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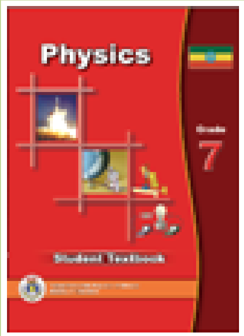


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# PHYSICS

## Grade 7

## Student Textbook


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Federal Democratic Republic of Ethi
Ministry of Education

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# Preface

This textbook is written for students studying physics in grade 7.Due attention is given to your level. It will guide you through the basic concepts and skills with *readings activities, questions* and *illustrations* to support the textbook. Each unit begins with the unit outcomes and followed by an introduction (overview).

The outcomes of the lesson are listed at the beginning. Basic definitions of the topic which represents the minimum learning competencies (MLCs) are in a **blue background box**. This is to help you in identifying the MLCs sentences easily. All "**activities**" are in a box and consecutively numbered. You will find photographs or pictures which illustrate the topic you are studying.

Each section has set of questions **(Check points)** linked to the MLCs. A number of **challenging questions** are inserted in the textbook. At the end of each unit there is a summary of what you have read. And also there are a unit review questions and problems to enable you to test your knowledge and understanding of the unit's content. Each unit is set out in the same way with unit title and number at the top of the page. The title is written on each page as a header.

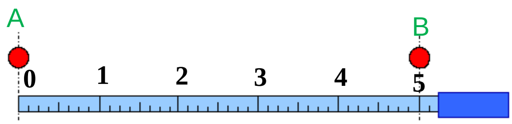
This textbook is just one resource which you will use to learn/ study introductory physics. You will find further information to support this textbook with your teacher, on the plasma programs, in other reference books and documents and with people in your communities.

# UNIT 1

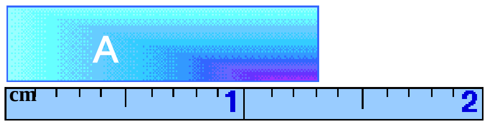
# PHYSICS AND MEASUREMENT

**Unit outcomes:** After completing this unit you should be able to:

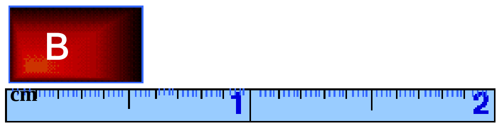
- ✓ appreciate the interrelatedness of all things.
- ✓ search for patterns or relationships in experimental data.
- ✓ use a wide range of possibilities for developing knowledge of the major concepts with in physics.




a) What is the distance between A and B?




b) What is the length of block A ($L_A$ = ?)




c) What is the length of block B ($L_B$ = ?)


d) What is the length of blocks A and B ($L_A + L_B$) = ?

# Introduction

In the lower grades you learnt about science in general. For example, environmental science and integrated science. In this and next grades you will learn about physics, chemistry and biology separately. In this unit you will learn what physics is and about measurement.

**Activity 1.1**

*Discuss the following questions in a group.*

i. What is science? What does science deal with?

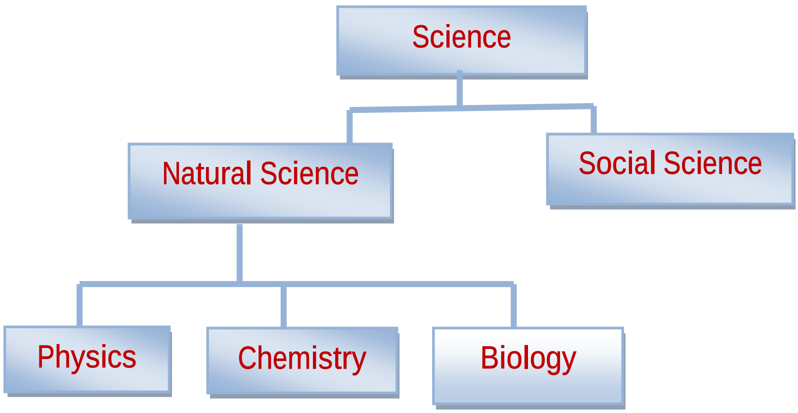
**ii.** What are the major branches of science?

Science is a systematized knowledge arising from observation, study and experimentation.

In a simple term, science is the study of the world around us. It deals with the knowledge of the world around us. The major classifications of science are given in chart 1.

- What are the two categories of science?
- Name the three branches of natural sciences?

**Chart 1. Classification of science**



## 1.1 Definition of Physics

### a) Meaning of physics

Physics is defined in different ways. The following is one definition of physics. Physics is a way of observation of the world around us. Through observation we understand our world and how objects in the world behave (laws of nature). Physics is simply the science of observation and measurement.

**Activity 1.2**

i. From the explanations given above, describe in your own words what physics is.
ii. What do we call the person who studies physics?

The word 'Physics' has its origin in the Greek word meaning ‘nature'.

Hence, physics is the branch of natural science. It is the study of the nature of matter, energy and their interactions. A person who studies physics is called physicist.


Isaac Newton (1643-1727) discovered the laws of motion and law of gravity.


Michael Faraday (1791-1867), discovered the generation of electricity from magnetism. He built the 1st dynamo.


James Prescott Joule (1818-1889) , studied the nature of heat and discovered the relationship between mechanical energy and heat energy


Marie Curie (1867-1934), won the Nobel Prize for the discovery of the elements polonium and radium.

Fig1.1 Some known physicists and their works

In order to understand, the definition of physics well, you need to have clear idea of **'matter'** and '**energy**'. Discuss with your friends and parents on the questions below and write a short note on:

### Challenging Questions

i. What is matter?
ii. Some properties of matter.
iii. What is energy?
Iv. Explain how matter and energy are interrelated.

**Activity 1.3**

Mention at least five areas of study or topics

i. related to physics
ii. not related to physics

## b) Purposes of studying physics

Physics is studied as a separate subject in grades 7 and 8 and also in secondary schools.

**Activity 1.4**

Discuss in a group with your friends why you study physics. Report your answers to the whole class.

***The following are some specific purposes of studying physics***

- Physics helps you to understand the working principles of many of your daily utensils and tools.
- Physics helps you discover some of the unknown parts of nature and makes you familiar with the modern world.
- Physics helps you to understand some of the natural phenomena in other subjects like: biology, chemistry, geology, astronomy, etc.
- Physics enables you to understand why it is difficult to walk on a smooth plane, why the electric fan moves, how the cars, airplanes, space-rockets, refrigerators, alarm-clocks, radios, televisions, etc work.

*Generally studying physics helps you to:*

- understand concepts, relationships, principles and laws of nature.
- do activities (experiments), to formulate and to check theories.
- describe some applications of physics on your daily life.
- solve practical problems (real life problems).
- understand the cause and effect of natural phenomenon.

### c) Areas of study where physics does not address

There are areas or activities which does not require direct knowledge of physics. For example, history, civics and ethical education, politics, religion, etc. are not directly related to physics.

### d) The main goal of the study of physics

The main goal of learning physics is to gain a better understanding of the world around you and the things in it. By understanding the world around you and the things in it, you discover facts. These facts form scientific concepts, theories, laws, principles and relationships. For example all objects fall towards the earth. This is a scientific fact. Corresponding to this there is a scientific law known as law of gravity; which is derived from that fact. Similarly when light falls on the surface of a mirror, it is reflected. Hence, from this fact, the law of reflection of light is derived.

**Activity 1.5**

Form a group with your friends and list down some examples of '*scientific facts*' and related '*scientific law'*.

| Scientific facts | Scientific laws/ principles |
|---|---|
| e.g. All objects fall towards the earth | Law of gravity |
| | |

### e) Relationship of physics to other sciences and disciplines

There is no clear boarder line between the different branches of natural sciences. Knowledge of physics overlaps with the knowledge of chemistry, biology, astronomy, etc. For example, chemistry and physics knowledge are studied as a subject called **physical science**/**physical chemistry**. The following are some areas of studies where physics is combined with other science disciplines.

- **Biophysics**: combination of biology and physics.
- **Astrophysics**: combination of astronomy and physics.
- **Geophysics**: combination of geology and physics.

## f) Branches of Physics

Physics is divided into different branches. Some of the branches of physics are given in Table 1.1

Table 1.1 Branches of physics

| Branches | Purpose |
|---|---|
| Mechanics | Deals with motion of a physical body. |
| Sound | Studies production, transmission and other properties of sound. |
| Optics | Studies production, transmission and other properties of light. |
| Electricity and Magnetism | Deals with charged bodies at rest and in motion and relationship between electrical and magnetic properties of bodies. |
| Heat | Deals with temperature, heat transfer and exchange in molecular level. |
| Nuclear physics | Deals with interaction in the atomic nuclear |
| Astrophysics | Deals with celestial bodies like planets, stars, galaxies, etc. |

**Activity 1.6**

Write five practical examples from your everyday life where the branches of physics are observed.

## g) Relationship of physics to engineering and technology

**Activity 1.7**

i. What is the relation between physics and technology?
ii. What are the differences and similarities between technology and engineering?
iii. Which comes first, physics or technology?

You have already seen what physics is. Now, you will see what a technology is.

Technology is the use of scientific knowledge to help human beings work easier and live better and enjoy their environment more. Things such as automobiles, TV sets, radio, airplane and home tools (appliances) are the products of technology. A person who studies technology is called a **technologist.**

Technologists apply physics and mathematical knowledge and skills to produce a very useful tool.

What are the products shown in Fig 1.2?

a) b) c) d)

Fig1.2 Products of Technology

Engineers are technologists who design, construct and assemble products.

What are the criteria for a good technological product?

*Products of engineers can be judged on six criteria. These are:*

1. Is the product functioning as it should?
2. Is the product durable?
3. Is the product cost effective? Cheap?
4. How does the product affect the individual?
5. How does the product affect the society it works in?
6. How does the Product affect the environment?

**Check point 1.1**

1. Explain what physics is.
2. List five branches of physics.
3. What is the purpose of learning physics?
4. Describe the relation ship of physics to:
   a. Biology
   b. Chemistry
   c. Astronomy
5. List some other disciplines related to physics.
6. What is the relationship of physics and technology?
7. What are the criteria for judging of good products in engineering?

## 1.2 Standardization and Measurement

**Activity 1.8**

i. Measure the length and width of this textbook.
ii. Calculate the area of this textbook using the above measured values.
iii. Measure the height of your friend, and let your friend measure your height also.
iv. What instrument did you use?
v. How did you write the measures of the textbook and your friend's height?

### Measurement

While you are doing Activity 1.8, you may come across units and numbers. These numbers by themselves means nothing. But when they are attached to some units of measurement like centimeter and meter they give you full information about your textbook and your friend's height.

i.e. - The length of this textbook is 24 centimeter.
- Its width is 17 centimeter.
- The height of your friend is 1 meter and 45 centimeters.

Measurement consists of the comparison of an unknown quantity with a known, fixed unit quantity. It consists of two parts:
i. the unit.
ii. the number indicating how many units there are in the quantity being measured.

Whenever you measure something, you simply compare two bodies. One of them being a '**standard**', and the other one being the body to be measured.

Measurement is one of the activities performed in physics. Physicists get quantitative information about objects through measurement.

### Standardization

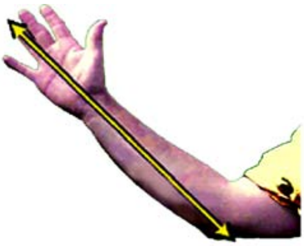
**Activity 1.9**

i. What traditional measuring units do you know that are used to describe length, time and mass?
ii. Are they reliable (dependable)?

In ancient times, people in Ethiopia used to measure physical quantities such as time, mass, length, etc using traditional units. They say '*Nigat*' or ' *Mishet*' as the sun rises or sets respectively. They say ' *Ekule- ken'* as the sun comes over head in the sky to measure time.

Lengths at olden days were measured in 'cubits', 'spans', 'foot' and, 'stride'.

a) Span



b) Cubit

Fig 1.3 Traditional length measuring units

We still find these traditional units of length and time in our country. But they are not reliable. They do not give exact information.

**Activity 1.10** ***Group work***

i. Select friends who are shorter and taller than you.

ii. Compare their cubits and spans. Are they the same?

iii. What can you conclude? Are the traditional measuring units of length reliable?

Standard units are conventional units which are used to measure physical quantities scientifically.

The development of science and technology came up with the development of **standard** and **reliable** units of measurement. Scientists all over the world met together and agreed to have a standard unit that can be used through out the world. These standard units are known as **System of International Units.** In short, it is written as the **SI units**.

## Physical quantities

You measured, the length, width and height of your textbook. These quantities are called physical quantities. Time and mass are also examples of phyical quanties.

Quantities that can be measured directly or indirectly are known as physical quantities.

Physical quantities are numbers with units which are used to describe physical phenomena.

The measured values of physical quantities are written in terms of a number and unit. Physical quantities and units can also be written using symbols.

**Note** $\ell$ = 24 cm, w = 17 cm

Where "$\ell$" is length
"w" is width

'$\ell$' and 'w' are symbols of length. The numbers 24 and 17 are numerical values 'cm' is the symbol of the unit of length called centimeter.

In activity 1.8, you measured directly the length and width of this textbook. But you calculated the area of it. What is the difference between the two ways of measuring things? The area of the book is calculated by combining two lengths, but not measured directly.

From this practical activity, you can see that some quantities are directly measured, while others are calculated by combining two or more measurable quantities. Hence,

Physical quantities are classified into two:

1. Fundamental physical quantities
2. Derived physical quantities.

**Fundamental physical quantities**: are those quantities which can be measured directly. They are not defined in terms of other physical quantities. Length, mass and time are examples of fundamental physical quantities. Fundamental physical quantities are also called basic physical quantities. The units used to measure the fundamental quantities are called basic units. You see seven basic units in Table 1.2. Can you name them?

Beside length, mass and time there are other four basic physical quantities in science. These are temperature, electric current, amount of substances and luminous intensity.

| Table 1.2 The seven fundamental physical quantities | | | |
|---|---|---|---|
| Basic quantities | | Basic units | |
| Name | symbol | Name | Symbol |
| Length | $\ell$ | Meter | m |
| Time | t | Second | s |
| Mass | m | kilogram | kg |
| Temperature | T | Kelvin | K |
| Current | I | Ampere | A |
| Amount of substance | M | Mole | Mol |
| Luminous Intensity | - | Candela | Cd |

## Challenging Questions

1. What fundamental quantities are combined to give area, volume, density, speed?
2. Explain how the basic units are combined to give the derived units of force, velocity, pressure and work.

**Derived physical quantities**: are quantities that can be measured indirectly. They are calculated by combining two or more fundamental quantities. Area and volume are examples of derived physical quantities. The derived quantities use derived units.

| Table 1.3 Some derived physical quantities. | | | |
|---|---|---|---|
| Name | Symbol | Unit | Symbol |
| Area | A | square meter | $m^2$ |
| Volume | V | cubic meter | $m^3$ |
| Density | ρ | $\frac{\text{kilogram}}{\text{cubic meter}}$ | $kg/m^3$ |
| Acceleration | a | $\frac{\text{meter}}{\text{second}^2}$ | $m/s^2$ |
| Force | F | $\frac{\text{kilogram-meter}}{\text{second}^2}$ | $kg.m/s^2$ = Newton(N) |
| Pressure | P | $\frac{\text{Kg.m/s.s}}{\text{square meter}}$ | $\frac{kg.m/s^2}{m^2} = \frac{\text{Newton}}{\text{square meter}} = N/m^2$ |

## Scalar and vector quantities

Some physical quantities are described completely by a number and a unit. A number with a unit is called a **magnitude**. However, other quantities have a direction attached to the magnitude. They can not be described by a number and unit only. Thus, physical quantities are grouped into two:

i. Scalar quantity
ii. Vector quantity

A scalar quantity is a physical quantity which has only a magnitude. No direction.

Time, mass, volume, density, temperature and energy are examples of a scalar quantity.

A vector quantity is a physical quantity which has both magnitude and direction.

Displacement, velocity and force are some examples of a vector quantity.

### Check point 1.2

1. What is measurement?
2. What are physical quantities?
3. Describe the difference between fundamental and derived physical quantities.
4. List seven fundamental physical quantities with their SI units.
5. List some derived physical quantities.
6. How can you distinguish between scalar and vector quantities? List examples of scalar and vector quantities in the given two columns

| Scalar Quantities | Vector Quantities |
|---|---|
| • ______________ | • ______________ |
| • ______________ | • ______________ |
| • ______________ | • ______________ |

# 1.3 Measuring Length, Mass and Time

## 1.3.1 Measuring Length

**Activity 1.11**

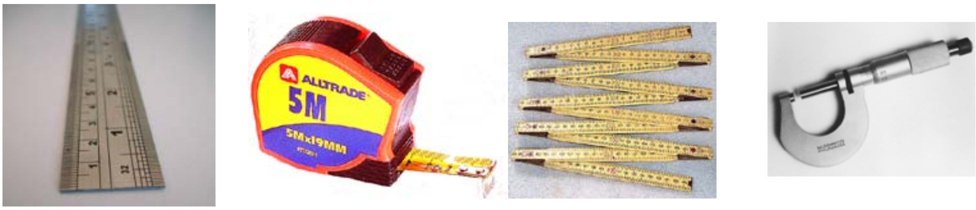
- What is the height and width of the blackboard?
- How far is your school from your home?
- What is the inside height and width of your classroom?

When you tell the distance between your school and your home, or the height and width of your classroom, you measure length.

> Length is one of the fundamental (basic) physical quantities that describes the distance between two points.

The symbol for length is "$\ell$". Sometimes, we can also use other symbols such as ‘*b*’,’*h*’ *and ’s’*.

When we measure length of an object, we are comparing it with a standard length that scientists have agreed to. The SI unit of length is METER (m). There are also other non-SI units of length. These are centimeter (cm), millimeter (mm) and kilometer (km).




a) Ruler b) Tape Measure c) Carpenter Rule d) Vernier Caliper

Fig 1.4 Length measuring instruments

**Activity 1.12**

Form a group with your classmates and do the following activities.

- Measure the length of different bodies using half meter ruler (50cm) and, write the length of the bodies using symbols.
- Estimate the
  a) Width of the blackboard
  b) Thickness of your physics textbook
  c) Width of the door of your classroom without using instrument.
- Now, measure the above quantities using length measuring instrument and compare with the estimated values.

| Table 1.4 Relationship between meter and other non- SI units | |
|---|---|
| 1 meter (m) | 1000 millimeters (mm) |
| 1 meter (m) | 100 centimeters (cm) |
| 1000 meters (m) | 1 kilometer (km) |
| 1 meter (m) | 0. 001kilometers (km) |
| 1 millimeter (mm) | 0. 001 m |
| 1 centimeter (cm) | 0.01 m |
| 1 kilometer (km) | 1000 m |

## Example 1.1

The distance between two electric poles measures 100 meters. What is this distance in: a. centimeter b. kilometer

N.B *Use Table 1.4*

| Given | Solution |
|---|---|
| $\ell$ = 100 m (distance) | a) Since 1 m = 100 cm |

Then 100 m = ?

$$\Rightarrow '\ell' \text{ in cm} = \frac{100\text{cm} \times 100\cancel{\text{m}}}{1\cancel{\text{m}}}$$

$$\ell = 10{,}000 \text{ cm}$$

b) 1 m = 0. 001 km

100 m =?

$$\therefore '\ell' \text{ in km} = \frac{100\cancel{\text{m}} \times 0.001\text{km}}{1\cancel{\text{m}}}$$

$$\ell = 0.\ 1\text{km}$$

### Challenging Questions

Write down the suitable unit of length you need to use to measure:

i. The distance between your school and your home.

ii. The thickness of your physics book.

iii. Your height.

### 1.3.2 Measuring Mass

So far you learnt how to measure length. Length is fundamental physical quantity in physics. The other important physical quantity you need to study is mass.

> Mass is a fundamental physical quantity. It is defined as the amount of matter contained in a body.

There are two ways of measuring the mass of a body.

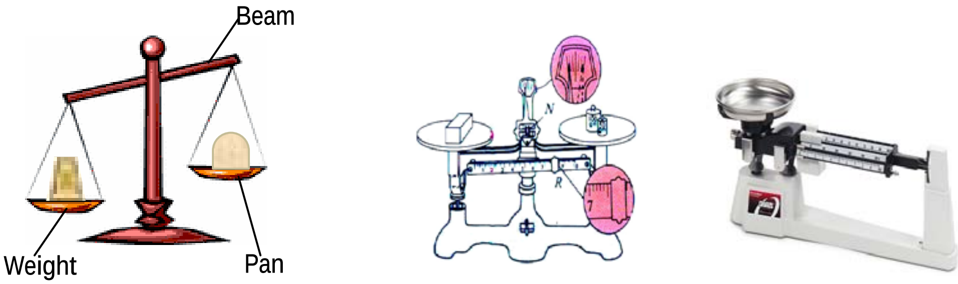
**i. Traditional way:-**

In traditional way things can be compared to each other to guess the approximate value of the mass of the bodies.

Note: A traditional instrument does not tell us the exact value of the mass of a body.

**ii. Scientific way**

In scientific way a mass is measured using an instrument called a **beam balance**. A beam balance consists of uniform beam having two pans suspended from each of its ends. Fig 1.5 show different mass measuring instruments. Tell where these instruments are used in our daily life.




a) Locally made beam balance b) Beam balance c) Triple beam balance

Fig 1.5 Mass measuring Instruments

| Activity 1.13 |
| --- |
| • Have you ever tried to measure the mass of a body using a beam balance?<br>• Visit a shop in your living area. Write down the procedures the shopkeeper uses to measure the mass of a body using a beam-balance. Report your observations to your class. |

The body to be measured is placed in one of the pans and a known **Standard mass** is placed in the other pan until a horizontal balance is obtained. At this moment the unknown masses of the body equals the standard masses.

The SI unit of mass is the kilogram (kg). Other non- SI units can also be used to measure masses. Some examples are given in Table 1.5.

Table 1.5 Relationship between units of mass

| | |
|---|---|
| 1000 kilogram | 1 ton |
| 100 kilogram | 1 quintal |
| 1 kilogram | 1000 grams |
| 1 gram | 0.001 kg |
| 1 milligram | 0.001 gram |

### Activity 1.14

i. Estimate without instruments the masses of the following bodies.
   a. Grade 7 Physics text book   b. One stick of chalk   c. One duster
ii. Now measure the masses of the above estimated bodies using a beam balance.
iii. Compare the estimated and measured values and calculate the differences. Give reasons for the differences.

### Example 1.2

1. In one of the pans of a beam balance the masses 1kg, 500g, 30g, 0.6g are placed to measure the mass of unknown body. What should be the mass of the body on the other side of a pan if they are in balance?

| Given | Required |
|---|---|
| m = 1kg, 500 g, 30 g, 0.6 g | total mass = ? |

**Solution**

m = the sum of the given masses

= 1kg + 500g + 30g + 0.6g   (change 1kg into g)

= 1000g + 500g + 30g + 0.6g

= 1530.6g or

= 1.53 kg

2. Abel and Zehara want to sit at the two ends of a SEE-SAW having equal distances from the pivot as shown in Fig.1.6. Zehara is 37 kg, and Abel is 29 kg. What additional mass ($m_x$) should Abel carry in order to balance the SEE-SAW.

Fig 1.6 See-Saw

| Given | Required | Solution |
| --- | --- | --- |
| $m_A = 29$ kg<br>$m_Z = 37$ kg | $m_x = ?$ | $m_A + m_X = m_Z$<br>$29kg + m_X = 37kg$<br>$m_X = 37kg - 29kg$<br>$= 8$ kg |

## Check point 1.3

1. What is a length? Name the measuring device of a length.
2. State the SI unit of length and some common non-SI units. Explain their relationship.
3. What is a mass? Name some measuring devices of a mass.
4. State the SI unit of mass and other commonly used non- SI units of mass. Explain their relationship.
5. What is time? Mention the measuring devices of time.
6. Write the relationship between SI unit of time and other commonly used non-SI units of time.

### 1.3.3 Measuring Time

What is time? The sun rises in the east in the morning and sets in the west in the evening. How long does the sun take to rise and set? People use the sunrise and sunset as a time measuring device. It is called **sundial**.

Time is a fundamental physical quantity. It describes the duration between the beginning and end of an event.
The SI unit of time is second (s). The symbol for time is 't'.

**Activity 1.15**

Discuss: how the sun rise and sun set is used to measure the time of a day. Draw a diagram of sundial at different times of the day.


a) Watch

b) Stopwatch

c) Digital watch

Fig 1.7 Time measuring devices

A clock and watch are the modern instruments used to measure time. Can you explain how the time measuring instruments indicated in Fig 1.7 are read?
To measure very small or large intervals of time, there are other non- SI units of time. These are minute (min), hour (hr), day, etc.

**Activity 1.16**

i. Measure the beat of your heart using a wrist watch (digital watch). Express it using symbols of quantity of time and unit of time.
ii. Tell your friends and teacher how you did your activity.

**Relationships between SI units and non- SI units of time**:

## Activity 1.17

i. Have you ever noticed the relationships between hour, minute and second? What are the relationships?
ii. Take a day (24 hrs) and list down activities you do through out the day.

| Time | Activity |
|---|---|
| Morning 12:00 | |
| 1:00 | |
| 2:00 | |
| etc. | |

Are you using your time wisely? Compare your time with your friends time. Who are not using the day wisely? Discuss with your friends.

Some wrist watches have an hour hand, a minute hand and a second hand. Can you define hour, minute and second using a wristwatch from your experiences?

- As the second hand completes one cycle, the minute hand moves one unit.(1 minute)
- As the minute hand completes one cycle the hour hand moves one unit (one hour).
- As the hour hand completes one cycle, we say 12 hours.

Table 1.6 Relationship between units of time

| | |
|---|---|
| 1 hour | 60 minutes |
| 1 minute | 60 seconds |
| 1 day | 24 hours |
| 1 week | 7 days |
| 1 month | 30 days |
| 1 year | 365 or 366 days |

## Example 1.3

1. Express the following times in minutes:
   a) 3 hours
   b) 3/4 hours
   c) 1.25 hours.

## Solution

a) 1 hr = 60min

3hr = ? $\Rightarrow t = \frac{3\cancel{hr} \times 60\,\text{min}}{1\cancel{hr}}$

$= 180$ min

b) 1hr = 60 min

$\frac{3}{4}$ hr = ? $\therefore t = \frac{\frac{3}{4}\cancel{hr} \times 60\text{min}}{1\cancel{hr}}$

$= 45$ min

c) 1hr = 60min

1.25 hr = ? $t = \frac{1.25\cancel{hr} \times 60\,\text{min}}{1\cancel{hr}}$

$= 75$ min

### Challenging Questions

Write down what unit of time, you need to use for measuring

a. The beat of your heart.
b. The duration of one period of your class.
c. The time you take to travel from home to school.

1. How many hours, minutes and seconds are there in one day?
2. Mention some traditional ways of measuring time.
3. How many days are there in a year?
4. How old are you? Write your age in
   a. years b. months
5. Express the following times in seconds:-
   a. 75 minutes b. 2 hours c. 0.6 minutes

## Summary

In this unit you learnt that:

- physics is a branch of natural science.
- physics deals with the laws of nature. Physicist is a person who studies physics.
- physics is applied to every development of science and technology.
- Mechanics, Sound, Optics, Electricity and Magnetism, Heat, Nuclear physics, and Astrophysics are different branches of physics.
- measurement is the comparison of an unknown quantity with a known one (standard unit).
- measurement of an object consists of two parts:
  - i. Unit of measurement,
  - ii. The numerical values of the measured object.
- standard units are conventional units which are used to measure physical quantities scientifically.
- traditional units are not reliable and not exact.
- physical quantities are quantities that can be measured directly or indirectly. They are expressed in terms of:
  - i. numerical values ii. unit iii. symbol
- scalar quantities have magnitude only. Direction is not associated with them.
- vector quantities have both magnitude and direction.
- length, time, mass, temperature, current, amount of substance and luminous intensity are fundamental quantities in science. The rest are derived physical quantities expressed by combining two or more of these fundamental quantities.
  1. The SI unit of length is meter (m).
  2. The SI unit of time is second (s).
  3. The SI unit of mass is kilogram (kg).

# Review Questions and Problems

## *I. Write true if the statement is correct and false if the statement is wrong.*

1. One meter is 100 kilometer.
2. There are seven fundamental quantities in physics.
3. The device used to measure a mass of a body is kilogram.
4. If kilogram is added to kilogram then we have a derived unit.
5. m/s is a derived unit.

## *II. Multiple choice*

1. Which one of the following is not a vector quantity?
   a) Displacement c) Force
   b) Density d) Velocity
2. Which one of the following is not a fundamental physical quantity?
   a) Time c) Force
   b) Mass d) Length
3. Which one of the following is a derived SI unit?
   a) Newton c) Kelvin
   b) Kilogram d) Second
4. 2 hr + 20 min + 60 sec are equal to ______ minutes.
   a) 120min c) 150 min
   b) 141min d) 161 min
5. Which one of the following quantities is measured by a balance?
   a) Length c) Mass
   b) Volume d) Density

## *III. Short answer questions*

1. Why do you think that measuring length, mass and time, using traditional methods are not reliable?
2. How many centimeters are there in 9.3 m?
3. Define the following terms.
   a) Physics e) Vector
   b) Standard units f) Length
   c) Measurement g) Time
   d) Fundamental physical quantity. h) Mass

4. **A large bottle contains a number of medicinal tablets each having a mass of 250 mg. The mass of all the tablets is 0.5 kg. Calculate the number of tablets in the bottle.**

## Challenging questions

1. **Meter, kilogram and second are the SI units of length, mass and time respectively. They are internationally agreed standard units. Write a descriptive note about the history, methods of determination and definition of meter, kilogram and second.**
2. **The following four SI units were named after famous scientists; Watt, Joule, Pascal and Kelvin. Find out:**
   i. **the area of physics to which each of these scientists made a significant contribution.**
   ii. **the physical quantity measured using each of the four units.**

# UNIT 2

# MOTION

**Unit outcomes: After completing this unit you should be able to:**

- ✓ understand concepts related to motion.
- ✓ develop skill of manipulating numerical problems related to motion.
- ✓ appreciate the interrelatedness of all things.
- ✓ use a wide range of possibility for developing knowledge of the major concepts with in physics.

## Introduction

Galileo Galilee(1564-1642.)

In this unit, you will be introduced to the basic concepts and relationships in motion.

Motion is one of the key topics in physics. Everything in the universe moves. We use some basic concepts when we express motion. These concepts are **distance**, **displacement**, **speed**, **velocity** and **acceleration**. Based on the path of a motion, there are different types of motions. Motion in a straight line is one of the forms of motion. It is the simplest form of motion in a specific direction.

Challenging Questions

What are the contributions of Galileo Galilee to science and physics?

## 2.1 Definition of Motion

**Activity 2.1**

Discuss the following questions with your friends

i. What is motion?
ii. When would you say an object is at rest?
iii. Assume you are in a car and the car is moving at a certain speed. Are you at rest or in motion?
iv. What do you understand by the term" reference frame"?

Consider your daily travel from your home to your school. When you go to the school, your journey begins from your home. Your home is your original position. After sometimes you will reach your school. Your school is your final position. In this process, you are continuously changing your position. You are increasing the gap between your present position and your home. This continuous change of position is known as **a motion**. Notice that your change of position is, observed by considering the distance from your school to home. Your home is taken as a **reference frame**.

Motion is a continuous change in position of an object relative to the position of a fixed object called reference frame.

The concepts of rest and motion are completely relative; a body at rest in one reference frame may be in motion in another reference frame.

A body is said to be at **rest** in a frame of reference when its position in that reference frame does not change with time. If the position of a body changes with time in a frame of reference the body is said to be in **motion** in that frame of reference

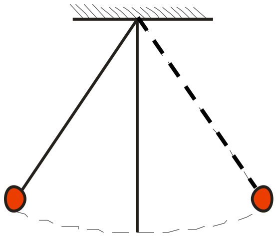
## Types of Motion

**Activity 2.2**

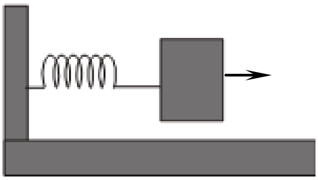
i. Observe the motions indicated in Fig 2.1.
ii. Have you noticed any difference between the motions in Fig 2.1 (a-d)? Describe them.
iii. Group these motions, based on their path.

a) A car moving on a straight line

b) Roundabout



c) Simple Pendulum



d) Spring-mass system

Fig. 2.1 Types of motion

In Fig 2.1 (a) you observe that a car is moving on a straight road. Its path is a straight line.

Fig 2.1 (b) shows that the path of the moving car is a curved line.
While Fig 2.1 (c and d) show the 'to and fro' motions of an object.
Based on the path followed, a motion is classified into four types. The followings are types of motion of a body.

1. **Rectilinear motion** is the motion of a body along a straight line.

   ***Examples***

   - Motion of a car along a straight level road,
   - A falling ball from a certain height.

2. **Curvilinear Motion** is the motion of a body along a curved path.

   ***Examples***

   - Motion of a car around a circular path,
   - The motion of a ball thrown horizontally from a certain height,
   - The motion of the moon around the earth.

**Note:** Circular motion is a special case of curvilinear motion, in which the body moves along a circular path.

3. **Rotary motion** is the motion of a body about an axis.

Examples

- The motion of the second or minute hand of a wrist watch,
- The motion of a wheel of a car.

4. **Vibratory motion** is a '**to** and **fro**' or **back** and **forth** or **up** and **down** motion of a body. This motion does not have constant velocity.

Examples

- The motion of a pendulum,
- The motion of objects suspended on a spring,
- Water wave, etc.

**Note:** Both rotary and vibrational motions are periodic motions. Periodic motions can have constant or non-constant velocities and they repeat themselves.

### Activity 2.3

Write down some examples of motion for each type from your daily experiences. Discuss them with your classmates, how they are different.

| Types of motion | Practical Examples |
|---|---|
| 1. Rectilinear | • ____________________. |
| 2. Curvilinear | • ____________________. |
| 3. Circular motion | • ____________________. |
| 4. Vibrational motion | • ____________________. |
| 5. Rotary motion | • ____________________. |

### Check point 2.1

1. State at least four types of motion, and give practical examples for each type.
2. Define what a motion is.

## 2.2 Motion Along a Straight Line

Motion along straight line path is known as a rectilinear motion.

| Activity 2.4 |
|---|
| • Discuss about the common features of motion along a straight line. |


Fig.2.2 In competition different athletes cover the same distance in different time

In a rectilinear motion, a body moves over a certain **distance** along a straight line and takes a certain **time.**

Athletes run different distances. They run 5,000 m, 10,000 m and so on. To cover these distances they take different times. Which distance is covered in the shortest possible time? What do you call the distance covered in a unit of time?

| Activity 2.5 |
|---|
| • What do you understand by the terms ' Scalars' and ' Vectors' in relation to motion?(Revision) |

**Distance:** As a car moves along a straight road we can easily observe the change of its position. What is the distance traveled by the car between the initial and the final position?

Distance is a physical quantity which describes the length between two points (places). It is the total path length traveled by a body.
It depends on the path followed.

To describe a distance it is not important to mention its direction. A distance is a scalar quantity.

Observe Fig.2.3, Two persons moved from point A to point B, in different paths: path 1 and 2. What would you say about the distance covered by the two persons?

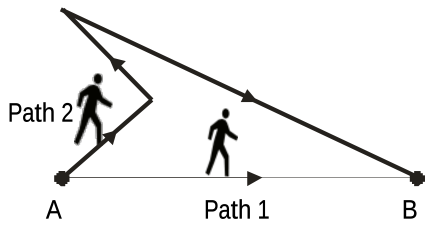



Fig.2.3. Variation of distance with the path followed

Do you remember the units of length from the previous unit? What is the SI unit of length? Do you think the units of length and distance are the same?

The symbol for distance is "s". The SI unit of distance is meter (m). Mostly, the distance covered by a moving car or airplane or train is measured by kilometer (km).

Fig.2.4 Football field

## Challenging Questions

What is the distance around a standard football field?

## Displacement ($\vec{s}$)

Azeb walked 300 m from A to B and returned back and walked 200 m and then stopped at C. What is her change in position from A to C?

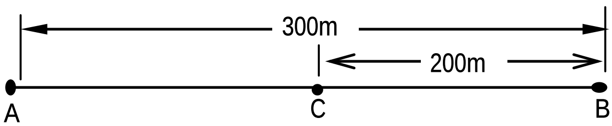



Fig.2.5 Finding change of position

When an object moves, it changes its position. This change of position in a certain direction is known as a **displacement**. A displacement is described by its magnitude and direction. It is a vector quantity.

As shown in Fig. 2.6. a body may move from A to B in different paths such as path 1, path 2 and path 3. The distance of the three paths is different. However, the displacement made is the same.

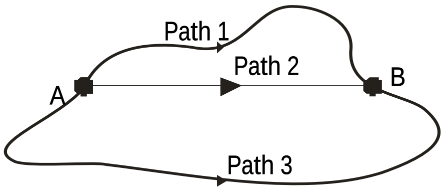



Fig.2.6 Displacement is independent of the path

**Activity 2.6** *Discuss with your friends*

Which path is the shortest? Which one of the paths has a fixed direction throughout its motion?(Fig 2.6)

As you know all the lengths of the paths are '**distances**'. Path 2 is a straight line and it is the shortest distance between the initial and final positions of the body. Hence, it is the displacement of the body.

This straight path having a fixed direction is said to be a displacement. Hence a displacement is the shortest distance in a specified direction.

The SI unit of displacement is the same as the SI unit of distance that is meter (m). The symbol of displacement is $\vec{s}$, with an arrow on the head of s. Displacement is independent of the path followed.

In Fig 2.7, you observe that displacement is the difference between the final position $\mathbf{x_f}$ and the initial position $\mathbf{x_i}$.

a) A displacement to the right of the origin, 'O' will be a positive displacement. That is,

$$s > 0 \text{ since } x_i < x_f .$$

For example, starting with $x_i$ = 60 m and ending at $x_f$ = 150m, the displacement is

$$\vec{S} = x_f - x_i = 150 \text{ m} - 60 \text{ m} = 90 \text{ m, to the right.}$$

b) A displacement to the left of the origin, 0 will be a negative displacement. That is,

$$\vec{s} < 0 \text{ since } x_i > x_f .$$

For example, starting with $x_i$ = 150 m and ending at $x_f$ = 60m, the displacement is

$$\vec{s} = x_f - x_i = 60 \text{ m} - 150 \text{ m} = -90 \text{ m (to the left direction)}$$

c) Positions to the right of the origin are positive.

Positions to the left of the origin are negative.

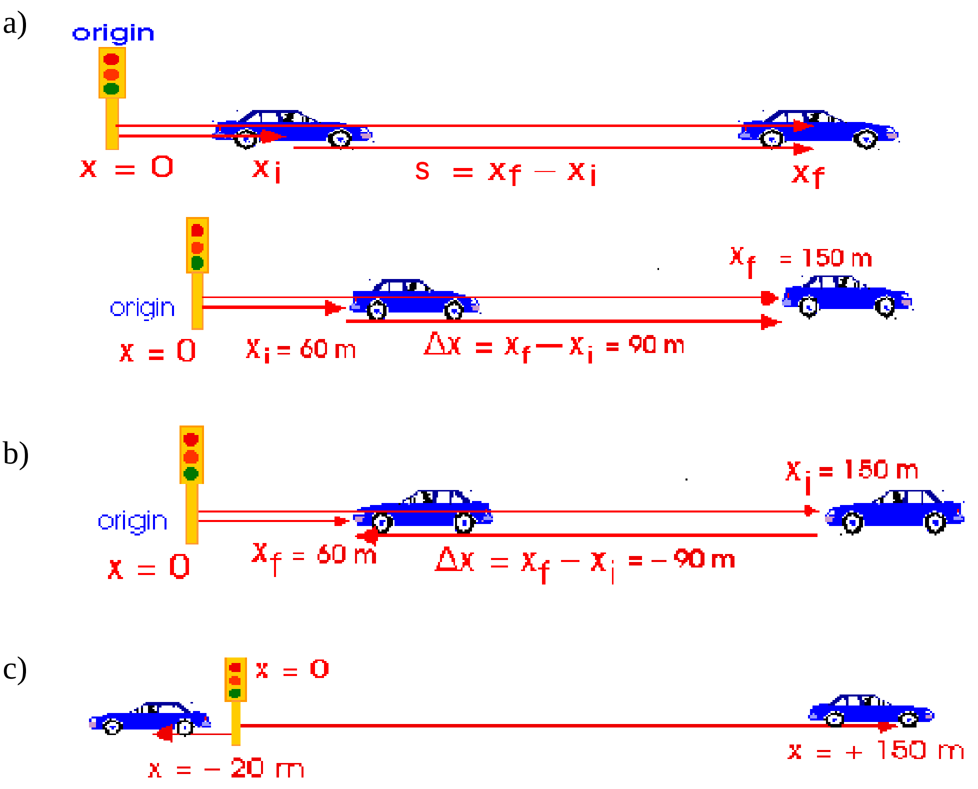



*Fig.2.7 Displacement of a car at different time along x -axis*

## Comparison of distance and displacement

**Activity 2.7**

- List down the similarities and differencec between a distance and displacement for rectilinear motion.

| | Similarities | Differences |
|---|---|---|
| Distance and Displacement | | |

## Speed (v)

**Activity 2.8**

Tirunsh Dibaba ran Bejing Olympic and covered 10,000 m distance in 28 minutes. Sileshi ran the same distance and it took him 24 minutes. What were thier average speeds? Who is the fastest?

Both athlets covered the same distance in different time. From the given informaton you can compute the distance they covered in one second. i.e. Tirunesh covered an average distance of 5.95 m in one second. While Sileshi covered 6.94 m in one second. Thus, the distance covered per unit time is called speed.

Speed is a quantity that describes how fast a body moves. Its symbol is ‘‘v’’
The SI unit of speed is meter per second (m/s).

In reality, a moving body does not have a uniform speed throughout its motion. Sometimes the body will speed up, sometimes it will go at a constant speed and at other times it may slowdown. For this reason the speed you calculate is an average speed.

An average speed is the total distance traveled divided by the total time taken.

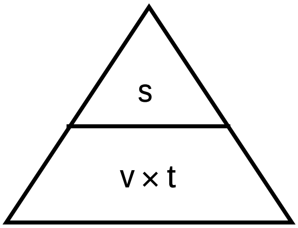
$$\text{Average speed} = \frac{\text{total distance traveled}}{\text{total time taken}} \Rightarrow v_{av} = \frac{s}{t}$$

The SI unit of average speed is m/s.

Rearranging the formula gives

$$s = vt \text{ and } t = \frac{s}{v}$$

Using the triangular symbol you can perform the above rearrangement of the formula




The unit of speed m/s can also be written as m $s^{-1}$.

Using the exponential expression, we write:

$$\frac{m}{s} = m \cdot \frac{1}{s^{+1}} = m \cdot s^{-1}$$

**Activity 2.9**

i. State some units of speed other than m/s.
ii. Express 1 km/hr in m/s.
iii. What is the conversion factor between m/s and km/hr?

## Example 2.1

1. Tirunesh Dibaba covers a distance of 5000m in 14.5 minutes. Calculate the average speed of Tirunesh in m/s.

| Given | Required | Solution |
|---|---|---|
| s = 5000 m<br>t = 14.5 min = 870s | $v_{av}$ = ? | $v_{av} = \frac{S_{tot}}{t_{tot}} = \frac{5000m}{870s} = 5.75m/s$ |

2. A bus is moving in a straight line at a speed of 25m/s. What time does the bus take to cover 5km?

| Given | Required | Solution |
|---|---|---|
| v = 25m/s<br>s = 5km = 5000m | t = ? | $v = s/t \Rightarrow t = s/v$<br>$= \frac{5000\cancel{m}}{25\cancel{m}/s}$<br>= 200sec |

3. Convert 20 m/s to km/hr.

**Solution**

1 m/s = 3.6 km/hr

$$20\text{ m/s} = x \qquad \Rightarrow x = \frac{20\,\cancel{\text{m/s}} \times 3.6\text{ km/hr}}{1\,\cancel{\text{m/s}}} = 72\text{ km/hr}$$

4. Convert 60 km/hr to m/s.

**Solution**

$$\text{km/h} = \frac{1}{3.6}\text{ m/s}$$

60 km/hr = x

$$x = \frac{60\,\cancel{\text{km/hr}} \times \frac{1}{3.6}\text{ m/s}}{1\,\cancel{\text{km/hr}}} = 16.67\text{ m/s}$$

## Exercises

Suppose four students. Almaz, Abebe, Sofia and Gemechu are running a 100m race. Alamz takes 12s, Gemuchu takes 13s, Sofia takes 14s and Abebe takes 15s to finish the race.

Calculate their speeds and record them on the chart given below. From the chart find:

a) Who is the fastest runner?
b) Who is the slowest runner?
c) What can you conclude about the relationship between speed and time?

| | Distance (m) | Time (s) | Speed ($ms^{-1}$) |
|---|---|---|---|
| Almaz | | | |
| Abebe | | | |
| Sofia | | | |
| Gemechu | | | |

Do you notice from the above chart that the speed increases as the time decreases to cover the same distance?

## Velocity

Velocity is a physical quantity that describes how fast a body moves as well as the direction in which it moves. Hence, velocity is a vector quantity. Its symbol is $\vec{v}$ (v with an arrow on the head)

Velocity is the rate of change of displacement $\vec{s}$ i.e. it is the displacement covered by the body per unit time.

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

$$\vec{v} = \frac{\vec{s}}{t}$$

The SI unit of $\vec{v}$ is $\frac{m}{s}$

Average velocity $(\vec{v}_{av})$ is the total displacement divided by the total time taken.

$$\text{Average velocity} = \frac{\text{Total displacement}}{\text{Total time taken}}$$

$$\overrightarrow{v_{av}} = \frac{\vec{s}_T}{t_T}$$

## Example 2.2

1. A car moves at a speed of 20m/s for 120 seconds due East. What is the displacement of the car?

| Given | Required | Solution |
|---|---|---|
| $\vec{V}$ = 20m/s due East<br>t = 120s | $\vec{S}$ = ? | $\vec{v} = \frac{\bar{s}}{t} \Rightarrow \vec{s} = vt$<br>$\vec{S}$ = 20m/s, East × 120 s<br>= 2400 m due East<br>= 2.4 km, due East |

2. A bus is moving due north for 2 hr and covered a distance of 72 km. What is the velocity of the bus?

| Given | Required | Solution |
|---|---|---|
| $\vec{s}$ = 72 km, due North<br>t = 2 hrs | $\vec{v}$ = ? | $\vec{v} = \frac{\vec{s}}{t} = \frac{72km}{2hr}$ due North<br>= 36 km/hr due North |

## Activity 2.10

- List down the similarities and differences between speed and velocity for a rectilinear motion.

| | Similarities | Differences |
|---|---|---|
| Speed and Velocity | | |

## Check point 2.2

1. What do you call a speed that has direction?
2. What are the main features of a velocity in a uniform motion?
3. A car moves at a speed of 20m/s east ward. What is the car's velocity in magnitude and direction?
4. A bus travels 43 km in the first hour, 40km in the second hour and 46 km in the third hour of its journey. Calculate its average speed.
5. The speed of an airplane is 360 km/hr, and another air plane has a speed of 120 m/s. which one of these two air planes has a greater speed?

## 2.3 Qualitative Exploration of Uniform Motion and Uniformly Accelerated Motion

### 2.3.1 Uniform Motion

**Activity 2.11**

The motions of two bodies are measured and recorded in tables 'A' and 'B'.

A)

| s(m) | 6 | 12 | 18 | 24 | 30 | 36 | 42 | 48 |
|---|---|---|---|---|---|---|---|---|
| t(s) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| v(m/s) | | | | | | | | |

B)

| s(m) | 4 | 9 | 15 | 22 | 30 | 39 | 49 | 60 |
|---|---|---|---|---|---|---|---|---|
| t(s) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| v(m/s) | | | | | | | | |

i. Calculate the speed of the two bodies and complete the tables.
ii. What is the difference between the speeds in A and B?
iii. What do you call the type of speed in A and in B

From table A you observe that when a body makes equal changes of displacement within equal interval of time, its velocity is said to be a **uniform velocity.** i.e. its speed is constant and the direction is fixed. A motion with a uniform velocity is called a **uniform motion**. For uniform motion $\vec{v} = \frac{\vec{s}}{t}$ and $\vec{s} = \vec{v} \times t$

Uniform motion is the motion of an object along a straight line with a constant velocity or speed in a given direction.

**Activity 2.12**

Suppose an object is moving at a constant speed of 2m/s in straight line. At the end of the first second, it travelled 2m away from its starting point. At the end of 2 second the distance travelled is 4m. Complete the table by filling the distance travelled in 3, 4 and 5 seconds.

| t(s) | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| s(m) | 2 | 4 | --- | ---- | --- |

Note that for a uniform motion, as the time increases the displacement also increases. If you plot a graph of s against t using data from the above table you will get the graph shown in Fig 2.8

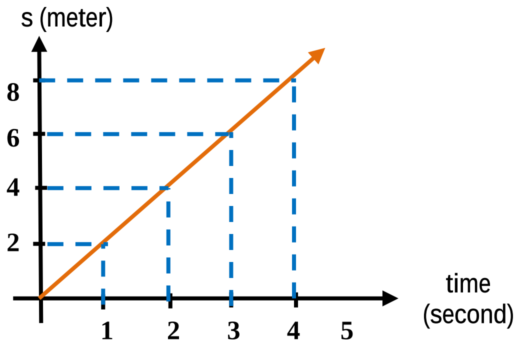



Fig.2.8 Graph of s against t for motion with constant velocity

From the graph in Fig.2.8, you can find the slope of the graph.

The slope of the graph $= \dfrac{\text{change in displacement}}{\text{change in time}}$,

$$\frac{\Delta\vec{s}}{\Delta t} = \frac{\vec{s}_f - \vec{s}_i}{t_f - t_i} = \frac{\vec{s}}{t}$$

But by definition: $\vec{v}_{av} = \dfrac{\vec{s}}{t}$

Hence, the slope of s against t graph of uniform motion equals average velocity.

## 2.3.2 Uniformly Accelerated Motion

In section 2.3.1 you learnt about uniform motion. That is, where the speed is constant and the direction is fixed in a straight line. In this section you will study another kind of motion; in which the velocity changes uniformly.

**Activity 2.13**

i. Explain what it means by the change of velocity.
ii. Describe the factors which could be affected when the velocity changes.
iii. What is acceleration? How is it different from velocity?

## Acceleration

Whenever the velocity of an object changes in magnitude, or direction or both simultaneously, it is said to be accelerated.

Acceleration is a measure of how much the velocity of an object changes in a unit of time (usually in one second).

Acceleration is the time rate of change of velocity.

$$\text{Acceleration} = \frac{\text{change in velocity}}{\text{time taken}}$$

$$\vec{a} = \frac{\vec{v}_f - \vec{v}_t}{t}$$

The symbol for acceleration is $\vec{a}$. It is a vector quantity

$\vec{v}_i$ is the initial velocity

$\vec{v}_f$ is the final velocity

t is the time taken

The SI unit of acceleration is meter/second/second = $m/s^2$

If a body starts from rest, then the initial velocity is zero ($\vec{v}_i$ = 0). If the velocity of a body decreases then the final velocity is less than the initial velocity. Such motion is called decelerating. **Deceleration** is called a negative acceleration. (that is $\vec{v}_f < \vec{v}_i$ ).

If the body comes to rest then, the final velocity is zero ($\vec{v}_f = 0$).

Uniformly accelerated motion is motion of an object along a straight line with a constant increase in its velocity.

## Examples 2.3

1. The speed of a car increases uniformly from 8m/s to 48 m/s in 10s . Calculate the acceleration of the car.

| Given | Required | Solution |
|---|---|---|
| $\vec{v}_i$ = 8m/s<br>$\vec{v}_f$ = 48m/s<br>t = 10s | $\vec{a}$ = ? | $\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{t}$<br>$= \frac{(48-8)\,m/s}{10\,s}$<br>$= \frac{40\,m/s}{10\,s}$<br>$\vec{a} = 4\ m/s^2$ |

2. A car started from rest and accelerated uniformly and reached a speed of 20m/s after 5 s. What is the acceleration of the car?

| Given | Required | Solution |
|---|---|---|
| $\vec{v}_i = 0\text{m/s}$<br>$\vec{v}_f = 20\text{m/s}$<br>$t = 5$ sec | $\vec{a} = ?$ | $\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{t}$<br>$= \frac{(20-0)\text{ m/s}}{5\text{ s}}$<br>$= \frac{20\text{ m/s}}{5\text{ s}}$<br>$\vec{a} = 4\text{ m/s}^2$ |

3. A bus initially at rest accelerated uniformly with an acceleration of 4 $\text{m/s}^2$. What is the speed of the bus at the end of 5?

| Given | Required | Solution |
|---|---|---|
| $\vec{v}_i = 0$<br>$\vec{a} = 4\text{ m/s}^2$<br>$t = 5$ sec | $\vec{v}_f = ?$ | $\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{t}$<br>$\vec{v}_f - \vec{v}_i = \vec{a} \times t$<br>$\vec{v}_f = \vec{a} \times t + \vec{v}_i$<br>$\vec{v}_f = 4\text{m/s}^2 \times 5\text{s} + 0$<br>$= 20\text{m/s}$ |

## Falling bodies

**Activity 2.13**

*Discuss what happens to the motion of a stone.*

i. When you throw a stone vertically upward in air.

ii. When you drop a stone from some height above the ground.

Gravity is the pulling force of the earth on a body. The first person who studied about motion of a falling body was **Galileo Galilee**. He showed that all bodies dropped from the same height fall to the earth with the same acceleration, which is known as the **gravitational acceleration** ($\vec{g}$). All objects falling freely in air accelerates uniformly by 9.8 m/s every second.

Motion of a freely falling body is the natural example of a uniformly accelerated rectilinear motion.

Free fall is the motion of a body under the action of the force of gravity.

### 2.3.3 Representation of Uniform Motion and Accelerated Motion Qualitatively Using Table

Walk one pace every 2 seconds. This is represented using dot plot.

| s against t Table | |
|---|---|
| t | s |
| 2s | 2 dot |
| 4s | 4 dot |
| 6s | 6 dot |

Dot plot for a constant velocity (Fig 2.8)

•  •  •  •  • .

2s  2s  2s  2s

$$\text{Velocity} = \frac{1\,\text{dots}}{2\text{s}} = \tfrac{1}{2}\,\text{dot/s}$$

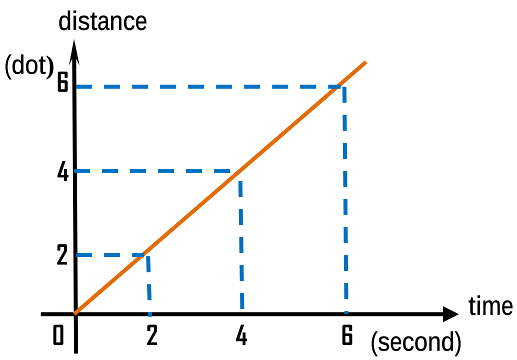



Fig. 2.9 Average velocity = slope of the s against t graph

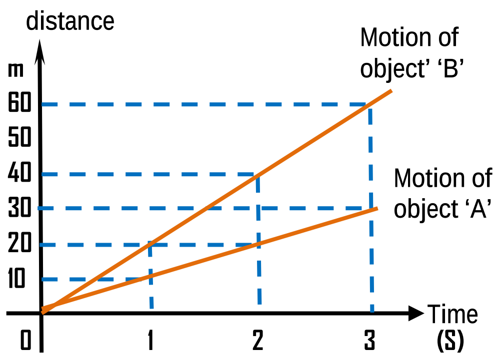



Fig. 2.10 Graphs of two bodies A and B travelling at different speeds.

From Fig 2.10 we calculate that:

$$\vec{v}_{av}(A) = \frac{10}{1}\,\text{dot/s} = \frac{20}{2\text{s}}\,\text{dot/s} = \frac{30}{3}\,\text{dot/s} = 10\ \text{dots/s}$$

$$\vec{v}_{av}(B) = \frac{20}{1}\,\text{dot/s} = \frac{40}{2}\,\text{dot/s} = \frac{60}{3}\,\text{dot/s} = 20\ \text{dots/s}$$

The slope with 20 dots/s has higher velocity than slope with 10 dot/s.

This means a steep slope has higher velocity than a gradual slope.

*Note that when you draw graphs of motions, you must*

1. *Label the axes*
2. *Put units clearly on both axes*
3. *Label each slope*
4. *Put their names on the graph*

Calculate the slope of the graph from initial and final as well as for several intervals. (see Fig 2.9 and 2.10)

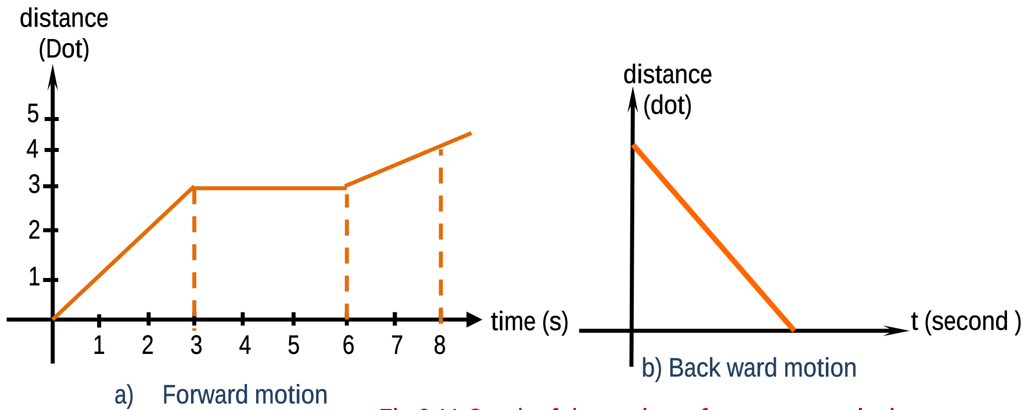



Fig 2.11 Graph of dot against t for constant velocity

Dot plot for a constant velocity (Fig 2.11 (a))

Jemila walked for 3 seconds. She then stopped for 3 seconds and started to move. ( see Fig 2.11a)

● ● ● ● ● ● ● ● ● ●

0 1 2 3 4 5 6 7 8 9

3 second rest

Average velocity = slope of the s against t graph

$$\vec{v}_{av} = \frac{3-0}{3-0}\left(\frac{\text{dots}}{\text{s}}\right)$$

$$= \frac{3}{3}\left(\frac{\text{dot}}{\text{s}}\right)$$

$$= 1\text{dot/s}$$

**Graphical representation of uniformly accelerated motion**

Dot plot for a uniformly accelerated motion

● ● ● ● ●

0s 2s 4s 6s 8s

The above dot spaces represent distances for accelerated motion every 2 seconds. Let us see the following examples that describe a uniformly accelerated motion. The tables are based on the motions of a bus and a car accelerating along a straight line.

| Table 1. Motion of a bus | | | | | | |
|---|---|---|---|---|---|---|
| $\vec{v}$ (m/s) | 0 | 10 | 20 | 30 | 40 | 50 |
| t (s) | 0 | 5 | 10 | 15 | 20 | 25 |
| $\vec{a}$ (m/s2) | | | | | | |

| Table 2. Motion of a car | | | | | | |
|---|---|---|---|---|---|---|
| $\vec{v}$ (m/s) | 0 | 20 | 40 | 60 | 80 | 100 |
| t(s) | 0 | 5 | 10 | 15 | 20 | 25 |
| $\vec{a}$ (m/s2) | | | | | | |

## Challenging questions

1. What are the accelerations of the bus and the car?
2. What difference do you observe from the above tables?

Motions of a bus and a car are given in Tables 1 and 2. Draw the v against t graphs for both objects.

Slope of the v against t graph is the acceleration of the moving object.

$$\text{Accelerations} = \text{slope} = \frac{\text{Change in velocity}}{\text{Change in time}}$$

$$\text{Acceleration of the Bus} = \frac{20 - 0\text{m/s}}{10 - 0\,(\text{s})} = 2\text{m/s/s} = 2\text{m/s}^2$$

$$\text{Acceleration of the Car} = \frac{40 - 0\text{m/s}}{10 - 0(\text{s})} = 4\text{m/s/s} = 4\text{m/s}^2$$

The slopes of $\vec{s}$ against t and $\vec{v}$ against t graph show velocity and acceleration respectively. But the area under the curves of graphs of $\vec{v}$ against t and $\vec{a}$ against t gives the total distance covered and change in velocity respectively.

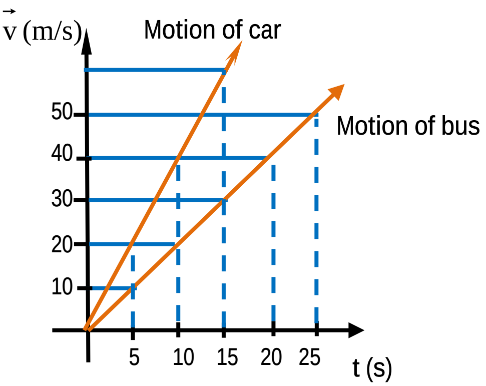



Fig 2.12 v against t graph for the motion of a bus and car

## Challenging Questions

1. Explain the difference between velocity and acceleration.
2. Describe the difference between uniform motion and uniformly accelerated motion.
3. A body accelerates uniformly from rest at $2 m/s^2$ for 5 seconds. Calculate its average velocity in this time.

### Check point 2.3

1. What does the slope of s against t graph stand for?
2. What happens to a velocity in a uniformly accelerated motion?

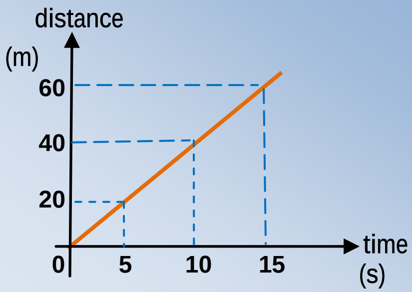



Fig 2.13 s against t graph

3. From the graph of Fig 2.13, answer the following questions.
   a) What is the distance travel by the body in 20 second?
   b) What is the time taken by it to cover a distance of 30 m?
   c) What is the speed of the body?

## SUMMARY

In this unit you learnt that:

- motion is a continuous change of position relative to a reference point. There are four types of motion. They are rectilinear, curvilinear, rotary and vibrational motion.
- distance is the length of a path between two points
- speed is the distance travelled divided by time taken. It describes how fast an object is moving in a unit time. When an object moves with constant speed in a straight line, the motion is known as Uniform rectilinear motion.
- displacement is the shortest distance in specified direction. It has both magnitude and direction. Hence it is a vector quantity.
- velocity is the time rate of change of displacement. It has both magnitude and direction.
- acceleration is the time rate of change in velocity
- the velocity of a body may increase or decrease with time. A body whose velocity is increasing is said to have 'acceleration' and a body whose velocity is decreasing is said to have deceleration or negative acceleration. Acceleration may happen due to:
    - either change in speed, or change in direction or change in both speed and direction simultaneously.
- uniformly accelerated motion of an object is a motion with constant acceleration in a given duration.
- freely falling body is a practical example of a uniformly accelerated motion on the earth.

# Review Questions and Problems

## *Solve the following*

1. A bicyclist travels with an average velocity of 15 km/h North, for 20 minutes. What is his displacement in km?
2. A car accelerates from rest to 90km/h in 10 seconds. What is its acceleration in $m/s^2$?
3. An aircraft landing on an aircraft carrier is brought to a complete stop from an initial velocity of 215 km/h in 2.7 seconds. What is its acceleration in $m/s^2$?
4. A certain car has an acceleration of $2.4 m/s^2$. Assume that its acceleration remains constant. Starting from rest, how long does the car require to reach a velocity of 90 km/h? How far does it travel while reaching that velocity?
5. *From the graph of Fig 2.14*
   a) Calculate the velocity of the motion
   b) What is the slope of the graph equals to?
   c) What is the distance traveled when t = 6 seconds?

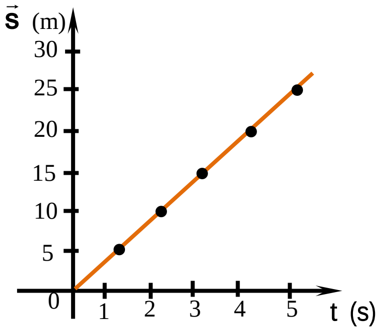



Fig. 2.14 Graph of s against t

6. *From the graph of Fig 2.15*
   a) Calculate the acceleration of the motion
   b) What is the slope of the graph equals to?
   c) What is the velocity when the time taken is 8 seconds?

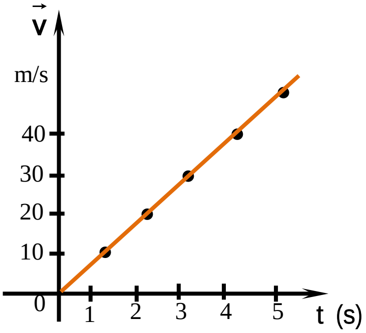



Fig. 2.15 Graph of v against t

7. **Data for a freely falling body is recorded as in table below :** ***Using the given data:***

| t(s) | v(m/s) |
|---|---|
| 0 | 0 |
| 1 | 9. 8 |
| 2 | 19.6 |
| 3 | 29.4 |
| 4 | 39.2 |

**a) draw the graph of velocity versus time.**
**b) calculate the acceleration due to gravity at the place where the data are taken.**
**c) Is the acceleration changing or constant?**

8. **What is the relationship between velocity and acceleration?**
9. **How does the velocity of a freely falling body change with time? How does the distance it has fallen change? How about the acceleration?**
10. **a) A car travels at a speed of 25 m/s. How far does it travel in 5 s?**
    **b) Draw a graph showing the distance versus time for the above car.**
    **c) What is the slope of the graph?**
11. **A train initially at rest, has a constant acceleration of 0.5 m/s$^2$**
    **a) What is its speed after 15s?**
    **b) What would be the total time it would take to reach a speed of 25 m/s?**
    **c) Draw the graph of speed against time for the train.**

# UNIT 3

# FORCE AND NEWTON'S LAWS OF MOTION

**Unit outcomes:** **After completing this unit you should be able to:**

- ✓ **develop a qualitative understanding of Newton's laws of motion and force in static situations.**
- ✓ **develop introductory skill of manipulating numerical problems related to Newton's law of motion and force.**
- ✓ **appreciate the interrelatedness of all things.**
- ✓ **use a wide range of possibilities for developing knowledge of the major concepts with in physics.**

## Introduction

In unit two of this book you learned important concepts that describe motion. The concepts such as speed, velocity and acceleration are used for describing various types of motion around you.

**Activity 3.1**

Discuss with your friends or parents.

- The concepts: speed, velocity and acceleration.
- The difference between uniform and accelerated motions.
- Do you think that force and motion have a relation? Explain.

The motion of bodies (relative to a chosen reference system) is either uniform or accelerated or slowed down, or change in directions. In the last three cases, the velocities of moving bodies are changing. That is, acceleration is produced. Clearly it is very important to be able to study acceleration. However, to understand acceleration in its full sense you must know how it emerges or is produced.

## 3.1. Force

**Activity 3.2**

Discuss the followings with your friends.

i. What is a force?
ii. Mention some examples of forces from your daily activities.
iii. explain the following phrases
  - Social force,
  - Political force,
iv. Explain the following actions.
  - A push you exert on a wall,
  - A pull exerted to drag a box on a table.
v. Do you think that forces in iii) and iv) are the same? Explain

The term force is used in different situations in the English language. Force is a technical term in physics. The term force in physics is different from the term force in political and social.

Force is a very important physical quantity. It is used to describe interactions between two bodies in nature. For example, when you kick a ball, tear a piece of paper, hold your exercise book and walk on the floor you apply forces. Hence, in physics the term 'force' is used to describe a 'push' or a 'pull' exerted on a body.

A force is a push or a pull exerted on a body by another body.

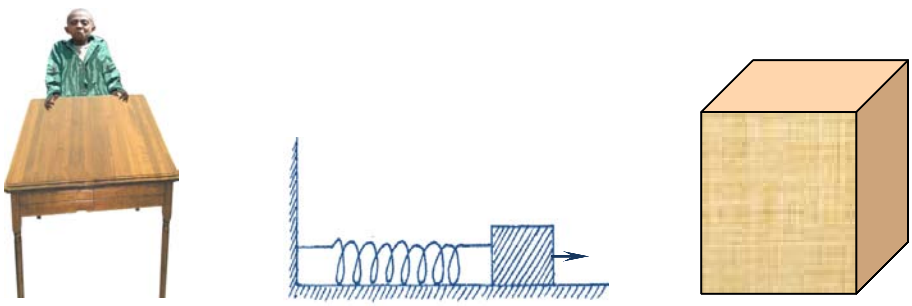
## Types of forces

**Activity 3.3**

i. Throw a ball vertically upward and observe its motion. What will happen to the ball? Will it continue to move upward forever? Why?
ii. Take a magnet and pieces of iron fillings. Move the magnet over the iron filings without a physical contact between the magnet and the iron fillings. Describe your observation for your teacher.
iii. Move your desk from its current position. Can you do it without a physical contact? Why?
**iv.** Explain the types of forces that exist in the above 3 activities.

You know that a force is a push or a pull. But do all bodies push or pull other bodies by making a physical contact only? From your Activity 3.3, you might have noticed that bodies could be in contact to each other or they could be without contact or at a distance from each other. Therefore, forces are classified into two broad categories known as: (i) **Contact forces** and (ii) **Non-contact forces**

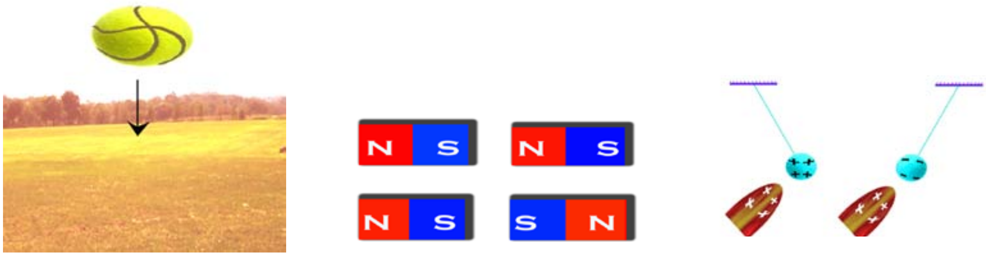
i. **Contact forces** are forces exerted when two objects are in touch or contact. **For example;**
   - A force exerted by a stretched or compressed spring.
   - An upward force exerted by a table on a box resting on it.



a) Pushing a table b) Stretching a spring c) A box resting on a floor

Fig.3.1. Examples of contact forces

ii. **Non-contact forces** are forces exerted without body contact. They are forces acting at a distance. Gravitational force, magnetic force and electrical forces are examples of non – contact forces.




A falling ball | Attraction or repulsion of two magnets | Electrostatic forces

Fig. 3.2 Different types of non contact forces

### Challenging Questions

1. Discuss examples of contact forces in Fig 3.1
2. Discuss the differences between gravitational force, magnetic force and electric forces. (Fig 3.2)

## Effects of a force

When a force is exerted on a body, the body may change its shape or size.

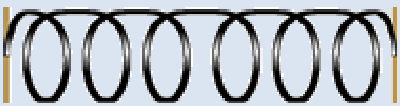
### Activity 3.4

Observe the activities shown in Fig 3.3

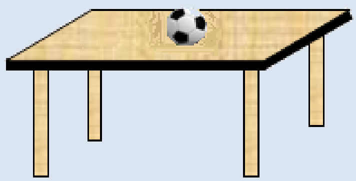
a. Explain the effects of forces in each activity.
b. Can you summarize the effects of force?

a) When the person kicks the ball the ball moves in the direction of the force

b) When the engine applies a force the car moves.



c) When a spring is stretched the size and the shape change.



d) When a ball roles over the table and falls off the table forces are exerted.

Fig.3.3 Different effects of forces

The change in shape or size of a body is known as deformation. There are two types of deformation;

I. Permanent

II. Temporary.

It is not simple to describe a force as you can describe some material objects such as a chalk, pen, orange etc. You can only say what a force can do. For example when a body at rest is acted upon by a force it will begin to move. If a body is already moving a force may change its velocity. That is, a force produces motion or changes motion of a body.

Force produces an acceleration of a body.

A force has the following main effects, when it is exerted on an object:

i. It changes the shape and size of the objects.

ii. It changes the magnitude or direction of motion of the objects. i.e. when a force is exerted on a body:

a. a stationary body starts to move

b. a moving body increases its speed,

c. a moving body decreases its speed and gradually stops moving

d. a moving body changes it direction.

## Measuring a Force

| Activity 3.5 |
|---|
| Do the following tasks with your friends.<br>i. Describe methods of measuring a force.<br>ii. What is the instrument used to measure a force?<br>**iii.** Mention the SI unit of force. |

A force is measured using an instrument called a **spring balance** (Fig 3.4 a). As you can observe from Fig 3.4 there is a stretch (increase in length) of the spring when it is pulled. We can use this increase in length of a spring to measure the magnitude of the force stretching the spring.

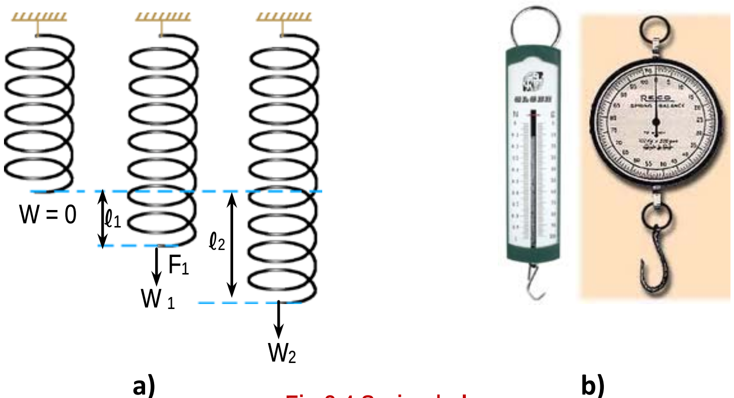



Fig 3.4 Spring balance

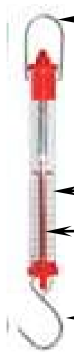
Each time an extra weight is added you find that there is the same extension because each object is identical.

They are attracted to the earth with the same force, so what we have found is that equal force produced equal extensions of the spring. **Newton meter** is the scientific instrument used to measure a force. The SI unit of force is **newton** symbolized by N**.** The unit newton is named, after the great scientist **Sir Isaac Newton**.

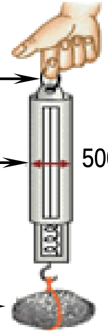
Fig 3.5 (a) illustrate the structure of a Newton meter. It is made up of a spring attached to a hook and a scale leveled in newton.

Fig 3.5 (b) measures the weight of stone in gram. When the spring balance is held by the hand it shows a certain weight for the piece of stone. Here the weight is 500 grams. To know the weight of the stone in newton you have to multiply by 10 $m/s^2$.

**Describing a Force:** A force is a vector quantity. (A vector quantity is a quantity which has both magnitude and direction.) To fully describe the force acting upon an object, you must describe both its magnitude and direction. For example, "10 N of force" is not a complete description of the force acting on an object. '10 N downwards' is a complete description of the force acting upon an object.




*a) Newton meter*




***b) Spring balance***

Fig 3.5 Force measuring instruments

**Check points 3.1**

1. What is a force in physics?
2. Name two types of force and give example for each type.
3. Describe some effects of a force.
4. Write the unit of force both in word and symbol.
5. Read the weight of a body from the spring balance.

## 3.2. Newton's Laws of Motion

In unit two of this book you learned about the motion of bodies in a straight line. In the first section of this unit, you learned the major effects of a force. Combining these two backgrounds, it is now necessary to study the relationship between force and motion.

Galileo Galilee (1564-1642 AD) and Sir Isaac Newton (1642-1727 AD) tried to explain the causes of motion of bodies in a certain direction or why bodies stop their motion. These ideas were put together by Sir Isaac Newton in the form of laws of motion called Newton's laws of motion.

### Newton's First Law of Motion

**Activity 3.6**

Discuss the following questions with your friends.

i. Place any object (text book, or pen, or eraser) on a floor.
ii. What happens to the state of motion of the object, when you don't exert a force on it?
iii. Exert a force (push or pull) on the objects. What happens to their states of motion?

Based on the discussion of activity 3.6 you can generalize that unless you or someone else exerts a force on the object, an object at rest will remain at rest. But when a force is applied it starts to move.

Similarly, a body moving with a constant velocity along a straight line will not increase or decrease its speed unless an external force is applied on it. These conditions led Newton to state the important law called Newton's first law of motion.

Newton's first law of motion states that: "an object continues in its state of rest or of uniform motion in a straight line unless it is forced to change that state by the application of an external force."

This means, in the absence of an external force, a body at rest will remain at rest and a body in motion will continue its motion in a straight line with uniform velocity. This law is also called the **Law of Inertia**.

This law points out that force is something that changes the state of a body. In other words we can say that if the state of a body changes, a force is acting on it. A force may be defined as a push or a pull which produces or tends to produce motion, stop or tend to stop motion.

## Activity 3-7

i. Discuss with your friends and report to your teacher. ( Fig 3.6)
   a. pull both cans with the same force. Which can is easy to move? Why?
   b. If both cans are moving towards you, which is easier to stop its motion?
   c. What do you call the property of a body to resist change in its motion?

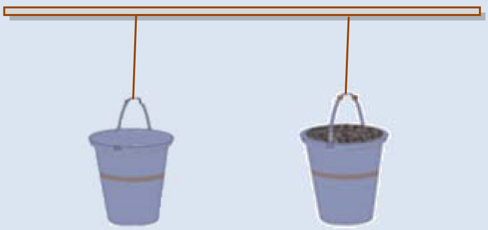

a) Empty can b) Can full of Sand

Fig 3.6 Bodies having different masses

ii. What is the use of seatbelt/safety belt in a car? Ask a driver or a traffic police and discuss your findings with your group members.

iii. When you are standing in a moving bus, you fall or tend to fall forward when it suddenly stops. How can you explain this effect? What are the forces acting on you?

iv. Explain the term 'inertia' using practical examples.

From your Activity 3.7 you noticed that an object at rest would insist to be at rest. A moving object would like to continue its uniform motion in a straight line. This is the property of all objects and it is known as **inertia**.

Inertia is the property of a body to retain its state of rest or state of uniform motion in a straight line in the absence of an external force.

## Activity 3.8

i. Place your pen on the surface of a floor. Push the pen and observe its motion. Similarly apply the same amount of force on a table; standing on a floor. What effects do you notice in both activities?

ii. Is the speed of the table the same as that of the pen?

iii. Do you think that for the same applied force the change in velocity is the same? Explain your answer.

From the above two activities you noticed that mass and inertia are the same. To move a large mass, a large force is required for motion to begin; and if the mass is small, a small force is required. We use the term mass instead of inertia in this book.

Generally large masses have greater inertia and smaller masses have less inertia.

## Activity 3-9

Do the following activity to understand the effects of inertia. (Fig 3.7)

i. Pile of four or five smooth wooden blocks on the top of a table.

ii. Give a sharp kick with a hammer on the bottom block.

iii. What did you observe?

iv. Why do the blocks of wood drop vertically down when the bottom block is kicked with the hammer?

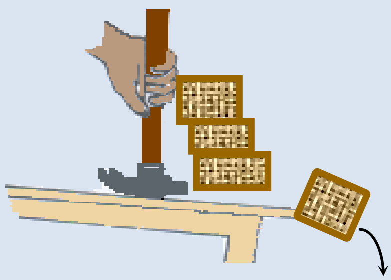


Fig.3. 7 A pile of wooden blocks

When the bottom block is given a sharp kick it causes out of the stack while the top three blocks drop vertically down as shown in Fig. 3.7. Do the rest in the same manner as the first. You will observe that when the kicked block moves away the remaining will be dropped vertically down.

**Activity 3.10**

i. Apply a force to move a heavy box placed on a smooth floor, it will resist to stay at rest or don't move. This means you didn't bring a change in motion even though you applied a force.
ii. Why do you think the body does not move when you apply a force?

The above activities show that mass and inertia are the same. To move a large mass, a large force is required, and to move a small mass, a small force is required. In this book we use the term mass instead of inertia.

## Newton's second law of motion

Newton's first law describes the qualitative property of a force. It describes how force changes the state of rest or uniform motion of a mass of body. In other words, it states that every change in the magnitude or direction of a body's velocity is caused by applying an external force.

In Newton's second law you will learn how to measure the magnitude of a force required to bring a given body to rest or set in motion.

**Activity 3-11**

- Consider two boxes 'A' and 'B' as in Fig 3.8. Let the mass of 'A' is 20 kg and that of 'B' is 40 kg. Both are at rest.
- Suppose you push separately the two boxes with the same force of 10 N. which box change its motion easily? Explain it.

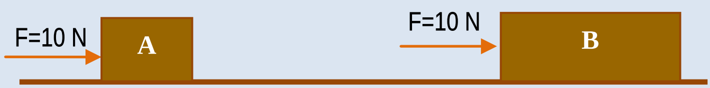



Fig.3.8 Different masses acted by the same force

Activity 3.11 helps you to know that, when the same force is applied on two bodies of different masses, the smaller mass accelerates more than the larger mass.

Mathematically you can state as follows. Acceleration is inversely proportional to the mass of a body for a given applied force. i.e. $\mathbf{a} \propto \frac{1}{\mathbf{m}}$ where 'm' is the mass of the body and 'a' is the acceleration. α is proportionality symbol.

## Activity 3-12

i. Consider two bodies of equal masses and different forces are applied to make them move. (Fig 3.9)

- Which one of the masses do you think will accelerate more?
- What do you conclude about force and acceleration?

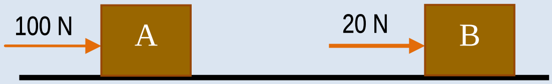



Fig. 3.9 Equal masses acted by different forces

Activity 3.12 helps you to observe that as the force increases the acceleration increases for a given constant mass.

Acceleration is directly proportional to the force applied. i.e. $\mathbf{a} \propto \mathbf{F}$. This means that the greater force you apply to an object the greater the acceleration is.

Combining Activities 3.11 and 3.12 together we get the following important law known as Newton's second law of motion.

**Newton's second law of motion states that:** "the acceleration of a body is directly proportional to the force '(F)' acting on the body and inversely proportional to the mass '(m)'of the body."

Mathematically expressed as:

$$\text{Acceleration (a)} = \frac{\textbf{force (F)}}{\textbf{mass (m)}}$$

Force = mass × acceleration

$F = ma$

The SI unit of force is newton, represented by 'N'. 1 N = 1 kg m/s$^2$

1 newton is the force needed to give an acceleration of 1m/s$^2$ to a mass of 1kg.

This law is valid for objects ranging from the size of atoms to size beyond the distances of galaxies and everything in between. This is why Newton's second law of motion is called the 'universal' law. It describes the way objects in the universe move.

**Activity 3-13**

i. Can you mention any other physics laws you know that applies universally?
ii. Discuss them with your friends.

**Example 3.1**

1. How large a force is required to set a 10 kg toy car in motion with an acceleration of 2 $m/s^2$.

| Given | Required |
| --- | --- |
| m = 10 kg<br>a= 2$m/s^2$ | F = ? |

**Solution**

According to Newton's $2^{nd}$ law of motion

F = ma

= 10 kg × 2$m/s^2$

= 20 kg $m/s^2$

= 20 N

2. A force of 30 N is applied on a box of unknown mass to set it with an acceleration of 5$m/s^2$. What is the mass of the box?

| Given | Required |
| --- | --- |
| F= 30N<br>a = 5$m/s^2$ | m = ? |

**Solution**

From F = ma, we get

$$m = \frac{F}{a} = \frac{30N}{5^m/_{s^2}} = 6\ kg$$

∴ m = 6 kg

- Verify that N/ ($m/s^2$) = kg

3. A girl pulls a box on a horizontal floor by applying a horizontal force of 100N. The mass of the box is 20 kg. What is the acceleration of the box?

| Given | Required | Solution |
|---|---|---|
| F = 100 N | a = ? | from F = ma, we have: |
| m = 20 kg | | $a = \frac{F}{m} = \frac{100N}{20kg} = 5\ N/kg$ |
| • Can you verify that $N/kg = m/s^2$? | | $\therefore a = 5m/s^2$ |

4) How much external force is required to accelerate a 1500 kg car at the rate of $6m/s^2$?

| Given | Required | Solution |
|---|---|---|
| m = 1500kg | F = ? | F = ma |
| $a = 6\ m/s^2$ | | $= 1500\ kg \times 6\ m/s^2$ |
| | | F = 9000 N |

Fig. 3.10. A man measuring his weight on a balance.

**Activity 3.14**

i. What is mass?
ii. What is weight?
iii. Explain the difference between mass and weight.

## Mass and weight

You learnt in unit one that the mass of a body depend on the quantity of matter it contains and being measured using a beam balance everywhere.

Mass is the amount of matter in a substance. The mass of a body characterizes its inertia and it is a scalar quantity which is measured in kilogram (kg). Thus the mass of a given body is the same everywhere. Whereas weight is the pulling force of the earth towards its center and it is a vector quantity.

If you throw a stone vertically upward, it will fall back to the earth. The same thing will happen every time you throw an object in any direction. The pulling of objects by the earth towards its center is called the force of **gravity**.

The pull of gravity acting on a body towards the centre of the earth is called the weight of a body. Thus the weight of a body is a force.

## What is the Difference between Mass and Weight?

Fig. 3.11 a and b shows two types of scales commonly used in the science classroom. These are **spring scale** and a **beam balance** scale.

a) Spring scale

b) Beam balance scale

Fig 3.11 Two types of scales for measuring mass

For example on earth the spring scale reads 100g with a mass attached to the hook (Fig 3.11 (a)). When a beam balance scales is used, you balance the scale on the right by a 100 g mass of substance.

If we were to take both scales to the moon, what would the spring scale read? How much mass would be needed to balance the 100g mass on the balance beam? Can you explain your answer?

In science or physics you need to recognize between '**weight**' and **'mass'**. They are two different physical quantities in physics.

### Activity 3.15

i. Have you noticed that people are using the terms 'mass' and weight interchangeably? Comment on it.

ii. What is the reading you get from a balance when you stand on it? Is it your weight or your mass?

According to Newton's second law, force equals to the product of mass and acceleration, that is F= ma. Similarly the force of gravity of the earth equal to the product of mass and acceleration due to gravity 'g', thus;

Weight (W) = mass (m) × gravitational acceleration (g) ⇒ W = mg
Where 'm' stands for mass and 'g' is acceleration due to gravity.

**Example: 3.2**

1. The mass of one quintal of 'teff' is 100 kg. What is its weight? Take $g = 10 m/s^2$.

| Given | Required | Solution |
|---|---|---|
| m= 100 kg<br>$g = 10 m/s^2$ | W = ? | From W = mg, we have<br>$= 100 kg \times 10 m/s^2$<br>= 1000 N |

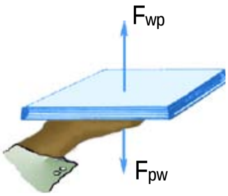
2. How much does a 100 kg body weight on the surface of the moon whose acceleration due to gravity is equal to $1.63 m/s^2$?

| Given | Required | Solution |
|---|---|---|
| m = 100 kg<br>$g = 1.63 m/s^2$ | W = ? | Using the definition of weight, we get,<br>W = mg<br>$= 100 kg \times 1.63 m/s^2$<br>= 163 N |

## Newton's Third Law (Law of Action and Reaction)

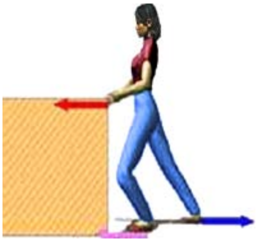
**Activity 3.16**

a) Kick a ball with your bare foot, what do you feel?
b) Hold your physics book by placing it on your palm. Do you feel that a force is exerted by the book on your palm? What about the reverse? Is there a force exerted by the palm on the book?
c) Push the wall of your classroom; do you feel that the wall is pushing against you?
**d)** Place a box on a table and let it stay at rest. What are the forces acting between the box and the table?




a) A book resting on a palm

b) A rocket moving upward



c) A girl pushing a box on a floor

d) Two persons pushing each other

Fig. 3.12 Action and Reaction forces

From Activity 3.16 you noticed that, it is not possible to exert a force on a body without the body exerting a force in the opposite direction. These forces are called the **action** and **reaction** forces.

Newton's third law states that "To every action there is always an equal and opposite reaction". That is, whenever one body exerts a certain force on a second body, the second body also exerts an equal and opposite force on the first. This law is also called the law of Action and Reaction.

Action and reaction forces always act on two different bodies and always exist in pairs. In Fig 3.12 the force exerted by the palm on the book is $F_{wp}$. It is applied to the book and is directed upwards. In return the weight will act on the palm with the force $F_{pw}$. This force is applied to the palm and is directed down ward. In this and in all other action and reaction cases it can be summarized mathematically as:

$\vec{F}_A = -\vec{F}_R$ where $\vec{F}_A$ is the action force and $\vec{F}_R$ **is the reaction force**.

The negative (-) sign indicates the reaction force is opposite in direction to the action force.

## Challenging Questions

1. When you push a wall with your hand you exert a force on the wall. Explain the forces between the wall and your hand
2. What are the forces exerted by the bodies indicated in Fig 3.12 (a, b, c and d)?
3. Indicate the action and reaction forces in the following actions.
   a) A student carrying his school bag.
   b) A horse pulling a cart.
   c) A bullet shot from a gun.

**Check point 3.2**

1. Define the term inertia.
2. What is the relationship between mass and inertia?
3. State a) Newton's first law of motion.
   b) Newton's second law of motion.
   c) Newton's third law of motion.
4. What are the relationships between force, mass and acceleration?
5. What is the difference between mass and weight?

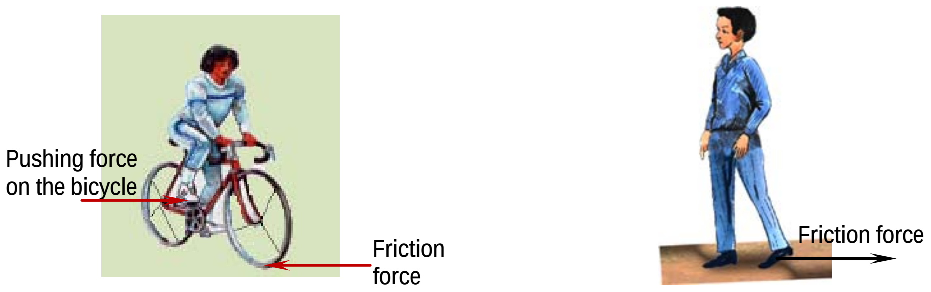
## 3.3. Frictional Force

In the previous sections you learnt about a force. You apply a force when you kick a ball and when you hold your physics book. A force is applied when a body accelerates.

**Activity 3.17** *Discuss with your friends on the following questions.*

i. Have you ever walked on a muddy road or on a smooth polished floor?
ii. Is it more difficult to walk on these surfaces than on a rough road (surface)? Why?
iii. What makes easier to walk on a rough road?
iv. What type of force is a friction force?

The two surfaces used in Activity 3.17 will slip you away since there is no sufficient friction force to prevent you from slipping. The force of friction is important for walking.




a) Motion of a bicycle on a straight road

b) A walking person

Fig 3.13 Fiction force on a bicycle and walking man

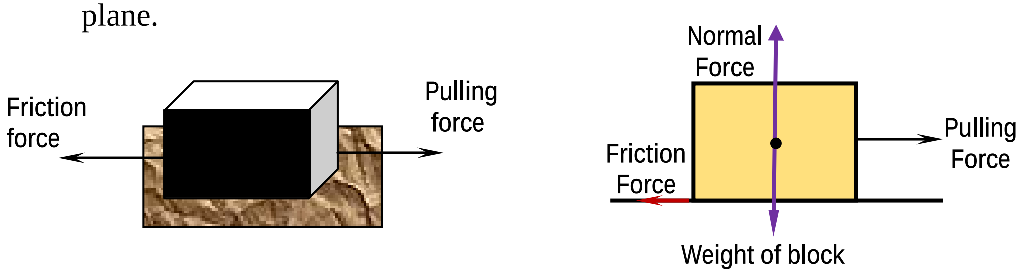
When an object moves over the surface of another object, it experiences a resistance or opposing force against the relative motion of the objects. This opposition or resistance to the motion of objects is called friction.

Friction force is the force that opposes the relative motion of two bodies in contact. If we try to push a block of wood across a table, there are two opposing forces that act on the block of wood. The force related to the push, and a force that is related to the friction. These two forces act in the opposite direction.

As frictional forces are decreased (for example, by placing oil on the table) the object moves further and further before stopping. This demonstrates Galileo's law of inertia which states: "an object in a state of motion possesses an inertia that causes it to remain in that state of motion unless an external force acts on it". Friction force always arises when one body tries to slide on another. The frictional force depends on;

i) The roughness of the surfaces in contact.

ii) The normal force (the force perpendicular to the surface). The normal force is the same as the weight of a body when it lies along a horizontal plane.




a) Rough surface

b) Normal force = weight of a block

Fig 3.14 Factors affecting frictional force

**Activity 3.18**

Prepare two boxes which have different masses. Try to push each box separately across a rough floor. Which one is difficult to push?

From activity 3-18 you learnt that heavier (bigger) objects are more difficult to move on a rough surface. i.e. because as the weight increases, the friction force also increases. That is because there is an increase in the force that presses the two sliding surfaces together. This force is the normal force reacting the floor on the block.

**Activity 3.19**

What causes friction?

## Types of frictional force

There are two types of friction;

i. Static friction ii. Kinetic friction.


a) Static friction b) Kinetic friction

Fig 3.15 Types of friction

**Activity 3.20**

i. Try to pull a heavy box across a floor; explain the force you needed, to start the motion and the force required during the motion to continue it moving.
   a) First pull it slowly and notice the force just needed to start it moving. (Fig 3.15 a)
   b) Then continue to pull it. (Fig 3.15 b)

ii. Which one has greater value? Starting force or force that keeps it moving?

From the Activity 3.20 you notice that the force required in setting the box into motion is larger than the force required to continue the motion of the box.

The friction force that opposes motion just before the box starts its motion is called the **static friction**. The force that is being constantly over come during the motion of the box is called the **kinetic friction**. Activity 3.20 shows that static friction is greater than kinetic friction.

Static frictional force is the maximum frictional force which enables to start the relative motion of two objects.

Kinetic frictional force is the force which arises when one body slides or moves over the other. The term "kinetic" means 'moving'.
Once the object begins to move, the force required is not so great. This shows that kinetic friction on a body is smaller than the static friction.

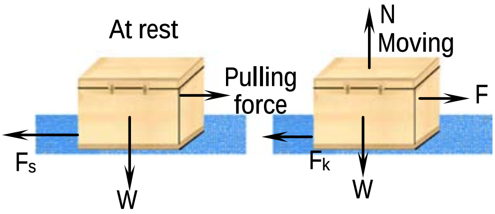



Fig 3.16 Relationship between Fs and Fk

If $F_s$ = static friction and

$F_k$ = kinetic friction

Static friction is greater than kinetic friction, $F_s > F_k$

## Factors affecting frictional force between two contacting surfaces

**Activity 3-21**

i. Try to slide your physics text on your mathematic textbook.
ii. Observe what force you apply to start the motion of the physics book.
iii. Next try to slide the physics textbook on your table. What do you notice?
iv. Are the forces you require to push the physics textbooks in the two situations the same?
   a. What is a normal force?
   b. How is friction affected by a normal force?

The two major factors that affect friction are;

1. The nature of contacting surfaces.
2. The normal force between the surfaces.

A normal force is a force that presses two surfaces together. It is perpendicular to the pressed surfaces. For a flat surface the normal force is equal to the weight of the sliding body.

How does a normal force affect the force of static or kinetic friction?

From the Activity 3.18 you have observed that both static friction and kinetic friction increases as the weight of the sliding body increases. Further the static frictional force, is greater than the kinetic frictional force. Therefore, frictional force is proportional to the normal force. Mathematically;

$F_s \sim N$ and $F_k \sim N$

Or $F_s = \mu_s N$ and $F_k = \mu_k N$

Where, $\mu_s$ is coefficient of static friction and $\mu_k$ is coefficient of kinetic friction. $\mu$ is a Greek letter read as *miu*.

The values $\mu_s$ and $\mu_k$ are positive and less than one. Since $F_s > F_k$ then $\mu_s > \mu_k$.

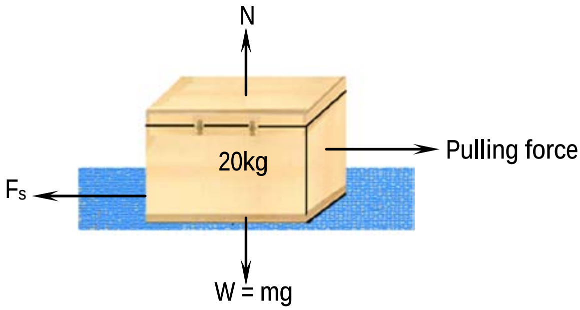



Fig 3.17 The normal force N is equal to mg

## Example 3.3

The coefficient of static friction between a block of wood and the floor is 0.2. The mass of the block is 20 kg. What is the static friction between the block and the level floor? (Take g = 9.8 m/s$^2$)

| Given | Required | Solution |
|---|---|---|
| $\mu_s = 0.2$ | $F_s = ?$ | $F = \mu_s N$ |
| m = 20 kg | | N = w = mg |
| | | N = 20 kg × 9.8 N/kg = 196 N |
| | | $F_s = 0.2 \times 196$ N |
| | | $F_s = 39.20$ N |

2. The force of static friction between a body of mass 50 kg and a horizontal floor is measured to be 103N. What is the coefficient of static friction between the body and the table?

| Given | Required | Solution |
|---|---|---|
| $F_s = 103$ N | $\mu_s = ?$ | since N = mg |
| m= 50 kg | | = 50kg × 9.8 N/kg |
| | | = 490 N |
| | | $\mu_s$ = Fs/N |
| | | Thus $\mu_s$ = 103N/ 490 N |
| | | $\mu_s$ = **0.21** |

Note: **Coefficient of friction /$\mu_s$ / is unit less.**

## Effects of Friction

There are some common effects of friction. Friction-

- Increases the work necessary to operate a machinery; i.e it causes wastage of energy.
- Causes wearing out of a surface
- Generates heat, etc.
- Causes walking possible on roads

Are these effects of friction useful or harmful? Which ones are harmful and which ones are not?

| Activity 3.22 |
| --- |
| i. Discuss some useful effects of friction from your daily experience (e.g. How fire is generated using friction).<br>ii. Mention also some harmful effects of friction. |

## Advantages of friction

Your discussion in Activity 3. 22 might have helped you to understand that there are some uses of friction. Among these uses or advantages of friction, the followings can be mentioned as examples.

i. **Walking**: The friction between your foot (shoes) and the ground enables you to walk. Where friction is very low like slippery mud surface, you will find it difficult to walk on it.

ii. **Tires**: The friction between the car tires and the road allows a car to move or to stop.

iii. **Brakes**: When the brakes of a car is applied, the brake shoes are pushed apart. This brings the brake lining and the drum into contact and the friction between them stops the car.

## Disadvantage of Friction

| Activity 3.23 |
| --- |
| Discuss with your friends or parents. Describing the disadvantages of friction. Example the making of fire in factories, vehicles, forests, etc. |

If you rub the palms of your hands together, they will become warm. This is because of friction. The same thing applies to all machines which have moving parts.

Heat is developed in the moving parts when the machine works. This is because some of the energy supplied to drive the machine is changed into heat. This is a wastage of energy. It is not used for the desired purpose. Some parts of machines also wear out because of friction.

### Challenging Question

Give some other advantages and disadvantage of friction.

## Reducing Friction

In order to increase the efficiency of machines and reduce the wearing out of machine parts, friction has to be reduced.

Some of the most commonly used methods of reducing friction are the following.

A. **Removing of roughness of the surfaces** Smooth surfaces have less friction than rough surfaces.

B. **Lubricating**; If you introduce liquid film such as oil between the surfaces, friction will be reduced. The oil fills the valleys and separates the surfaces so that the hills and valleys do not hold each other.

C. **Rolling bodies**: The most effective and commonly used method of reducing friction is to use rolling bodies instead of sliding bodies. That is wheels, roller bearings and the ball bearings are used to reduce friction. Fig 3.18 illustrates the difference between sliding and rolling bodies.

a) A sliding body b) A rolling body

Fig 3.18 Rolling reduces friction

I think in this unit you have acquired the knowledge of force and you have also got some answers for your doubts which you always ask yourself why I fell when something hits me. Why I tend to be pushed forward when the bus suddenly stops, etc.

You might have asked yourself why do I fell when I step on a banana scrap. This is because of friction. As friction is necessary for motion it is also harmful for machines. You have a responsibility as a citizen to keep machines not to wear out due to friction, and do the necessary things to reduce friction.

Since this topic is very important and more applicable in all aspects of life you have to have an active participation in the class and outside in the community to give awareness how to reduce friction in machines.

**Check point 3.3**

1. What is a frictional force?
2. Name examples where frictional force plays an important role in our daily life.
3. State the factors on which a frictional force depend on.
4. What is the difference between static friction and kinetic friction?
5. Describe two methods of reducing friction.

## Summary

In this unit you learnt that:

- force is a push or a pull that produces motion, stops or tends to stop motion.
- the relationship between a force and the motion produced is described by Newton's three laws of motion.

The Newton's laws of motion are:

1st law: A body at rest remains at rest, and a body in motion continue to move with a uniform speed in a straight line unless it is acted upon by an external force.

2nd law: The acceleration is directly proportional to the applied force and inversely proportional to the mass of the body, (F=ma).

3rd law: For every action there is an equal and opposite reaction.

- the unit of force is Newton, 1N is defined as a force that acts on a mass of 1 kg and produces an acceleration of 1 $m/s^2$.
- weight of a body is the gravitational force acting on the body. The weight of an object of mass 'm' is W= mg.
- frictional force is directly proportional to the normal force and is directed parallel to the surfaces of the moving bodies.

$$F_f = \mu F_N$$

- **the coefficient of friction 'μ' is defined as the ratio of the frictional force** to the normal force.

$$\mu = \frac{F_f}{F_N}$$

# Review Questions and Problems

## *I. Fill in the blank spaces with the appropriate word(s).*

1. The cause for the change in the state of rest or motion of an object is_______________.
2. According to Newton's 2nd law of motion, force is the product of ________and __________.
3. Action and reaction forces are always _______ in magnitude and ________in direction.
4. The pull of gravity on a 1 kg body on the surface of the earth is _________Newton.
5. The gravitational force with which the earth attracts a body is called __________.

## *II. Short answer questions*

1. Define a force.
2. Explain how the weight of a body changes as the body is taken farther away from the surface of the earth.
3. What are the units of g, $F_N$ and μ?
4. Explain why the friction between two pieces of wood is reduced when they are smooth and polished.

## *III. Solve the following problems.*

1. How much force is needed to accelerate a toy car of mass 8 kg at $2 m/s^2$?
2. A trolley of mass 20 kg was originally at rest on a smooth horizontal surface. By how much will it accelerate if a pulling force of 22 N is applied on it horizontally?
3. What is the weight of a 60 kg boy on the surface of the Earth? Take $g = 10 m/s^2$.
4. A 90 kg body is taken to a planet where the acceleration due to gravity is 2.5 times that of the earth. What is the weight of this body on the surface of this planet? Take $g = 10 m/s^2$.

5. A car of mass 1500 kg starting from rest can reach a speed of 20 m/s within 10 seconds. Calculate the accelerating force of the car engine.
6. If the force acting on a body of mass 40 kg is doubled. By how much will the acceleration change?
7. A block of mass 5 kg is being pulled along a board horizontally with a constant velocity; the coefficient of friction between the two surfaces is 0.25.
   a) What is the normal reaction force between the board and the block?
   b) What is the frictional force that opposes the motion?

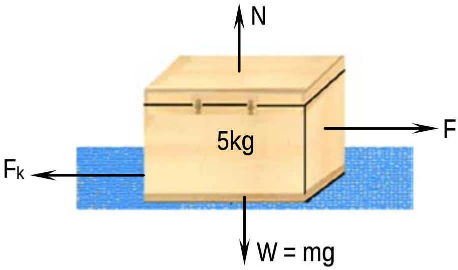


Fig 3.19

8. A 75 N horizontal force is sufficient to move a 150 N box on a level road at a uniform speed. What is the coefficient of friction between the box and the road?

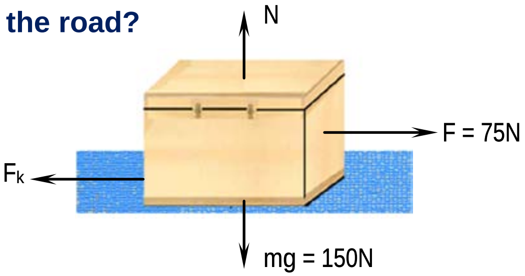


Fig 3.20

9. A space woman has a mass of 65kg on the earth surface. What is her weight on:
   a) the earth, where $g = 10\ m/s^2$?
   b) the moon, where $g = 1.6\ m/s^2$?

# UNIT 4

# WORK, ENERGY AND POWER

**Unit outcomes:** **After completing this unit you should be able to:**

- ✓ **understand concepts related to work, energy and power.**
- ✓ **develop skill of manipulating numerical problems related to work, energy and power.**
- ✓ **appreciate the interrelatedness of all things.**
- ✓ **use a wide range of possibilities for developing knowledge of the major concepts with in physics.**

## Introduction

In the last three units you learned some properties of physical quantities, measurements of physical quantities, their SI units, motion of bodies, force, and relationship between force and motion. In this unit you will learn the concepts of work, energy, power and the relationship among them. What is work? How do you define energy? People commonly think of work as being associated with doing something. But now, you will go through the scientific meanings of work, energy, power and their relationships. The term energy has a much wide scope than it will be implied in this unit. Energy in this unit is limited to mechanical energy that is kinetic energy and potential energy.

## 4.1 Work

### Activity 4.1

Discuss the following questions with your friends.

i. What is work in a day to day life and in physics?
ii. When do we say work is done?
iii. Explain the term 'work' especially from the point of view of science/physics.

From the discussion in Activity 4.1 you might have come across different meanings of work.

The usual meaning of work is quite different from the scientific meaning of work. In every day activity, the term work is used equally for mental work and for physical work involving muscular force.

Identify the following activities as: work is done and work is not done.

- You may read a book,
- Engage yourself mentally in thinking about a simple or difficult problem;
- You might be holding a weight with out moving, or carrying a load and moving with uniform horizontal velocity.

In all these activities, according to the scientific definition, you are not doing any work at all.

According to physics, work is said to be done when energy is transformed from one form to others. Work is done, when a force F is applied to a body and the body moves through a distance s on the direction of the force.

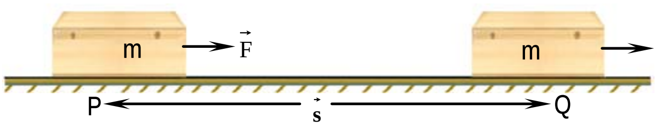



Fig. 4.1 A force $\vec{F}$ does a work

In Fig 4.1 A force (F) moves a block of mass (m) from point 'P' to 'Q' through a displacement ($\vec{s}$). Hence, work done = applied force × displacement

$$W = \vec{F} \times \vec{s}$$

Where W is work done, $\vec{F}$ is the applied force and $\vec{s}$ is the displacement.

Work is equal to the product of the force and the distance through which it produces. Although both force and displacement are vector quantities, but work is a scalar quantity, having only magnitude.

Lifting a load from the ground and putting it on a shelf is a good example of work. The force is equal to the weight of the load, and the distance is equal to the height of the shelf.

If the force acts in a direction other than that of the motion of the body, then only that component of the force in the direction of the motion produces work. If a force acts on a body constrained to remain stationary, no work is done by the force. Even if the body is in motion, the force must have a component in the direction of motion. The person walking a distance carrying a block of mass is not doing work in carrying the mass (Fig 4.2)

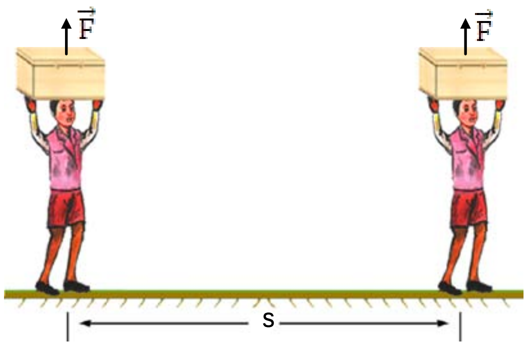


Fig 4.2. A man walking a distance 's', carrying a block of mass "m"

| Activity 4.2 |
|---|
| Discuss with your friends. The work done by a man carrying a load and walking a distances. |

The SI unit of work is **newton meter (Nm)** which is called **Joule (J)**. One **Joule (J)** of work is done when a force of one newton (N) moves an object through a displacement of one meter (m).

1Joule (J) = 1 newton (N) × 1 meter (m).

The unit of work, 'Joule' is named in honor of the famous English physist **James Prescott Joule** (1818-1889), who had contributed a lot on heat energy.

When large or small quantities of work are measured we can use prefixes attached to Joule such as kilojoule (kJ), Megajoule (MJ), millijoule (mJ) and so on. For example 1 kiloJoule (kJ)= 1000 J

1 MegaJoule (MJ)= 1,000,000 J

1 MilliJoule (mJ)= 0.001 J

## Worked Examples 4.1

1. A box is pushed by a force of 180N without acceleration 5m along a horizontal floor. How much work is done?

| Given | Required | Solution |
|---|---|---|
| F = 180N | W = ? | $W = \vec{F} \times \vec{s}$ |
| $\vec{s}$ = 5m | | W = 180N × 5m |
| | | = 900N.m |
| | | = **900 J** |

2. A mass is displaced from its original position through a distance of 20 m by a force of 100 N.
   a. How much work is done?
   b. What would be the work done, if the force is doubled, having the same displacement.
   c. What would be the work done, if the distance is halved, while the force remains constant?

| Given | Required | Solution |
|---|---|---|
| $\vec{F} = 100\ N$ | $W = ?$ | a) $W = \vec{F} \times \vec{s} = 100\ N \times 20\ m$ |
| $\vec{s} = 20\ m$ | | $= 2000\ Nm$ |
| | | $= 2000\ J = 2\ KJ$ |
| | | b) when $F = 200\ N$ |
| | | $W = \vec{F} \times \vec{s} = 200N \times 20\ m$ |
| | | $= 4000\ Nm = 4000\ J = 4\ kJ$ |

$\therefore$ When the force is doubled, the amount of work done is also doubled.

c) Half of 20 m = 10 m, s = 10 m

$$W = \vec{F} \times \vec{s} = 100\ N \times 10\ m = 1000Nm$$

$$= 1000J = 1kJ$$

3. How much force is required to lift a load of 50 kg vertically to a height of 2m, if the work done is 1000 J.

| Given | Required | Solution |
|---|---|---|
| $W = 1000\ J$ | $F = ?$ | $W = F.S$ |
| $\vec{s} = h = 2m$ | | $F = \frac{w}{s} = \frac{1000\ J}{2m} = 500\ N$ |

**Check Points 4.1**

1. **What are the conditions for doing work?**
2. **Write the equation used for calculating work in symbols.**
3. **Calculate the work done by Girma, when he lifts a 20 N load to a height of 1.5m.**
4. **What happens to the work done when a force is doubled and the distance moved remain the same?**

## 4.2. Energy

**Activity 4.3**

Discuss with your friends the following points;

i. Lift a heavy stone up in air. Does it have energy?
ii. Now, drop the stone and break another small stone or wood.
iii. What is energy?
iv. Explain the relationship between work and energy.
 What does a body that has energy do? How do you measure the energy of a body?

In the previous section you learnt that work is something that is done on objects. In this section you will learn that energy is something that objects possess. A body is said to possess energy when it is capable of doing work. Thus, the energy of a body is measured by the quantity of work that the body does.

Energy is the capacity to do work. Energy is also a scalar quantity as work. The SI unit of energy is the same as the unit of work, Joule (J).

**Activity 4.4**

Discuss the following questions in a group.

i. Explain the different forms of energy.
ii. Which forms of energy do you think is mostly used in our country?
iii. Discuss the transformation of energy from one form to another.

The world we live in provides us with different forms of energy. Electrical energy, Chemical energy, nuclear energy, solar energy, sound energy, heat energy, mechanical energy, and energies from wind and water are some of the forms of energy.

In this section we focus on mechanical energy. Mechanical energy is the energy possessed by an object due to its motion and position related to the earth's surface.

There are two types of mechanical energy: These are:-

i. Kinetic energy (K.E) and
ii. Potential energy (P.E)

*Kinetic Energy (K.E):* kinetic energy is the energy of a body due to its motion. For example: running cars, thrown stones, rotating wheels or thrown spears, etc. have kinetic energy due to their motion. The kinetic energy of a body of mass m traveling at speed v is mathematically expressed as:

$$\text{i.e. K.E.} = \frac{1}{2}(\text{mass}) \times (\text{speed})^2$$

$$\text{K.E} = \frac{1}{2} mv^2$$

Kinetic energy is a scalar quantity, it has only magnitude

## Worked Example 4.2

A bullet of mass 20g is fired at a speed of 250 m/s. What is its kinetic energy?

| Given | Required | Solution |
|---|---|---|
| m = 20g | K.E = ? | $K.E = \frac{1}{2} mv^2$ |
| = 0.02kg | | $= \frac{1}{2} \times 0.02\ kg.\ (250\ m/s)^2$ |
| **v** = 250m/s | | $= \frac{1}{2} \times 0.02 \times 62500\ (kg.\ m^2/s^2)$ |
| | | = 625 J |

### Challenging Question

Discuss with your friend about the kinetic energy of the bullet in the above example; when

a) The velocity is constant, but the mass is doubled,

b) The mass is constant, but the velocity is doubled.

*Potential Energy (P.E)* is the energy associated with the position of a body relative to the earth's surface. For example, lifted masses above the earth's surface possess potential energy. The term "potential" means "stored".

The potential energy of a body of mass (m) lifted to a height of 'h' above the ground is mathematically expressed as:

$$P.E = weight \times height \quad (where\ w = mg)$$

$$\Rightarrow P.E = mgh$$

This is an expression for potential energy of a body due to its position. You will learn in higher grades other types of potential energy.

## Worked Example 4.3

An 80 kg stone is lifted to the top of a building 30m. How much does the potential energy of the stone increased? (take $g = 10\ m/s^2$)

| Given | Required | Solution |
|---|---|---|
| m = 80kg | P.E=? | P.E = mgh |
| h = 30m | | $= 80kg \times 10m/s^2 \times 30m$ |
| $g = (10\ m/s^2)$ | | = 24000J |
| | | = 24 KJ |

## Worked Examples 4.4

1. How fast must a car of mass 800 kg move in order to have a kinetic energy of 640 kJ?
   If the mass is reduced to 400 kg; for the same kinetic energy, what would be its speed?

| Given | Required | Solution |
|---|---|---|
| m = 800 kg | v = ? | $K.E. = \frac{1}{2} mv^2$ |
| K.E = 640,000J | | $\Rightarrow 640{,}000J = (\frac{1}{2} \times 800\ kg)\ v^2$ |
| = 640 kJ | | $\Rightarrow v^2 = \frac{640{,}000J}{400\ kg}$ |
| | | $v^2 = 1600\ m^2/s^2$ |
| | | $v = \sqrt{1600} = 40m/s$ |

- If the mass is halved i.e. m =400 kg, then, $K.E = \frac{1}{2} mv^2$

$$640{,}000J = \frac{1}{2} \times 400\ kg \times v^2$$

$$v^2 = \frac{640{,}000J}{200kg} = 3{,}200\ m^2/s^2$$

$$v = \sqrt{3{,}200} \approx 56.57m/s$$

2. A crane is used to lift a concrete in sites where high buildings are being built. How much is the energy expended to lift a concrete of mass 320 kg to the top of a building 40 m high? (Crane is a device used to lift weights.)

Fig 4.3 A crane

| Given | Required |
|---|---|
| m = 320 kg | P.E = ? |
| h = 40 m | |
| $g = 10m/s^2$ | |

**Solution**

When a body of mass 'm' is lifted up it possesses a potential energy. Thus,

$$P.E = mgh$$
$$= (320\ kg)(10m/s^2)(40\ m)$$
$$= 128{,}000\ J$$

3. How high should a body of mass 100 kg be lifted in order to have an energy of 1MJ?

| Given | Required | Solution |
|---|---|---|
| m = 100 kg<br>g = $10 m/s^2$<br>P.E = 1 MJ = 1,000,000 J | h = ? | From the relation PE = mgh, we get<br>$h = \frac{PE}{mg} = \frac{1,000,000 J}{(100 kg)(10 m/s^2)}$<br>Thus, h = 1000 m |

**Check points 4.2**

i. What is the relationship between work done and energy?

ii. Name the two types of mechanical energy.

iii. On what quantities does the kinetic energy of a body depends on? Express it in equation (use symbols).

iv. On what quantities does the potential energy of a body depend on? Express it in equation (using symbols).

v. A ball of mass 0.25kg is kicked with a speed of 80m/s. What is its kinetic energy?

vi. a. Write a brief description on the difference between KE and PE.

b. Mention some practical examples for each types of energy.

c. Is there any transformation from KE to PE or vice versa? Explain your answer and give practical examples.

## 4.3. Transformation and Conservation of Energy

**Activity 4.6**

**Discuss with your friends:**

Consider the following different cases:

a. Hydroelectric power stations (Koka Dam, Gilgel Gibe dam etc) supply electric energy to our cities.

b. Using fuel energy in our home to cook some thing.

c. Using dry cells (chemical energy) for lighting a torch, and listening to a radio, etc.

What happens to these different forms of energy? Is energy creatd or destroyed in each case? Explain it.

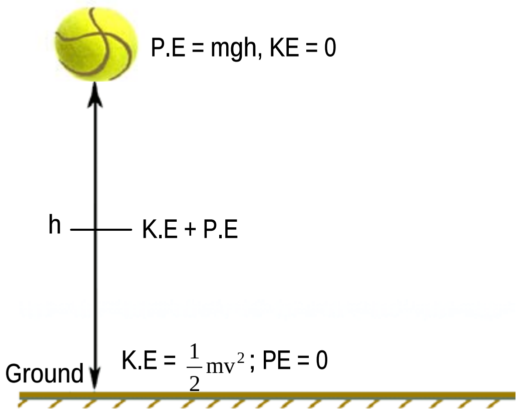



Fig 4.4. Transformation of mechanical energy in falling object

In our daily life, we use different forms of energy. Energy change (transformation) is needed to enable people, machine, computers and other devices to do work. For example, it is our daily experience to see chemical energy of coal, petroleum or gas being changed into heat and light energies in our stoves. But in this topic you shall see only the transformation of potential energy to kinetic energy and viseversa.

For example, consider a ball of mass (m) falls down from the top of a building of height (h) (sec Fig 4.4_). When it is at the top of the building it has only potential energy. That is, P.E. = mgh.

As it starts to fall down, it possesses both potential energy and kinetic energy. The potential energy that it had at the top of the building has now partly changed into kinetic energy. That is, P.E + K.E= mgh +1/2 $mv^2$.

Finally as the ball strike the ground it possesses only kinetic energy. This means the potential energy of the ball at the top of the building is totally changed into kinetic energy. That is K.E = ½ $mv^2$.

In this process, the potential energy at the top equals the kinetic energy at the ground level. $mgh = \frac{1}{2} mv^2$

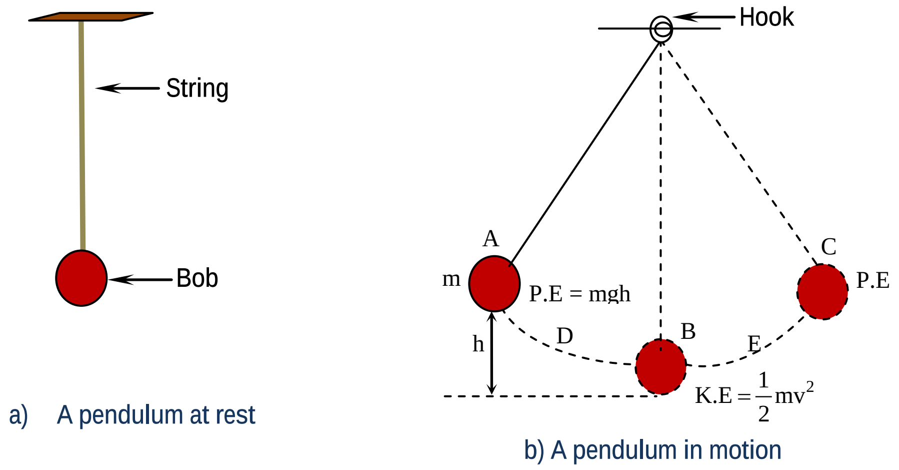



Fig 4.5. Transformation of mechanical energy in a simple pendulum

**Activity 4.7**

*Do the following activities in a group.*

Use the following materials: a bob (small mass), a string and a suspended hook from a tall table.

i. Tie the bob to one end of the string and mount it to the hook as shown in the (Fig 4.5a )

ii. Displace the bob of the pendulum to position 'A' as shown in Fig 4.5 (b) and release it.

**iii.** Explain the law of transformation and conservation of energy

From Activity 4.7 you notice that in a pendulum K.E. and P.E are interchanged continuously. The energy of the bob is all P.E. at position A of the swing and all K.E. as it passes through its equilibrium position (point B)

At other positions such as points D and E it has both P.E and K.E (see fig 4.5 b). Eventually the pendulum stops. At this moment all the energy is changed into heat as a result of overcoming air resistance (air friction).

The law of conservation of Energy is one of the universal laws of nature and it is stated as follows.

"Energy is neither created nor destroyed". It only transforms from one form to other forms.

## Energy of falling water

The mechanical energy that a body possesses exists as potential energy or kinetic energy or both. Let us consider the transformation and conservation of mechanical energy of falling water.

Falling water is the main source of hydro-electrical energy in our country, yet we have not used it exhaustively.

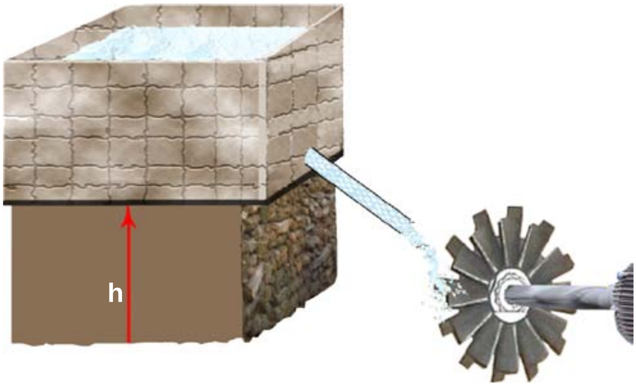



Fig 4.6 A water falling from a tower has potential energy and kinetic energy at the turbine

The diagram in Fig 4.6 shows that the water at the intake tower have only a potential energy due to its position (M.E= P.E). But after it has started to fall through the pipe it acquires a kinetic energy due to its motion. This kinetic energy is used to turn the turbine blades and make the generator to rotate. Finally when the water reaches the turbine blades it has only kinetic energy (M.E= K.E). When the water passes through the pipe its energy is the sum of both kinetic energy and potential energy.

i.e. M.E= P.E. +K.E

Note that the mechanical energy of the water at the dam tower is only potential energy and at the bottom is only kinetic energy. Energy of falling water shows that the total M.E of the system remains constant.

## Wind energy

### Activity 4.8

Group discussion

i. What is a wind?

ii. What form of energy does it have?

iii. Mention some practical examples where wind is used to do useful work.

A giant wind mill called wind turbine with two or more blades mounted on a tall tower can drive an electrical generator attached to it. This is done when the wind with a kinetic energy rotates the blades. Hence the rotated wind mill causes the generator to rotate and produce electric current. The electric energy produced by a wind mill can be used to lift water from a deep well and to light homes.

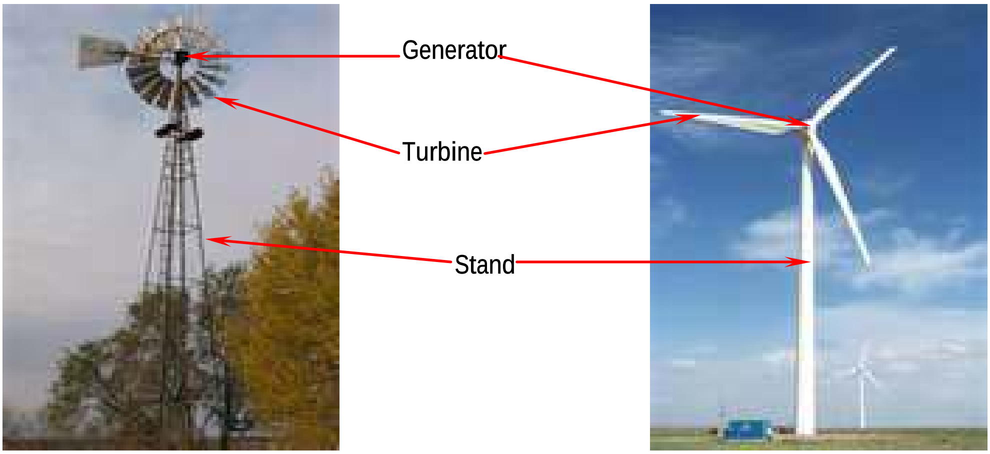



Fig 4.7 Wind mill changes kinetic energy into electrical energy

### Check points 4.3

1. What do you understand by the terms:
   a) transformation b) conservation?
2. State the laws of conservation of energy.
3. Explain the different forms of energy possessed by falling water from a high dam to the ground.
4. What form of energy does a wind have? Give examples where wind energy is used by human being.
5. Consider a falling object or an oscillating pendulum. Describe the energy changes in each case.

## 4.4 Power

**Activity 4.9**

1. Discuss with your friends and family members what is meant by the term "power" in daily life.
2. Give some examples for:
   - Physical power
   - Political power
   - Personal power
   - Power of persuasion
3. What is the difference between power in daily life and power in scientific usage?
4. Lemlem displaces a block to a 10 m distance in 2 minutes. Tigabu displaces the same block to the same distance in 5 minutes. Who has more power? Lemlem or Tigabu? Explain it.

In most cases we say the same amount of work is done in raising a given weight through a given height, but we never ask in how many seconds or hours the work is done. However, it is necessary to consider the time taken to do the work. Power is a physical quantity that explains the time rate of doing work.

Power is the rate of doing work or rate of energy expenditure

$$\text{power} = \frac{\text{Work done}}{\text{time taken}} = \frac{\text{Energy transfered}}{\text{time taken}}$$

$p = w/t$

(where P = power, w= work, and t = time taken)

Like work and energy, power is also a scalar quantity.

The SI unit of power is Joule/second, which is called Watt. A power of 1W is developed when there is a transfer of 1J of energy in one second.

1W = 1 J/s

When larger quantities of power are involved we can use kilowatt (kW) and Megawatt (MW).

Where 1 kW= 1000 W

1 MW= 1,000,000 W

## Worked Examples 4.5

1. A machine lifts a 50 kg mass to a height of 60 m in 4s. Calculate the power developed by the machine (take g= 10 $m/s^2$)

| Given | Required | Solution |
|---|---|---|
| m= 50 kg<br>h= 60 m<br>t= 4s<br>g= 10 $m/s^2$ | P = ? | power = $\frac{\text{Energy transferred}}{\text{Time taken}}$<br>but Energy transferred = PE= mgh<br>Thus power, P= mgh/t<br>$P = \frac{(50\ kg)\ (60\ m)\ (10\ m/sec^2)}{4s}$<br>Therefore P= 7500 W= 7.5 KW |

2. Calculate the power of a pump that can lift 300 liters of water through a vertical height of 12 m in 8 sec
   (Note that 1 liter of water= 1 kg of water)

| Given | Required |
|---|---|
| h= 12m<br>t= 8 sec<br>m= 300 kg<br>g= 10 $m/s^2$ | P = ? |

**Solution**

power, P = mgh/t

$\frac{(300\ kg)\ (10\ m/s^2)\ (12m)}{8\ s} = 4500W = 4.5\ Kw$

**Check point 4.4**

i. What is the power of an electric "mitad" which transfers 2 kJ of electric energy in one second?

ii. A bucket full of water weighs 3 kg and a water well is 10 m deep. A girl draws water from the well. It takes the girl 2 minutes to draw a bucket full of water from the well.
   What is the power of the girl? (take g= 10 $m/s^2$)

## Summary

In this unit you learnt that:

- work is said to be done when energy is transformed. Work is done when a force is applied over a distance in the same direction as the force:- W = F. s
- the SI unit of work and energy is Joule (J).
- Work, Energy and Power are scalar quantities.
- Mechanical Energy is the sum of kinetic energy and potential energy of a body.
- kinetic energy of a body is the energy due to motion and it is expressed as: $KE = \frac{1}{2} mv^2$.
- potential energy of a body is the energy due to its position and is expressed as $PE = mgh$.
- power is defined as the rate of doing work or the rate of transfer of energy and it is expressed as $P = \frac{W}{t}$
- the SI unit of power is Watt (W) which is Joule per second (J/s).

# Review Questions and Problems

*I. Fill in the blank with the appropriate word or phrase.*

1. Work is defined as the product of _________and________.
2. The SI unit of work is ____________.
3. ____________ is the capacity of doing work.
4. The units of Work, Energy and power are________ units.
5. The direction of applied force has to be _______ to the distance in order to say work is done.
6. ____________ tells us that energy is neither created nor destroyed but changes from one form to another.
7. ___________ is the time rate of doing work.
8. The SI unit of power is____________.
9. Mechanical energy is the sum total of_______ and ________.

*II. Solve the following problems.*

1. A force of 200 N is exerted horizontally on a box of mass 18 kg to displace it through a distance of 6 m. How much work is done?
2. An object of mass 20 kg is lifted to a 25 m building. How much potential energy is stored on the mass? (Take g= 10 $m/s^2$)
3. A crane lifts a 450 kg concrete to the top of a 50 m building in 5 s. Assuming g= 10 $m/s^2$, calculate;
   a) The potential energy of the concrete.
   b) The power developed by the crane
4. An artificial satellite of mass 900 kg is launched at a speed of 11,000m/s from its launching station. How much is the kinetic energy imparted to it?
5. How high should a 2 kg mass be lifted from the ground if it is thrown upward at speed of 15 m/s? (Assume g = 10 $m/s^2$)
6. An electric motor pumps 200 liter of water to a reservoir of height 6m in 2 s. Take g = 10 $m/s^2$. Calculate the power developed by the motor. Take 1 liter of water = 1kg of water.
7. An electric iron is labeled 1000W. How many Joule of energy is consumed if it is used for one hour?

# UNIT 5

# SIMPLE MACHINES

**Unit outcomes:** **After completing this unit you should be able to:**

- ✓ **understand concepts related to simple machines.**
- ✓ **develop skill of manipulating numerical problems related to simple machines.**
- ✓ **appreciate the interrelatedness of all things.**
- ✓ **use a wide range of possibilities for developing knowledge of the major concepts with in physics.**

## Introduction

Do you recall the different types of simple machines from your science courses?

| Activity 5.1 |
| --- |
| Group the following devices as machines or not machine: knife, scissors, screw, computer, bottle opener, axel, typewriter, electric motor, lever, pulley and wedge. |

In science there is no difference between machines and tools or devices. They mean the same thing. In this unit you will learn about some machines which help you make your work easier and be done conveniently. You will also learn about the purposes of some simple machines interms of their velocity ratio, mechanical advantage and efficiency.

To understand the purposes of machines, you need to revise the concepts of force, work, weight, ratio and percentage, because you often use them in this chapter.

## 5.1 Definition of Machines

**Activity 5.2**

i. As a student you use daily a sharpener, or a cutter or a blade to sharpen a pencil. Describe what advantage you get by using these devices.
ii. From your daily experience mention some devices or tools which help people make their life easier. Discuss with your friends how they make their work easier.
iii. What are machines? Can we call the above tools as machines? Why?
iii. Write the names of tools that you think are not machines.

Had there been no blade, cutter or sharpener, what would you use to sharpen your pencil? You might use your teeth or knife to sharpen your pencils. This idea is inconvenient for work. We use different tools in our daily activities to make our work easier.

Knife, scissors, screw, bottle opener, axel, lever, pulley and wedge, etc. are some machines or tools which make our work easier.

A machine is any device which helps us to do work easier.

Machines are energy transforming devices. Actually machines do not create energy or change one form of energy into another. They simply transfer mechanical energy involving a small force into mechanical energy involving a large force.

Machines act as force or speed multipliers. They are used to make work easier.

## Why do we use machines?

### Activity 5.3

Discuss the following questions with your friends or parents.

i. Why do people use inclined plane to raise different objects on a truck? (Hint is it to decrease the required force or to increase the speed?)

ii. Why do people use a bicycle instead of walking or running on feet? (Hint is it to save energy? or to decrease the required force? or, to be faster?)

**iii.** Why do we use a fixed single pulley to take water from a deep well?

Effort is the force you exert on the machine.

Load is the force exerted by the machine.

While you discuss the questions in Activity 5.3., you need to use the terms **effort** and **load**,

**Effort (E)** is the force exerted on a machine by an external body like a human being.

**Load (L)** is the force exerted by a machine on an object to be lifted or moved. It is the force with which the machine does work against resisting force like a weight and a friction force.

Having this in mind, think why people use a bicycle, an inclined plane and fixed single pulley. People use machines at least for one of the following purposes. These are:

1. to multiply force.
2. to multiply speed (distance)
3. to change the direction of force.

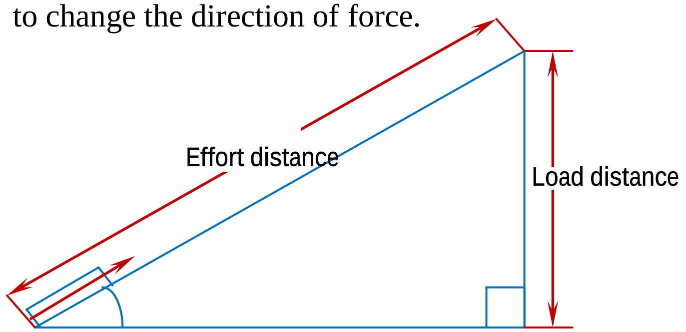



Fig 5.1 Inclined plane

Let us take an inclined plane shown in Fig 5.1. The force exerted by an external body to pull or push a block along the inclined plane is an **effort**. The distance moved by the effort is **effort distance.**

The block is lifted to certain height using the inclined plane.
The weight of the block is the **load;** while the distance raised is called the **load distance**.

In an inclined plane a small effort is used to lift the heavy load. Hence the inclined plane is used to multiply a force. It is a force multiplier machine.

Machines are said to be *force multipliers* when they enable us to lift big load by applying small effort. Load is greater than effort.

**For example**, if you raise a load of 400N by an effort of 40N using a machine, you are able to exert 10 times the original effort. In such cases the machine is a force multiplying tool.

Let us take another type of machine called a bicycle. People prefer to ride a bicycle rather than to walk on their feet. (Fig 5.2)

In a bicycle, the small distance moved by a person on a pedal is multiplied by the wheels of the bicycle and a long distance is covered during the same time. Hence a bicycle is called a speed multiplier or a **distance multiplier.**

Machines are said to be distance multipliers when they enable people to lift a load through a large distance by moving the effort through a small distance


Fig 5.2 Bicycle

Thus the distance moved by the effort is less than the distance moved by the load.

***Example***

Suppose in a machine an effort moves 1m in one second to lift a load, and the load moves 5m at the same time. The speed with which the effort moves would be 1m/s and that of the load is 5m/s. Here the speed of the effort is multiplied by five. In such cases the machine is used as a speed multiplier or a distance multiplier.

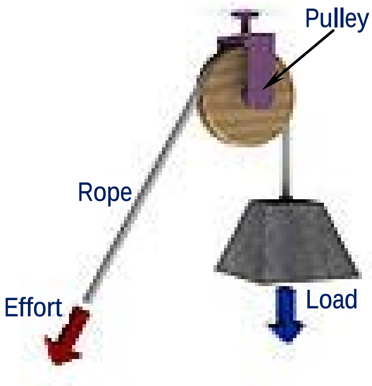


Fig 5.3 Single fixed pulley

**Activity 5.4**

Does a machine multiply a force and distance at the same time? Discuss your reason with friends.

A pulley is another example of a machine. A single fixed pulley is shown in Fig 5.3. It is used to raise a load like a pail of water from a deep well or turned over car from a ditch.

To raise a load upward a downward effort is applied. The effort applied is of the same magnitude as the load, but opposite in its direction. Thus, a fixed single pulley is a direction changing machine.

**Check point 5.1**

1. What is a machine?
2. Describe three purposes of using simple machines.
3. Can a machine be a force and distance multiplier at the same time?
4. Define the terms
   a) effort
   b) load

## 5.2. Mechanical Advantage, Velocity Ratio and Efficiency of Machines

### a) Mechanical Advantage (MA)

**Activity 5.5**

i. Can you measure the advantage of a given machine? How?
ii. Consider a load of 120N is moved by applying an effort of 30N to the machine. What is the advantage that you obtain by using the machine?
iii. What is the term used to describe the advantage of a machine?

From activity 5-5(ii) you observed that to move a load of 120N the applied effort is only 30N. Here you can say that the machine multiplied the applied effort. Hence the advantage you obtain by using the machine is, four times the original force. The advantage you get from a machine is called **mechanical advantage (MA)**.

The Physical quantity which is used in describing the advantage of a machine is known as Mechanical Advantage MA. It tells us the number of times a machine multiplies the effort.

For any machine the mechanical advantage is the ratio of load to effort.

$$\text{i.e.} \quad MA = \frac{\text{Load (L)}}{\text{Effort (E)}} \quad = \quad \mathbf{MA} = \frac{L}{E}$$

What can you say about the unit of MA from the above expression?

**Worked Example 5.1**

A load of 360N is moved by applying an effort of 60N to a machine, What is the mechanical advantage of the machine?

| Given | Required | Solution |
|---|---|---|
| L = 360N<br>E = 60 N | MA = ? | MA = L/E = 360N/60N = 6 |

This means the machine is used to multiply the applied force by 6. From the above example it is clear that MA is a dimensionless physical quantity. i.e. it has no unit.

There are two kinds of Mechanical Advantage

a. Actual Mechanical Advantage - the mechanical advantage that the machine provides in a real situation (with friction).

b. Ideal Mechanical Advantage is the mechanical advantage that the machine provides without friction.

Note: The MA of a machine depends on the friction between the load and the machine.

## b) Velocity Ratio

**Activity 5.6**

*Discuss with your friends.*

i. What will happen to the MA if the machine is totally frictionless?

ii. Does the machine require more effort or less?

From your discussion in activity 5.6, it is understood that the effort required will be less as the machine is frictionless. i.e. There is no resistant force required to be overcome.

The velocity ratio (VR) characterizes the frictionless mechanical advantage of a machine. Velocity ratio is also called ideal mechanical advantage (IMA).

Velocity ratio of any machine is defined as the ratio of the distance moved by the effort to the distance moved by the load. i.e.

$$\mathbf{VR} = \frac{\text{Distance moved by the effort}}{\text{Distance moved by the load}} \frac{(S_E)}{(S_L)}$$

$$\mathbf{VR} = \mathbf{S_E/S_L}$$

Velocity ratio of a machine has no unit.

Velocity ratio of a particular machine is constant. When you reduce friction, the actual mechanical advantage is closer to the ideal mechanical advantage. If frictional force is zero then VR = MA.

**Worked Example 5.2**

A machine raises a load to 2m, when the effort is moved by 8m. What is the velocity ratio of the machine?

| Given | Required |
| --- | --- |
| $S_E = 8m$<br>$S_L = 2m$ | VR = ? |

**Solution**

$$VR = \frac{S_E}{S_L}$$

$$= \frac{8m}{2m} = 4$$

This means that the effort moves four times faster than the load or the effort distance is four times that of the load distance.

### c) Efficiency (η)

**Activity 5.7**

i. How could you describe the terms 'input work' and 'output work'?
ii. What is wastage energy?
iii. Explain both 'efficiency' and 'wastage energy' for a machine. How are they related?

Efficiency has many meanings in everyday life. In science it has a specific meaning related to output and input work.

i. **Input work ($W_i$)** is the work done on the machine by the effort. It is equal to the product of the effort (E) and distance moved by the effort ($S_E$).

$$W_i = E \times S_E$$

ii. **Output work ($W_o$):** is the work done by the machine on the load (object). It is equal to the product of the load (L) and distance move by load ($S_L$).

$$W_o = L \times S_L$$

When you apply a force on a machine, you do work on it (input work). At the same time the machine also does work on the load (output work). In actual case the output work is less than the input work. Can you give reason why it should be less?

## Worked Example 5.3

Suppose, a force of 80N is applied through a distance of 5m in pulling 300N box up an inclined plane whose upper end is 1m above ground level.

The input work is 80N×5m = 400J.

The output work is effectively the raising of the 300N box a distance of 1m or 300N×1m= 300J. The 300J is sometimes called **useful work**.

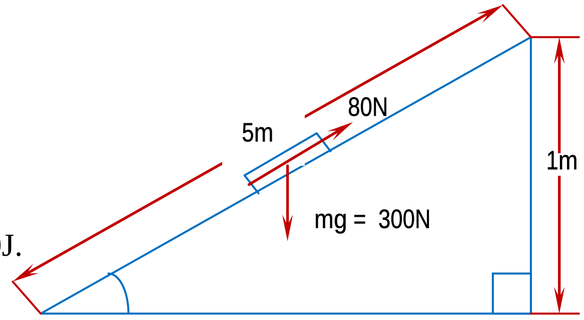



Fig 5.4 The efficiency of an inclined plane

The difference between the input work and the output work (useful output work) 100 J is the work done against friction. It is called **wastage** energy.

The phrase "efficiency of a machine" refers to the performance of a machine. It denotes how much energy the machine transfer or change to the output work.

Efficiency of a machine is defined as the ratio of the output work to the input work. Multiplying the ratio by 100 means that the efficiency is written as a percentage

$$\text{Efficiency} = \frac{\text{Output work}}{\text{Input work}} \times 100\%$$

$$\Rightarrow \eta = \frac{W_o}{W_i} \times 100\%$$

Where $\eta$ is efficiency, $W_o$ is output work, and $W_i$ is input work. The Greek letter $\eta$ is read as eta.

**Note:** If there is no friction, the efficiency of a machine is 100% i.e, $\eta$=1 and MA = VR. A machine with efficiency of 100% is called an **ideal machine**.

## Challenging question

Can a machine with efficiency of 100% or more be produced in this world? Explain your answer.

## Worked Examples 5.4

1. What is the efficiency of a machine that has an input work of 4200J and produces an output work of 3200J?

| Given | Required | Solution |
|---|---|---|
| Work in put = 4200J | $\eta$ = ? | $\eta = \frac{\text{work out put}}{\text{work in put}} \times 100\%$ |
| Work out put= 3200J | | $\eta = \frac{3200J}{4200J} \times 100\%$ |
| | | $\eta$ = 76.2% |

2. A certain machine is used to lift a load of 250N. When an effort of 50N is applied to the machine, the load is raised by 1m and the effort is move by 6m. Calculate
   a) work done on the load
   b) work done on the machine
   c) the efficiency of the machine.
   d) wastage energy.

| Given | Required | Solution |
|---|---|---|
| L = 250N | a. $W_o$=? | a. Wo=L × $S_L$= 250N x 1m = 250J |
| E = 50N | b. $W_i$= ? | b. $W_i$= E × $S_E$= 50N × 6m=300J |
| $S_L$= 1m | c. $\eta$=? | c. $\eta = \frac{W_o \times 100\%}{W_i} = \frac{250J \times 100\%}{300J}$ =83.3% |
| $S_E$= 6m | d. wasted energy = ? | d. W.E= $W_i$-$W_o$=300J-250J=50J |

### Check point 5.2

1. Define a) Mechanical Advantage (MA)
   b) Velocity Ratio (VR)
   c) Efficiency
2. What is a) work output?
   b) Work input?
3. What is the effect of friction on the efficiency of a machine?

## 5.3. Types of Simple Machines

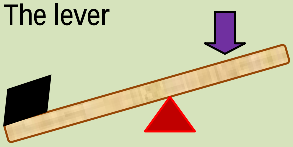
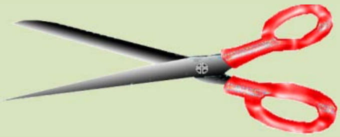
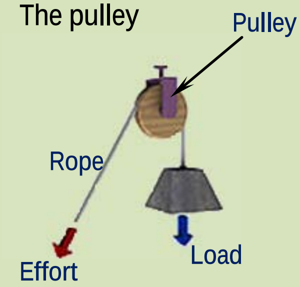
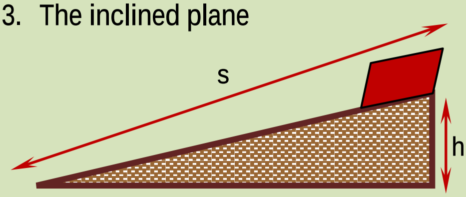
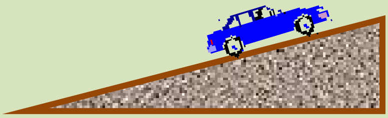
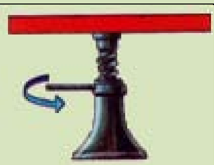
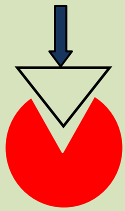
| Types of simple machines | Practical Examples |
| --- | --- |
| 1. The lever  |  |
| 2. The pulley   |  |
| 3. The inclined plane   |  |
| 4. Wheel and axle  |  |
| 5. The screw  |  |
| 6. The wedge  |  |

Fig 5.5 Six types of machines

## Challenging questions

Explain what the practical examples in Fig 5.5 illustrate and where they are used. Give other examples from your locality for each type of simple machines.

### Activity 5.8

i. Observe Fig 5.5 and state the six types of simple machines.

ii. List at least two additional examples for each type of simple machine used in your locality.

**There are two groups of machines in general:**

**i. Simple machine** is a device that changes the direction or magnitude of a force. A simple machine uses single applied force (effort) to do work against single load force. Ignoring friction, the work done on the load is equal to the work done by the applied force.

Simple machines do not contain a source of energy, so they cannot do more work than they receive from the input force. When friction is ignored, the work output (that is done on the load) is equal to the work input (from the applied force).

Simple machines are of six types. They are;

1. The lever
2. The pulley system
3. Inclined plane
4. Wheel and axle,
5. The wedge,
6. Screw and gears

ii. **Compound machines** are machines made by combining two or more simple machines together. For example lawn mowers, typewriters and automobiles are compound machines.

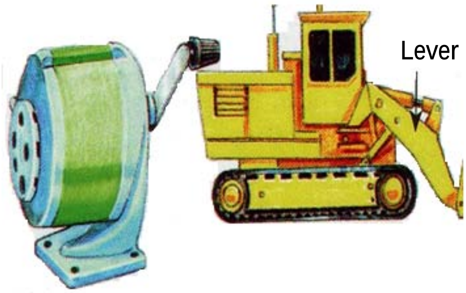



Fig 5.6 Compound machines

At this level you will focus only on common simple machines like lever, pulley and inclined plane.

**1. The lever**

## Activity 5.9

Observe Fig 5.7 and Fig 5.8 answer the following questions

i. What is lever? Name the different parts of a lever.

ii. Give some examples of lever, which are used in your daily activities.

iii. Are levers force multipliers or speed multipliers?

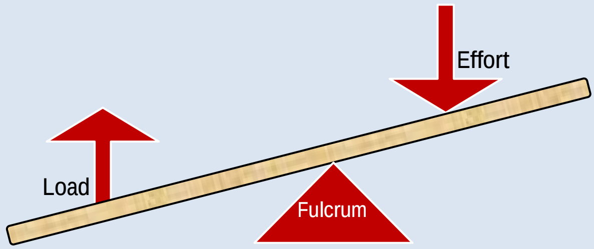



Fig 5.7The three important parts of a lever

Fig 5.8 Examples of a lever

When we use a spoon to put sugar into a glass of tea, the spoon is used as a lever. Similarly, when we also use a crowbar to lift a heavy load we use it as a lever. Have you seen people rowing a boat in a lake? The bar of wood that they use for rowing is used as lever.

The scissors, the forearm and the spade are some additional examples of levers. Generally there are different levers which we use in our daily life.

Lever is a rigid bar of wood or metal that is free to turn about the supporting point which is called fulcrum (F). Lever also consists of effort point (E) and load point (L) in addition to the fulcrum (F).

Fig 5.7 shows the three important points on a lever. They are **effort**, **load** and **fulcrum**. The distance between load and fulcrum is called **load-arm** and the distance between effort and fulcrum is called **effort- arm.**

"Give me a place to stand, and I shall move the earth with a lever"

Fig 5.9 Archimedes

There are three orders (classes) of levers. They are classified into three depending on the position of the fulcrum in relation to the load and the effort. (see Fig 5.10)

i. **First order**: The fulcrum is located between the effort and the load. For example, a crowbar and a pair of scissors.

ii. **Second order**: The load is situated between the fulcrum and the effort, For example, a wheelbarrow and a nutcracker.

iii. **Third order**: The effort is applied between the fulcrum and the load, For example, a nail clipper and tongs.

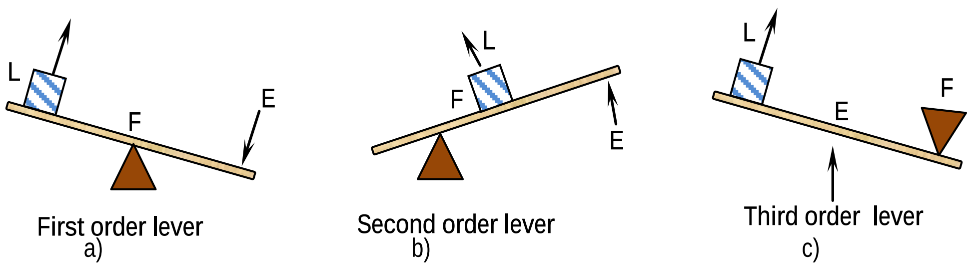



Fig 5.10 Three types of a lever

## Mechanical advantage of a lever

The MA of a lever is the ratio of the load to the effort.

$$\therefore \text{MA} = \frac{F_L}{F_E}$$

A lever is a force multiplying machine if the fulcrum is near to the load. It is a speed multiplying machine, if the fulcrum is near to the effort.

### Worked Example 5.5

1. Refer to the lever in the fig 5.10 (a). A load of 400N is lifted by applying a force of 160N on the lever. If the load is 20cm from the fulcrum and the effort is 80cm from the fulcrum, calculate:
   a) The VR of the machine
   b) The MA of the machine

| Given | Required | Solution |
|---|---|---|
| L = 400N | a. VR = ? | a. $VR = \frac{S_E}{S_L} = \frac{80cm}{20cm} = 4$ |
| E = 160N | b. MA = ? | b. $MA = \frac{\mathbf{L}}{\mathbf{E}} = \frac{\mathbf{400N}}{\mathbf{160\,N}} = \mathbf{2.5}$ |
| $S_E$ = 80cm<br>$S_L$ = 20cm | | |

### Worked Example 5.6

2. A simple lever starts in a horizontal position and moves to the position shown in Fig 5.11.

**Calculate:**

a. The work input
b. The work output
c. The efficiency

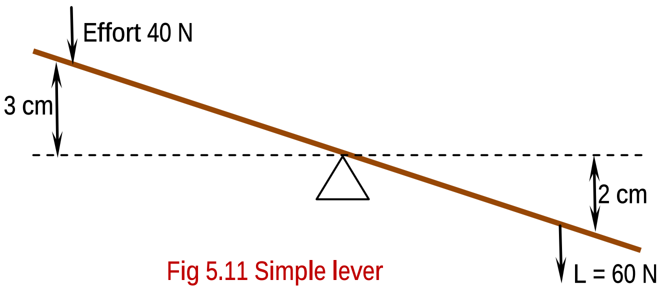



Fig 5.11 Simple lever

| Given | Required | Solution |
|---|---|---|
| L= 60N | a. work in put | a. Work in put = E × $S_E$ |
| $S_L$= 2 cm = .02m | b. work out put | = 40N × 0.03m = 1.20J |
| E = 40N | c. η = ? | b. Work out put = L × $S_L$ |
| $S_E$ = 3cm = (0.03m) | | = 60 N×0.02m = 1.20J |
| | | c. $\eta = \frac{\text{Work out put}}{\text{Work in put}} \times 100\% = \frac{1.20J}{1.20J} \times 100\%$ |
| | | = 100% |

**2. The Pulleys**

A Pulley is a circular body (wheel) with groove surface and is free to rotate about its center. The effort is applied to a rope which passes over the pulleys groove.

A pulley:

- changes direction of force.
- multiplies the effort.

Basically there are two types of pulley systems.

a) **Single Fixed pulley:** is a pulley that does not move together with the load. That is the axle is ‘’fixed’’ or “anchored” in places.

b) **Single Movable pulley:** is a pulley that moves together with the load. It has a free axle.

**a. The single fixed pulley**

The force on the rope is called a **tension.** From, Newton’s third law, the load is the same as the weight (action and reaction forces). The force on the rope turns around the wheel with the same magnitude but opposite in direction. This means the load and the effort are equal in magnitude but opposite in direction.

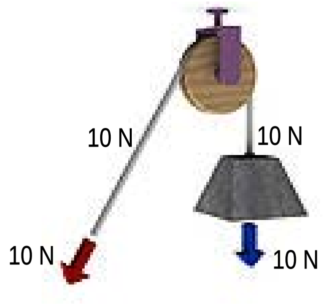


Fig 5.12 Single fixed pulley

- It is used to change the direction of the effort.
- The tension is the same throughout the rope, Neglecting the weight of the rope, wheel and any friction in the pulley bearing, we have

Load (L) = Effort (E)

$\therefore$ MA= $\frac{L}{E}$ = 1 and VR= $\frac{S_E}{S_L} = 1$

i.e, A single fixed pulley has a mechanical advantage of 1. This means that there is no multiplication of effort.

### b. The single movable pulley

The tension on the rope is equal to the effort applied. The total upward pull on the pulley is equal to the load. This means that the effort is half of the load or the load is twice the effort.

$$\therefore \text{Mechanical advantage} = \frac{\text{load}}{\text{Effort}} = \frac{L}{E} = 2$$

i.e. The single moveable pulley has a mechanical advantage of 2.

Fig 5.13 Single movable pulley

## Project Work

Construct a single fixed and single movable pulley and determine their purposes.

Apparatus:- Two piece of penstocks, (pulley from science kit ) two thin wire (paper-clips), two 50cm strings, ruler, and stand.

Procedure:-

1. Insert the wires (paper-clips) in each penstock or pulley.
2. Suspend the paper –clip on the stand or on the table as shown in Fig 5.3 to make a fixed pulley.
3. Tie the load with string and pass it over the fixed pulley
4. Measure the height of the load and effort above some reference frame (ground or table ).
5. Apply a force to lift the load.
6. Measure the new height after applying a force and compare distance moved by load and effort.
7. Tie the other paper- clip with the stand or table and pass it over the pulley as shown in Fig 5.13 to make it a movable pulley.
8. Suspend the load on the pulley as shown in fig 5.13.
9. Measure height of load an effort above some reference frame (ground or table).
10. Apply a force to lift the load.
11. Measure the new height after applying a force and compare the distance moved by load and the effort.
    i. Which distance is grater for fixed pulley? Is it $S_E$ or $S_L$.
    ii. What is the purpose of single fixed pulley?
    iii. Which distance is greater for simple movable pulley "Is it $S_L$ or $S_E$.
    iv. What is the purpose of single movable pulley?

### 3. The inclined plane

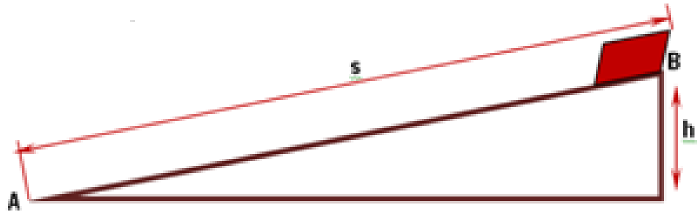



Fig 5.14 Inclined plane

When an object is heavy and difficult to lift on a car, people usually put a plank (heavy wooden board) and incline it on the car and then pull or push the object up along the plank easily.

An inclined plane is a sloping surface or ramp which allows a load to be raised more gradually using a smaller effort than the load if it were lifted vertically upwards.

Inclined plane is a plane whose angle to the horizontal plane is less than $90^0$.

In Fig 5.14 an object of a certain weight is raised by pulling it along the inclined surface. As the load is drawn up from A to B, the effort is applied over a distances s while the load is raised vertically a height h. Thus:

i. Velocity Ratio = $\frac{\text{Distance moved by effort}}{\text{Distance moved by load}}$

$$VR = \frac{\text{length of inclined surface}}{\text{height of inclined plane}}$$

$$\Rightarrow VR = \frac{s}{h}$$

For a frictionless inclined plane, output work = input work,

ii. Mechanical Advantage = $\frac{\text{load}}{\text{effort}} = \frac{L}{E}$

The mechanical advantage of a frictionless inclined plane is the ratio of the length of the sloped surface to the height it spans.

**Activity 5.10**

i. Which distance, $S_E$ or $S_L$ is greater in an inclined plane?

ii. What is the purpose of using inclined plane? Is it to multiply speed or force?

## Worked Example 5.7

In Fig 5.14, the length of the plane is 4m and the height is 1m. What will be the velocity ratio of the incline plane?

| Given | Required | Solution |
|---|---|---|
| s = 4m<br>h = 1m | VR = ? | $VR = \frac{s}{h} = \frac{4\cancel{m}}{1\cancel{m}} = 4$ |

It implies that if there is no friction this incline plane multiplies the effort by 4.

### Torque

**Activity 5.11**

A father and a son are playing a see saw.

i. Do they balance each other?
ii. Who should sit nearer to the fulcrum to balance?
iii. What are the conditions for them to balance?

Torque is the action of a force to turn things around. Torque measures the effectiveness of the force in turning an object about a given axis. Torque is the product of force and a perpendicular distance as shown in Fig 5.15. It is a vector quantity; it has both a magnitude and direction. Torque = force × perpendicular distance from the axis.

The direction of a torque is either clockwise or anti-clockwise.

An object is said to be balanced when the clockwise torque is equal to the anti clockwise torque. In such condition there is no motion (or no turning effect).

Anti clockwise torque = clockwise torque

$$F_1 \times r_1 = F_2 \times r_2$$

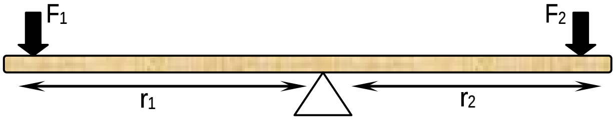



Fig 5.15 Torque

## Worked Example 5.8

A 5m long lever is used to balance a load of 1200 N by a force of 80 N, when the fulcrum is located at a distance of 2m from the load and 3m from the effort.

a) What is the clockwise torque?
b) What is the anticlockwise torque?
c) What is the MA of the lever?
d) What is the VR of the lever?

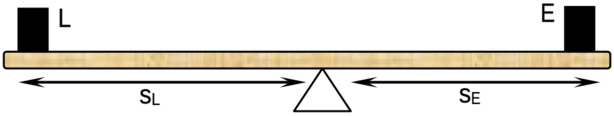



Fig 5.16 Computing a torque

| Given | Required |
|---|---|
| L = 120 N | a) Clockwise torque = ? |
| E = 80 N | b) Anti clockwise torque = ? |
| $S_L$ = 2m | c) MA = ? |
| $S_E$ = 3m | d) VR = ? |

**Solution**

a) Clokwise torque = E × $S_E$ = 80N × 3m = 240 Nm

b) Anticlockwise torque = L × $S_L$ = 120N × 2m = 240 Nm

c) MA = $\frac{L}{E} = \frac{120N}{80N}$ = 1.5

d) VR = $\frac{S_E}{S_L} = \frac{3m}{2m} = 1.5$

**Check point 5.3**

1. Mention and describe the types of simple machines.
2. What is the significance of simple machines in your daily life?
3. Explain how you can calculate MA, VR and η for
   a) Lever b) Inclined plane c) Pulley
4. What is a torque?

## Summary

In this unit you learned that:

- machines are devices which help us do our work easier. We use machines to multiply distance (speed), multiply force or to change direction of a force.
- effort is a force applied on a machine.
- load is a force exerted by the machine.
- a machine is said to be force multiplier if Load > Effort, speed multiplier if $S_E < S_L$.
- M.A of a machine is defined as the ratio of load to effort.
- V.R of a machine is defined as the ratio of $S_E$ to $S_L$.
- efficiency of a machine is defined as the ratio of output work done to input work done.
- lever is a rigid bar that is free to turn about the supporting point called the fulcrum.
- pulley is a wheel and it is free to rotate about an axis through its center. The simplest form of a pulley is single fixed pulley and single movable pulley.
- inclined plane is a slope or ramp which allows a load to be raised more gradually by a small effort.
- Torque is the turning effect of a force.

# Review Questions and Problems

## *I. Choose the best answer.*

1. **Which one of the following is not the purpose of machines?**
   a. **Multiplying force** c. **Transfering energy**
   b. **Multiplying speed** d. **Multiplying energy**
2. **Which of the following machines is not an example of a lever?**
   **a. Wedge b. Spade c. Forearm d. Hammer**
3. **Velocity ratio of a single fixed pulley is always equal to**
   **a. 2 b. 1 c. 3 d. 4**
4. **The Velocity ratio of a single movable pulley is always equal to**
   **a. 2 b. 1 c. 3 d. 4**

## *II. Fill in the blank with the appropriate word or phrase.*

1. **A device that changes only the direction of force is known as ________**
2. **___________is a force applied on a machine.**
3. **The ratio of effort distance to load distance is called _______.**
4. **__________ is the ratio of load to effort.**
5. **The Output work divided by input work for a machine is called _______.**

## *III. Short answer questions.*

1. **Is there any real machine where its efficiency is 100%? Why?**
2. **Can you explain the three main important reasons why we use machines?**

## *IV. Work out problem*

1. **Group the basic simple machines lever, pulley and inclined plane as force multiplier, speed multiplier, and change direction of effort.**

| Force multiplier | Speed multiplier | Change direction of effort |
|---|---|---|
| | | |
| | | |

2. **If a load of 24N is moved by applying an effort of 6N to the machine, what is the M.A of the machine?**
3. **A 500N car is pulled up to 20m plank to a flat from 5m above the ground by an effort of 150N parallel to the plank. Calculate:**
   **a. VR of the machine** **d. output work**
   **b. MA of the machine** **e. efficiency**
   **c. input work**

# UNIT 6

# TEMPERATURE AND HEAT

**Unit outcomes:** After completing this unit you should be able to:

- ✓ understand concepts related to temperature and heat.
- ✓ develop skill of manipulating numerical problems related to temperature.
- ✓ appreciate the interrelatedness of all things.
- ✓ use a wide range of possibilities for developing knowledge of the major concepts within physics.

## Introduction

So far, you studied three basic physical quantities mass, length and time. In this unit you will learn the fourth basic physical quantity called **temperature.**

This unit introduces the concept of temperature and discusses the differences between temperature and heat. The unit also presents temperature measuring instruments (scales), conversion of temperature scales, sources of heat and effects of heating.

## 6.1. Definition of Temperature

**Activity 6.1:** ***Questions for Discussion***

i. What is a temperature?
ii. How do people express temperature in their daily life?
iii. Is there a difference between temperature and heat? Explain it.

People usually use the word hot, warm, cool and cold to express the temperature of an object. Do you feel the differences between hot and warm, cold and cool? These words are not very accurate to tell the temperature of an object. Most people are confused and they use the words heat and temperature interchangeably. But heat and temperature are two different physical quantities.

**Activity 6.2:** ***Discuss the following questions***

iv. Consider you have three cups of tea filled with hot, lukewarm and cold water.

Step i. immerse your left hand finger in hot water and the right hand finger in cold water.

Step ii. Take out your hands from the hot and cold water.

Step iii. Quickly, put both your fingers in the lukewarm water. What do you feel on your left and right fingers? Is there any difference?

v. What is the difference between heat and temperature?

As you withdraw your finger from the hot water and put it in the lukewarm water, you feel cold. When you withdraw your hand from the cold water and put it into the lukewarm water, you feel warm. **Can you tell which is hot and which is cold**?

From this activity you will learn that testing the hotness or coldness of a body by feeling is not reliable, because the lukewarm water is cold for one finger and hot for the other. So you can not conclude that the lukewarm water is hot or cold.

Temperature is a fundamental concept as the three fundamental quantities: mass, length, and time.

Substances are made up of small particles called atoms and molecules. These small particles are symbolized by small circles, like marbles, (Revise your chemistry lessons). The particles in a solid are fixed in a position, but vibrate back and forth about the fixed point. The particles in liquids and gases are always in motion. These particles have energy due to their motion called kinetic energy. (See Fig 6.1)

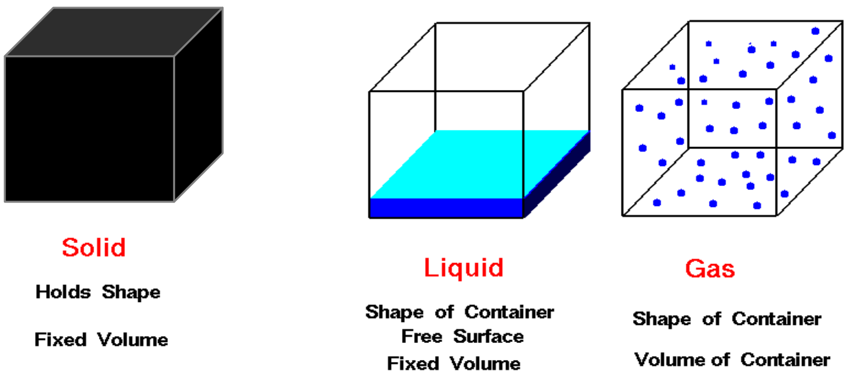



Fig 6.1 Three states of a substance

When a substance is made hotter, the speed of these particles increases, and gain kinetic energy. In science, heat is a form of energy. Heat is the total kinetic energy of all the particles in the substance. While 'temperature' is the measure of the average kinetic energy of the particles in the substance.

Thus temperature can be defined as the hotness or coldness of a body or as the average kinetic energy of the particles of a body.

A body having particles with small kinetic energy has low temperature.

Temperature is a measure of the average kinetic energy of the particles in a substance. It does not depend on the size of the body. For example, the temperature of a small cup of boiling water is the same as the temperature of a large pot of boiling water. But these two bodies have different heat.

Temperature is an intensive property of a body. That means, it does not depend on the system size, the amount or type of particles in the system. Temperature is intensive as pressure and density. For example, the density of a substance remains the same as the mass and the volume change. Density is an intensive quantity. By contrast, mass and volume are extensive properties and depend on the amount of material in the system. Similarly heat is an extensive quantity. That is, it depends on the amount or size of the particles in the substance. For example 100 liters of boiling water has different heat, but the same temperature to 1 liter of boiling water. If they are poured on ice the 100 liter water will melt more ice than the 1 liter of boiling water.

**Check point 6.1**

1. Explain the term 'temperature'.
2. Describe the difference between temperature and heat.
3. How can we relate the temperature of a body with the kinetic energy of its particle?
4. Temperature is an intensive property of a body, while heat is an extensive quantity. Explain it.

## 6.2. Measuring Temperature

**Activity 6.3**

i. Explain the local methods of measuring (estimating) temperature in every day life.
ii. What is the drawback of using our sense organs for knowing the temperature of a body?
iii. Have you seen a clinical thermometer used by medical personnel? What is there in the thermometer?
iv. How do we measure temperature?

In everyday life, people use their hands to check the temperature of another body. For example, consider a soft drink which is taken out from a refrigerator. By holding the surface of the bottle, you can say that "it is too cold" lukewarm or "warm". Similarly for hot bodies, people use their hands. For example, mothers use their hands to check whether the water is hot or lukewarm for their babies. But it is impossible to measure the temperature of a body accurately by touching or using our sense perceptions.

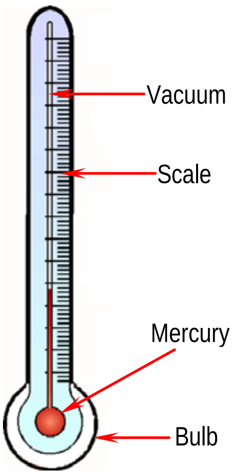
To measure the temperature of a body accurately we need a special instrument called thermometer.

Thermometer is a device used to measure the temperature of a body. It measures temperature in degrees (°).

The first thermometer was made in 1592, by the Italian scientist called Galileo.

A thermometer consists of a tube of uniform thin bore with a small bulb at its bottom. The tube is commonly filled with mercury or alcohol to a certain height. It operates by contraction and expansion of the mercury or alcohol in the bulb.

There are different types of thermometers, having different ranges and different substances in it. Some of them are:




a) Mercury Thermometer

b) Clinical thermometer

Fig 6.2 Different types of thermometers

i) **Mercury Thermometer**: It operates based on the expansion of mercury with increase of temperature. Clinical thermometer and laboratory thermometer are made of mercury. The clinical thermometer is used by health officers in hospitals and in clinics. The laboratory thermometer is used by scientist for research purposes.

ii) **Alcohol thermometer**: It is used to measure very low temperature. It ranges from -80°C to 100°C

**Check point 6.2**

1. How can you measure accurately the temperature of a body?
2. Describe different types of thermometers.
3. Explain how a mercury thermometer functions. Draw a thermometer and label it.

## 6.3. Temperature Scales

**Activity 6.4**

i. What temperature scales do you know? Describe them.
ii. In what tempreature scales, do medical personnels and meteorologist read the temperature of bodies?

These days different temperature scales are in use. But at this level, you will only study the three most common temperature scales; namely the

1. Centigrade (Celsius) scale
2. Fahrenheit, scale
3. Kelvin scale

In making a thermometer, two temperatures of a body are marked on it as fixed points.

These are the **lower fixed point** (melting point of ice) and the **upper fixed point** (boiling point of water) at sea level.

**I. The Celsius scale**

The Celsius scale or centigrade scale was devised by the Swedish astronomer, Anders Celsius (1701-1744), He assigned the value 0 to the ice point and 100 to the boiling point. By dividing the space between the two fixed points into 100 equal parts (divisions) a Celsius scale is obtained. Each division or unit is called **Degree** (°).

Temperature in Celsius scale is denoted as °C. It is read as degree Celsius. (Fig 6.3)

### Challenge question

Do you know how much is the normal human body temperature in degree Celsius?

## II. The Fahrenheit scale

The Fahrenheit scale was devised by the German scientist Daniel Fahrenheit. He assigned the value 32 to the ice point and 212 to the boiling point.

Since the difference between the ice point and boiling point is 180; one can obtain the Fahrenheit scale by dividing the space between the two fixed points into 180 equal parts. Temperature in Fahrenheit scale is denoted by $^0$F, read as degree Fahrenheit (see Fig. 6.3.)

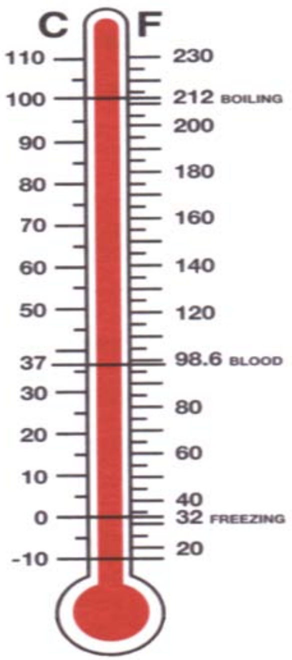



Fig. 6.3 Comparison of Celsius and Fahrenheit thermometers

This temperature scale is sometimes used in connection with reporting on the weather but is not commonly used in everyday life in one country and for scientific works in a laboratory.

## III. The Kelvin Scale

A new type of temperature scale called **Kelvin** scale is devised by Lord Kelvin. He assigned 273 to ice point and 373 to boiling point. By dividing the space between the two fixed points into 100 equal parts Kelvin scale is obtained. This scale is used commonly for scientific works.

Temperature exists much colder than the freezing point of ice, 0 °C on Celsius scale. Experiments suggest that there is a limit to how cold things can get.

At a temperature of - 273°C or 0 K all the heat energy will be removed from a substance and the particles in the substance stop to move. We call this lowest possible temperature **Absolute Zero.**

The SI unit of temperature is Kelvin, symbolized by K. It does not have degree symbol on it.

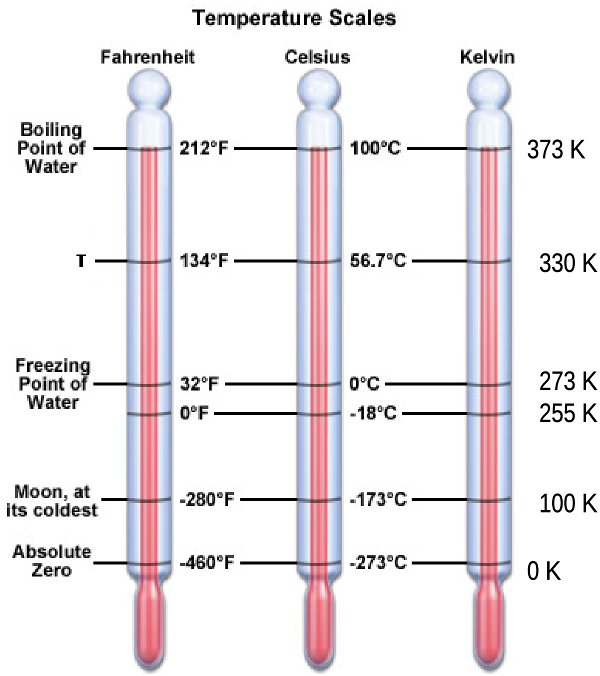



Fig. 6.4 Thermometer reading from different scales

## Reading a thermometer

When the temperature of the surrounding air rises, the volume of the mercury will expand, causing the mercury inside the tube rise, so that one can read out of the marked scale on the tube and know the temperature. Contrary to this, when the temperature of the air falls, the mercury inside the tube will contract. This will cause the level of the mercury inside the tube to drop. The temperature can thus be read from the corresponding scale on the tube.

### Activity 6.5: Measuring temperature of a bodies

Materials you need: water at different temperature, thermometer.

i. Try to measure the temperature of water in different containers and your body temperature using a thermometer.
ii. Record the measured values in a table with proper units.
iii. Compare the temperatures of different bodies. Which are hotter, hottest, coldest?

### Check point 6.3

1. What are the different temperature scales? What are the fixed points in each scale?
2. Explain what it means by lowest and upper fixed points.
3. What is the SI unit of temperature?
4. How many divisions are there between the lowest and upper fixed points, in each scale?

## 6.4. Conversion of Temperature Scales

To change the reading of one temperature scale to another, we use, the following relationships. Ratio of interval between boiling point and ice point= Ratio of differences between the lower and unknown point.

i.e.

$$\frac{\text{intervals in Celsius}}{\text{interval in Fahrenheit}} = \frac{T_C - \text{ice point in Celsius}}{T_F - \text{ice point in Fahrenheit}}$$

$$\frac{100}{180} = \frac{T_C - 0}{T_F - 32}$$

a) To convert Celsius scale to Fahrenheit or vise-versal, we use the relationship:

$$T_F = \frac{9}{5}T_C + 32°$$

$$T_C = \frac{5}{9}(T_F - 32)$$

b) To convert Celsius scale to Kelvin or vise-versal, we use the relationship:

$$T_K = T_c + 273°$$

$$T_C = T_K - 273°$$

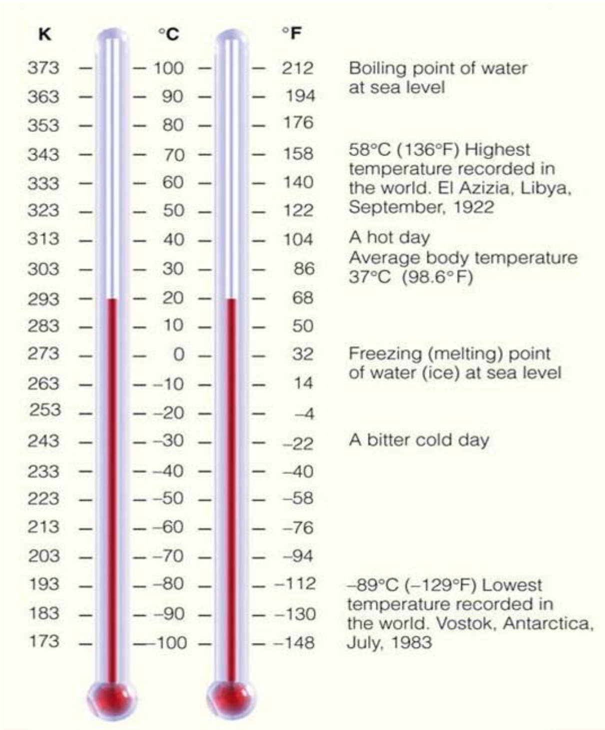



Fig. 6.5 Reading a temperature on different thermometer scale

## Worked examples

1. The temperature of a room is 20°C. What is the temperature of the room in:

   a) Fahrenheit scale? b) Kelvin scale?

| Given | Required |
|---|---|
| $T_C = 20°C$ | a) $T_F = ?$ |
| | b) $T_k = ?$ |

**Solution**

a) $\frac{9}{5}T_C + 32° = \frac{9}{5} \times 20° + 32°$

$= 36° + 32°$

$= 68°F$

b) $T_k = T_c + 273°$

$20° + 273°$

$= 293k$

2. What will be the temperature reading in Celsius scale when the reading in Fahrenheit scale is zero?

| Given | Required | Solution |
|---|---|---|
| $T_F = 0$ | $T_C = ?$ | $T_C = \frac{5}{9}(T_F - 32°)$ |
| | | $= \frac{5}{9}(0 - 32°)$ |
| | | $= \frac{5}{9}(-32°) = \frac{-160°}{9}$ |
| | | $= -17.8°C$ |

**Check point 6.4**

1. Write the mathematical relations between Celsius and Fahrenheit scales.
2. Convert 56 °C to °F and K.
3. Convert 210 °F to °C and K.

## 6.5. Sources of Heat

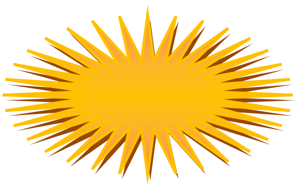
**Activity 6.6- Discuss**

i. What is heat?
ii. Why do we need heat?
iii. Mention some soures of heat in your daily life.
iv. What is the difference between heat and temperature?

## What is heat?

Heat was thought to be a substance called calorie. People thought that a hotter body contained more "calorie" than a cold body. But, series of experiments have showed that heat is not a substance. Heat is produced by energy changes. And heat is a form of energy. Do you know how ancient people were producing heat for cooking? Discuss with your friends and parents.

The sources of heat energy in our country are: fire wood, the sun, charcoal, petroleum fuel, electric heater, etc. You can add to these some sources of heat used in your locality.



a) The sun

b) Electric stove

c) Charcoal

Fig 6.6 some sources of heat

The most plentiful source of heat is the sun. The sun energy is important for life. Plants, animals and human beings need the sun energy for living on the earth.

Fig.6.6 shows some sources of heat. For what purposes do people use heat?

Temperature is the measure of the hotness and coldness of an object where as heat is a form of energy that can be transferred from a hotter body to a colder body.

**The SI unit of heat energy is Joule.**

In our country, majority of the people use fire wood and kerosene as sources of heat energy to cook their food and for other purposes.

Since both fire wood and kerosene are non renewable energy suppliers we must use them wisely. Or we need to use renewable energy suppliers such as solar energy, wind energy and water energy.

So as a citizen you are expected to use these energy sources wisely and you are also responsible to tell this idea for your family or friends.

**Check point 6.5**

1. List some every days sources of heat.
2. Explain the direction of heat flow from one body to another.

## 6.6. Effects of Heating

**Activity 6.7**

Discuss with your friends

i) What happens to a body, when you heat it? Make a list of these effects.

ii) Classify these effects into three groups.

When we heat a body, different effects may happen. When you heat a body it either burns, or melts, expands, rises in temperature, glows into red, or glass breaks, etc. These effects of heating can be grouped into the following three categories.

a) temperature rise,

b) expansion,

c) change of state.

### a) Heating causes temperature rise

**Activity 6.8** *Heating body causes temperature rise*

i. Materials required : a beaker, water, a source of heat, thermometer and a stand
ii. Assemble the apparatuses as shown is Fig 6.7
iii. Take the temperature of the water before heating it
iv. Now start heating the water and measure its temperature after every one minute.
v. Record the measured temperature with respect to time taken.
   - interpret the recorded data
   - What do you conclude?

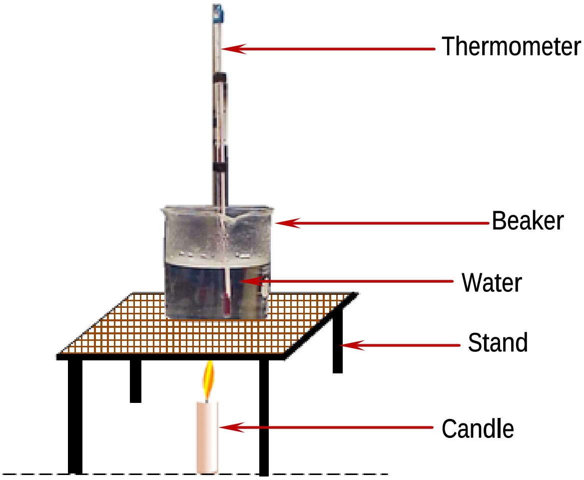



Fig 6.7 Heating water

| t | Min | 0 | 1 | 2 | 3 | 4 | |
|---|---|---|---|---|---|---|---|
| T | (°c) | | | | | | |

As heating increases, the kinetic energy of the particles increases. This causes an increase in the temperature of the substance. Generally, as a body receives heat, its temperature rises.

## b) Heating causes expansion

Since heating increases the kinetic energy of molecules, the molecules move faster and farther apart. This results in an overall increase in the size of the substance. Expansion is an increase in size of the body.

Gases, liquids and solids generally expand when heated and shrink when cooled.

To observe the effect of heating on the size of solids you can do the following activity.

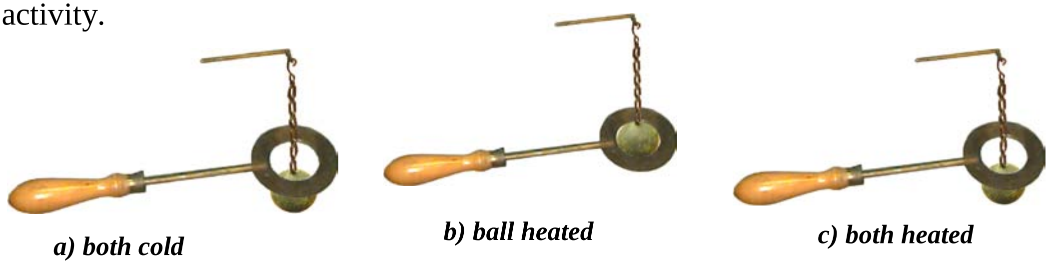



Fig 6.8. Expansion of solids

## Activity 6.9 *(Ball and ring experiment)*

*Materials required:* metal ball with handle or string, metal ring with handle, source of heat.

*Procedure:*

1. At room temperature, the ball will just get through the ring. (see Fig 6.8 (a)
2. Heat only the ball and try to pass it through the ring. (Fig 6.8 (b)
3. Heat both the ball and the ring simultaneously but separately and then try to pass the ball through the heated ring as in Fig.6.8 (c).
   i) What do you observe from this activity?
   ii) Why didn't the ball pass through the ring after being heated?
   iii) Why did the heated ball pass through the heated ring?

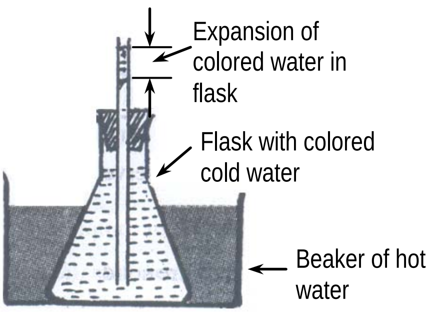



Fig 6.9 Water in a tube expands by heating

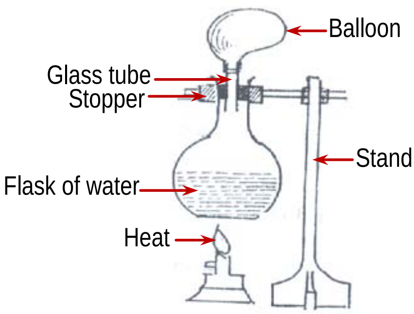



Fig 6.10 Air expands

Fig 6.9 and Fig 6.10 illustrate the expansion of liquid water and air in a bottle respectively.

### c) Heating causes changes of state

## Activity 6.10

i. What are the three states of matter?

ii. What are the three state of water called?

A substance exists in three states. They are solid, liquid and gaseous states. In solids the particles are closer together in a fixed pattern where the separating distance of adjacent particles is constant. The particles of liquids are not usually as close together as in solid and are not held in any fixed pattern. In a gas or vapor the average separation of the particle is comparatively large.

Water is the most commonly found liquid substance on earth. It can exist as solid, liquid and gaseous states.

- Solid water (ice) exists below 0 $^{o}$c.
- Liquid water (water) exists between 0 $^{o}$c – 100 $^{o}$c.
- Gaseous water (Vapor) exists from 100 $^{o}$C and above.

The change of solid water (ice) to water and change of water to vapor are called changes of state.

**Melting**: solid ⟶ liquid

**Boiling**: liquid ⟶ gas (vapor)

### Challenge question

1. Have you noticed the cooling effect when your arm is cleaned by alcohol during injection?
2. Do you know how your body removes unwanted heat?

## Melting

When a solid is heated sufficiently it changes its state of solid to liquid. The process of changing a solid to a liquid state is called **melting**.

A definite temperature at which the solid body starts to melt is called the **melting point** of the solid. Different solid substances have different melting points. For example, solid water (ice) melts into liquid water at 0 $^{o}$C and solid iron melts into liquid iron at 1536 $^{o}$C.

## Boiling

When water is heated, bubbles of water vapor are first formed at the bottom and sides of the container. As the water is continuously heated, its temperature rises, and its molecular bonds break and move farther apart. The process of changing a liquid into gaseous state is called **boiling**.

The definite temperature at which liquid starts to boil is called the **boiling point** of the liquid. For example, water boils at 100$^{o}$c and mercury boils at 357$^{o}$C.

## Evaporation

Evaporation is the change of liquid to vapor at the surface of a body at any temperature. During heating the molecules near the surface of the liquid escape into the air; but not all molecules have enough energy to escape.

For example, water in a pond, lake or ocean, wet clothes, bottle covered with sacks evaporates as it is heated by the sun. (Fig. 6.11).

Discuss what things fasten evaporation?

Evaporation is fastened by exposing a body to a) source of heat, b) wind and c) when the body has wide surface area. For example, a pond of water evaporates quicker in a sunny, windy day and when it has wide surface area. On the opposite, evaporation is slower in rainy day, in still air, and when the surface area is narrow.

When the liquid molecules evaporate, they cool the surface from which they escape because they absorb heat. Thus, evaporation causes cooling of a body.

Table 6.2 Difference between boiling and evaporation

| Boiling | Evaporation |
|---|---|
| • Happens at boiling point. | • Happens at any temperature |
| • Happens throughout the liquid body. | • Happens on the surface of a body- solid or liquid |
| • Has no cooling effect. | • Has a cooling effect on a body. |
| • Does not depend on wind & surface area. | • Is fastened in hot and windy day and where the body surface is wide. |

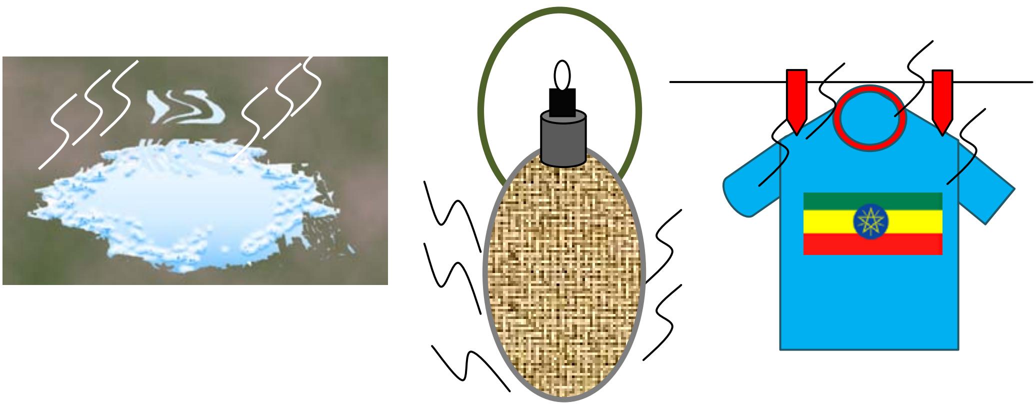


Fig 6.11 Evaporation in different bodies

## Activity 6.11

To observe cooling effect of evaporation

i. Put your fingers into alcohol and immediately expose your fingers to the air. What do you feel?

**ii.** Explain what happens to the alcohol and to your fingers.

Cooling effect of evaporation has some uses. For example refrigerators, freezers and air conditioning system use cooling by evaporation on a large scale. Evaporation is also important in water cycle for making rain on the earth's surface.

## Activity 6.12

To measure melting point of ice and the boiling point of water.

Measure the temperature of solid ice, melt the ice and heat the resulting water until it vaporizes and record the boiling point of the water. What do you observe on the boiling point of water? Does it boil at 100 $^0$C in your area?

### Check point 6.6

1. Describe the three major effects of heating.
2. Explain the differences between 'evaporation' and 'boiling'.
3. What are the factors that affect the rate of evaporation?

## Summary

In this unit you learnt that:

- temperature is the measure of hotness or coldness of a body. Or it is the measure of the average molecular kinetic energy of a body. An instrument which is used to measure temperature of a body is called thermometer.
- a given thermometer can read temperature of a body in one of the following three scales. These are Celsius scale ($^oc$), Fahrenheit scale ($^oF$), and Kelvin scale (K).
- the following formulae are useful in converting out temperature scale in to another scale.
- $T_C = \frac{5}{9}(T_F - 32°)$

  $T_F = \frac{9}{5} T_C + 32°$

  $T_K = T_C + 273°$
- heat is a form of energy. We can get heat from the sun, the food we eat, electric energy, kerosene and firewood.
- some of the effects of heating a body are expansion temperature rise and change of states. Gases expand much more than liquids and solids. Liquids expand more than solids.
- the change from solid to liquid is called melting. The change from liquid to vapor is called boiling. The rate of evaporation depends on) the heat supplied, surface area of the body (liquid) and the wind around the surface.

# Review Questions and Problems

***I. Write true if the statement is correct and false if the statement is wrong.***

1. When air is warmed, it expands.
2. Heat and temperature are the same.
3. Electrical energy can be used as the source of heat.
4. Friction produces heat energy.
5. Many substances expand when cooled.
6. Heating speeds up the movement of molecules.

***II. Match the word or words in the column A with correct explanations in column B***

| Column A | Column B |
|---|---|
| 1. Expansion | a) the measure of hotness or coldness. |
| 2. Temperature | b) 100 divisions between freezing and boiling point of water |
| 3. Centigrade scale | c) decrease in size |
| 4. Contraction | d) increase in size |
| 5. Thermometer | e) substance that can produce heat |
| 6. Fuels | f) instrument for measuring temperature |
| 7. Sun | g) the source of radiant energy |
| 8. Boiling | h) is a cooling process |
| 9. Evaporation | i) takes place throughout the entire liquid |

***III. Short answer questions.***

1. What device do you use to measure temperature?
2. What are the boiling and melting point of water?
3. What happens to a body when it is heated?
4. Name the three different temperature scales.
5. What is the difference between boiling and melting?
6. What is meant by expansion effect of heating?
7. What is the difference between boiling and evaporation?
8. What are the three factors affecting the rate of evaporation?

### *IV. Fill in the blank spaces with appropriate word.*

1. **Almost all materials ____________when their temperature is raised and shrink when their temperature is lowered (cold).**
2. **________ is the measure of average kinetic energy of the particles of a substance.**
3. **The SI unit of temperature is _________.**
4. **The SI unit of heat is _______________ .**
5. **The hotness or coldness of a body is measured by a quantity called _________.**
6. **________ is the change of liquid into vapor from the surfaces of a body.**

### *V. Problem*

1. **What is the temperature reading in Kelvin scale if the reading in Celsius scale is 50 °C.**
2. **The temperature of an object is 40 °C. What is this temperature in Fahrenheit scale?**
3. **What will be the temperature reading in Fahrenheit scale when the reading is 310 K?**

# UNIT 7

# SOUND

**Unit outcomes:** **After completing this unit you should be able to:**

- ✓ **understand concepts related to sound.**
- ✓ **develop skill of manipulating numerical problems related to sound.**
- ✓ **appreciate the interrelatedness of all things.**
- ✓ **use a wide range of possibilities for developing knowledge of the major concepts with in physics.**

## Introduction

One of the most commonly observed phenomenon in nature is sound. You hear different sounds throughout the day. The sound of cars, barking of dogs, friends chatting, a teacher talking and music are some examples of sound. All the above mentioned sounds stimulate your ears and make you recognize the sources of sound and the messages sent through sound.

In this unit you will learn, what a sound is, production and transmission of sound, speed of sound in different media, reflection of sound (echo) and some applications of echo.

## 7.1. Definition of Sound

**Activity 7.1**

i. Give some sources of sound.
ii. What organ do you use to hear sound?
iii. Explain in your own words, what is meant by 'sound'.
iv. For what purposes do you use sound?

Have you ever tried to play a "guitar" or "kirar"? When you strike each string, it starts to vibrate and as a result you hear musical sound.

When a tuning fork is struck against a hard object, the prongs vibrate (moves backward and forwards). The vibrations travel away from the tuning fork as a wave called **sound wave.** (Fig 7. 1)

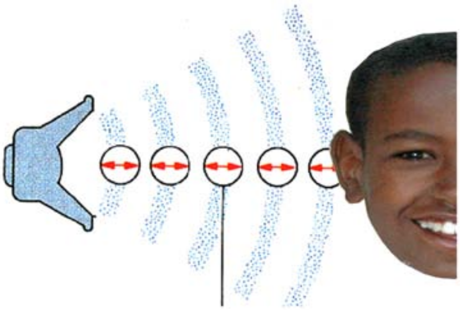



*Fig. 7.1 Sound is heard by ears*

Sound is a form of wave. If your ears are in the path of the sound wave, then you will hear the sound.

Sound carries energy. It loses its energy as it travels. So, the further the sound travels, the more energy it loses and the quieter the sound becomes. Our ears are designed by nature to pick up sound transmitted through different materials.

Sound is a form of energy. It is generated by the series of vibrations of an object. Every sources of sound are in a state of vibration.

There are other kinds of sounds that human ears cannot hear but other animals can hear.

**Check point 7.1**

1. What is sound?
2. How does sound reach the ear?

## 7.2. Production and Transmission of Sound

**Activity 7.2** *Group work*

i. Take different materials from your locality: whistle a ruler, a tuning fork, etc and produce a sound using them.
ii. Explain how each material produces sound.
iii. How does the sound reach your ears? Explain it.

Let us see how a ruler produces sound. Take a ruler and press one end of it firmly against a table top such that the other end of the ruler projects outwards from the edge of the table as shown in Fig 7.2.

*Fig. 7.2 A Vibrating Ruler*

When the ruler is struck sharply, the free end vibrates up and down. When this free end of the ruler vibrates up and down, it produces sound. Thus sounds are produced by vibrating objects.

**Activity 7.3**

i. Cut a long rubber band. Hold one end between your teeth and the other end with one hand stretching the rubber band to some length.
ii. With your other hand pull the centre of the rubber band to one side and quickly let it go. Repeat it for some times. Have you seen the band vibrating? Does it make sound?

This activity leads you to construct different kinds of string musical instruments, such as, “guitar,” “masinko,” and “kirar.” Which part of the instruments mentioned above do you think vibrates to produce sound?

## Activity 7.4 *Individual work*

Copy the following table on your note book and try to record the vibrating part of different musical instruments given in the table below.

| Sources of sound | Vibrating part |
|---|---|
| 1. Drum | 1. ________ |
| 2. Guitar | 2. ________ |
| 3. Kirrar | 3.________ |
| 4. Masinko | 4. ________ |
| 5. Flute | 5. ________ |

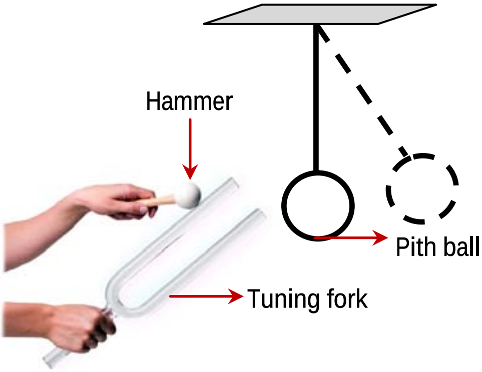



*Fig. 7.3.Vibration of a tuning fork*

## Activity 7.5

i. Tie a pith ball with a thread and suspend it from any height. Bring a tuning fork and touch it as shown in Fig 7.3. What do you observe?

ii. Strike the tuning fork with a rubber hammer or on table edge and touch the pith ball. What do you observe?

iii. What does this show?

When you touch the pith ball with a tuning fork, nothing happens to the pith ball. Now strike the tuning fork by the hammer on the prong by holding on its stem. Then touch the pith ball with the fork, you can see the pith ball will fling away. This shows that the energy on the prong is transferred to the pith ball, and the pith ball starts to vibrate.

All the sounds you hear are produced by a vibrating object. The air near the vibrating object is set in motion in all direction. The produced sound travels in every direction, in the form of energy and reaches your ear. The bell sound in your school is heard any where around the bell in all directions. Sound travels in all directions and around corners.

### Challenging questions

1. What are the three requirements of sound?
2. Write some sources of sound?
3. What does vibration mean?

## Transmission of sound

**Activity 7.6**

To show the transmission of sound through solids.

Two students sitting at the two ends of a table will do this activity.

*Step i.* Let one student from one end scratch the table with his/her finger nail slightly while you are sitting on another end of the table and hearing. Have you heard the scratch or not?

*Step ii.* Now let the other student who was sitting place his/her ear against the table while you are scratching. Ask the student who placed his/he ear against the table , what he/she has heard. Can you tell the difference between Step 1 and step 2? What do you conclude from this activity?

(a) (b)

*Fig 7.4 Sound travels through solids*

Sound needs material medium for its transmission. Being in a classroom you hear the school bell ringing, student shouting in a field, telephone call, or an ambulance siren. How does the sound travel and reach your ear? The material through which the sound traveled and reached your ear is called a **medium**. (Media is the plural of medium). Fig 7.4 and Fig 7.5 show solid and liquid bodies transmit sound through them.

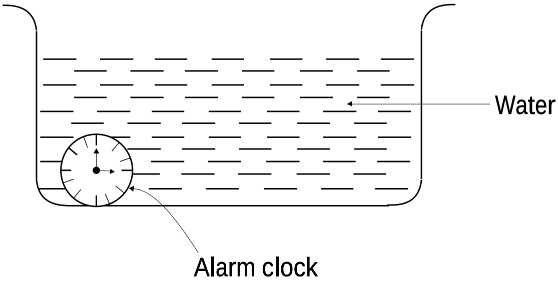



*Fig 7.5 Sound travels through water (Liquid)*

To observe the travel of sound in a liquid, take an alarm clock and place it at the bottom of a bowl of water. Press the alarm clock with your finger and listen to the sound of clock from outside. Do you hear the sound of the clock?

All materials can transmit sound, but the degree of transmission is not the same for all materials. Solids are better transmitters of sound than liquids and air (gases). Do you know why?

Sound needs material medium for its transmission; it cannot travel through a vacuum. This fact can be demonstrated using an electric bell jar by pumping the air out by a vacuum pump while the bell is ringing as in Fig 7.6. As the air is moved out the sound becomes fainter and fainter until it finally ceases to be heard.

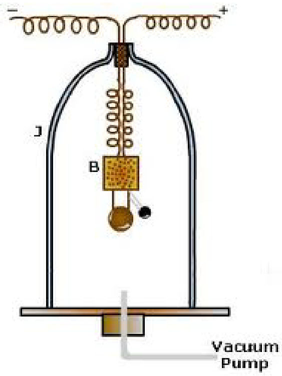



*Fig 7.6. Sound cannot travel through a vacuum*

This happens because there is no air to carry sound. If the air is now allowed to enter the bell jar again, the sound of the ringing bell will be heard.

**Check point 7.2**

1. Describe how sound is produced.
2. Explain the importance of material medium for the propagation of sound.

## 7.3. Speed of Sound in Different Media

### Speed of sound in air

During a thunderstorm you may see a distant lightning flash some seconds before you hear the thunder. This suggests that the speed of sound in air is much less than the speed of light.

When a train is about one kilometer away from you, you can often see the smoke coming out from the nozzle before you hear the whistle. This again means that sound cannot travel as fast as light in air.

**Activity 7.7**

i. When do we hear sound clearly? Is it during a night or a day?
ii. What will you do to the volume of the radio and TV set when you listen to the news or music during a day and a night? Do you change the volume according to the time or not?

The speed of sound in air is about 331 m/sec at 0°C. The speed of sound increases by 0.6 m/sec for every degree Celsius increase in temperature. The speed of sound in air at any temperature ($v_T$) can be calculated as $\mathbf{v_T = v_0 + \frac{0.6}{1^0c} \times T}$ where $v_0$ is the speed of sound at $\mathbf{0\ ^\circ C}$ and "T" is the change in temperature. Speed of sound in liquids and solids is not affected significantly by the change in temperature, but affected by their body structure.

The difference in speeds of sound in different materials can be easily understood from the structure of molecules of a substance. (From your chemistry course revise what molecules are and their structure in different states of substances).

The transmission of sound in different substances depends on the structure of the particles in the substances.

Since the particles in solids are close to each other they easily pass the sound to the next particles by collision and the sound moves faster.

But in liquids and in gases, the particles are far apart and the collision between the particles takes place rarely. They pass the sound slower than in solid. Similarly the particles in gases pass the sound much slower than in liquid. Thus, sound travels slower in liquid than in solid and sound travel slower in gases than in liquids.

The speed of sound in water is greater than the speed of sound in air and its speed in steel is greater than the speed in water. The speed of sound in different material is given in Table 7.2

Table 7.1. Speed of sound in various substances at 0 °C

| Substance | Speed (m/s) 0 °C |
|---|---|
| Gases | |
| Oxygen | 316 |
| Air | 331 |
| Liquids | |
| Ethanol | 1150 |
| Mercury | 1438 |
| Water (distilled) | 1410 |
| Sea water | 1450 |
| Solids | |
| Lead | 1948 |
| Copper | 4998 |
| Glass | 5628 |
| Steel | 5948 |

**Activity 7.8 Questions- use Table 7.1**

i. In what material does sound travel fastest?
ii. In what material does sound travel slowest?
iii. Compare the speed of sound in liquid and in solids.

**Example 7.1**

1. A thunder was heard 4 s later after the lightning is seen. If the distance of the lightning is 1396 m away from the observer, what is the speed of sound at that temperature?

| Given | Required | Solution |
|---|---|---|
| t = 4s | v = ? | s = vt |
| s = 1396m | | $v = \frac{s}{t}$ |
| | | $v = \frac{1396\ m}{4s}$ |
| | | = 349 m/s |

**Check point 7.3**

1. Describe how it is possible to determine the speed of sound in air?
2. What is the factor affecting the speed of sound in air?

## 7.4. Reflection of Sound (Echo)

**Activity 7.9**

Discuss with your friends on the following questions

i. What do you hear if you shout in a big empty hall standing on one corner?
ii. What do you call this sound?

When you throw a ball towards the wall the ball bounces and returns to you. We call this the reflection of the ball. The same is happening when you shout in an empty hall. The sound will bounce back from the wall and comes towards you.

We call this the reflection of sound. The reflection of sound from hard surfaces is called an “**echo**”.

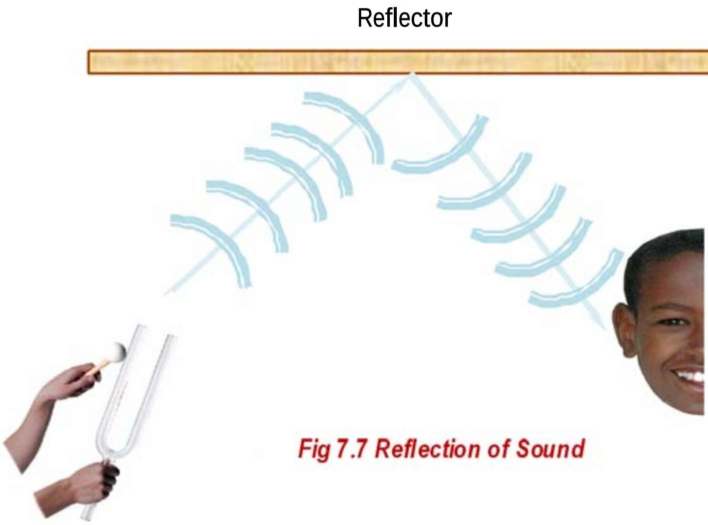



*Fig 7.7 Reflection of Sound*

Whenever sound meets a boundary or an obstacle on its way, some of the sound energy is absorbed and other is reflected. This reflection of sound at a boundary is called an echo.

Hard substances such as walls, rocks, hills, metals, wood, buildings, etc. are good reflectors of sound since they are polished and hard. But when sound strikes soft surfaces such as wool, cloth, etc. most of the sound energy is absorbed.

When you shout or whistle while you are at some distance away from a tall building or a mountain, you may be able to hear the original sound and the reflected sound as two separate sounds. This will be true if the echo/reflected sound reaches you 0.1 sec later than the original sound. This means that your ear is able to distinguish the two sounds as a separate ones only if they reach you at least 0.1 second later.

**Check point 7.4**

1. What is echo? Explain how it occurs.
2. Give at least three examples for each of the following
   a) Sound reflectors
   b) Sound absorbers.

## 7.5. Application of Echo Sounding

**Activity 7.10**

Measuring the speed of sound using the echo method.

i. Go out into an open field in a group where you can find a big tree or a mountain.
ii. Stand infront of the tree (mountain) and clap your hands or shout loudly.
iii. Do you hear the echo of your clap. Move back and forth until you hear the echo.
iv. Ask your friend to measure, the time taken for the clap sound to move to the mountain /big tree/ and comes to you as an echo using a stop watch .
v. At this point, measure the distance between the place where you stand and the big tree or (bottom of the mountain).
vi. Apply the formula of speed. $v = \frac{s}{t}$ and calculate the speed of sound for that day (temperature).

From the above activity, you can calculate the minimum distance of the reflecting surface and speed of sound taking 0.1 second as the minimum time required to have an echo reach you.

i.e. 2s = vt (since the distance traveled by the sound is the sum of the distance from the source to the reflector and back from the reflector to the source)

$$\Rightarrow s = \frac{vt}{2} = \frac{331\text{m/sec}}{2} \times 0.1\,\text{sec} = 17\text{m}$$

Hence, the minimum distance for an echo to be produced is 17 m. No separate echo can be heard for distances less than 17 m if the speed of sound at that temperature is 340 m/sec.

When sound strikes a reflecting surface obliquely, nearly all the sound is reflected. This fact has been applied in the doctors stethoscope for listening to sounds of heart beat, or lung movement. These are some applications of an echo in medical field.

**Example 7.2**

What is the speed of sound at a given temperature if an echo is heard 4 seconds later from a mountain which is 664 m away?

| Given | Required |
|---|---|
| s = 664 m<br>t = 4s | v = ? |

**Solution**

$$\text{Speed of sound} = \frac{\text{Total distance}}{\text{Total time}} = \frac{2s}{t}$$

$$= \frac{2 \times 664\text{m}}{4\text{s}} = 332\text{m/s}$$

The above sample problem shows the importance of the echo method in finding the speed of sound in air.

On the other hand, knowing the speed of sound in air at a certain temperature, and recording the time interval between hearing the original sound and the echo will enable us to calculate the distance of the reflecting surface. The echo method is used to measure the depth of a sea or an ocean.

**Check point 7.5**

1. State some examples of applications of echo.
2. Explain how an echo from a cliff could be used to measure the speed of sound in air.

## Summary

In this unit you learnt that:

- sound is a wave heard by the ears. Sound is produced by vibrating objects and travels through solid, liquid and gas media. Sound is a form of energy.
- the speed of sound in solid is greater than the speed of sound in liquid, and the speed of sound in liquid is greater than the speed of sound in gases.
- as the sound travel against different bodies, it either reflects totally or partially reflected or partially absorbed. Sound travels in all direction and around corners. The reflection of sound from hard surfaces is called an echo. An echo is used to measure the distance of cliffs, sea bed or big building from a given sources of sound.

# Review Questions and Problems

***I. Write true if the statement is true and false if the statement is false***

1. **All sounds are produced by the vibration of bodies.**
2. **Sound travel through vacuum.**
3. **Sound is transmitted faster in air than in liquids.**
4. **As the temperature of air rises the speed of sound in air decreases.**
5. **The speed of sound in air is four times as its speed in steel.**
6. **The speed of sound in air is greater than the speed of sound in solids.**

***II. Fill in the Blank spaces with appropriate word or words.***

1. **The three prerequisites of having sound are________, __________, ________.**
2. **An echo is not produced unless the reflecting surface is at least __________ meters from the source of sound.**
3. **The speed of sound in air at 0 $^{o}$C is__________ m/s.**

***III. Short answer Questions***

1. **Explain how sound is produced.**
2. **What is sound?**
3. **Explain how an echo is formed.**
4. **Explain why the speed of sound in solid and liquid are greater than the speed of sound in gases.**
5. **List two applications of an echo.**

***Iv. Match column A with column B***

| Column A | Column B |
|---|---|
| **1. Sound** | **a) the speed of sound in glass at 0°c** |
| **2. Echo** | **b) the speed of sound in air at 0°c** |
| **3. 4998 m/s** | **c) the speed of sound in copper at 0°c** |
| **4. 5628 m/s** | **d) the reflection of sound** |
| **5. Flute** | **e) a series of disturbances in material to which the human ear is sensitive** |
| **6. 331 m/s** | **f) Air vibrating musical instrument.** |

### *v. Problems*

1. **How far away should a cliff be from a source of sound to give an echo in 5.3 seconds? (Given speed of sound at 0 °C =331 m/s)**
2. **A ship's sonar sends messages and receives the echoes from the ocean bottom 0.6 seconds after the sound is sent down from the ship. How deep is the water beneath the ship? (Given speed of sound in still water = 1450 m/s)**
3. **How far away is a train if you see the steam from its nozzle 4.5 seconds before you hear its sound? (Take speed of sound as 331 m/sec)**

# UNIT 8

# ELECTRICITY AND MAGNETISM

**Unit outcomes:** **After completing this unit you should be able to:**

- ✓ **understand concepts related to electricity and magnetism.**
- ✓ **develop skill of manipulating numerical problems related to electricity and magnetism.**
- ✓ **appreciate the interrelatedness of all things.**
- ✓ **use a wide range of possibilities for developing knowledge of the major concepts with in physics.**

## Introduction

This unit is made up of two main topics called electricity and magnetism. It treats magnetism first and then electricity. Magnetism deals with the properties of a magnet while electricity deals with the properties of electrons at rest and in motion. The relationship between magnetism and electricity will be treated in grade 8.

## PART-1 MAGNETISM

### 8.1. Magnets

**Activity 8.1**

Do the following activity with your friends and answer the given questions

i. Visit a radio repair shop or shoes shops or a science kit in your school. Ask the responsible person to show you magnets.

ii. What is a magnet?

iii. In what shapes do you find a magnet?

iv. What materials does it attract?

A Magnet is a piece of iron that attracts substances like iron, steel, and nickel at a distance.

The word "**magnet**" comes from the name "**magnesia**". Magnesia was an ancient city in Middle East, where the first magnet was discovered. This magnet was in a form of stone and it was called **lode stone** meaning leading stone. Lode stone is a naturally found magnet.

Magnet can be natural or artificial. A lodestone is naturally occurring magnet. Artificial magnets are magnets that are produced by people. They are usually made of iron and alloys of iron such as steel. Artificial magnets have different shapes such as bar, horse–shoe, U-shaped and cylindrical. See Fig 8.1 to identify the shapes of magnets.

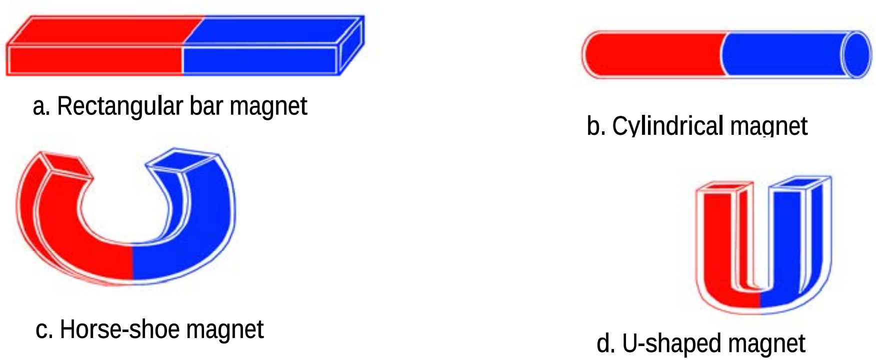



Fig. 8.1 Different shapes of magnets

## Magnetic and non-magnetic substances

From Activity 8.2, it is very simple to observe that all materials are not attracted by magnets. Hence materials are classified into two: as magnetic and non-magnetic materials (substances).

## Activity 8.2 *To identify whether a material is magnetic or non magnetic*

i. Collect some materials like iron nail, coins, pins, pen, wood stick, rubber, etc.

ii. Bring a magnet near to these materials and try to attract them one by one.

iii. Fill the table shown bellow using ✕ or ✓symbols for the result of your activity. ✕ for not attracted and ✓ for attracted .

| Material | Attracted | Not attracted |
|---|---|---|
| ___ ___<br>___ ___<br>___ ___ | | |

Does the magnet attract all the materials?

- Substances that can be attracted by a magnet are called magnetic substance. Iron, steel, nickel, and cobalt, are examples of magnetic substances.
- Non-magnetic substances are substances which cannot be attracted by magnets. Rubber, paper, wood, plastic, copper, Aluminum, gold, and glass are examples of non-magnetic substance. All metals are not attracted by a magnet.

## Activity 8.3- *Making a magnet*

I. *Materials required:* a large nail (steel bar), small pins, and a bar magnet.

ii. Procedure-*1.* Move the end point of the nail around in a small pile of pins (number of pins lying on one another).Dose the nail pick up any pin?

iii. *Procedure-2.* Using one end of a magnet, stroke the nail repeatedly in one direction only. Lift away the magnet each time when you reach the end of the nail. Return to the point of the nail where you started the stroking and stroke again. As shown in Fig 8.2

- Now bring the stroked nail near to the pins again. What happens this time? Will the pins be attracted or not? Repeat this process.

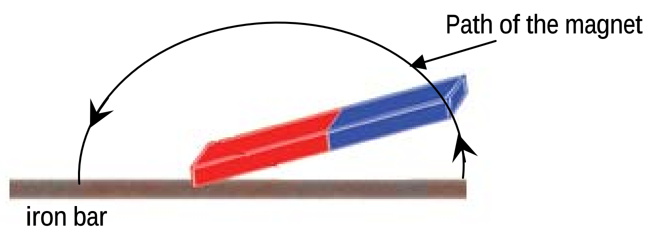



Fig 8.2 magnetizing an iron bar by stroking

The process of making a magnet by stroking or other methods is called **magnetization**.

From the process of magnetization in activity 8.3, the end of the nail or steel bar, where the stroking ends will be magnetized opposite in polarity with the polarity of the permanent magnet. i.e. if the stroking is with North pole of the permanent magnet, the last end of the steel bar will be magnetized as a South pole and vice versa.

This method has a disadvantage that the magnet produced by this process will not have both the poles at the two exact ends. Then it will be better to use other methods like a double stroking method or electricity to avoid this problem.

## Properties of magnets

You have learnt in unit 3 of this book, that magnets exert a force at a distance. It attracts iron materials or repels other magnets at a distance. In this section you will learn more properties of a magnet.

### a) Magnetic poles

If a magnet is dipped into iron filings and then shaken lightly, the iron filings stick to the ends of the magnet. From this activity we observe that the force of a magnet is concentrated at the two ends. These ends of a magnet are called **magnetic poles**.

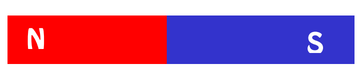



Fig 8.3 N and S poles of a magnet

Magnetic poles are the two ends of a magnet where the attractive forces are strong.

If a magnet is suspended from a thin thread, it always points in the same direction toward the geographic north - south direction.

The end of the magnet that points north is called the North Pole (in short N. pole). The other end that points south is called the South Pole (in short S-pole).

The following are some basic properties of any magnet:

i. A magnet attracts pieces of iron and steel.
ii. If a magnet is suspended freely, it always comes to rest with its ends pointing in a north-south direction.
iii. A magnet has two poles.
iv. No matter what its shape or its size may be the two poles always exist in pairs.

## b) The laws of magnetism

### Activity 8.4 *Observing the laws of magnetism*

Materials required: Two bar magnets and a thread

i. Suspend one magnet with a thread and hold the other magnet with your hand.
ii. Bring close the north pole of one magnet to the south pole of another magnet. What do you observe? Record your observation.
iii. Bring close to each other the north poles or the south poles of two magnets. What do you observe? Record your observation.
iv. What do you conclude from these observations?

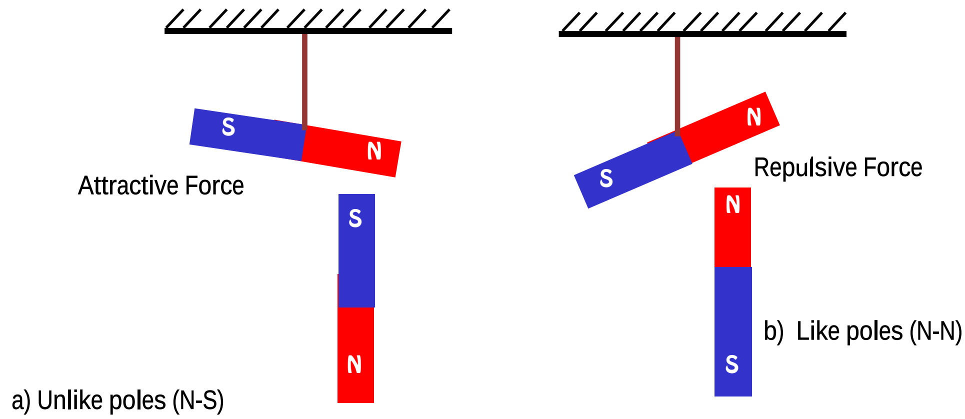



Fig 8.4 Forces between poles of magnets

Activity 8.4 leads you to the following conclusion. Magnetic poles exert forces on other magnetic poles.

The law of magnetism states that: unlike poles attract each other and like poles repel each other.

If you break a bar-magnet into two pieces, then, the north and south poles will not be separated. But, each piece will become a full magnet having both North and South poles. Thus, an isolated magnetic pole does not exist.

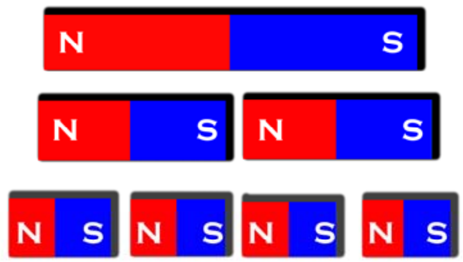



Fig 8.5 Breaking a magnet

### Challenging Question

Suppose a certain magnet is broken into two parts, what will happen to the two magnetic poles (N and S)?

## A compass

**What is a compass?**

A compass is a small suspended magnet used to show the geographic northern direction.

a) Pocket Compass b) Compass Needle

Fig 8.6 Different shapes of a compass

A compass consists of a bar magnet that is mounted on a sharp point so that it can turn freely in the horizontal plane see fig 8.6 and 8.7. When the mounted magnet comes to rest, its North Pole points towards the geographic north. A compass helps people in traveling on sea, land and air; because it always points in the northern direction.

Navigators and pilots make use of a compass to find their directions in their journey.

**Activity 8.5** ***How to make a compass***

Tie a string around a cylindrical magnet. Suspend the magnet away from other magnets and magnetic materials. When the magnet comes to rest, notice in which direction it is pointing. Does the magnet line up in a north-south direction?

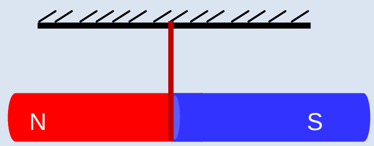



Fig 8.7 Freely suspended magnet points N-S direction

From Activity 8.5 you learn that magnets that are free to moe can be used as a compass. You can easily make a compass of your own as illustrated in Activity 8.5.

## Earth's magnetism

**Activity 8.6.** ***Group Discussion***

Discuss with your friends or parents.

Why does a compass or a suspended magnet always point to the geographic north pole?

In olden days, it was believed that some objects in the sky such as the North Star, made a compass turn to the north-south position.

But now the answer for the above question is the magnetic nature of the earth.

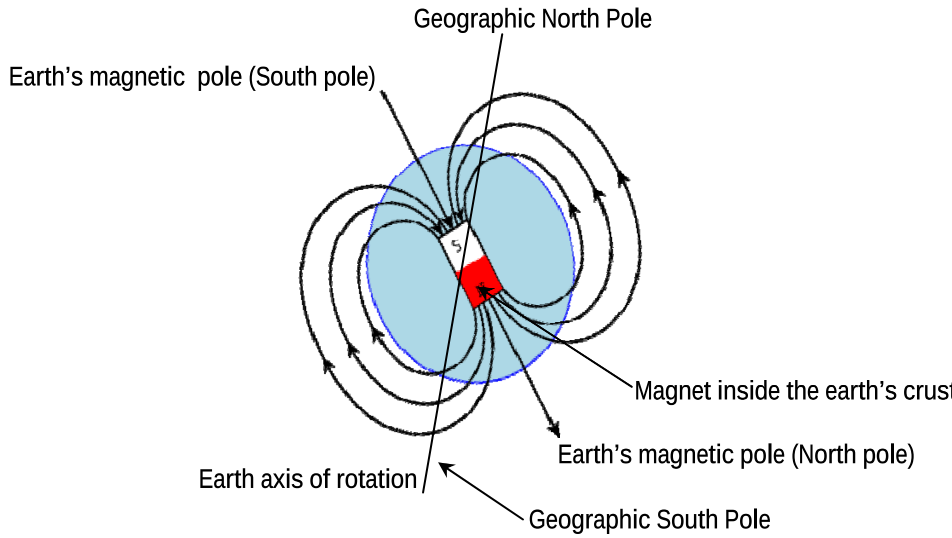



Fig 8.8 The earth's magnetism

Scientists explain the earth as a big magnet. They assume that a big magnet exists inside the earth. Its north pole is found in the geographic south-pole and its south pole is at the geographic north-pole. A suspended magnet or a compass always points in the geographic North, because of the magnetic property of the earth.

The earth's magnetic south pole attracts the North-pole of a compass or a suspended bar magnet.

The earth's magnetic field resembles that of a huge bar magnet with the magnetic poles near to the geographical north and south poles. (Refer to section 8.2)

## Six things to know about magnets

You need to remember the following six basic facts about how magnets behave:

1. A magnet has two ends called poles. One of which is called a North Pole or north-seeking pole, while the other is called a South Pole or south-seeking pole.
2. The north pole of one magnet attracts the south pole of another magnet, while the north pole of one magnet repels the other magnet's North Pole. The law of magnet states that: like poles repel and unlike poles attract each other.

3. A magnet creates an invisible area of magnetism all around it called a magnetic field.
4. The north pole of a magnet points roughly toward Earth's North Pole and vice-versa. That's because the earth itself contains magnetic materials and behaves like a huge magnet.
5. If you cut a bar magnet in half, it's a bit like cutting an earthworm in half! You get two brand new, smaller magnets, each with its own North and South Pole.
6. If you rub a magnet a few times over an unmagnetized piece of a magnetic material (such as an iron nail), you can convert it into a magnet as well. This is called **magnetization**.

**Check point 8.1**

1. What is a magnet?
2. What are the properties of a magnet?
3. Distinguish between magnetic and non-magnetic substances. (Give some examples for each.)
4. What is a magnetic pole?
5. State the law of magnetism.
6. What is a compass? Describe its uses.
7. Explain why a suspended magnet always points to the geographic north and south poles.

## 8.2. Mapping Magnetic Lines of Force

**Activity 8.7**

Discuss with your friends.

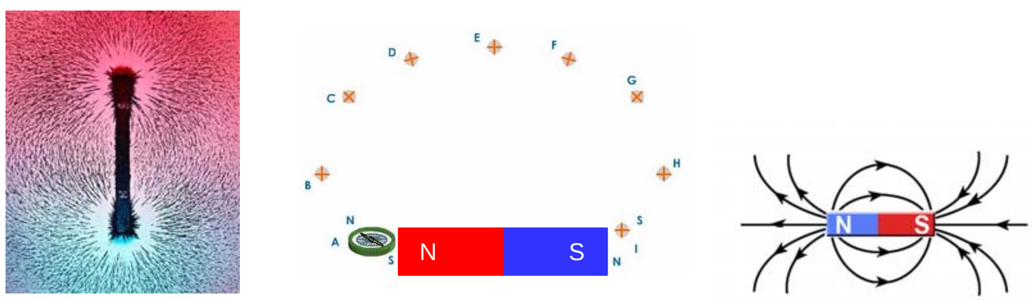
i. What is a non-contact force? How do you explain magnetic force as a non-contact force?

ii. Describe the magnetic field and magnetic lines of force for a magnet.

## Activity 8. 8 *Mapping a magnetic field*

a) Observing magnetic lines of force.
*Materials required*: iron filings, a bar magnet, paper sheet.
*Procedure*:- put a paper on a bar magnet lying on a table top.
- Sprinkle the iron filings on the paper covering the magnet.
- What do you observe? What do you call the space around the magnet?

b) Mapping a magnetic field using compass
*Materials required*: pocket compass, bar magnet and a sheet of paper.
*Procedures*: place a magnet on a sheet of paper.
- Place a compass near the North Pole and mark its direction.
- Repeat this activity for different places around the magnet.
- Draw the directions of the compass at different pointers.
- The compass shows the directions of the magnetic field represented by the magnetic lines of force.




a) Iron filing around a bar magnet.
b) Compass around a bar magnet.
c) Magnetic lines of force around a bar magnet.

Fig 8.9 Mapping lines of force

You have already learnt that a magnet exerts a force at a distance. The space around a magnet is called **magnetic field**.

**Magnetic field** is a region where a magnetic pole would experience a force or exerts a force. Magnetic field is represented by imaginary lines of force called **magnetic lines of force**.

Magnetic lines of force are imaginary lines which continuously represent the direction of the magnetic field.

### Properties of magnetic lines of Force

1. The magnetic lines of force of a bar magnet always emanate from the North Pole and following a curved path enter to the south pole. Then they reach back the North pole moving inside the magnet from south pole to the North pole of the magnet. Thus they are closed lines.
2. Magnetic lines of force never cross each other.
3. Near the magnetic poles, where the magnetic force is stronger, the lines of force are closer. Going away from the magnetic poles, the strength of the magnetic force decreases and the lines become sparse.

- A magnet exerts a force at a distance.
- The direction of the magnetic filed shows the direction of magnetic force.
- The closeness of the magnetic field lines shows the strength of the magnetic force.

**Check point 8.2**

1. What are magnetic lines of force?
2. Describe the common properties of magnetic lines of force.
3. Sketch the magnetic lines of force
   a) For a bar magnet b) between two unlike magnetic poles.

## 8.3. Uses of Magnets

In Activity 8.1 you visited different shops where magnets are used for different purposes.

| Activity 8.9 |
|---|
| Mentions some common uses of magnets. |

Magnets have different applications (uses). Some of these uses are:-

- Magnets in compasses are used to indicate directions on seas, oceans, air and ground.
- They are used for lifting up iron or steel to higher places.

- They are used in the construction of electric bells, motors, radio, generators, etc.
- They are used to separate magnetic substances like iron from mixtures of different non-magnetic materials.

**Check point 8.3**

1. List and describe some uses of a magnet.

# PART-2 ELECTRICITY

## 8.4. Electrostatics

**Activity 8.10**

Discuss the following observations with your friends or family.

i. What causes sparks and crackling sound when you take off your nylon clothes? Why does a comb made of plastic pick up scraps of light paper or dust particles when dropped after combing hair?
ii. What do you understand by the term "electrostatics"?
iii. What are electric charges?

In this section you will begin to study important phenomena about electric charges at rest. All the sparks you see and the crackling sound you hear when you take of nylon clothes are the effects of electric charges at rest. The study of electric charges at rest is called **electrostatics**.

When two materials rub together, there is friction. This friction causes rubbed materials to attract unrubbed materials. For example, if a rod of glass is rubbed with fur, it gains the power to attract light bodies such as pieces of paper or aluminum-foil or a pith ball. A body made attractive by rubbing is said to be **'electrified' or 'charged'**.

The branch of electricity that studies electric charges at rest is called electrostatics.

## What are charges?

**Activity 8.11**

Revise your chemistry knowledge to answer the following questions with your friends.

i. What is an atom?
ii. What are the two types of charges?
iii. What type of charge is carried by protons?
iv. What type of charge is carried by electrons?
**v.** When do we say an atom is electrically charged?

The results of numerous experiments indicated that under certain circumstances, matter exhibited a 'new' property. This property was eventually traced to the atom and is called **electric charge**.

Electric charge is an inherent physical property of certain sub-atomic particles that is responsible for electrical and magnetic phenomena. Charge is represented by 'Q' and the unit of charge is the Coulomb (C).

The smallest particle of an element is called an **atom**. The three important particles of an atom: **protons**, **electrons** and **neutrons** are known as the basic building blocks of all atoms. Fig 8.10 shows a model of how these particles are thought to form an atom. The protons and the neutrons are held together at the centre of the atom called the **nucleus**. The electrons exist around the nucleus. They revolve in orbits around the nucleus at high speed.

Electric charge is a characteristic property of many subatomic particles. Electric charge is the property of a matter that exhibits attraction or repulsion over other matter.

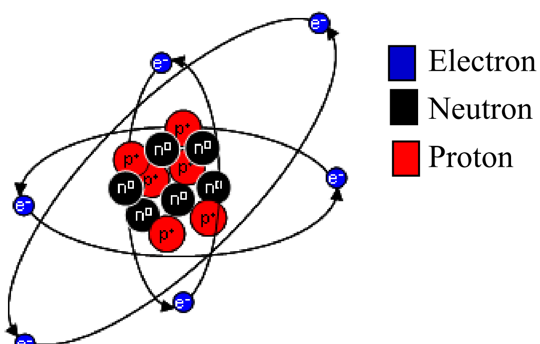



Fig 8.10 Structure of an atom

## Types of charges

The idea of electricity is based on the theory that all matter are built up of atoms. Each atom has a tiny core called the **nucleus** and around this nucleus spins a number of electrons. The nucleus consists of neutron and proton.

## Negative and positive charges

As it is mentioned above an atom consists of neutron, proton and electron particles.

i. Neutron is a neutral particle; it does not have a charge.
ii. Proton is positively charged particle.
iii. Electron is a negatively charged particle.

Hence there are two types of electric charges called positive and negative charges. A negative charge is carried by electrons and a positive charge is carried by protons.

The allocation of signs to charges was made randomly many years ago. We use this assignment today.

## Note the following points carefully

i. Every matter is electrical in nature.
ii. We have two types of charges.
iii. In the normal state, the number of electrons is equal to the number of proton in an atom. Therefore, an atom is neutral as a whole. This explains why a body does not exhibit any charge under ordinary conditions.
iv. If some electrons are removed from a neutral body, there occurs a deficit of electrons in the body and consequently the body has surplus positive charge.
v. If a neutral body is supplied with electrons, there occurs an excess of electron and consequently the body is said to have a negative charge.

**Check point 8.4**

1. What does the term electrostatics stand for?
2. Describe the two types of electric charges.
3. What charges are carried by
   a) Protons
   b) Electrons

## 8.5. Methods of Charging a Body

Charging is the process of electrifying bodies i.e. removing from or adding electrons to a body.

There are different methods of charging a body:-
i. Charging by rubbing ii. Charging by conduction

### i.Charging by rubbing

**Activity 8.12** ***Charging a body by rubbing***

*Apparatus*:- a piece of paper, a polythene rod (plastic comb, plastic ruler, ball point, pen.) woolen cloth or you can use your hair.

*Procedure*:

i. Tear pieces of paper into bits and put them on the table.
ii. Touch the bits of paper with a polythene rod without rubbing, observe what happens.
iii. Now rub the polythene rod with woolen cloths (your hair) and bring it close to the bits of paper. Observe what happens. Do you explain why it happens this way?

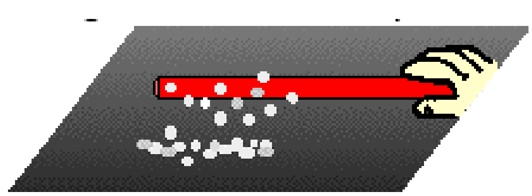


Fig 8.11 Charged plastic rod attracts pieces of paper

From the structure of an atom we could understand that the rubbing of two bodies cause a transfer of electrons from one body to another. One of the bodies gains electrons, while the other loses electrons.

For example in Activity 8.12, when a plastic rod is rubbed with woolen clothes (your hair) electrons will be transferred from the plastic rod to the woolen cloth (you hair). Hence, the plastic rod is negatively charged while the woolen clothes is charged positively.

Similarly when a glass rod is rubbed with silk, electrons will be transferred from the glass to the silk. Hence the glass is positively charged while the silk is negatively charged.

### ii. Charging by conduction (sharing)

When a neutral body is made to contact or touch a charged body, it shares the charges and becomes charged. Charging by conduction involves sharing of electrons between the charged and uncharged bodies.

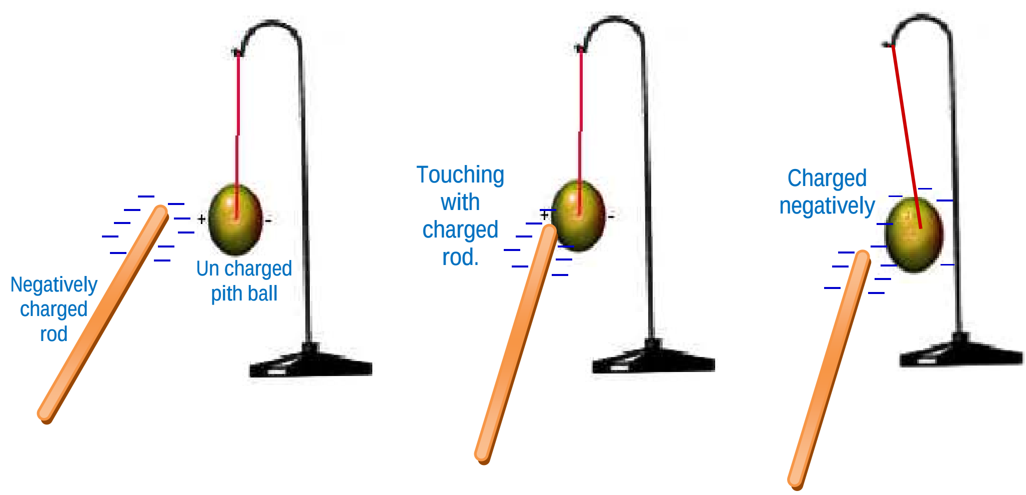



Fig 8.12 Charging pith ball by conduction

For example, consider a charged body that has surplus of electrons. If you bring this charged rod near the uncharged body it attracts the uncharged body. When the charged body touches the uncharged body, same negative charges transfer to the uncharged body and make it negatively charged. Then the two bodies repel each other, because they have the same charges. The process of charging a body by touching it with a charged body is called "**charging by conduction or sharing**".

**Discharging a body** is the process of removing electric charges from a charged body**.** A charged body can be made to lose its charges by touching it with a conductor. When a body is discharged, it becomes neutral.

**Check point 8.5**

1. Explain the term charging.
2. State two methods of charging a body.
3. Compare charging by rubbing and charging by sharing.
4. When do we say a body is charged positively?
5. When do we say a body is charged negatively?

## 8.6. Law of Electrostatics

**Activity 8.13** ***Illustrating the law of electrostatics***

*Material required*: pith balls, glass, rubber rods, woolen cloth, silk cloth

*Procedure*:

i. A pith ball is charged positively by conduction or touching with a charged glass rod. (Fig 8.13(a)
ii. Observe what happens.
iii. Repeat this activity with rubber rod rubbed with silk. Charge another pith ball by touching. (Fig 8.13 b)
iv. Bring two balls one touched with charged glass rod and another ball touched with charged rubber rod.
v. Bring these charged balls, closer to each other. Fig 8.13 (c)
vi. Observe what happens.
vii. These two balls attract each other because they carry different charges.

Conventionally negative charge is represented by (-) and positive charge is represented by (+).

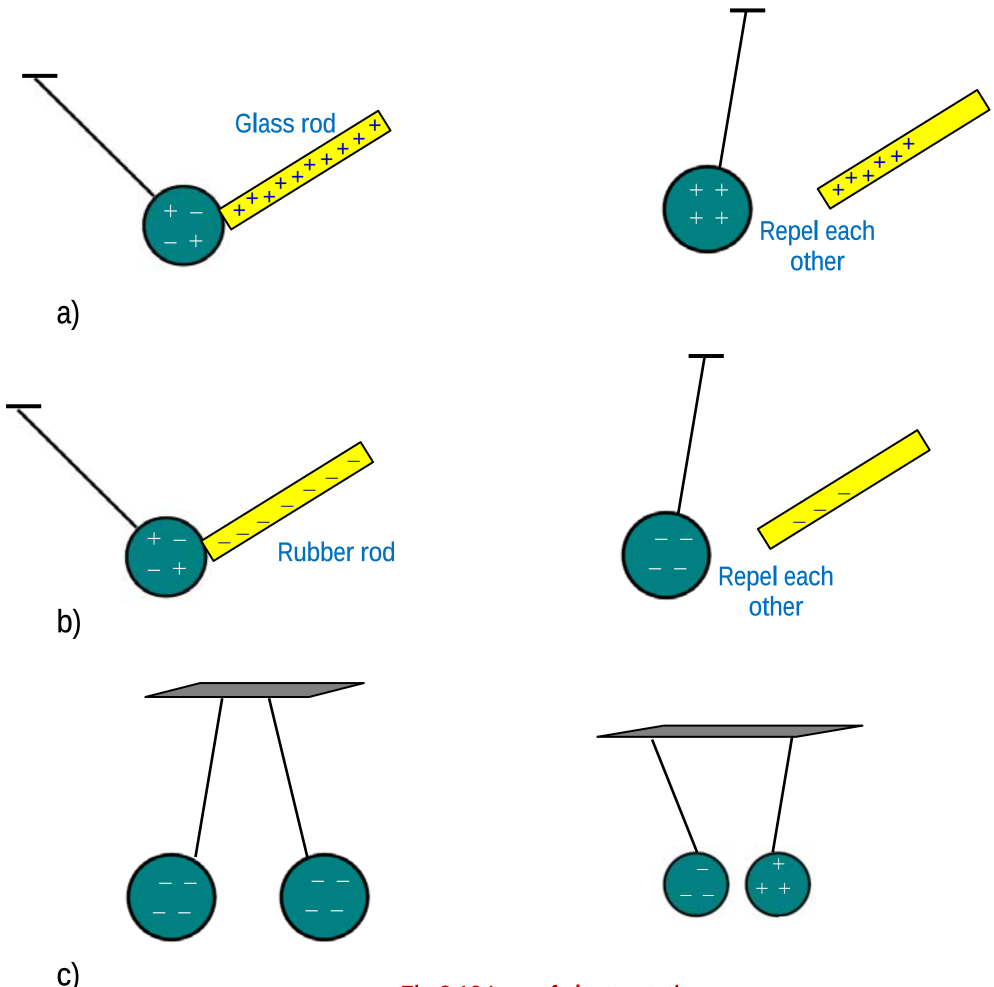



Fig 8.13 Law of electrostatics

You have learnt in unit 3 of this book that electric charges exert a force at a distance. It either attracts or repels other charged bodies without direct contact. Electric charges have similar properties as magnetic forces. They are non-contact forces.

All charged bodies exert forces on each other;

i) Like charges repel each other

ii) Unlike charges attract each other.

This is the law of electrostatics.

## Electroscope and its use

From different activities in the previous sections, you studied how charged bodies are detected and the existence of two kinds of electric charges.

An electroscope is a simple device used to study the properties of charges. It enables us to determine both the sign of the charge and the magnitude of the charge on a body.

a) Aluminum leaf electroscope

b) Locally made electroscope

Fig 8.14 Electroscope

Fig.8.14 (a) shows an aluminum foil electroscope. It consists of a brass rod, on which is mounted a brass cap, at the top, and a brass plate at the bottom, with thin leaves of aluminum foil attached to the brass plate. The brass rod is mounted on a metal case, and supported by a plug of insulating material. The metal case has glass windows to allow the aluminum leaves to be seen.

## Uses of electroscope

An electroscope is used:

i. To illustrate that charges move through metals.
ii. To test whether a body is charged or not.
iii. To detect the sign of a charge on a body. i.e. to check whether a body is negatively or positively charged.

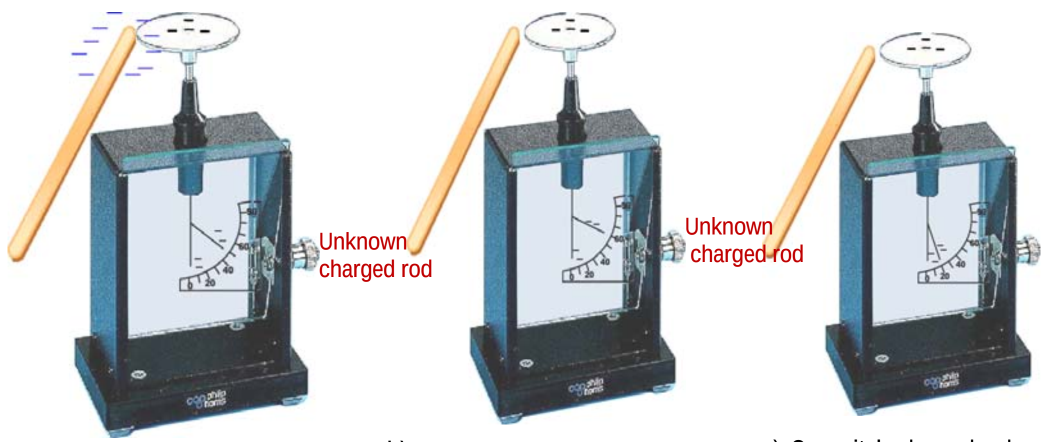
## Activity 8.14 *Detecting whether a body is charged or not*

Charge a glass rod by rubbing with silk clothes. Bring the charged rod near to the cap of a neutral electroscope without touching. The leaves of the neutral electroscope will diverge to show that the nearby rod is charged. The leaves will not show any deflection when uncharged rod is brought near to the cap of the neutral electroscope.

Fig 8.15 Deflected leaves of an electroscope

## Activity 8.15 *Detecting the sign of charges on a charged body*

i. An electroscope must be charged first to use it to detect the sign of charges on a charged body. A neutral electroscope does not help us to detect the sign of charge on a charged body.
ii. Charge the electroscope negatively by touching its cap with a negatively charged rod. Then bring another charged rod whose sign is not known near the cap of the charged electroscope without touching it.
iii. If the divergence of the leaves increases, we can conclude that the near by charged rod have similar (--) charges as the charges of the electroscope. But if the original divergence of the leaves decreases when the unknown charged rod is brought near to the cap of the electroscope, then the sign of the unknown charged body is opposite (+) to the charge of the electroscope.




a) Charged Electroscope.

b) Similarly charged rod causes electroscope to increase in deflection.

c) Oppositely charged rod causes electroscope to decrease in deflection.

Fig 8.16 Detecting the sign of unknown charged body

**Project work:** Making your own electroscope

Materials required:

- Small medicine bottle with plastic lid or cork.
- Aluminum foil obtained from the inside of a chewing gum or cigarette packet.
- Copper wire (from electric wire) or paper clip.

Procedure:

1. Bend the copper wire at one end.
2. Pierce the bottle lid with the copper wire and push the wire through it.
3. Tie the aluminum foil with silk thread or fasten it with a sellotape
4. Close the bottle with the bend of the wire at the top. This is a locally made electroscope.
5. Use this electroscope to demonstrate the uses of electroscope.

For example, you can bring an uncharged body near the cap of a positively or negatively charged electroscope. What do you think will happen to the leaves? Will the leaves decrease or increase its divergence?

**Activity 8.16** ***Complete the following table considering testing charged and uncharged bodies***

| Charge on electroscope | Charge on unknown body | Leaf divergence |
|---|---|---|
| - | - | Increase |
| - | + | Decrease |
| neutral | - | Decrease |
| + | + | |
| + | neutral | |
| - | neutral | |

An increase in leaf divergence occurs when the charge on the electroscope and the charged body are having the same sign of charge. A decrease in the leaf divergence does not only mean the body and the electroscope are oppositely charged. The body can also be uncharged. Hence the best test for the sign of charge on a body is the increase in divergence of the leaf.

**Activity 8.17** ***Identifying a material as a conductor or an insulator using an electroscope.***

Apparatus: an electroscope and different materials like plastic rod, glass rod, wood, metallic materials like copper, tin, aluminum, etc.

Procedure: charge an electroscope (either positively or negatively)

Hold the different materials to be tested in your hand and place it on the cap of the electroscope. (Note: the materials are not charged.)

If the leaf collapses very rapidly (immediately), the material is a good conductor. Because the charge from the electroscope moves through the conductor to your hand. If the leaf remains diverged as it was previously, the material is an insulator. Because the charges from the electroscope do not move through the insulator to your hand.

Can a conductor be charged?

As you have observed in previous pages, insulators like glass rod and plastic rods can be easily charged.

Charging a conductor is possible, but not as easy as in an insulator. In a conductor, charges spread through its body. If it is touched or held with hands, the charges move to your hands. To avoid the flow of charges to other bodies you can use a conductor with insulating handle, or support the conductor with insulating stand for example, the metal rod in an electroscope is charged using insulating materials like rubber.

## 8.7. Electric Current and Potential Difference

In Section 8.6 you learnt the properties of charges at rest. This section introduces you to the properties of moving charges.

**Activity 8.18**

i. What is an electric current?
**ii.** Discuss what makes electric charges flow in a wire.

### Electric current

When two oppositely charged bodies are connected by a metallic conductor a movement of charges occurs. The electrons flow from the negatively charged body to the positively charged body. This motion of electric charges is called **electric current**.

The strength of an electric current in a conductor is determined by the number of electrons which pass through the conductor at a point in a given time interval.

Electric current is the rate of flow of electric charge. It is the amount of charge that flows per second.

$$\text{Electric current} = \frac{\text{Charge moved}}{\text{Time taken}} \Rightarrow I = \frac{Q}{t}$$

Where I is the current
Q is the amount of charge flow
t is time taken.

The SI unit of electric current is **Ampere**, symbolized by A. One ampere is equal to one coulomb moved in one second. Here, electric charges are measured in coulomb (C) and time in second(s).

$$1A = 1\frac{c}{s}$$

1 milliampere (1mA)= 0.001A

1 microampere(1µA)= 0.000001A. µ is a Greek letter, read as '*miu*'.

Electric current is measured with a device called an **ammeter**.

The electric current in a conductor is not visible. We can only notice its effects. The effects of electric current are heating, lighting, magnetic, etc.

## Worked examples

1. A charge of 120 C passes through a conductor every 1 minute. What is the charge that flows every second?

| Given | Required | Solution |
|---|---|---|
| Q = 120 C | I = ? | By definition $I = \frac{Q}{t}$ |
| t = 1 minute | | $I = \frac{120\,C}{60s} = 2A$ |
| = 60 s | | |

Therefore, the charge flow per second = 2A.

2. How much charge flows through a conductor if a current of 1.5A flows for 2 minutes?

| Given | Required | Solution |
|---|---|---|
| I = 1.5 A | Q = ? | Q = It |
| t = 2 minutes | | Q = (1.5A) (120s) |
| = 120 Seconds | | Q = 180 C |

## Sources of potential difference

**Activity 8.19** *Group discussion*

i. Explain what causes water to flow from high level to low level in a pipe.
ii. Explain the importance of gravitational potential energy in water flow.

The potential difference between two positions causes water to flow. Similarly charges flow because of the potential difference between two points.

We have seen that current is a flow of charge through a conductor. For charges to flow through a conductor a source that supply energy to move charges to the end points are necessary. The common sources of potential difference are **electric cells** and **generators**. **Battery** is a combination of two or more electric cells. It is a common source of potential difference.

- A source of potential difference provides electric current. Potential difference is also called **voltage.**
- The unit of potential difference (voltage) is Volt (V)
- The instrument used for measuring potential difference is a **voltmeter**.

## Primary and secondary cells

**Activity 8.20**

Collect different dry cells from your locality. Study the types and value of potential difference of each cell.

Of all the sources of potential differences, the most widely available is the chemical cells. Chemical cells change chemical energy into electrical energy. Electric cells are of two types: **primary** and **secondary** cells.

1. **Primary cells** are cells which can produce current as a result of chemical changes taking place between their various components. Once they are used exhaustively they cannot be used again. Example of this type is a dry cell. A dry cell has two terminals labeled as '+' and '–'. The potential difference between these terminals is 1.5 volt (1.5V). Two or more dry cells are connected in series to obtain greater potential difference. 3 dry cells connected in series give 4.5V.
2. **Secondary cells** can be recharged and used again and again. A typical example of this type is car battery. They are also known as storage cells or accumulators.

**Check point 8.7**

1. What is an electric current?
2. List some sources of potential difference.
3. What is the difference between primary and secondary cells?
4. A current of 90 milliAmpere (mA) flows for 150 s. What amount of charge are transferred during this time?

## 8.8. Electric Circuit

Electric current needs a complete path to flow from one point to another. A complete path through which electric current flows is called an **electric circuit**. A simple electric circuit is constructed from a source of potential difference, a device, and a switch. These elements are connected to each other by connecting wires. See Fig 8.17.

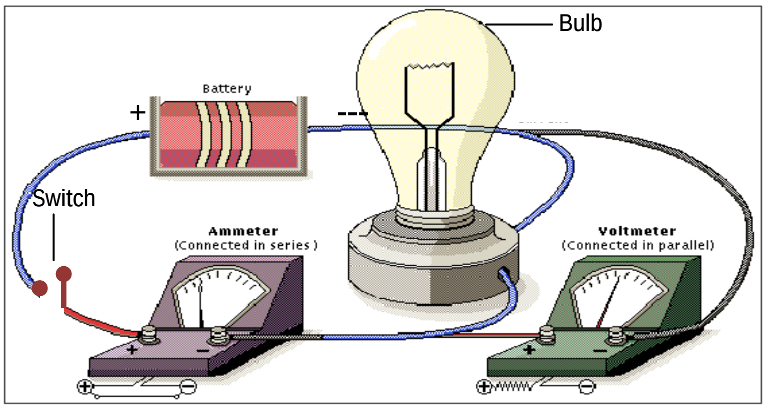



Fig 8.17 Simple electric circuit

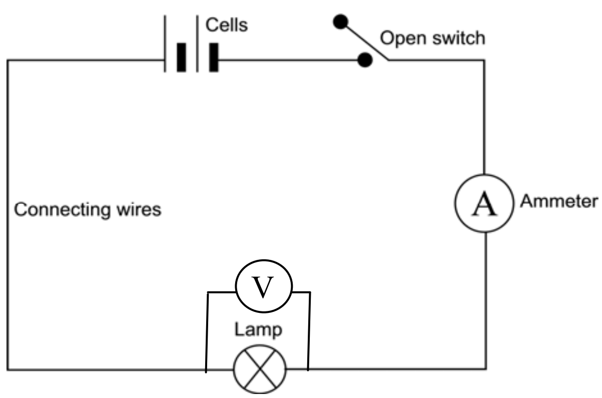



Fig 8.18 Electric current drawn with symbols

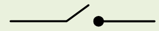
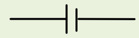
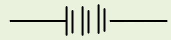
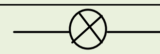
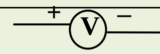
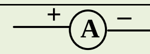
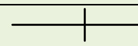
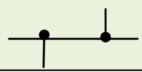
| Items | Symbols |
|---|---|
| Switch |  |
| Cell |  |
| Battery |  |
| Lamp |  |
| Resistor |  |
| Voltmeter |  |
| Ammeter |  |
| Crossing wires |  |
| Joined wires |  |

Fig 8.19. Symbols of elements of an electric circuit

## Direction of electric current

Electric current has a certain direction of flow in an electric circuit. This direction is determined by the type of charged particles flowing through the circuit. Suppose the end points of a metallic conductor are connected to the two terminals of a source of potential difference, the free electrons of the conductor move from the negative to the positive terminal of the source across the conductor.

**Electron current** is the flow of electrons from the negative terminal to a positive terminal of the source. The direction of electric current is the direction in which electrons are actually moving.

However, before the discovery of electrons as moving particles, it was assumed that current is the flow of positively charged particles from positive terminal to negative terminal.

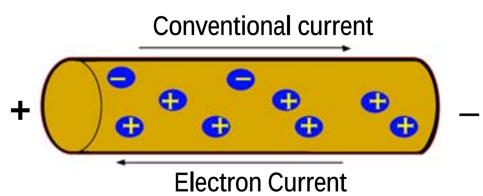



Fig 8.20 Direction of electric current

This kind of current is called **conventional current.** It is in opposite direction to that of electron current. Thus, conventional current is the agreed direction of electric current in a circuit, and this current direction is consistently used in this and other physics books.

## Conductors and Insulators

Conductors are materials made up of atoms with a large number of free electrons. Free electrons are in the outer most orbit of an atom. They are free to move because they are far from the nucleus. Consequently the flow of charges (electrons) is possible through conductors. Conductors are materials that allow an electric current to flow through them. Opposite to conductor we have insulators. Insulators have few free electrons or no free electron. Thus, the flow of charges through them is highly restricted. Insulators are materials that do not allow an electric current to pass through them.

A simple electric circuit is used as a tester to check whether a material is a conductor or insulator.

### Activity 8.21

To test whether materials are conductors or insulators.

*Materials required*:- a simple circuit with a bulb, connecting wires, dry cells, different materials to be tested

- Example, metallic materials, wood, plastic, cloth, , etc.

*Procedure:*

1) Arrange the circuit as shown in Fig 8.21
2) Put the different materials between points A and B and observe what happens to the bulb. Check whether the bulb gives light or not. Complete the following table by writing "gives light, do not give light"

| materials | Gives light | No light |
|---|---|---|
| Rubber rod | | |
| metallic materials | | |
| wood | | |
| plastic | | |
| Cloth | | |
| Water | | |

3) classify materials that give light as conductors and those which don't give light as insulators

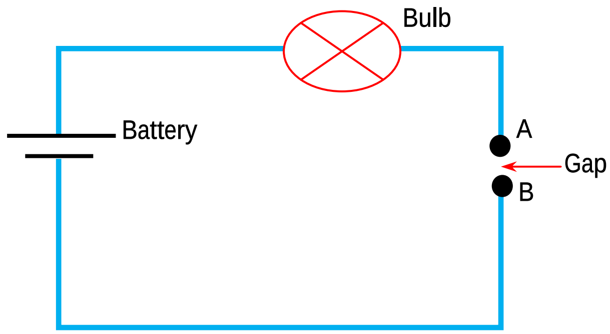



Fig 8.21 Simple circuit as a tester

**Check point 8.8**

1. What is an electric circuit?
2. List the elements of simple electric circuit. (Draw a simple electric circuit using symbols).
3. Define conductors and insulators. (Give examples of each.)
4. Explain the way to identify a material as a conductor or an insulator using a simple circuit.

## Summary

In this unit you learnt that

- a magnet attracts irons and nickels. Magnets can be categorized in to two main types. Natural and artificial magnets. A magnet has two poles. The North Pole and the South Pole. Magnetic Poles can never be separated by breaking a magnet into pieces. The law of magnetism is stated as: Like poles of a magnet repel each other and un-like poles attract each other.
- we can produce a magnet, but the period of permanency depends up on the type of the stroked metal.
- a suspended magnet called a compass always rests in north – south direction, due to the magnetic effect of the earth. Materials which are attracted by a magnet are called magnetic materials. And the materials which are not attracted by a magnet are called non- magnetic materials.
- electrostatics is the study of electric charges at rest. It is the basis of the study of electricity. Friction causes charges to transfer from one body to another body. The process of charging materials by friction is called charging by rubbing. The law of electrostatic is stated as: like charges repel and un-like charges attract each other.
- discharging is the process of removing charges from a charged body.
- electrons carry negative charges, protons carry positive charges and neutrons carry no charge and it is called a neutral particle.
- a device which detects the presence of charges on an object is called an electroscope. The study of electric charges is best illustrated by an electroscope.
- electric current is the time rate of flow of charge. The SI unit of current is Ampere (A). Conventional current flows from the positive (+) terminal to the negative (-) terminal of the source while electron current flows from the (-) terminal to the (+) terminal of the source.
- current and voltage are measured with an instrument called Ammeter and Voltmeter respectively. The unit of voltage or potential difference (P.D) is Volt. (V)

# Review Questions and Problems

## I. Write true if the statement is correct and false if the statement is wrong.

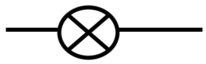
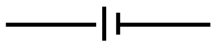
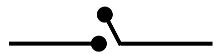
1. Magnetic poles always appear in pair.
2. Iron and nickel are examples of magnetic materials.
3. The two ends of a magnet are called magnetic poles.
4. Two similar magnetic poles attract each other
5. If one end of an iron bar attracts one pole of a compass needle, then the iron bar must be a magnet.

## II. Match the terms in column A with the phrases in column B.

| A | B |
|---|---|
| 1. Electron current | a) device used to identify whether a body is charged or not |
| 2. Law of electrostatic | b) flow of electrons from – terminal to + terminal. |
| 3. Electroscope | c) unlike charges attract each other and like charges, repel each other |
| 4. Coulomb/ second | d) unit of electric potential difference |
| 5. Volt | e) Ampere. |

## III. Multiple choice question- chose the best answer among the given alternative answers.

1. Which of the following devices consists of a magnet
   a) Telephone c) electric motor
   b) radio d) all of the above
2. Which one of the followings can be picked up by a magnet.
   a) Iron and Steel c) wood
   b) plastic d) all non metals
3. Which of the following substances cannot be magnetized?
   a) Iron b) nickel c) Aluminum
4. The Magnetic attraction is greater
   a) At the middle c) a and b
   b) at the poles d) none

5. Magnets are made of ________
   a) Iron c) a and b
   b) steel d) copper
6. Which one of the follow diagrams represents a battery?
   a)  c) 
   b)  d) 
7. Which one of the following instruments measure electric current?
   a) Voltmeter c) electroscope
   b) Ammeter d) electric cur
8. A pith ball is positively charged. What happens when a negatively charged body is brought near to it?
   a) They repel each other.
   b) They attract each other.
   c) Share their charges and remain neutral
   d) Nothing happens.

## *IV. Fill in the blanks with a correct word or words.*

1. Like poles ______ each other and unlike poles _______ each other.
2. ________ is a natural magnet.
3. Artificial magnets are made of _______ or ______.
4. We call the ends of the magnets _______.
5. Magnets are made in the shape of _________, ________ , ____ etc.
6. _______ are materials that allow electric current to pass through them.
7. ________ is the rate of flow of electric charges through a point.
8. Charging by sharing is called ________.
9. A body is said to be ________ charged if it gains electrons.
10. A neutral sub atomic particle is called ________.

## *V. Questions*

1. How do you know which end of a magnet is North Pole?
2. State the law of magnetism.
3. What are the essential parts of an electroscope?
4. What is meant by a non magnetic material?

5. Name three common magnetic materials.
6. Mention some applications of a magnet in our daily life.
7. What is measured in a) coulomb and b) ampere?
8. What is the electric current when 10 coulombs of charges pass a point in 2 second?
9. What are the amounts of charges that pass a point if 4 Amperes flows for 3 seconds?
10. Explain the difference between a conductor and an insulator of electric current.
11. Take a hand torch and study parts of its electric circuit. Draw the circuit diagram of a torch.
12. What are essential parts of an electroscope? Draw an electroscope and label it.
13. What is the difference between conventional current and electron current?
14. How do charges transfer from one body to another?
15. You know that when you comb your hair, charges will be transferred from the hair to the comb. What is the charge on the comb and your hair after combing?
16. If you rub a balloon with wool or duster you can charge it negatively. Where do these extra charges come from?
17. State what happens when.
    a) A glass rod is rubbed with fur.
    b) This glass rod is touched with your finger