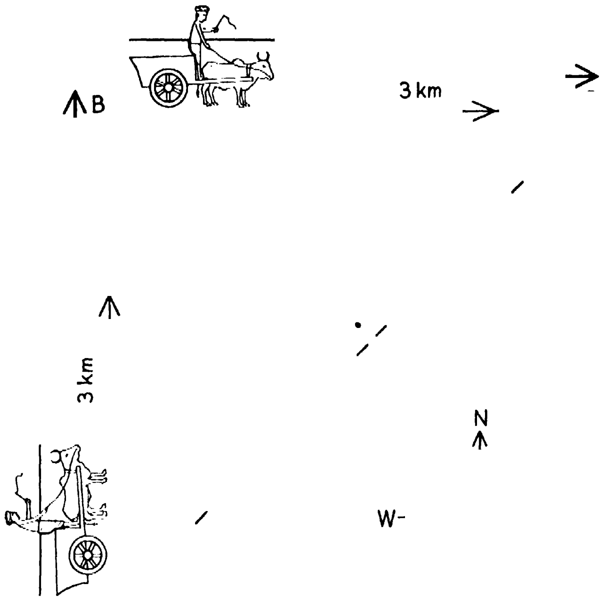


Fig. 5—8
A trip AB followed by a trip BC is equivalent to the trip AC.

is a different kind of addition from adding numbers. In this example, the displacement of the cart is AC which is less than the distance actually travelled by the cart, which is (AB + BC).

In order to indicate the trip from A to B, we have drawn an arrowhead at B in the direction from A to B. The direction of the arrowhead indicates the direction of the trip and the length of the arrow tells us the distance travelled. When we went to refer of this trip, instead of writing 'trip AB' we write the symbol AB. This symbol is the vector symbol, AB meaning that the trip took place along the direction AB. We will come across various such examples of addition of vector quantities as we proceed in our study of physics.

Exercise

(whereever necessary, use a graph paper for solution).

1. A boy walks a distance 400 m. from A eastward to a point B. He then turns north and walks a distance of 300 m. Find the displacement and the total distance travelled. (Use a scale 500 m = 1 cm.)
2. You start on a bicycle from your house and move a distance of 2 km eastward to go to a vegetable shop. You then turn north to buy some grocery at the grocery shop 4 km away. You then turn north-west and go to a laundry to pick up clothes. The laundry is at a distance of 6 km from the grocer's shop. You return home directly from the laundry. Find out the displacement at the end of the journey and the total distance travelled. Find the distance of the laundry from your house,
3. You start from home in the morning and walk a distance of 500 m to your school. In the evening you return home, may be along a different path *via* your friend's house, walking a distance of 800 m. What is the displacement after you reach home and what is the total distanee travelled ?
4. In the previous chapter you were asked to measnre the distance from Delhi to Bombay by rail. You also measured the same distance along the straight line joining the two cities. Now if the mail train goes from Delhi to Bombay, what will be the total distance travelled and what will be its displacement ?

5–4 Speed and Velocity

Let us return to our discussion of motion. We have seen that the motion of a body is characterised by a change in its position with respect to other bodies. There are several types of motion, such as that of a man walking along a road, a bob of a pendulum swinging back and forth, a wheel of a bullockcart rotating about its axis, a spring vibrating and so on. For the present we will confine

our attention to the simplest of all these motions, that is, the motion along a straight line. Even in this type of motion, some objects move slowly while some others move fast. A man on the average takes 15 minutes to cover a distance of 1 km., whereas a cyclist may cover it on an average in five minutes. A car, which moves even faster, may hardly take two minutes to cover the same distance. Thus, to describe any motion we will try to find out how fast the motion takes place. For this, we have to measure not only a given distance but also the time taken to cover that distance. Let us for the time being forget about the direction. Let us suppose that a body is moving with a constant speed, that is to say that it covers the same distance in equal intervals of time. A boy, for example walks a distance of 1 km in 20 minutes, another kilometer in another 20 minutes, another kilometer in the third 20 minutes, and so on. The boy covers the same distance, whether it is during the first 20 minutes, the second 20 minutes or the third 20 minutes, and so on. His speed is constant. His speed will be obtained by dividing the distance covered by the time taken to cover that distance. We then get the speed of the boy as :

$$\text{Speed} = \frac{\text{distance covered}}{\text{time taken}}$$

$$= \frac{1 \text{ km}}{20 \text{ minute}}$$

$$= \frac{1000}{20} \text{ or } 50 \text{ metres per minute.}$$

Question

To determine the speed of the body which is moving uniformly, does it matter as to when you count the time and find the distance covered during that time-interval !

Exercise

The speed of a body is the distance covered by it in a unit of time. The unit of measuring speed is the unit of distance divided by the unit of time. A boy is walking 50 metres per minute, express his speed in kilometres per hour and centimetres per second.

Distance Time graph

If we plot a graph between the distance travelled and the time taken, we will get a graph as shown in figure 5-9. At the end of

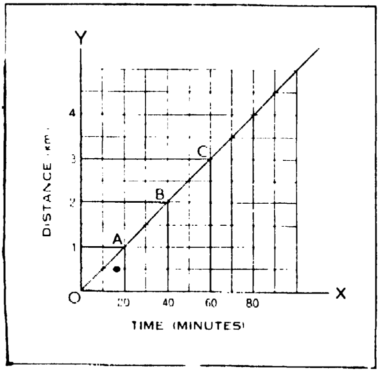


Fig. 5—9

Distance-time graph showing motion with a uniform speed.

first 20 minutes the boy will have gone a distance of 1 km. At the end of second 20 minutes he will be at a distance of 2 km. At the end of third 20 minutes he will be at a distance of 3 km. and so on. These observations are plotted on the graph by points A, B, C, etc. Join all these points. You will see that you get a straight line. Thus, if a body is moving with a constant speed the graph between the distance and the time taken to cover the distance will be a straight line. Let us see whether this is always so.

Question

1. *A car covers a distance of 40 km in the first hour, it covers another 40 km in the second hour, if moves in the third hour also the same distance of 40 km. It the car continues to travel the same distance every hour, what type of curve will you get between the distance travelled and the time taken to travel it ? What will be the distance travelled after ten hours.*
2. *A mail train starts from Delhi at 8.30 A.M. Its speed is constant and is equal to 60 km. an hour. Plot a graph*

between the distance travelled and the time. At what time will the train be at a distance of 120 km from Delhi.

3. *Two friends leave Delhi for Chandigarh in their cars. A starts at 5.00 A.M. and moves with a constant speed of 30 km/hour, whereas B starts at 6.00 A.m. and moves with a constant speed of 40 km/hour. Plot the distance-time graph for their motions and find out at what time the two friends will meet, and at what distance from Delhi ?*

Speed-Time Graph

You can described the motion with constant speed by plotting another graph which gives a relation between the distance travelled every hour against time. Such a graph is called a speed-time graph. For example, take a car moving with a constant speed such that it covers a distance of 40 km each hour. If you plot a speed-time graph of this motion, you will get a straight line parallel to the time axis as shown in figure 5-10(a). This graph gives a relation between speed and time. Now, let d stand for the distance travelled by the body; v for its speed and t for the time needed to cover the trip. If the body moves with the contant speed of v metres per second it will cover a distance v metres in the first second $2v$ metres at the end of another second, $3v$ metres at the end of the third second, and

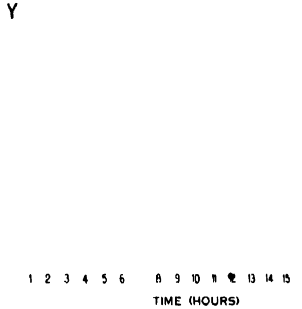


Figure 5—10(a)

Speed-time graph for a motion with a uniform speed.

so on. Thus, after t seconds it will have covered a distance $v \times t$. Thus we get d, the distance travelled as equal to the product of the constant speed and time.

We. therefore, write

$$d = v \times t$$

Using this equation, we can also get the distance travelled with the help of a graph as shown in figure 5- 10(a). The distance travelled will be equal to ($v \times t$) which is numerically equal to the area of the rectangle OABC as in figure 5-10(b). Knowing the area, it is possible to determine the distance travelled in a given time.

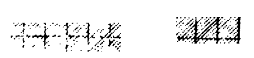


Fig. 5—10 (b)
The distance covered during the time interval OC is given by the shaded area OABC.

Activity

1. Plot a graph between speed and time in each of the exercises given earlier on pages 71 and 72. Compute the distance travelled in seven hours.
2. The above graphs have different scales along horizontal and vertical directions which differ not only numerically but also in the nature of units. What are these scales and units ? What is the unit of area of rectangle OABC in figure 5-10 (b) ?

Trolley Experiment

Let us do a simple experiment to demonstrate motion with constant speed. We use a four-wheeled trolley and a glass bottle as shown in figure 5-11. The bottle has a narrow opening near its bottom and through this opening passes a small capillary tube with a stopcock. The bottle is filled with coloured water. This is easily done by adding a few drops of ink to the water. With the help of

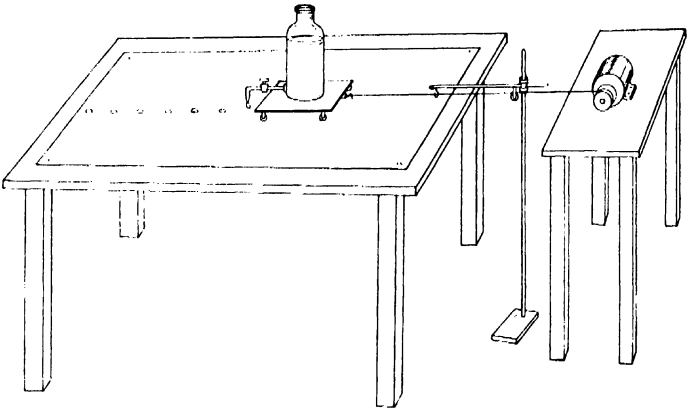


Fig. 5—11
A trolley experiment to demonstrate a uniform motion

a stopcock the flow of water can be adjusted drop by drop. Start the stopclock with the fall of a drop. Begin counting when the next drop falls and stop the clock with the fall of the hundreth drop. From the total time, we can find the time taken between the fall of two consecutive drops. Now, tie a light thread to the trolley, and pass the other end of this thread over an axle of a small motor kept about 1 m. from the table. With the bottle kept on the trolley switch on the motor. The trolley will start moving leaving behind a trail of drops. For recording the observations, a white sheet of paper is kept on the table below the trolley. One typical set of readings is given in figure 5-12 and in Table 5-1 (*a*), (*b*).

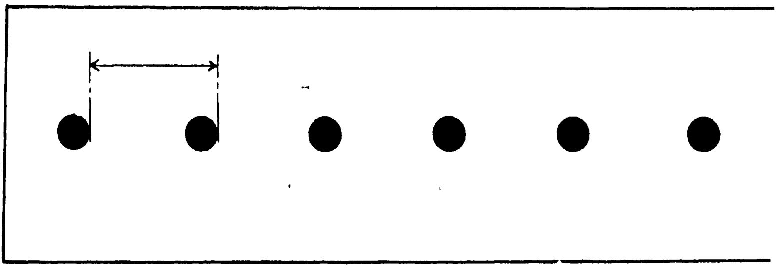


Fig. 5—12
A trail of water-drops left by a trolley moving with a uniform speed

TABLE 5-1 (*a*)

No. of observations	*Time-interval for 100 drops*
1	734 sec
2	736 sec
3	736 sec
Average interval for 100 drops	736 sec*
Average time interval for I drop (between the two consecutive drops)	7.36 sec

TABLE 5-1 (*b*)

No. of drops	*Distance from the starting point O in cm*
1	2.0
2	4.0
3	5.9
4	7.9
5	9.8
6	11.8
7	13.8
8	15.7
9	17.8
10	19.8

Now let us plot this motion. Take a graph paper and plot the distance travelled along the vertical axis and the time taken to travel it along the horizontal axis. In the first 7.36 sec, the trolley moves a distance of 2.0 cm.

This is represeuted by the point A in figure 5-13. In the second interval of 7.36 sec, the trolley moves a distance of 2 cm i.e. in 14.72 sec, it has moved a distance of 4.0 cm. In 22.28 sec, the distance covered is 5.9 cm. This is represented by the point C. We thus plot all the readings. Draw a straight line passing through the largest number of points. May be, one or two points are slightly below or

*From the table I (*a*), we find that the average time interval for 100 drops is $\frac{735+635+736}{300}$ or 735.666 sec. Since the minium time interval measured with the stop clock used in the experiment was 1 second, we have to round off the average value to the nearest second (*i.e.* a fraction of the second should not be retained in the value). Hence we round off the above figure to 736. In writing the average value for one drop, we will retain (as a rough rule) as many figures (disregarding the position of decimal) as there are in the original observed value which is three figures in our case.. Hence we write the average value for one drop as 7.36 sec.

above the straight line. We take it that the motion of the trolley is described by the straight line.

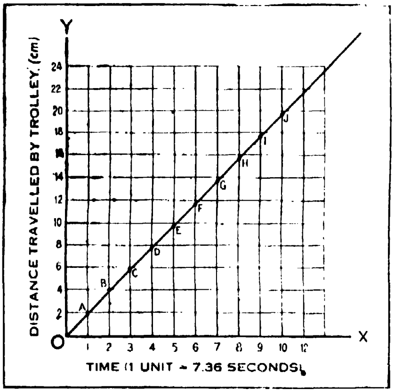


Fig. 5—13
Distance-Time graph for a trolley moving with a uniform speed

We can also plot a speed-time graph from these observations. In the first interval the speed of the trolley is 2.7 mm/sec. In the second interval is 2.7 mm/sec. In the third interval it is 2.6 mm/sec. Similarly the speed in other intervals of time can be calculated. We find that the trolley moves with a uniform speed of 2.7 mm/sec. The slight discrepancy in the speed is really due to errors in the measurement of length and time. Plotting these observations on the speed-time graph, we draw a graph as shown in figure 5-14.

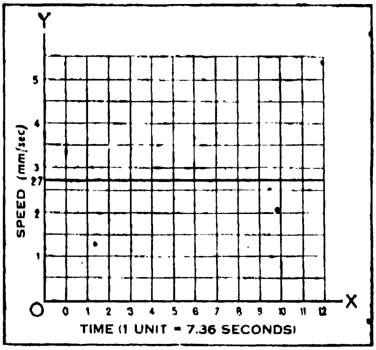


Fig. 5—14
Speed-Time graph for the trolley moving with a uniform speed

Let us do another experiment. Take a narrow tube about a metre long closed at one end. Cut a narrow strip from a centimetre graph paper and paste it along the entire length of the tube. Leave some portion from the open end and make graduations on the paper from say 0 to 75 cm. Fill this tube with mobil oil, Til oil or groundnut oil and fix it in a clamp such that it makes a small angle to the horizontal as shown in figure 5-15. Take a small steel ball

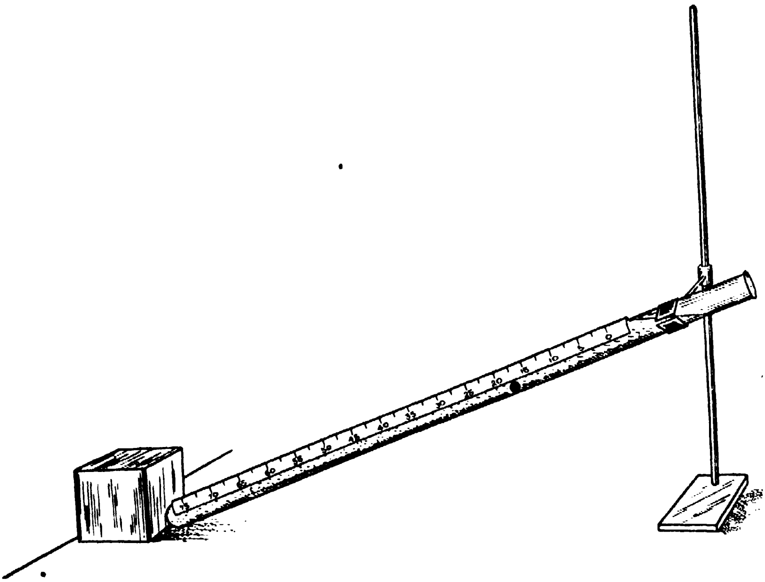


Fig. 5—15
An experiment showing uniform motion

and insert it in the tube from the open end and see that it moves smoothly inside the tube upto the closed end. With the help of a magnet remove this ball from within the tube. Take a stop watch and insert the ball again from the open end. The moment ball passes the zero mark, press the button of your stop watch and note the time as the ball crosses successive 5 cm marks. In one such typical experiment using a glass tube of 4 mm internal diameter, filled with mobil oil and inclined at an angle of 25° to the horizontal, following observations were recorded. The steel ball had a diameter of 2.6 mm. One such tube and the ball has been supplied in the kit.

Distance travelled by the the ball in cm inside the tube filled with mobil oil and inclined at an angle of 25° to the horizontal	*Time taken in seconds*
0	
5	10
10	20
15	31
20	42
25	53
30	64
35	76
40	87
45	99
50	111
55	123
60	135
65	148
70	160
75	174

(a) Plot the distance-time and speed-time graph for the motion of the ball in the tube.

(b) From the distance-time graph find the time required for the ball to move a distance of 28 cms.

(c) From the distance-time graph find the distance travelled by the ball in 60 seeonds.

(d) From the speed-time graph, determine the distance travelled by the ball in 60 seconds.

(e) Change the inclination of the tube to the horizontal and study the motion of the ball in each case. Plot the distance time and the speed time graphs in each case. Does the speed of the ball change with the inclination of the tube?

Activity

6. From the distance-time graph in figure 5-13,
   (a) find out the time taken for the trolley to cover a distance of 15 cm.
   (b) find the distance travelled in 120.40 sec.

2. From the speed time curve, find the distance travelled by the trolley in 110.40 sec. Compare your answer with that obtained from the earlier example.

3. In another experiment with the trolley, following observations were recorded.

Numberof drops	*Distance from the starting point*	*Average time-interval between consecutive drops*
1	2.6 cm	
2	5.2 ,,	
3	7.8 ,,	
4	10.5 ,,	
5	13:2 ,,	
6	15.7 ,,	
7	18.5 ,,	
8	21.2 ,,	
9	23.7 ,,	
10	26.3 ,,	8.20 sec.

(a) Plot the distance-time and speed-time graph for the above motion.

(b) From the distance-time graph find the time required for the trolley to move a distance of 20 cm.

(c) From the distance-time graph find the distance travelled by trolley in 41 sec.

(d) From the speed-time graph, determine the distance travelled by trolley in 41 sec.

Velocity

In the above discussion we have overlooked the direction in which the motion took place. As in the case of displacement, if we associate direction with the speed of the body, we have a new quantity called *Velocity* which not only tells us how fast the object is moving but also the direction in which it is moving. If we are told that a car is moving with the speed of 40 km per hour, we will naturally ask in which direction the car is moving because we do not fully know the motion of a car unless we know the direction of its motion. If the car is moving at the speed of 40 km per hour due north, we will say that the car has a velocity of 40 km per hour north. As you will have noticed, the speed of the car in a definite direction gives its velocity. Velocity like displacement, is a vector quantity. In order to designate the velocity of a body properly we have to be careful about the way we write it. We always draw an arrowhead to indicate the direction of motion. Let us take concrete examples. First take the case of two cars moving with equal speeds of 40 km per hour in opposite directions as shown in figure 5-16 (a). Are their velocities same? Now take another case. The two cars are moving with equal speeds of 40 km/hour along east and north respectively as shown in figure 5-16 (b). You will realise that although their speeds are equal, their velocities are different.

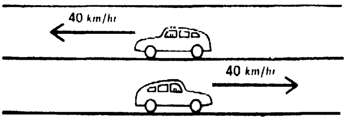


Fig. 5—16 (a)

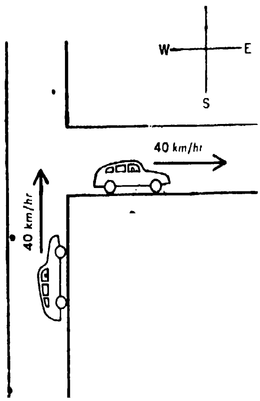


Fig. 5—16 (b)

Two cars moving with equal speed but with different velocities

Question

1. *Two cars are moving with the speeds 40km per hour and 50 km per hour respectively along north. Are they moving with equal velocities ?*
2. *A cyclist starting from O moves north with a velocity of 30 km per hour, for one hour. He then turns towards the east ana moves with a velocity of 30 km per hour for 2 hours. Find out the displacement.*

5 5 Non uniform motion

In all the above examples, we had a body moving with constant speed. But in fact it is very difficult to have bodies moving with constant speeds. Even a man walking along a road often changes his speed depending upon whether the road is free or whether a truck is coming along or even whether he is tired or fresh*. If you have a car ride sitting next to the driver, you will notice that the speed of the car changes during the journey. When the driver presses the accelerators the car picks up speed and moves faster. On the other hand, when he puts on the brakes, the car slows down and its speed decreases. Thus in practice we have to deal with situations in which the speed of a body changes continuously during motion. Let us take as an example, the motion of a cyclist with varying speed. His motion in one typical case has been tabulated as under :

TABLE 5-2

No.	*Duration of time-interval*	*Speed during the interval*	*Distance travelled*
1	first 10 minutes	160 m/minutes	1,600 m
2	next 15 minutes	200 m/minutes	3,000 m
3	next 12 minutes	120 m/minutes	1,440 m
4	next 20 minutes	250 m/minutes	5,000 m

You can graphically plot this motion by plotting the distance travelled against the time taken to travel it. You will get a graph

*A cyclist, too, changes his speed.

as shown in figure 5-17. This graph is not a straight line; this again shows that during motion, speed changes with time. You can also plot another graph of speed against time. Thus, you will get a curve as show in figure 5-18. The graph immediately enables us to see as to when the cyclist was moving fast and when he was moving slow. Can the graph tell us how far the cyclist goes in each time interval ? During any one of the four intervals the cyclist travels a distance with uniform speed given by equation.

$$v = d/t$$

$$\text{and} \quad d = v \times t$$

In any given time-interval, say CF, the height of the line DE above the horizontal axis tells us the speed during this interval. The product

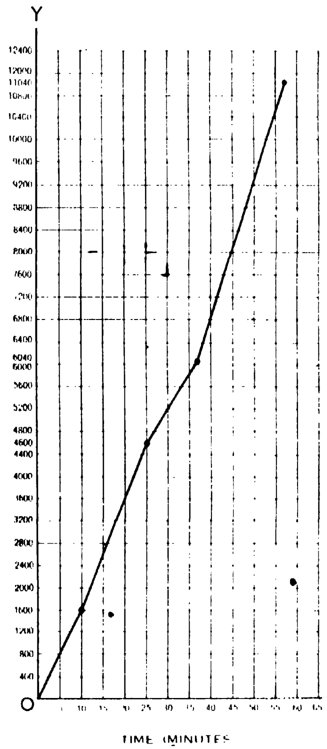


Fig. 5—17

of the height CD and the base CF of the rectangle CDEF is equal to the product of speed and the time-interval during which the cyclist moves with this speed. Using the above relation, we note that this product will be equal to the distance travelled by the cyclist in the time interval represented by CF in figure 5-18. In other words, the area of the rectangle constructed on any given time interval on the graph of figure 5-18 will give the distance covered by the cyclist in that time-interval. Thus, in the first time-interval OC, the distance travelled would be equal to area OABC shown shaded in figure 5-18. In the second interval the distance travelled would be the area of the rectangle CDEF and so on. Thus we see that by adding all these areas, we can know the distance travelled up to the end of the fourth interval. In determining the area it is necessary to be careful about the units in which you measure the time and the speed, and the scale you have used to plot the graph. In figure 5-18, 1 cm

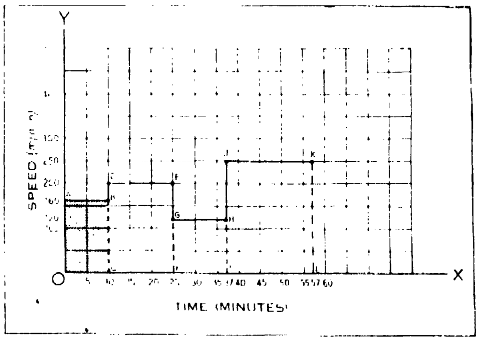


Fig. 5—18

Speed-Time graph representing the motion of a cyclist. Shaded area OABC gives the distance covered in time OC.

along the vertical axis represents 100 m/min whereas 8 cm along the horizontal axis is equal to ten minutes. The length of CD is 2 cm which represents 2×100 or 200 m/min. On the other hand, the length CF is equal to 1.5 cm which represents 15 minutes. Hence the area of rectangle CDEF is equal to 200 m/min $\times$ 15 min which is equal to 3000 m.

Activity

A car travels at varying speeds such that during the first five minutes, its speed is 10 km/h. during the second five minutes its speed is 20km/h; during the third five minutes it speed is 30 km/h; during the next forty-five minutes its speed is 40 km/h and during the last ten minutes its speed is 5 km/h. Plot a speed-time graph for this trip and find out.

1. How far does the car travel in the first thirty minutes, in the next thirty minutes and in the last ten minutes ?
2. What is the total distance of the trip ?

Let us discuss a few more examples of non-uniform motion. Throw a ball high up in air. What do you observe ? Why does the

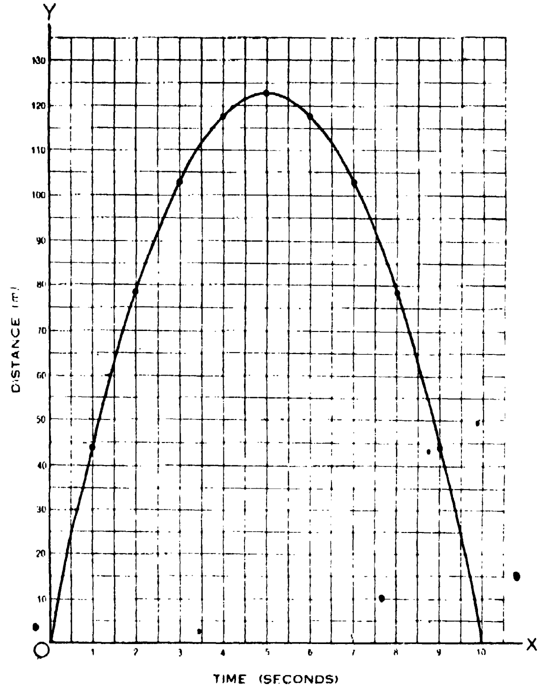


Fig. 5—19

Distance-Time graph for a ball thrown vertically up with a velocity of 49 m/sec.

ball fall down on the earth and not keep going up ? Have you ever wondered why the ball comes back ? Now look at the figure 5-19 It represents the position of a ball that is thrown up with a velocity of 49.0 m/sec. In this graph the vertical axis represents the height of the ball at any instant of time. You will notice that in this graph the speed is continuously changing—there is no part of the curve which is a straight line and we cannot say that the motion during that time is uniform. The motion of a ball thrown up in the air is thus an example of a non-uniform motion. Roll the ball on the ground. What heppens ? Does it keep rolling for ever ? What type of motion is this ?

The trolley experiment which we have described earlier can be suitably modified to demonstrate non-uniform motion. To the trolley we tie a light thread and we pass this thread over a pully clamped near the edge of the table. To this end of the thread we attach a pan. The arrangement is shown in figure 5-20. We now put a few

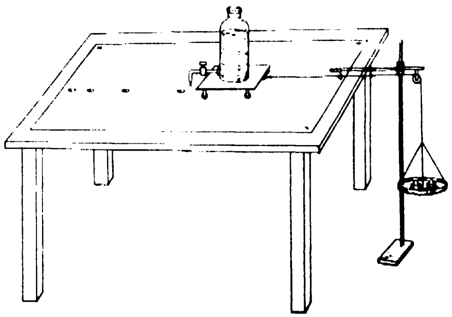


Fig. 5—20
The trolley experiment to demonstrate non-uniform motion

weights on the pan so that the trolley just begins to move. The drops are recorded on a white sheet of paper kept below the trolley. A typical set of observations is shown in figure 5-21 and Table 5-3.

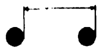


Fig. 5—21
trail of water-drops left behind by a trolley in non-uniform motion

TABLES 5-3 (*a*) TABLE 5-3 (*b*)

No. of observation	*Time interval for 100 drops*	*Average time interval for a single drop*	*Number of drops*	*Distance from the starting point O*
1	60		1	2.2 cm
2	60		2	6.7 ,,
3	61		3	13.4 ,,
Average time		0.60 sec	4	22.4 ,,
Interval for	60 sec		5	33.8 ,,
100 drops			6	47.4 ,,
			7	63.0 ,,

From the above tables, we find that the time-interval between consecutive drops is 0.60 seconds, and the distance between these marks is 2.2 cm, 4.5 c.m. 6.7 cm, 9.0 cm, 11.4 cm, 13.6 cm 15.6 cm, respectively. From these readings we construct a distance-time graph.

The graph is shown in figure 5-22 and it demonstrates that the motion of the trolley is a non-uniform motion.

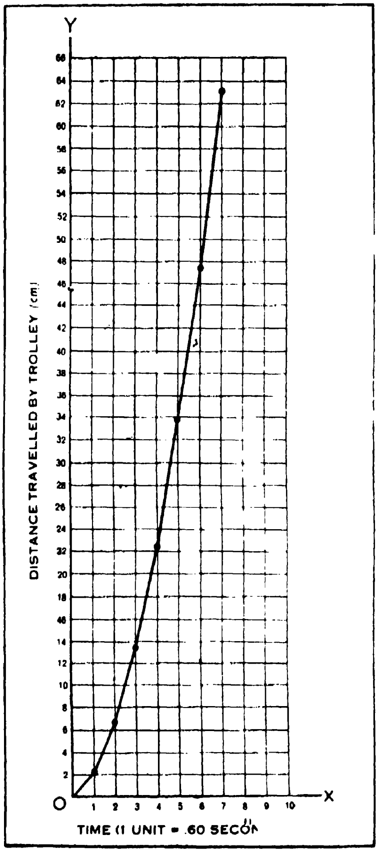


Fig. 5—22

Distance-Time graph showing a non-uniform motion of a trolley

Activity

In an experiment on accelerated motion using a trolley, following data were recorded :

No. of drops	*Distance from the Starting point*	*Average time interval between consecutive drops*
1	1.6 cm	
2	4.9 cm	
3	9.5 cm	
4	16.1 cm	0.30 sec
5	24.3 cm	
6	34.8 cm	
7	46.5 cm	

1. Plot the distance-time gragh for the above motion.
2. Change the weights on the pan and repeat your experiment. What do you find ?

You will learn more about non-uniform motion next year. In nature we find bodies of various shape and size moving. In most cases they have non-uniform motion. The question that may perhaps bother you is "what causes motion?" This is a basic question. We will examine this question in some detail next year.

CHAPTER 6

Forces

6–1 Introduction

As the story goes, Sir Isaac Newton, one of the greatest physicists, was relaxing one day in his orchard, when he saw an apple falling from a tree. This observation set him thinking as to why the apple fell *down*. Indeed, he began to enquire why the apple did not go up or sideways. This may appear very strange to you and you will perhaps say that when an apple becomes ripe enough, it should necessarily, fall down from the tree. The possibility of an apple going up will, perhaps, not even strike most of us. Newton considered all the possibilities and, from this simple obsesvation concluded that the fall of the apple must be due to the pull of the earth on the apple. If you take a ball in your hand and let go, you know that the ball falls down. The fall of the ball, like the fall of an apple, is due to the earth's pull. The earth pulls the ball and, therefore, it falls down. If you jump up in the air, you also come down. You are similarly pulled by the earth. You can yourselves find various other examples that demonstrate the pull of the earth on various bodies. Thus you can see that the earth pulls all these bodies towards itself, that is, this pull is universal. The moon is pulled by the earth ; a flying aeroplane is pulled by the earth ; a tree on the top of a mountain is pulled by the earth so also is the water in a waterfall ; and so on. This pull is called the pull due to gravity or the force of earth's attraction. Later you will learn that the pull exerted by the earth is not the peculier property of the earth. You will see that every body pulls every other body towards itself. Thus two paper weights placed on the table also pull each other. If you do not see them moving towards each other, it is because the force

between them is extremely small and there is another force opposing this pull, balancing the force of attraction. You will learn about this force later. Let us now consider a few consequences of the earth's pull.

6 2 The pull due to earth

You know that the earth is almost spherical in shape. On a small globe representing the earth, let us think of a person standing in a place marked A in the northern hemisphere. His position on the globe will be as shown in figure 6-1. Can you imagine how a

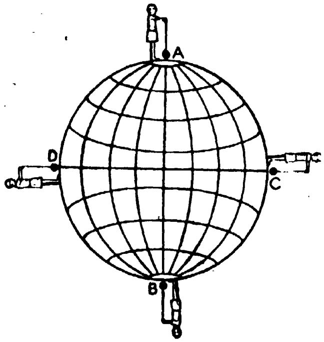


Fig. 6—1

person will stand in a place B diametrically opposite to A ? Will the head or the feet of this person be towards the feet of the person standing in A ? Of course, the person standing in B will have his feet on the ground, as you can see in figure 6-1. But doesn't this figure appear very strange ? Aren't you surprised that the man in B does not fall off the earth ? Can you explain why he does not fall ? You might as well wonder why the persons in places C and D do not fall off the earth. And now, instead of considering how a person stands, we may consider how a small bob of iron suspended with a piece of thread will hang at various places on this globe. Will it hang vertically pointing towards the centre of the earth at each place ? If you imagine various such bobs suspended at different places on the earth, will all these point towards the centre of the earth ? From the above analysis you see that a bob suspended at a given place hangs *vertically at that place.* Have you seen the use of such a bob ? You have perhaps seen a mason using a similar bob to find out whether the wall he is making is exactly vertical or not (figure 6-2). A bob like the one used by a mason is called the *plumb line.*

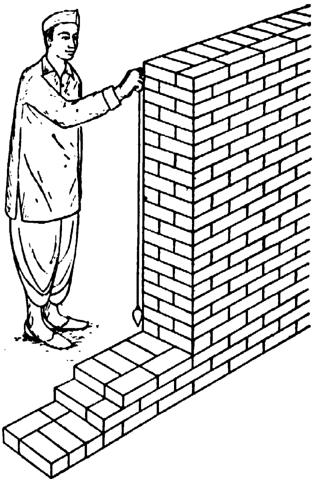


Fig. 6—2 A mason using a plumb line

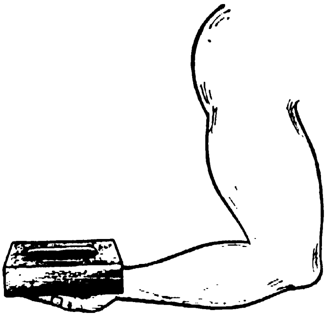


Fig. 6—3

Take a tennis ball in your hand. If you release it, the ball will fall down. Now take a brick and release it. What do you find ? This also falls down in the same way as the tennis ball fell. Hold this brick on the palm of your hand as shown in figure 6-3. Can you hold it for long ? Do you feel that the muscles of your arm are strained ? Does it mean that you are preventing the brick from falling down and in doing so you are applying a certain muscular force ? By applying this force you are, in fact, balancing the earth's pull. If you apply greater force than that required to hold the brick steady, you will find yourself lifting the brick. This will become more clear from the following experiment.

Muscular Pulls

Take a bucket and hold it in your hand as shown in figure 6-4. Let go the bucket. What happens ? Again hold the bucket in your hand as shown in figure 6-4. Are you applying any force ?

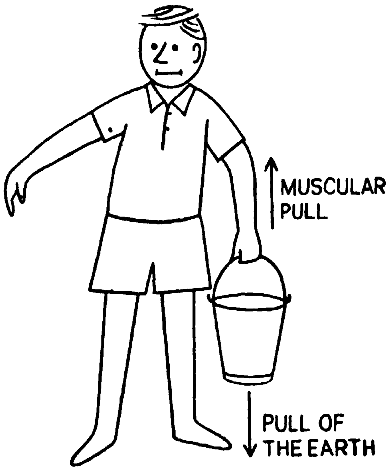


Fig. 6—4

Yes, you are pulling the bucket up to balance the downward pull of the earth on the bucket. If you pull with a greater force, the bucket will come up. In this example, the force that you have applied is that of a muscular pull. Now fill the bucket with water. Can you lift the bucket full of water with the same force as before ? May be the bucket is so heavy that you can't lift it off the ground. What does this mean ? Does it mean that your pull is less than the earth's pull and cannot balance it ?

Have you seen a tug-of-war ? If you haven't you can see one shown in figure 6-5. Each party tries to pull the rope towards itself. When the two pulls are equal the rope does not move and

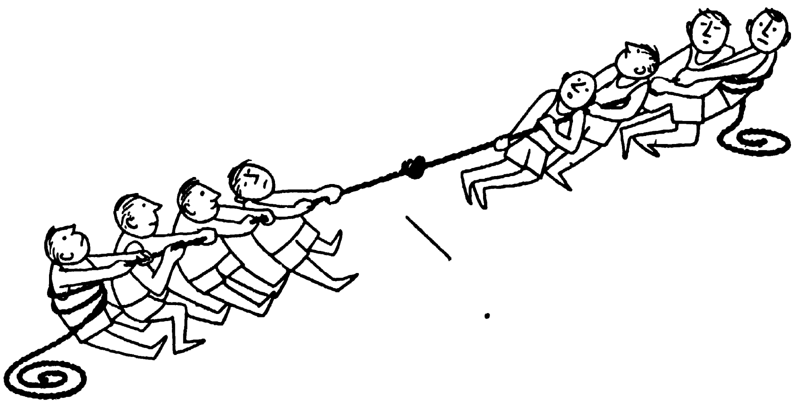


Fig. 6—5

the central mark does not shift. However, when the pull exerted by one party is greater than the pull exerted by the other, the central mark moves towards the side which exerts a great pull, and they say that the party to whose side the central mark moved has won the tug of war. In the example of bucket given above, a similar tug of war is going on. You are pulling the bucket up whereas the earth is pulling the bucket down. When the bucket is steady, neither going up nor going down, the two pulls are exactly equal. When the bucket is full of water and you have lifted it, who has won the tug of war—you or the earth ?

Take the case of a pendulum. Is the earth pulling the bob down ? If so, why does the bob not fall own ? Is the string pulling the bob up ? You will perhaps be able to answer this question after doing following experiments with a rubber band and a spring.

Elastic pulls in rubber and in springs

Take a rubber band. It has certain length. You can measure this length. Take the two ends of the rubber band in your two hands and pull it as shown in figure 6-6. What happens to the length of the rubber band ? Now suspend the rubber band from a stand and tie a small pan to it as shown in figure 6-7. Put a marble in the

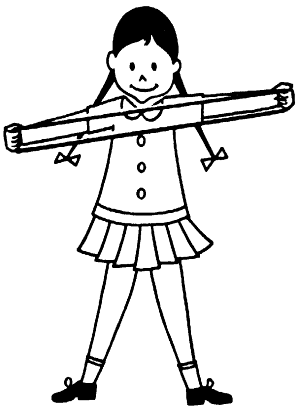


Fig. 6—6
A girl pulling a rubber hand.

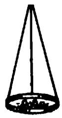


Fig. 6—7
The earth's pull on the marble stretches the rubber band.

pan. Does the length of the rubber band increase or decrease ? You will find that after putting the marble in the pan the rubber band gets stretched in the same way it got stretched when you pulled both its ends with your hands. Why does it get stretched when you put a marble in the pan ? Is it due to the earth's pull on the marble ?

Note the extension (increase in the length) in the rubber band due to one marble in the pan. Next put two marbles in the pan. Does the length increase still further ? If so, why ? Is it because the earth's pull on the loaded pan is now greater than it was before ? Find out the increase in the length by successively adding ten marbles of the same size. Plot a graph between the increase in length and the number of marbles. One such typical set of readings is given in Table 6-1, and the corresponding graph is shown in figure 6-8. This shows that the increase in length of the rubber band is the

TABLE 6-1

No. of marbles	*Length of the rubber band*	*Increase in the length of the rubber band*
0	5.5 cm	
1	5.6 „	1 mm
2	5.7 „	2 „
3	5.8 „	3 „
4	5.9 „	4 „
5	6.0 „	5 „
6	6.2 „	6 „
7	6.2 „	7 „
8	6.3 „	8 „
9	6.4 „	9 „
10	6.5 „	10 „

same for each marble, which means that if we add say five marbles to the pan, the increase in length will be five times the increase in length for one marble. This can be expressed by saying that the increase in length of the rubber is *proportional* to the number of marbles in the pan. This also means that the increase in length is *proportional* to the earth's pull on the marbles.

When the marble is in the pan the earth is pulling the marble down. We find that the rubber band extends by a definite amount. The pull of the earth is always acting upon the marble, then why

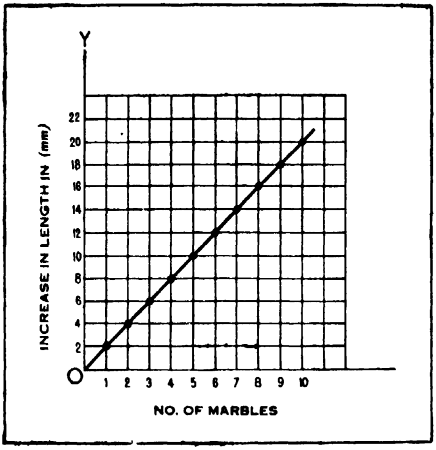


Fig. 6 –8
A graph showing increase in length of the rubber band against the number of marbles in the pan.

does the rubber band not extend futher ? Does it not suggest that some other force must have developed in the rubber band which opposes the pull of the earth on the marble and balances it ? To find this out, let us do the following experiment. Hold the rubber band in your hand and pull it. Its length increases. What happens if you release your pull ? Does the rubber band attain its original length ? If so, we have got the answer to the above question. While you were pulling the rubber band a certain opposing force was created in it ; this force made it go back towards is original length. In the same way, when a marble is put on the pan, the earth's pull on the marble causes an extension in the rubber band. But in doing so an opposite force is created in the band making it go back to its original length. This opposing force in the band is proportional to the extension. Thus as soon as the marble is kept in the pan, the earth's pull is greater than the opposing force. As the extension increases so also does the opposing force and a stage is reached when the earth's pull on the marble is equal to the opposite pull in the rubber band. When this stage is reached no further extension takes place. What happens if you pull the rubber band too much ? Does it regain its original length after the release of such a large pull ? Could one pull a rubber band indefinitely ?

Take a spring and suspend it from a stand as shown in figure 6-9. Attach a pan to the spring and note the position of the pointer on the scale as shown in figure 6-9. Put a small steel ball in the pan

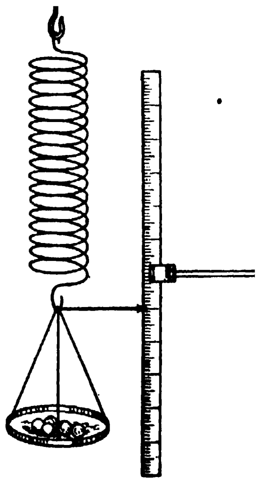


Fig. 6—9
The earth's pull on the steel balls stretches the spring.

and note the position of the pointer again. You will find that the length of the spring has increased. Put another steel ball of equal size in the pan. The length of the spring increases further. Here again, you can plot a graph between the increase in length of the spring and the number of steel spheres. A typical set of readings is given in Table 6-2 and the corresponding graph is shown in figure 6-10. Can yon use the spring to measure the earth's pull on various bodies ? We will discuss this in the next chapter.

TABLE 6—2

No. of steel spheres	*Length of the the spring*	*Increase in the length of the spring*
0	4.0 cm	
1	4.1 ,,	2 mm
2	4.2 ,,	4 ,,
3	4.3 ,,	6 ,,
4	4.4 ,,	8 ,,
5	4.5 ,,	10 ,,
6	4.6 ,,	12 ,,
7	4.7 ,,	14 ,,
8	4.8 ,,	16 ,,
9	4.9 ,,	18 ,,
10	5.0 ,,	20 ,,

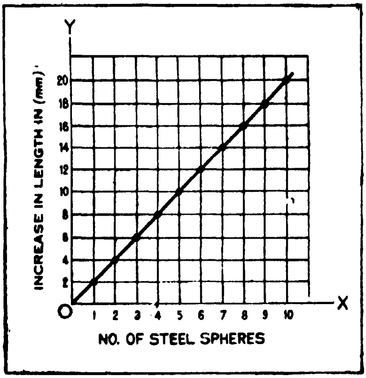


Fig. 6—10
A graph showing the increase in length of spring against the number of steel spheres in the pan.

In this example, what is it that prevents the spheres from falling down ? Is it the force created in the spring due to extension which tries to put the spheres up and balances the earth's pull ? As in the case of the rubber band, we see that we can create an opposing pull in the spring by increasing its length. A similar pull can be created by compressing the spring. Let us do the following experiment.

Take a spring, as shown in figure 6-11 and measure its length. Place a steel ball on the platform attached to the spring at its top.

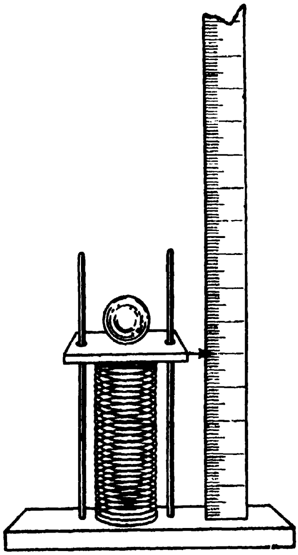


Fig. 6—11 compression of a spring by a steel ball

Find the new length of the spring. Has it increased or decreased ? Put another sphere on the platform. What do you find ? Does the length decrease further ? Is the earth pulling these spheres down ? What prevents the spheres from falling to the ground ? Is the compressed spring trying to push the sphere up to balance the earth's pull ? How is this push created ? Is it due to the change in the length of the spring ? Can you use this method also to measure the magnitude of the earth's pull on a body ?

Push and pull in spring can be demonstrated by yet another experiment. Take a spring as shown in figure 6-12. Put a steel sphere in front of the spring as shown in the figure. Press this sphere with your hand. What happens to the length of the spring ? In this example you are trying to push the sphere towards A. What is it that tries to balance your push ? In any particular position, the sphere is pressed on to the spring and the spring is pushing the sphere out. The two pushes balance each other. What happens if you release you push ? Does it show that the spring was pushing the ball out ?

Activity

A spring can be used to measure muscular pull. One such apparatus is shown in figure 6-13. Hold it in your hands

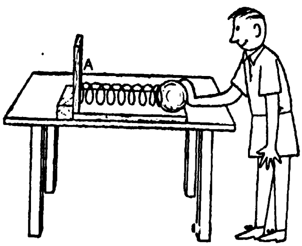


Fig. 6—12 showing push and pull with the help of a spring

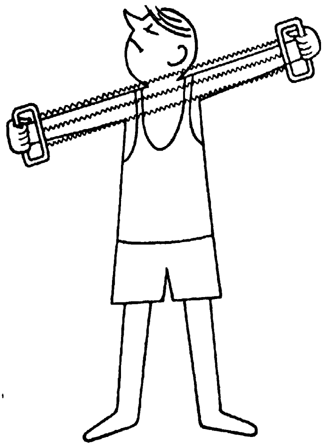


Fig. 6—13 A boy stretching a chest expander

as shown and stretch the spring. What do you find ? How much can you stretch ? Compare your muscular pull with those of your friend's.

6—3 Frictional Force

Take a big table. Give it a small push. Does it slide ? If not, increase your push. Do you succeed in pushing the table ? May be you don't. Try to pull the table. What do you experience ? Why do you find it difficult to slide the table over the floor ? Is it that there is some force opposing the force of your pull or push ? Is the earth's pull on the table the opposing force ? But the earth's force of attraction on the table is acting vertically downwards whereas your pull is acting in the horizontal direction as shown in figure 6-14. Clearly, therefore, the earth's pull is not the opposing force

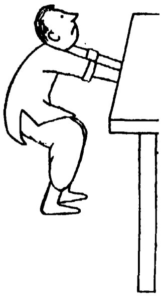


Fig. 6—14
A man pulling a table against friction.

because it is not acting in the direction opposite to the force of your pull. The force which opposes your pull must be acting in the horizontal plane but in a direction opposite to that of your pull. There is thus a tug-of-war between the force of your pull and the opposing force. If your pull is smaller than the opposing force, the table will not slide at all. But when a sufficiently large push or a pull is exerted so as to balance the opposing force, the table will slide. This opposing force is called the *frictional force*. The frictional force invariably comes into play whenever one surface slides over another. From the following experiments we can learn more about the force resulting from the friction between two surfaces.

Take a wooden block and keep it on the table as shown in figure 6-15. Tie a thread to the block and fasten its other end to

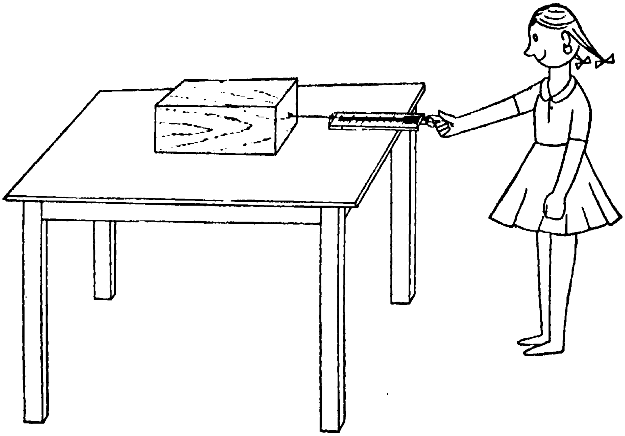


Fig. 6—15
Measuring the force of friction between the wooden block and the top of the table with the help of spring.

a spring. Pull the spring as shown in the figure. What do you observe ? Does the block slide ? If it does not, pull the spring more till the block begins to slide. Note the extension in the spring. Why did the block slide ? Did the spring give the pull necessary to balance the force of friction between the block and the table top ? Repeat the experiment a number of times. Each time note the reading of the pointer on the spring at which the block starts moving. Next, note the reading while the block is moving slowly. Repeat this several times. Record your readings in the following table.

TABLE 6-3

	Extension in the spring when the block starts moving	*Extension in the spring while the block is moving slowly*
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Is there any difference between the two readings ? You may, perhaps, conclude that the force required to start the block moving is greater than the force required to keep it moving. How will you explain this ? You may say that there are different forms of friction. In the above experiment the force required to start the block moving gives us the measure of the *starting friction* and the force required to keep the block moving gives us the measure of *sliding friction.* When a cart or a trolley is moving on the ground, another kind of friction, called *rolling friction*, comes into play. You will learn more about this friction later.

In the experiment described above, remove the spring. Tie a thread to the block and pass it over a pulley fastened at the edge of the table as shown in figure 6-16. To the other end of the thread tie a small pan. Put a few marbles in the pan. Does the block slide ? If not, go on putting more marbles in the pan till the block just begins to slide. Find the number of marbles. How do you compare this experiment with the above experiments ? What made the block slide ? Is it the earth's pull on the marbles ? Can you measure the force of friction between the two surfaces in terms of the earth's pull on a body ? Find the number of marbles in the pan required to slide the block. What does this number tell you ?

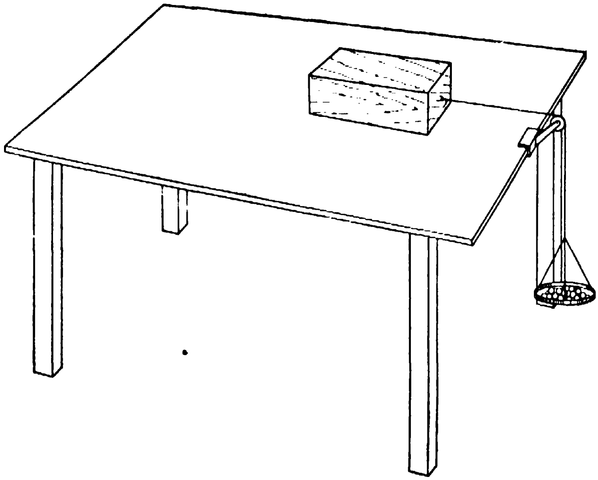


Fig. 6—16

An experiment to measure the force of friction betwean the block and table top in terms of the earth's pull on the marbles

Question

A trolley is a familiar example of how a huge load is carried from one place to another (figure 6-17). What will happen if the wheels are removed ?

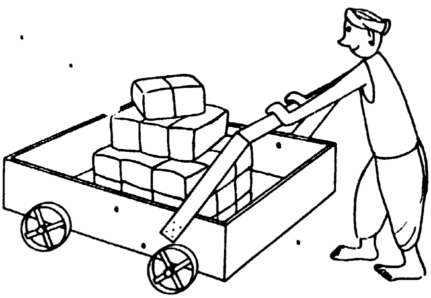


Fig. 6—17

Activity

When you try to push a trunk you may perhaps find that a large push is required to slide it. If you put iron rollers below the trunk, as shown in figure 6-18, and push the trunk again, will the push required be more or less ?

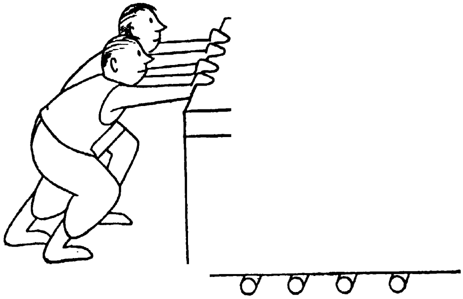


Fig. 6—18

Frictional force which is created between two surfaces in contact, plays a great part in the motion of objects. We have considered some familiar examples of force which is nothing but a push or pull. When we apply a force to the chair we either push it or pull it. When we pull a rubber band or a spring, we create a force which pulls back the band or the spring to its original length. In some cases, however one can create a pull or push without intimate contact. Earth's pull is one such example. When a ball falls down due to the earth's pull there is no contact between the ball and the earth. We have a few more examples of pushes and pulls wherein there is no intimate contact. These are discussed below.

6 – 4 Magnetic and electric forces

Place a few iron nails on a table. Take a magnet in your hand and bring it close to the nails as shown in figure 6-19. What do you find ? Why are the nails pulled towards the magnet ? Is it because the magnet exerts some force on these nails ? Now bring an iron bar near the nails. Why are the nails not pulled towards the bar ? Try this with bars of other materials like copper or brass. Do they pull the iron nails ? You will see that it is only a magnet that can exert a force on the iron nails and pull them. This pull is, therefore, called the *magnetic force*. We will learn more about the magnetic force from the following experiments.

Take a wooden trolley and place it on a table. Keep a small block of iron on the trolley as shown in figure 6-20. Take a magnet and mark its ends as A and B. Bring the end A of the magnet close

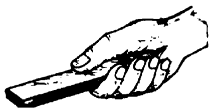


Fig. 6—19

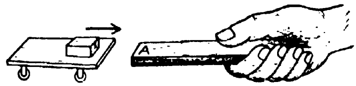


Fig. 6—20

to the trolley and see what happens. Why is the trolley pulled towards the magnet ? We will say that the magnetic force on the iron block pulled the trolley towards the magnet. Remove the magnet and bring its end B close to the trolley. Does the magnet pull the trolley again ? Is it that only the ends of a magnet exert pull on an iron block ? Repeat the above experiment by taking another magnet. Do you find again that both the ends of this magnet also pull the trolley ? Let us do some more experiments.

Activity

On the trolley, replace the iron block by blocks of wood, copper, glass, etc. Does the magnet pull them ? Later, you will learn why a magnet exerts pull only upon certain materials like iron or nickel but not on others like wood, copper or glass.

Take two magnets. With a piece of chalk mark them 1, 2 and mark their ends A, B and C, D. Place the magnet 1 on the trolley. Take magnet 2 in hand and bring it close to the trolley. Let the end C of magnet 2 be close to the end A of magnet 1 as shown in figure 6-21. What do you find ? Is the trolley pulled towards the magnet 2 or pushed away ? Remove the magnet away from the trolley. Now bring the end D of magnet 2 close to the end A of magnet 1. Do you find any difference in the behaviour of the trolley ? Is it not surprising ? Why do you find this difference ? We will see that if the end A of magnet 1 was pulled towards the end C of magnet 2, then the end A of magnet 1 was pushed away when the end D of magnet 2 was brought close. The force between A and C, and A and D is not of the same nature. Can you explain this strange behaviour ? You will say that the force between the two ends of magnets can be attractive as well as repulsive in nature. Let us confirm this further. Bring the end C of magnet 2 close to the end B of magnet 1 kept on the trolley. What do you find ? Remove magnet 2 away and now bring the end D close to the end B of magnet 1. Do you again find the difference in the behaviour of the trolley ?

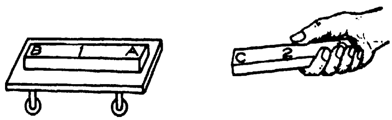


Fig. 6—21

This attractive as well as repulsive nature of a magnetic force can be demonstrated by yet another experiment. Take two disc magnets as shown in figure 6-22. Mark their faces as A, B and C, D. Take a glass cylinder so that these magnets can just slide in it. Push the first magnet inside the cylinder so that the face A is facing upwards. Now push the second magnet inside the cylinder, say, with its face C facing A. What do you find ? You might find the second magnet falling and resting on the first magnet. If so, take it out and again push it inside the cylinder but now with its face D towards A. What do you observe ? Figure 6-22 is a typical photograph of one such experiment. Does it not look surprising ? Why does the upper magnet float ? Why does not the upper magnet fall under the force of the earth's attraction ? Repeat the experiment with faces B and C and then with B and D facing each other. Explain your findings. With the help of these experiments, you will find that a magnetic force can indeed be attractive as well as repulsive. What is the nature of the earth's pull ? How does the earth's pull differ from a magnetic force ?

Fig. 6—22 A floating magnet

Electric Force

Take a glass rod and some tiny bits of paper. Lay the bits of paper on the table. Take a piece of silk and rub the glass rod with it. Bring the glass rod close to the paper bits. Do you find anything happening to the paper bits ? If so, why are the paper bits pulled towards the glass rod ? You may say that the glass rod exerted some force on the paper bits. Does the glass rod always pull small bits of paper ? Take another glass rod and bring it close to the bits of paper. What do you observe ? Are the paper bits pulled towards the glass rod ? No. So you have observed that a glass rod rubbed with a piece of silk pulls the paper bits whereas an ordinary glass rod which has not been rubbed with a piece of silk does not pull the paper bits. Why is this so ? What has the rubbing of the glass rod with a piece of silk to do with the force of attraction between the glass rod and the paper bits ? Is it only the glass rod rubbed with a piece of silk that pulls paper bits ? Rub articles like combs or pens, briskly on your clothing or on a piece of wool, silk,

* This experiment may not work during the rainy season.

nylon and bring them near the bits of paper. You will find here, too, that the paper bits are pulled towards the rubbed objects. Now take a metallic rod, say a copper rod, and rub it with a piece of silk. Bring the rod near the bits of paper. What do you observe ? Why are the bits of paper not attracted towards the copper rod ? Later on, you will learn that when objects like a glass rod, comb or pen, are rubbed they get an electric charge. These objects are then called *charged bodies*. The force which a charged body exerts is called the *electric force*. Is it that only the tiny bits of paper are pulled towards the charged bodies ? To find this, lay tiny bits of thread on the table. Rub the glass rod with silk and bring it close to the bits of thread. You will find that even these bits are pulled towards the glass rod.

Let us do some more experiments to learn about the electric force. Rub the glass rod with a piece of silk and bring it close to the paper bits. The paper bits cling to the glass rod. Watch these paper bits for some time. You may see some of these 'flying off' as if they are pushed away. Why does this happen ? Is it that these paper bits now experience a force of repulsion ? Is the electric force attractive as well as repulsive ? To understand this, let us do the following experiments.

Take two small pith balls (or small plastic balls or small pieces of cork) and tie them with a piece of thread. Suspend them close to each other from a stand as shown in figure 6-23. Take a glass rod and rub it with a piece of silk. Bring it close to the pith balls and touch both the balls with it, turn by turn. Repeat this a number of times. What happens to the pith balls ? Why are the pith balls pushed away from each other ? Is this because of the force of repulsion between the (charged) pith balls ? What happened when we touched the pith balls with the charged glass rod ? Did the pith balls get similar charge from the glass rod ? If this is so, we will say that the electric force between similarly charged pith balls is repulsive.

Next, take an ebonite rod and rub it with a piece of wool. Bring the ebonite rod close to one of the pith balls and touch it. Do it a number of times. In the same way, bring the charged glass rod near the other pith ball and touch it. Do this again a number of times. What do you observe in this experiment ? Why are the pith balls pulled towards each other ? Is this because of the force of attraction between the charged pith balls ? How is this experiment different from the previous experiment ? Are the pith balls

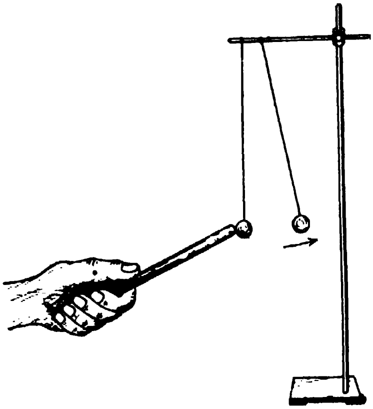


Fig. 6—23
A push between two similarly charged bodies.

in this experiment attracted towards each other because they have opposite charges ? Later on you will learn that the charge developed on a rubbed ebonite rod is not of the same kind as the charge developed on a rubbed glass rod.

Activity

1. Take a small plastic ring and keep it on a clean glass plate.Take a glass rod and rub it with a piece of silk. Bring the rod near the ring and touch it. Do it a number of times. Next rub the glass rod with the piece of silk and bring, it near the ring but do not touch it. You will find the ring moving away from the glass rod. Next, take an ebonite rod and rub it with the piece of wool. Bring it near the ring. What do you observe ? Explain your findings.
2. Take a balloon and blow some air inside it. Rub it briskly over your clothings and hold it against a wall.

Remove your hand. Does the balloon stick to the wall ? If so, how will you explain this ?

3. Take a watch glass and invert it on a table. Take a dry clean glass rod of say 100 cm. and balance it carefully on the watch glass. Rub another glass rod on silk cloth and bring it near one end of the balanced glass rod. What happens ? Next balance a charged glass rod and then bring a charged glass rod and a charged ebonite rod near it by turn. Record your observations.

From these experiments, you will see that similar to magnetic forces, force between charged bodies can be either a pull or a push.

We have seen some examples of forces. They can all be described in terms of a push or a pull. Earth always exerts a pull on all bodies. Magnetic and electric forces can be either pushes or pulls. In some cases, such as in the earth's pull on a body or magnetic forces between two magnets or electric forces between two charged bodies, we can have pushes or pulls without an intimate contact.

CHAPTER 7

Weight and Gravitational Mass

7–1 Introduction

In the study of Physics, we are really out to explore the nature of the physical world around us. In the process, we have learnt something about the measurement of length, area, volume and time. Combination of space and time gives motion and it is motion which gives a life like appearance to this world of ours. This must have of course raised several questions in your mind. What is it that moves? What causes motion? These are very important questions which we will discuss as we proceed. Let us take the first question : what is it that is in motion. The objects in motion in this physical world are matter of every kind, in a variety of forms and shapes. We have the sun and the stars, the earth itself with its soil, rock, air and sea, the living plants and animals and even all of us, in motion.

Let us look at these actors—matter in various forms and shapes. There are ants, crows, elephants, grain of wheat. peas, stones etc, etc. They exhibit such a wide variety. No two grains of wheat or rice are alike. Similarly no two stones are alike. As against the wide variety in matter, there seems to be some kind of sameness about time and space One metre is like any other metre. Similarly one second is like any other second. Indeed any length, be it a distance of a distant planet or the diameter of a small wire, can be compared with the metre. Similarly any time interval, howsoever small or large it may be, can be compared with a second. Naturally we might ask ourselves a question—can we find some sort of a universal measure for matter as we have for space and time ? Once we do this, then we will be able to compare a grain of sand with the moon, air in the cycle-tyre with a chapati.

Is there a measure for matter—not of this or that special feature, not of colour or texture or hardness, but of something common shared by all objects in this universe ? Let us look at some of the possibilities.

A brick contains a certain amount of matter. We expect two similar bricks together to contain twice as much matter as either one. However, no two bricks are exactly alike. Let us think of 25paise coins. They all seem alike. They all seem to have the same volume. It seems reasonable to suppose that the count of the number of 25 paise coins defines the quantity of matter in the coins. Of cource we could cut the coins in half and get a different count of the number of pieces without changing the amount of matter present. The volume occupied by the metal is not changed when we cut some of the pieces in half. It may, therefore, seem reasonable that volume is a better measure for matter than the count of pieces. This seems reasonable because all objects have volume. Let us look more closely whether volume occupied by a body can be used as a measure of the quantity of matter contained in it. A little thought will show that this is not a reliable measure. Take a cycle tube. Pump air in it. You can put a lot of air in the tube without appreciably changing its volume.

Take 200 ml of water in a measuring jar. Put a spoon full of water in it, note the change in the reading on the jar. You can find the volume of the spoonful of water. Now take a spoon full of sugar and put it in water. Stir the water well and measure the change in level. Is the change in level on addition of a spoonful of sugar and a spoonful of water the same ? Do you get the same rise in level? Think of a few more experiments to show that volume is not a good measure for the quantity of matter.

7—2 Weight

In the previous chapter we discussed about pushes and pulls and learnt that the earth pulls every other body towards itself. We can measure the magnitude of the earth's pull on bodies by using a rubber band or a spring. Indeed, when we take two bricks in two hands and feel them, we can say which has more matter. Let us find whether earth's pull on bodies is a good measure of the quantity of matter.

Take a spring and suspend it from a stand. Attach a small pan to the free end of the spring. Fix a scale behind the spring so that you can read the position of the pointer attached to the spring as shown in figure 7-1. Take number of marbles of the same size. Put one such glass marble in the pan and observe the

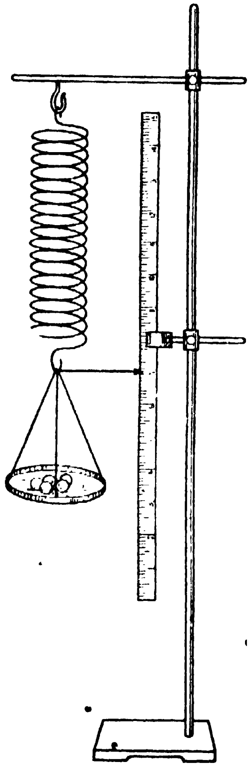


Fig. 7—1

Extension in the spring due to marbles in the pan.

position of the pointer on the scale. Put another marble and note the position of the pointer. Do it successively for ten marbles. Plot a graph between the increase in length of the spring and the number of marbles. A graph plotted in one such typical experiment is shown in figure 7-2. Now, in the empty pan, if you put, say, an ink pot and determine the extension, can you find out the pull of the earth on the ink pot in terms of the pull of the earth on the marble ?

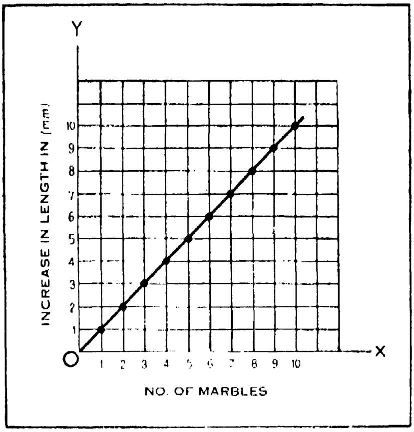


Fig. 7—2

Graph showing increase in length against number of marbles.

In one typical experiment it was found that the increase in length on putting the ink pot in the pan was 10 mm. From the graph you will find that the same extension is produced if ten marbles are put in the pan. Is it right to say that the earth's pull on the ink pot is equal to the earth's pull on ten marbles taken together ? Let us find out by doing the following experiment. Take the same spring and put ten marbles in the pan. Remove the marbles and keep them in a container. Next, put sugar in the pan so as to produce the same extension in the spring. Take sugar out and keep it in another container, Now, put small pebbles in the pan and obtain the same extension. Take out these pebbles and keep them in the third container. Repeat the same process with sand, wool and cotton. Now take another spring with a pointer and a scale. Put each of these substances in turn in the pan. What do you observe ? Is the extension in this spring due to all these substances the same ? If so, is this extension different from the extension observed in the previous spring ? You can in fact verify that whichever spring you take the extension produced by these substances will be the same, even though the extension produced by each changes from one spring to another What is common to all the substances that you have stored in the containers ? They have different volumes, different tastes, different colours, sizes and shapes and yet they have something in common. Each one produces an equal extension in the spring. Perhaps, you will answer this and say that the earth's pull on each of them is the same. *The pull of the earth on a body or the force of attraction due to the earth on the body is called the weight of the body.* We thus see that the weight of ten marbles is equal to the weight of the sugar in the second container, which, in turn, is equal to the weight of the pebbles in the third container, and so on. You will see that you can compare the weights of two bodies by comparing the earth's pull on these bodies with the help of a spring. Let us examine the possibility of using earth's pull on a body i.e. the weight of a body as a measure of matter in the body.

Take a spring and a scale. Suspend a metal block by a string and note the position of the pointer. Take a beaker full of water and gradually raise it so that the metal block is immersed in water as shown in figure 7-3. What do you find ? Is the extension of the spring more or less ? Is it correct to say that the weight of the metal block decreases when immersed in water ? We will not discuss here why the metal block loses weight on putting it in water. If you repeat the experiment with some other liquid you will find a different weight of the same metal block. Does the above experiment indiate that the weight of a body is not constant and is not a good measure of the matter in the body ?

To understand this further, consider the following experiment (although it cannot be done easily). Imagine that you have a very sensitive spring balance. Take a metal block and find out the extension of the spring due to it. Next take the same spring deep down in a mine. If you could do that you will find that the extension of the same spring due to the same metal block is different. If you were to repeat the same experiment at different parts of the globe, say at the North Pole, or in London, Delhi, Colombo or any other

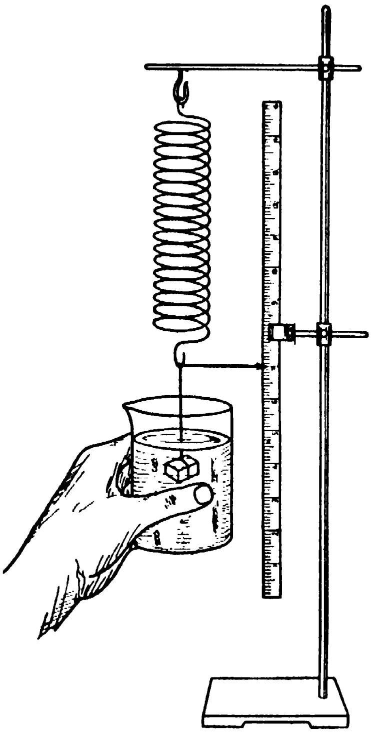


Fig. 7—3
The earth's pull on a block immersed in water.

place, you would again find that the extension produced in the spring due to the same metal block at these different places is slightly different. *This experiment will show that the weight of the same body is different at different places.** If, however, you repeat the experiment at a given place a number of times, the extension produced by the same same body in a given spring would always be the same. Again take the same spring and the metal block, and measure out

* It may be noted that the change in the weight of a body in various locations on the earth's surface is negligibly small. The following table gives the values of the weight of a kilogram at various places measured in relative units as measured by the extension in a given spring.

(*continued on next page*)

thequantity of sand which produces the same extension in the spring as the metal block. If you were to take these two things to different places on the globe you would find that at a given place on the globe they produce the same extension in the spring (but at different places this common extension will be different). From these experiments, we conclude :

1. The weight of a body changes from place to place.
2. If two bodies have equal weights at a given place then they will have equal weights at any other place.

You must have read in the newspapers that American astronaut Armstrong landed on the moon on 21st July 1969. Let us imagine that he carried with him a spring balance, a metal cube and a stone which produces the same extension in the spring as produced by the metal cube. Before his lift off on 16th July, he checked that the metal cube and the stone caused an equal extension in the spring. When Apollo-11 was orbiting round the earth he found that the extension caused by the metal cube as well as the stone was zero. On his landing on the moon, he found that although the extension produced by the metal block and the stone is the same, the extension in the spring on the moon was roughly 1/6th of the extension in the same spring on the earth. What do these observations indicate?

Place	*Weight of 1 kilogram as determined by the extension of a spring in relative units.*
North Pole	1.002
Madras	0.997
Algiers	0.9992
Greenwich	1.0005
Paris	1.0003
New York	0.9999
Leningrad	1.0013
Rome	0:9997
Hongkong	0.9982
Tokyo	0.9991
Melbourne	0.9993

Do these indicate that the earth's pull on the metal block and the stone is six times greater than the pull of the moon on these bodies ? Will Armstrong's weight on the moon as measured by a weighing machine be the same as on earth ?

Let us do some more experiments. Take 64 small cubes as shown in figure 7-4. Put all these cubes in the pan of the spring balance, as shown in the figure. Note the extension in the spring. This extension in the length of the spring is a measure of the weight

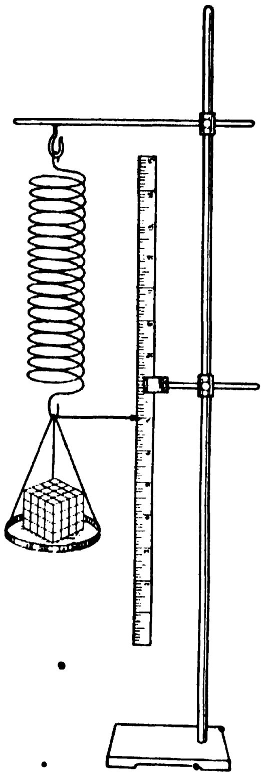


Fig. 7—4

of 64 cubes. Remove 32 cubes from the pan. Note the extension again. What do you find ? Is the extension with these 32 cubes half of the extension observed with 64 cubes in the pan ? Repeat the experiment by reducing the number of cubes in the pan to 16. What do you find ? Can you draw any conclusion from your observations ? Is it correct to say that if you halve the number of cubes the weight is also halved ? Does this mean that the weight of a body at a given place is proportional to the quantity of material contained in the body ?

Let us do a similar experiment with water. Remove the cubes from the pan attached to the spring. Take an empty beaker and place it in the pan. Note the position of the pointer. Take a measuring jar and fill it with water up to, say, 10 ml mark. Pour this water in the beaker. Note the position of the pointer again. Find the difference between the two positions of the pointer. It gives you the extension in the spring due to the weight of 10 ml of water. Next, pour another 10 ml of water into the beaker and now find the extension in the spring due to 20 ml of water. Is this extension due to 20 ml of water double the extension due to 10 ml of water ? Repeat the experiment by successively pouring 10 ml of the water in the beaker and find the extension in the spring due to 30 ml, 40 ml

TABLE 7-1

Length of the spring with empty beaker
in the pan –12.0 cm

Quantity of water	*Length of spring*	*Extension in the spring*
10 ml	12.3 cm	3 mm
20 ,,	12.6 ,,	6 ,,
30 ,,	12.9 ,,	9 ,,
40 ,,	13.2 ,,	12 ,,
50 ,,	13.5 ,,	15 ,,
60 ,,	13.8 ,,	18 ,,
60 ,,	14.1 ,,	21 ,,
80 ,,	14.4 ,,	24 ,,
90 ,,	14.7 ,,	27 ,,
100 ,,	15.0 ,,	30 ,,

50 ml, and so on. Plot the graph between the volume of water in the beaker and the corresponding extension produced in the spring. In one such typical experiment, the observations shown in Table 7-1 were obtained. The graph between the extension and the quantity

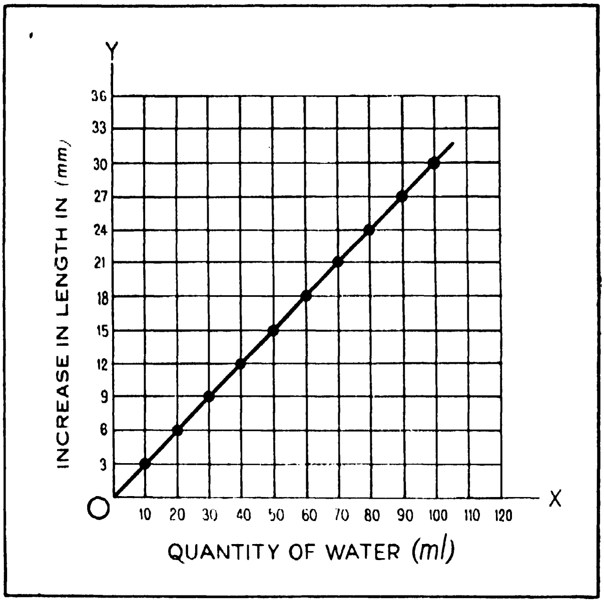


Fig. 7—5

Graph showing increase in the length of the spring against quantity of water in a beaker.

of water is shown in figure 7-5. You will find that the weight of water as measured by the extension of a spring is proportional to the quantity of water. Indeed, *the weight of a body at a given place is proportion to the quantity of material contained in it.*

Activity

Take a block of plasticine. Put it in the pan of the spring. Note the extension. Take away the block. Mould the block now into a cube and keep it again in the pan. Note the extension in the spring. Next, roll the cube into a sphere and find the extension that this sphere produces in the spring. What do you find ? Is the extension same or different in these three cases ? Explain your finding.

7—3 Gravitational mass

In the foregoing analysis we have seen that the weight of a body changes from place to place and therefore the weight of a body is not a good measure of the matter contained in the body. However it has been observed that if two bodies have equal weights at a given place, they will have equal weights at any other place. Can you draw any further conclusion from the above ? You might say that although the weight of a body is not constant and differs from one place to another, yet two bodies which have the same weight at a given place have something in common which remains so irrespecpective of the place. What is this common property. This common property of the two bodies is the amount of material they contain. *The amount of material contained in a body is called gravitational mass.* You will see now that the two bodies which have the same weight at a given place also have the same gravitational mass. If these two bodies are taken to some other place on the globe their weights will be different but again the common property, *i.e.* their gravitational masses will be equal. They will thus produce the same extension in the spring. So, if you want to compare the gravitational masses of two bodies, you can compare their weights at a given place. But how will you determine the mass of a body ? To find this out, let us do the following experiment.

Take the spring and a few small steel balls. Put the balls one after the other in the pan of the spring. Note the extension in the spring after putting each ball in the pan. Plot the graph between the number of balls and the extension in the spring. Can you find the quantity of sugar which will produce the same extension in the spring as produced by two balls ? Can we then say that the mass of the quantity of sugar is equal to the mass of the two balls ? Can you determine the mass of a potato in terms of the mass of the ball ?

Let us proceed as follows. Instead of taking a scale calibrated in centimetres, let us take a plain sheet of paper and paste it behind the spring as shown in figure 7-6. Mark the position of the pointer as zero on the paper sheet. Put a steel ball in the pan. Mark the

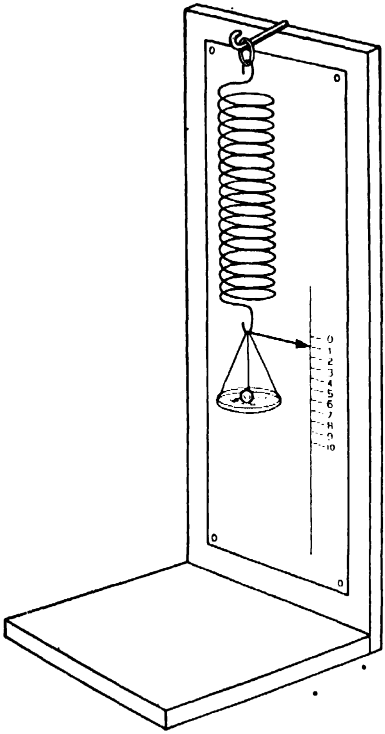


Fig. 7—6

Calibration of a spring balance.

new position of the pointer as 1. Next, put another ball in the pan and mark the position of the pointer as 2. Repeat this process for 3, 4, 5......10 balls. You will have the spring whose extension is directly calibrated in terms of the mass of a ball. Now put two potatoes in the pan and find the position of the pointer. What is the mass of the two potatoes equal to ? You may take any other body like an onion or a brinjal and find out their masses in terms of the mass of a steel ball. You see that in this experiment we have taken the mass of a ball as a unit and we are expressing the masses of all other bodies in terms of the mass of a ball. We could, indeed, have taken any other body as a unit of mass. In the earlier experiment you had plotted the graph between the volume of water in the beaker and the correponding extension produced in the spring. You can now calibrate the scale in terms of the mass of say 10 ml of water. You can then find the mass of any other body in terms of the mass of 10 ml of water. Similarly, you could have taken any other body like a marble and calibrated the scale of your spring in terms of the mass of this unit.* You will thus see that in

Fig. 7—7 (a)
International kilogrcm kept at Sevres, Paris.

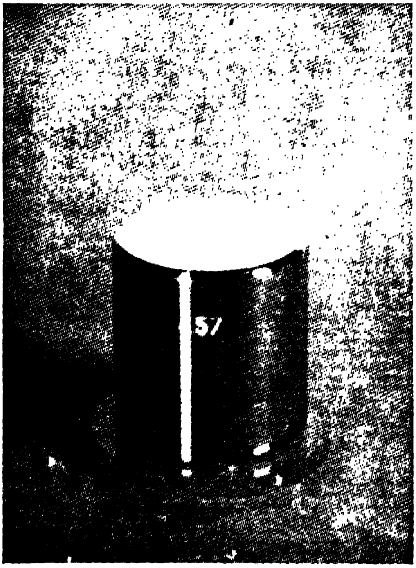


Fig. 7—7 (b)
Prototype kilogram kept at National Physical Laboratory, New Delhi.

* It may be noted that this calibration may change slightly from place to place because the extension produced in the spring at different places is slightly different.

the measurement of mass what one does is to compare the mass of a given body with the mass of another body taken as a unit. In the above example, we considered a few such units like the mass of a cube, the mass of a marble, or the mass of 10 ml of water. But, as in the measurement of length, volume, time, etc., one must take a unit for the measurement of mass, which is acceptable all over the world. A cube, a marble, etc., cannot be taken as the standard units. To overcome this difficulty, a cylindrical block of platinum-irridium alloy was preserved at the International Bureau of Weights and Measures at Sevres, near Paris, along with the International Standard Metre (Figure 7-7 (*a*)). The mass of this block is the standard and is called a kilogram. A national prototype of the kilogram is kept at the National Physical Laboratory, New Delhi (Figure 7-7 (*b*).) To facilitate the measurement of bigger and smaller masses, we have the multiples and submultiples of a kilogram. These are :

1 metric ton 1000 kilograms (kg)
1 quintal 100 kilograms (kg)

$$1 \text{ gram (g)} = \frac{1}{1000} \text{ kg} = 10^{-3} \text{ kg}$$

$$1 \text{ decigram (dg)} = \frac{1}{10} \text{ g} = 10^{-1}\text{g}$$

$$1 \text{ centigram (cg)} = \frac{1}{100} \text{ g} = 10^{-2}\text{g}$$

$$1 \text{ milligram (mg)} = \frac{1}{1000} \text{ g} = 10^{-3}\text{g}$$

Questions

1. How many kilograms are there in 4273 grams ?
2. Convert 783 mg into grams and kilogram.

7—4 Measurement of Gravitational Mass

From the foregoing discussion, it is clear that for measuring the mass of an unknown body you should have a set of standard masses for comparison. Having defined the unit of mass, i.e. a kilogram, let us now proceed to learn about the measurement of the mass of an unknown body. Take a spring with a pointer fixed to it as shown in figure 7-8. Behind the spring fix a scale or a sheet of paper as shown. Tie a pan to the lower end of the spring. Mark the position of the pointer as zero. Put 10 g on the pan and mark the new position of the pointer. Add another 10 g on the pan and mark the position of the pointer as 20 g. Repeat this process successessively for 30, 40, 50......100 g. Let us call these marks 'major marks'. Divide the space between the major marks further into 10 equally spaced 'minor marks', as shown in figure 7-8 (a). Thus the 7th minor mark after the 20 g mark will be read as 27 g. Similarly, the third mark after 70 g mark will be read as 73 g and so

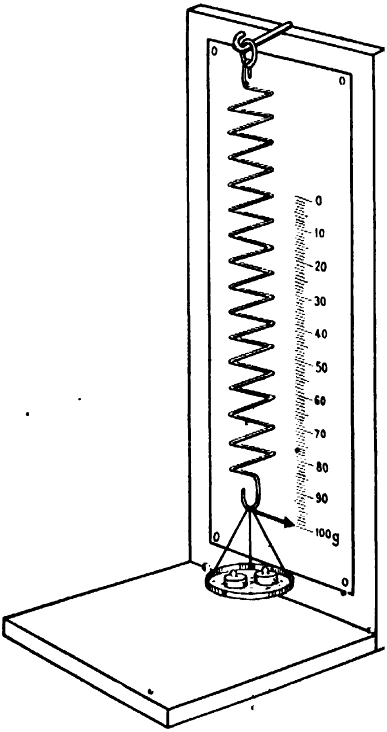


Fig. 7—8 (a)
Making a balance with the help of a spring.

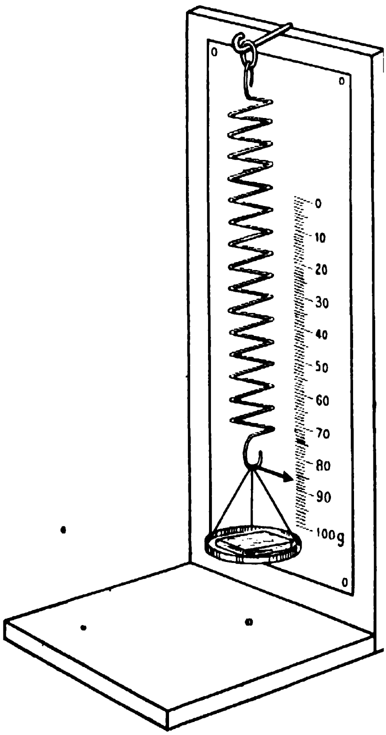
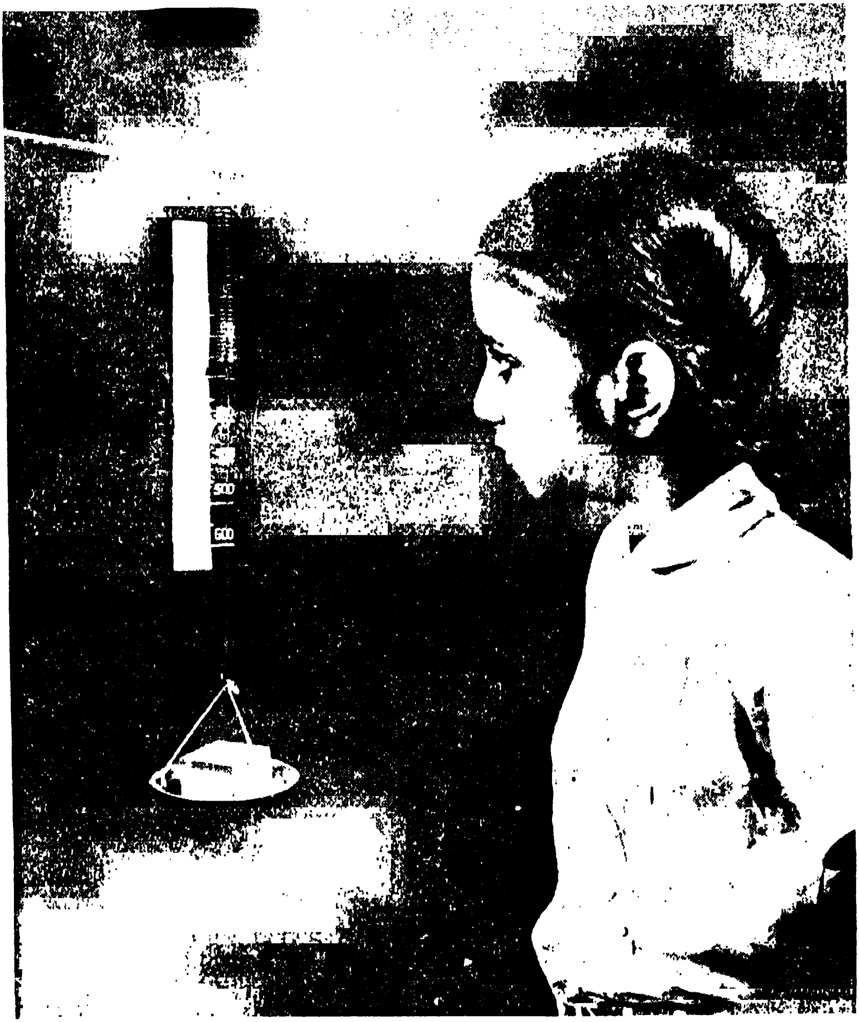


Fig. 7—8 (b)
Weighing a pocket book.



on. We then have the scale behind the spring calibrated in grams from 0 to 100 g. Such an apparatus is called a spring balance. Our spring balance is now ready to measure the mass of a body. You will see at the place of calibration, the scale of this balance reads grams directly. Suspend an unknown body, say a pocketbook, from the pan, as shown in figure 7-8 (b). Read the position of the pointer. If, for example, the pointer stands at the 87 g mark, we will say the mass of the pocket-book is 87 g. You will see that when you suspend the book the extension produced in the spring is the same as that due to 87 grams suspended from the pan. We have thus compared the earth's pull on the pocket-book with the earth's pull on 87 grams. We then say that because the earth's pull on the pocket book is the same as that on the 87 grams, the mass of the pocket-book is equal to 87 g.

We can also make a spring balance in which compression instead of extension is used to calibrate the scale. Do the following experiment. Take a hollow cylinder of glass and to its bottom fix a spring as shown in figure 7-9. Now fix a small pan at the top of

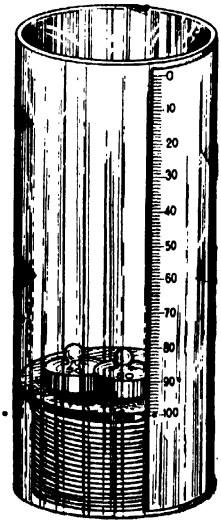


Fig. 7—9
Another type of spring balance

the spring. Attach a light pointer to the spring as shown in the figure. Paste a white sheet of paper behind the pointer and mark the position of the pointer as zero. Put 10 g on the pan and mark the new position of the pointer as 10g. Repeat the experiment for 20 g, 30 g, 40 g......100 g put on the pan. Calibrate the scale in grams as before. You have now got another kind of a spring balance. How does this spring balance differ from the one you made before ? Put the pocket-book on the pan of this balance and determine its mass. Does your reading tally with that obtained with the help of the other spring balance ? Have you seen these spring balances being used for measuring masses ? Have you seen a weighing

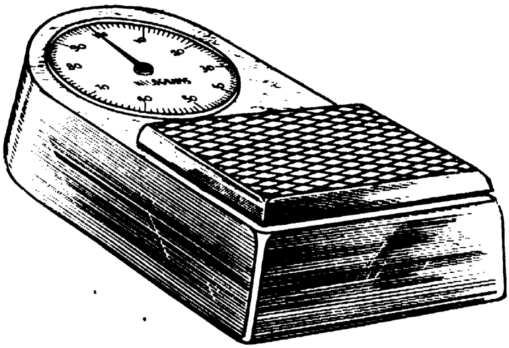


Fig. 7—10 (a)

A Weighing Machine

machine ? figure 7-10 (a) shows such a machine. A spring is used in such a machine and the compression is calibrated in kilograms.

Figures 7-10(b) and 7-10(c) show other spring balances in common use.

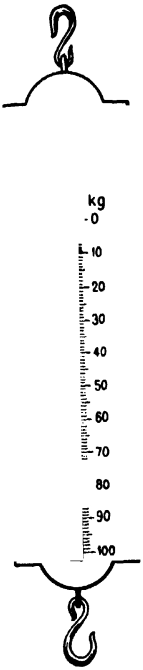


Fig. 7—10 (b)

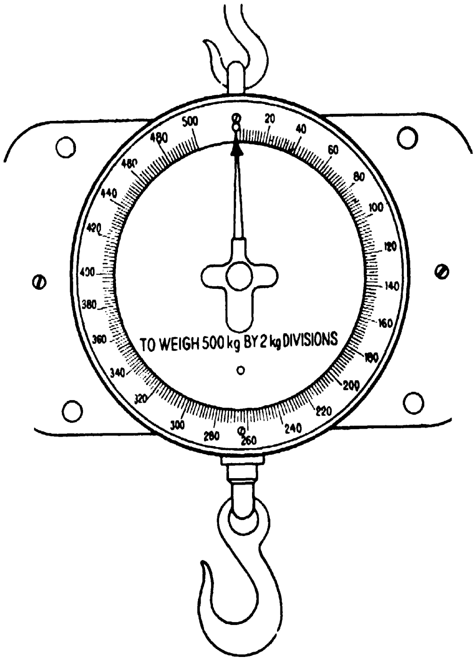


Fig. 7—10 (c)

Various types of spring balances.

Activity

Determine the masses of the following articles with the help of the two spring balances that you have made : fountain pen, geometry box, drinking glass, a glass marble and a steel ball. Take ten observations for each body. Do you find any difference between the readings obtained with the two balances ?

In our earlier experiments, you have seen that the earth's pull on a body could also be measured with the help of a rubber band. Can you make a balance from a rubber band ? Let us now do the following experiment. Take a small rubber band with hooks at each end and fix it to a small wooden plank as shown in figure 7-11. Attach a pointer to the rubber band and and fix a strip of white paper on to the plank. Suspend a small pan from the lower hook.

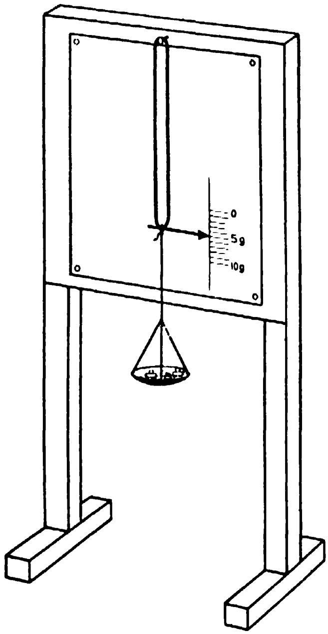


Fig. 7—11
Making a balance with the help of a rubber band.

Mark the position of the pointer as zero. Now put one g in the pan. Mark the new position of the pointer as 1 g, as shown in figure. Next, put 2 g in the pan and mark the position of the poiner again. Mark it 2 g. Repeat the experiment with 3, 4, 5......10 g added successively on to the pan. Why are these marks equidistant ? You will see now that you have got another balance which can determine the masses of the bodies in the range 1 g –10 g. The principle of construction of this balance is the same as that of the spring balance. Now, take an eraser and put it in the pan. Note the position of the pointer. If, for example, it stands at the 9 g mark, you will say that the mass of the eraser is 9 g. What will you read if the pointer lies between the 9 g mark and 10 g mark? Can you use this balance to measure the mass of, say, a large block of iron?

Activity

(1) Determine the masses of a fountain pen, a glass marble, a steel marble, and 5 ml of water with the help of the rubber band balance and the spring balance. Compare the two readings. Do you find any difference?

(2) Make a rubber band balance, and a spring balance. Calibrate them. Find out which one has a better sensitivity.

It is seen that using a spring balance or a rubber band balance and comparing the extension produced by a kilogram and that produced by a given body, we can find the gravitational mass of a body. Through these experiments, we have seen that we can compare a grain of sand with a stone, a piece of chalk with a potatoe etc. The concept of mass is a basic concept and we will learn more about this in the next year.

CHAPTER 8

Electricity

8 1 Introduction*

Most of you have seen during nights the electric lights in streets or on the railway stations you have visited. You may have noticed that the lamp posts are connected with each other by long metallic wires (sometimes these wires are underground and may not be visible). During daytime the lights are switched off and they do not glow. Something must be happening in the wires to make the bulbs glow in the night. When the bulbs glow we say that an electric current is flowing through the bulbs and the wires. We shall not attempt here to learn about the nature of this current but will rather try simple experiments to show some effects of current.

Let us first start by studying the lighting effect of an electric current. Take a torch cell, a torch bulb fixed in a bulb holder and various materials like copper wire, cotton thread, rubber bands, iron wire, aluminium wire, silk thread and strips of paper. Take two copper wires and connect them to the two terminals of the bulb holder. Connect the other two free ends of these copper wires to the terminals A and B, of the cell as shown in figure 8-1. Observe the glow of the bulb. Remove the copper wires and in their place connect two pieces of thread between the bulb holder and the cell. What do you find? Remove one piece of thread and instead connect a copper wire between the cell and the bulb holder. Does the glow in the bulb reappear ? Now remove the other piece of thread and

* Caution : Never play with electric supply in the house because it can be fatal.

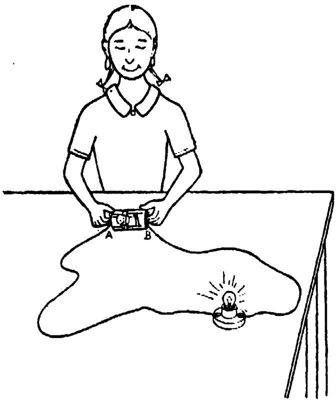


Fig. 8—1
Glowing of a bulb due to passage of an electric current through it.

in its place connect a copper wire between the bulb holder and the cell. Does the bulb glow now ? How will you explain these observations ? Remove the copper wires between the bulb holder and make the connections between the cell and the bulb holder with the help of other materials- aluminium wire, iron wire, silk thread, rubber band and paper strip. Observe in which case does the bulb glow. Enter your observations in the following Table. Put a cross in the proper column.

TABLE 8-1

Name of the substance	*The bulb glows*	*The bulb does not glow*
Copper wire		
Cotton thread		
Aluminium wire		
Iron wire		
Silk thread		
Rubber band		
Paper strips		

What do you learn from the above experiment ? You will see that certain materials like copper wire, aluminium wire, iron wire which when connected between the cell and the bulb holder make the bulb glow. These materials are called *conductors*. Other materials like cotton thread, silk thread and rubber band do not help the bulb to glow. These materials are called *insulators*.

Let us do another experiment. Take the torch cell and the torch bulb fixed in the bulb holder. Select various combinations of materials like copper wire and aluminimm wire, copper wire and iron wire, aluminium wire and cotton thread, aluminium wire and rubber band, iron wire and silk thread, iron wire and cotton thread, iron wire and aluminium wire and connect them between the cell and the bulb holder. Observe in which case does the bulb glow. What conclusions do you draw from this experiment ? Will it be right to conclude that the bulb glows only when the two connecting links are of conducting materials ? You will see that when one link is of insulating material the bulb does not glow. Let us do more experiments.

Make the connections between the cell and the bulb holder with the help of copper wires. Take pliers and cut one copper wire near the middle. Does the bulb continue to glow ? You will see that the bulb stops glowing the moment the copper wire is cut. This is because even though the connecting link was of a conducting material, the break in the conducting link caused the bulb to stop glowing. The bulb glows only when there is a continuity of connections. Let us try to understand the above experiment. The cell is a source of an *eleciric current*. When we connect the cell to the bulb by means of two copper wires, the electric current flows from the cell through one copper wire into the bulb and back to the cell through the other copper wire. This causes the bulb to glow. Thus when the path of electric current sent by the cell is in the form of a continuous closed loop the bulb glows. This continuous path of an electric current in a closed loop is called a *circuit*. Now, if the circuit is broken anywhere as in the case when we cut the copper wire or wnen a part (however small) of the circuit is replaced by an insulator, or when one of the connections either at the cell or the bulb is removed, the current stops flowing and the buld does not glow. We, thus, come to an important conclusion that, in order that the current flows through the circuit, the entire path of the current should be made up of some conductor without any break.

Now let us look at the cell more carefully (figure 8-2). The

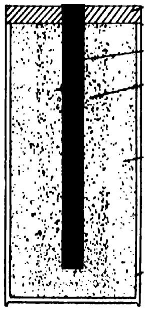


Fig. 8—2
A dry-cell (battery).

terminal A is a small metal cap which, if you could look inside, is fixed on a carbon rod. This is called the positive terminal of the cell. The metal (zinc) case serves as the other terminal and is called the negative terminal of the cell* If you repeat the above experiments by interchanging the connections on the cell you will find that this has no effect on the glow of the bulb. The bulb glows as long as the path of the current through the bulb is in the form of a continuous closed loop.

Let us get one more cell which means that we have another source of electricity. See whether you can make the bulb glow brighter by using this additional source of electricity. Try various combinations of these two cells as shown in figure 8-3 and discover for yourself which arrangement of cells makes the bulb glow

* Caution : Never connect the two terminals of the cell directly with a copper wire because it will damage the cell permanently.

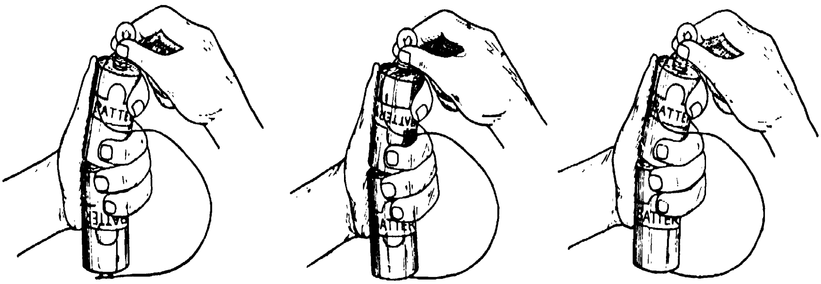


Fig. 8—3
Combinations of dry-cells.

brighter. In which combination do you find that the bulb does not glow ?

Activity

1. Take a torch bulb, a bulb holder, a torch cell and two wires provided with crocodile clips at both ends. Connect the circuit as shown in figure 8-4. Connect the two

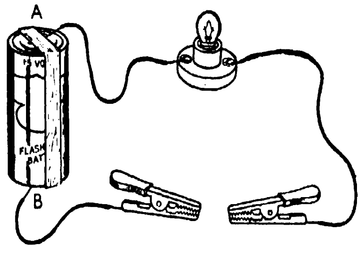


Fig. 8—4

crocodile clips to the following substances mentioned in Table 8-2, one by one, and see through which of these substances electric current flows. Put a cross against the correct answer. In the second column of the Table 2, write down whether the substance is a conductor or an insulator, e.g. you will find that the coin is a conductor.

TABLE 8-2

Name of the substance	*Electrical nature of the material*	*Current flows*	*Current does not flow*
Coin			
Eraser			
Wooden rod			
Match stick			
Nickel coin			
Piece of cloth			
Iron nail			
Saucer			
Porcelain disc			
cork			

2. Make the connections as shown in figure 8-4. Touch the crocodile clips. The bulb glows. Change the position of the bulb in the circuit. Does the bulb continue to glow ? Does the bulb glow brighter if it is farther away from the cell ? What conclusions do you draw from this experiment ?

8-2 Flow of electric current produces heat

In the above exercises you have seen that when the electric current flows through the bulb it begins to glow. Allow it to glow for some time and touch it. Do you find it warm ? Let us do another experiment.

Take, say, 50 cm. of copper wire and nichrome wire of standard gauge (SWG)* No. 30 coiled on a pencil as shown figure 8-5. Take a dry cell, and a switch and connect them to the two free ends

*	*Diameter mm*
No. 10 SWG	3.251
No. 15 SWG	1.828
No. 20 SWG	0.9144
No. 25 SWG	0:5080
No. 30 SWG	0.3150
No. 40 SWG	0.0048

of the copper wire and the nichrome wire as shown in figure 8-5. A switch is a simple device to make or break contact between two

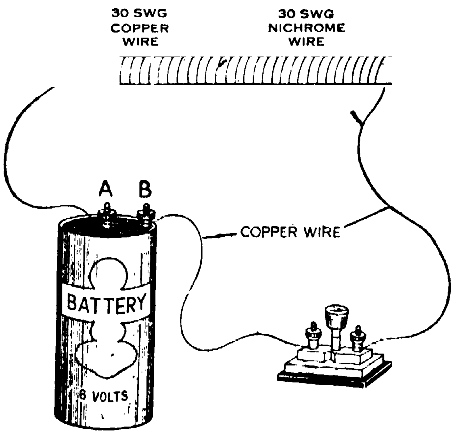


Fig. 8—5
Passage of an electric current through a metal wire produces heat

metal wires. Make a contact through the switch and allow the current to pass for two minutes. Place your hand near the wires. What do you find ? You will find that the nichrome wire becomes appreciably hot whereas the copper wire is less hot.

From these experiments it will be clear that when electric current flows through conductors such as nichrome wire, copper wire, heat is produced. The heat produced depends upon the metal used. Have you seen any of the applications of the heating effects of electricity in everyday life ? The working of an electric iron, electric heater and electric kettle depends on the heating effects of electricity.

8-3. Electric current affects magnetic needle

Have you seen a compass needle ? It is a small magnetic needle free to move on a pivot and enclosed in a tiny box as shown in fig. 8-6. Place this compass needle on the table. Mark the directions in which the needle points. Rotate the compass needle

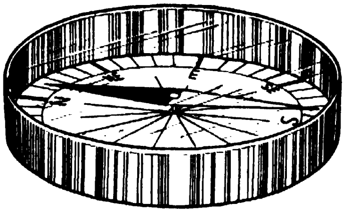


Fig. 8—6
A magnetic Compass needle.

in the horizontal plane. Do you find that the compass needle always points in the same direction ?

Now keep this compass needle on the table. Bring a copper rod near it. Do you find any change in the direction of the compass needle ? Repeat the same experiment with a wooden rod, a brass rod, an eraser, iron needle and a magnet. Which of these substances affect the direction of the compass needle ? You will find that it is the iron needle and the magnet which affect the direction of the compass needle. This is because of the magnetic force which comes into play between the compass needle and the ends of the magnet and the iron needle. Play with the compass needle and the magnet and find out whether the two ends of the magnet affect the compass needle the same way ? Repeat the experiment with the iron needle. Observe and record the behaviour of the compass needle in the two cases. Let us do an experiment to see whether electric current produces magnetic effects.

Connect the circuit containing a straight long copper wire, a bulb, a switch and a cell as shown in figure 8-7. Place underneath the wire a small compass needle. Adjust the direction of the wire in such a way that it is approximately along the direction pointed out by the compass needle. Make a contact through the plug and complete the circuit. What do you find ? Does the needle change its direction ? Remove the plug. What effects do you observe ? From these observations you will see that when the current flows as indicated by the glowing of the bulb, the magnetic needle underneath is affected in the same way as if it was affected when you bring a magnet near it. However, when the flow of current was stopped the needle came back to its original direction as if there was no mag-

Fig. 8--7
An electric current deflects a compass Needle

net around. Reverse the connections of the cell and repeat the above Experiment. What do you find ? We conclude from this experiment that whenever the current flows through a wire it exerts a magnetic force on the compass needle.

Activity

1. In the experiment described above change the distance between the compass and the current carrying wire and see how the effect in the compass needle changes.
2. Take a bar magnet and suspend it with a piece of thread. Allow it to come to rest. In which direction does it point ? Take a wooden bobbin and wind an insulated copper wire on it as shown in figure 8-8. Suspend the bobbin with a piece of thread and connect the circuit as shown. When you put the switch on, in which direction does the bobbin come to rest ? Is it also the direction in which the bar magnet came to rest ? Remove the switch. Hold the bobbin in your hand and bring one of its ends near one end of the suspended magnet. Close the switch. Does it affect the magnet ? Now remove

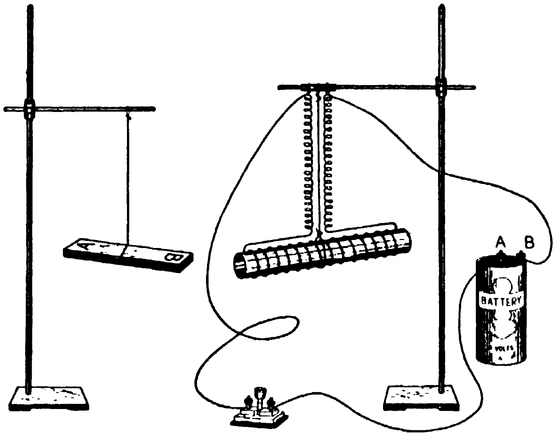


Fig. 8—8

An experiment showing Magnetic effects of an electric Current.

the switch. Does the magnet come back to is original position ? Now bring the other end of the bobbin near the same end of the magnet. Put on the switch. What do you find ? Instead of a bobbin, repeat the experiment with another bar magnet. Do you observe similar effects ?

All these experiments show that the flow of electric current is associated with magnetic phenomena. This discovery of a close relationship between electricity and magnetism was very accidental. In 1819, Hans Christian Oersted, a Danish school teacher, was attempting to demonstrate that there was no relationship between electricity and magnetism. This he did by turning on the electric current through a wire kept at right angle to a magnetic needle. No effect on the needle was observed. But when he kept the wire along the needle, in the words of one of his pupils. "He was quite struck with perplexity to see the needle rotating on completing the circuit." This observation, indeed, brought out the close relationship between electricity and magnetism and, as in our experiments done earlier, showed that an electric current affects a magnetic needle.

8 4 Electricity can produce chemical effects

Let us do following experiments. Take a cell, a small bulb, a switch and two aluminium plates. Connect the circuit as shown in figure 8-9. Touch the two aluminium plates. Does the bulb glow ? Does it imply that by touching the plates we can close the circuit ? Now take a beaker containing copper sulphate solution. Put the two plates in the beaker as shown in figure 8-9. The two plates

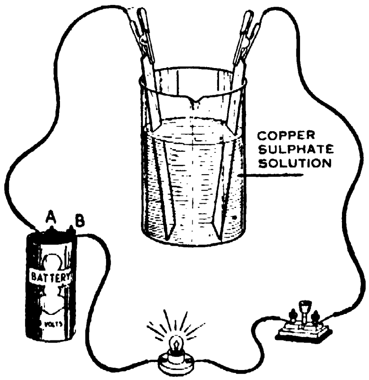


Fig.8—9

Experiment showing chemical effect of electric Current

are not touching each other yet the bulb glows! Can you infer that in this case the circuit is completed by the copper sulphate solution ? keep the switch on for about ten minutes. Remove the switch and then take off the two plates. What do you find ?

Do you find that one of the plates is coated with some deposit? Clean the plates. Reverse the connections to the cell. Put the plates back into the solutions. Allow the current to pass for some time. Remove the plates. What do you find ? Is it the same plate that is coated with the deposit or is it the other plate that is coated ? This coating is of copper. Does your experiment suggest that some chemical change takes place in the copper sulphate solution when an electric current flows through it ?

Activity

Repeat the same experiment taking water, water with a few drops of lemon and solution of common salt. Which of

these allow the flow of electric current ? Note carefully any thing that you observe happening on or near any one of the plates.

From all these experiments we find that an electric current produces several effects. It makes the bulb glow. It produces heat in a coil. It deflects a compass needle lying nearby. It can bring about chemical changes. This must have roused curiosity in your minds as to what an electric current is and how are these effects brought about. We will try to answer these questions as we proceed in our study of Physics.

Dear Reader :

We have great pleasure in sending you a copy of an experimental edition of the Physics text book for the age group 10+ (class V).

With the explosion of knowledge connected with science and technology, it has been realised all over the world that the teaching of Physics at elementary levels should be based more on an experimental approach which, it is hoped, will provide a sense of inquiry in the young minds. For the first time in our country, a large section of physicists in the universities are collaborating in the programme of improvement in Science education in schools. This book is a result of this collaboration. The authors are well aware of the shortcomings in this book which have resulted out of the short time at their disposal in getting out this experimental edition.

The volume is being sent to you with a definite purpose. It is needless to say that your constructive suggestions for its improvement will go a long way in revising this experimental edition and bringing out the first set of books for Physics for Indian schools. With this objective we enclose a questionnaire which you may kindly fill after studying the book and return it to us.

Yours sincerely
(V. G. BHIDE)

National Physical Laboratary
New Delhi 12.

COMMENTS ON THE NCERT PHYSICS STUDENTS' TEXT-1

Name, designation and address
of person making comments.

Date

(If the space provided against the question is not sufficient please attach additional sheet. In your comments, please indicate wherever possible, the page, paragraph and line (s) on which a comment is primarily based).

Chapter	I	II	III	IV	V	VI	VII	VIII
1. Is the matter presented in the chapter comprehensible to the students of the age group to which it is intended ? If not, what are the portions which you consider as above the standard ? How should these be modified to suit the students' comprehension ? Would you suggest any addition to the text ?								
2. Do you think that the development of concepts are natural and continuous ? Are there any places where it appears to be abrupt ? Suggest how these could be improved.								
3. Do you think that the approach to the topic is such as would induce curiosity and a sense of inquiry in the mind of the student ? If not, what modifications should be made to achieve this ?								
4. Do you think the language is simple enough ? If not, kindly make concrete suggestions Indicate the places where the language should be changed.								
5. Do you think there are places where the meaning is not clear/is ambiguous/confusing ? If so, indicate the places. How can they be improved ?								
6. Do you think that the practical experiments suggested are adequate and bring out the desired results. If not, what additional experiments would you like to suggest.								

(If the space provided against the questions is not sufficient, please attach additional sheet. In your comments, please indicate wherever possible, the page, paragraph and line (s) on which a comment is primarily based).

Chapter	I	II	III	IV	V	VI	VII	VIII
7. Are the students activities stimulating enough? If not, what modifications would you like to suggest?								
8. Do you think the teacher will be able to plan and conduct the practicals and demonstrations without much difficulty? If not, which experiments appear difficult? Can you suggest ways of simplifying them?								
9. Are present illustrations adequate? What changes or additions would you like to suggest?								
10. The aim of this text is to bring out clearly basic concepts in Physics and promote a sense of inquiry in the students. Do you think that this would be achieved by the text? What changes, if any, would you suggest in this regard?								
11. Any other remarks.								

Signature