SCIENCE

Grade 11

Part - II

Educational Publications Department

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The National Anthem of Sri Lanka

Sri Lanka Matha
Apa Sri Lanka Namo Namo Namo Namo Matha
Sundara siri barinee, surendi athi sobamana Lanka
Dhanya dhanaya neka mal palaturu piri jaya bhoomiya ramya
Apa hata sepa siri setha sadana jeewanaye matha
Piliganu mena apa bhakthi pooja Namo Namo Matha
Apa Sri Lanka Namo Namo Namo Namo Matha
Oba we apa vidya
Obamaya apa sathya
Oba we apa shakthi
Apa hada thula bhakthi
Oba apa aloke
Apage anuprane
Oba apa jeevana we
Apa mukthiya oba we
Nava jeevana demine, nithina apa pubudukaran matha
Gnana veerya vadawamina regena yanu mana jaya bhoomi kara
Eka mavakage daru kela bevina
Yamu yamu vee nopama
Prema vada sema bheda durerada
Namo, Namo Matha
Apa Sri Lanka Namo Namo Namo Namo Matha

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ஒரு தாய் மக்கள் நாமாவோம்
ஒன்றே நாம் வாழும் இல்லம்
நன்றே உடலில் ஓடும்
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ஒற்றுமை சிறக்க வாழ்ந்திடுதல்
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யான்று மழியாச் செல்வமன்றோ

ஆனந்த சமரக்கோன்
கவிதையின் பெயர்ப்பு

Being innovative, changing with right knowledge
Be a light to the country as well as to the world.

Message from the Hon. Minister of Education

The past two decades have been significant in the world history due to changes that took place in technology. The present students face a lot of new challenges along with the rapid development of Information Technology, communication and other related fields. The manner of career opportunities are liable to change specifically in the near future. In such an environment, with a new technological and intellectual society, thousands of innovative career opportunities would be created. To win those challenges, it is the responsibility of the Sri Lankan Government and myself, as the Minister of Education, to empower you all.

This book is a product of free education. Your aim must be to use this book properly and acquire the necessary knowledge out of it. The government in turn is able to provide free textbooks to you, as a result of the commitment and labour of your parents and elders.

Since we have understood that the education is crucial in deciding the future of a country, the government has taken steps to change curriculum to suit the rapid changes of the technological world. Hence, you have to dedicate yourselves to become productive citizens. I believe that the knowledge this book provides will suffice your aim.

It is your duty to give a proper value to the money spent by the government on your education. Also you should understand that education determines your future. Make sure that you reach the optimum social stratum through education.

I congratulate you to enjoy the benefits of free education and bloom as an honoured citizen who takes the name of Sri Lanka to the world.

Akila Viraj Kariyawasam
Minister of Education

Foreword

The educational objectives of the contemporary world are becoming more complex along with the economic, social, cultural and technological development. The learning and teaching process too is changing in relation to human experiences, technological differences, research and new indices. Therefore, it is required to produce the textbook by including subject related information according to the objectives in the syllabus in order to maintain the teaching process by organizing learning experiences that suit to the learner needs. The textbook is not merely a learning tool for the learner. It is a blessing that contributes to obtain a higher education along with a development of conduct and attitudes, to develop values and to obtain learning experiences.

The government in its realization of the concept of free education has offered you all the textbooks from grades 1-11. I would like to remind you that you should make the maximum use of these textbooks and protect them well. I sincerely hope that this textbook would assist you to obtain the expertise to become a virtuous citizen with a complete personality who would be a valuable asset to the country.

I would like to bestow my sincere thanks on the members of the editorial and writer boards as well as on the staff of the Educational Publications Department who have strived to offer this textbook to you.

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9.1 Temperature

Daily weather report transmitted through television channels may be familiar to you. Do you remember hearing that the lowest temperature was reported from Nuwaraeliya while the highest temperature was reported from Trincomalee on a particular day?

Can you remember that it is difficult to dry washed clothes on rainy days and that they dry fast on warm sunny days?

Figure 9.1

Try to recall the coolness experienced in eating an ice-cream and the warmness felt in drinking a hot cup of tea.

The physical quantity that describes each of the instances above is the temperature.

Temperature can be specified as a fundamental property of any material object. An ice cube has a very low temperature. Temperature of warm water is higher than the temperature of cold water.

Our body too has a temperature. Therefore we can say whether the temperature of a certain object is higher than or lower than the temperature of our body by touching the object.

Temperature is measure of the mean kinetic energy possessed by the particles that form an object.

9.1.1 Measuring temperature

By touching various objects we can get a rough idea about their temperature. However, since the temperature felt by touching is not so accurate and cannot be expressed as a numerical value, it is not a suitable method for measuring temperature. Therefore, the scientists in the past had realized the necessity for constructing a device for measuring temperature.

• Thermometers

The device employed to measure temperature is known as the thermometer. World's first thermometer was invented by Galileo Galilei around 1600 A.D.

Figure 9.2 -Thermometer constructed by Galileo

Figure 9.3- Galileo Galilei

Various types of thermometers are in use at present. We will only be focusing on the glass - mercury thermometer and the glass-alcohol thermometer in this chapter.

Glass-mercury Thermometer

The glass – mercury thermometer is constructed by connecting a narrow glass tube to a bulb containing mercury. When the temperature rises, the mercury in the bulb expands and moves up along the narrow tube. The temperature can be read from the scale marked on the tube according to the length of the mercury column.

Although the volume expansion due to a small temperature difference is small, the length of the mercury column rises up by a clearly visible amount as the diameter of the narrow tube containing mercury is very small. A glass – mercury thermometer is shown in Figure 9.4.

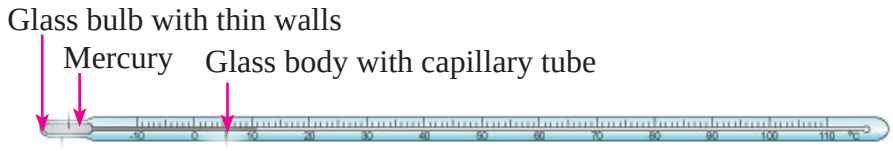


Figure 9.4 – A glass-mercury thermometer

Mercury is commonly used in thermometers as it has a uniform expansion over a broad range of temperatures, is a good thermal conductor and is a liquid over a broad range of temperatures (from – 39 ^{o}C to 357 ^{o}C). However, due to the toxicity of mercury, use of glass-mercury thermometers is on the decline.

Glass-Alcohol Thermometer

Glass-alcohol thermometer is constructed in the same manner as the glass - mercury thermometer, but replacing mercury by ethyl alcohol (ethanol). Since the melting point of ethanol is -115 ^{o}C, it is suitable for measuring low temperatures much below 0 ^{o}C. Ethanol is a suitable liquid for thermometers as it has a high expansion relative to most other liquids and as the expansion increases uniformly with temperature. Since purified ethanol is a colorless liquid, it is colored with a coloring material in order to see the alcohol column clearly.

Digital Thermometer

In addition the thermometers mentioned above, digital thermometers from which the temperature can be read directly are also commonly used today. In constructing digital thermometers, an electrical property such as the resistance which depends on the temperature is used instead of the expansion caused by an increase in temperature.

Figure 9.5 - A Digital thermometer

9.1.2 Temperature Scales

There are three temperature scales widely used for temperature measurements. They are the Celsius, Fahrenheit and the Kelvin scales.

- **Celsius Scale**

The Celsius scale has been formed by taking the temperature at which pure ice melts into liquid water under the pressure of one atmosphere as the zero temperature (0 ^{o}C) and the temperature at which water vaporizes into steam under the same pressure as 100 ^{o}C.

These two temperatures have been chosen for the Celsius scale as the temperature

at which ice melts into water and the temperature at which water boils can be easily obtained and as these temperatures have fixed values apart from the variation with pressure.

The definite temperatures used in forming a temperature scale are known as **fixed points**. For the Celsius scale, these two fixed points are divided into 100 divisions.

• Fahrenheit Scale

For the Fahrenheit scale too, the melting point of ice and the boiling point of water are used as the two fixed points. However, here the melting point of ice is taken as 32 ^{o}F and the temperature range between the two fixed points are divided into 180 divisions. Accordingly, the boiling point of water is 212 ^{o}F.

• Kelvin Scale

The zero values of the Celsius and the Fahrenheit scales have been chosen according to the wishes of the people who introduced them. However, the British scientist Lord Kelvin later showed that there is a minimum value to the temperature that any object can reach. This temperature is known as the **absolute zero** temperature.

The temperature of an object is a measure of the mean kinetic energy of the particles that constitute the object. The temperature of the object decreases when the kinetic energy of the particles decreases. When the kinetic energy of all the particles become zero, the temperature of the object reaches the absolute zero. Its temperature cannot be decreased below this value. This temperature has been found to be - 273.15 ^{o}C according to the Celsius scale.

Figure 9.6 -Lord Kelvin

The Kelvin scale is defined so that its zero (0 K) is at the absolute zero temperature. However, in this scale, a temperature difference equal to 1 K is chosen to be equal to a temperature difference of 1 ^{o}C.

Accordingly, the melting temperature of ice is 273.15 K and the boiling temperature of water is 373.15 K. These temperatures are approximately taken as 273 K and 373 K respectively.

The international unit of measuring temperatures is the Kelvin (K).

For extra knowledge

- Celsius scale was introduced by Anderse Celsius (1701 – 1744).
- Fahrenheit scale was introduced by Gabriel Fahrenheit (1686 – 1736).
- Kelvin scale was introduced by Lord Kelvin (1824 – 1907).
- Clinical thermometer was constructed by Clifford Olbert (1836 - 1925).

9.1.3 Relationship between Celsius and Kelvin scales

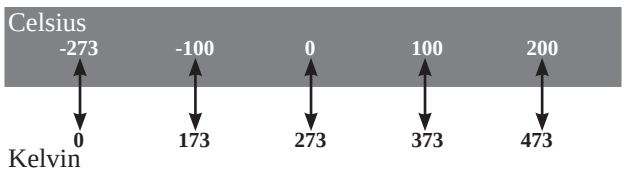


Figure 9.7 - Celsius and Kelvin scales

Since the difference between the Kelvin and Celsius scales lies only in the temperature chosen for their zero values, in order to convert a temperature measured in Celsius into the Kelvin scale one only needs to add 273. In order to convert a temperature measured in Kelvin into the Celsius scale one has to subtract 273.

Example 1

(i) How many divisions in the Kelvin scale are equal to one division in the Celsius scale?

(ii) What has to be done in order to convert a temperature value given in Celsius into Kelvin?

(iii) Indicate the temperature 50 ^{o}C in Kelvin.

(iv) What has to be done in order to convert a temperature value given in Kelvin into a value in Celsius?

(v) Indicate the temperature 373 K in degrees Celsius.

Solution

(i) 100 Celsius divisions = 100 Kelvin divisions
1 Celsius division = 1 Kelvin division

(ii) 273 Has to be added to the given value.

(iii) 50 ^{o}C = 50 + 273 K
= 323 K

(iv) 273 Has to be subtracted from the given value.

(v) 373 K = 373 – 273 ^{o}C
= 100 ^{o}C

Exercise 9.1

(1) Convert the temperatures given in degrees Celsius below into Kelvin.

(i) 10 °C (ii) 27 °C (iii) 87 °C (iv) 127 °C (v) 100 °C

(2) Convert the temperatures given in Kelvin below into degrees Celsius.

(i) 0 K (ii) 100 K (iii) 273 K (iv) 373 K (v) 400 K

9.2 Heat

Let us put equal volumes of water into two identical vessels at room temperature. Next let us insert two thermometers and arrange the set up above two bunson burners as shown in the Figure 9.8. Now let us light up the bunson burner in Figure 9.8(b) while leaving that in Figure 9.8(a) as it is.

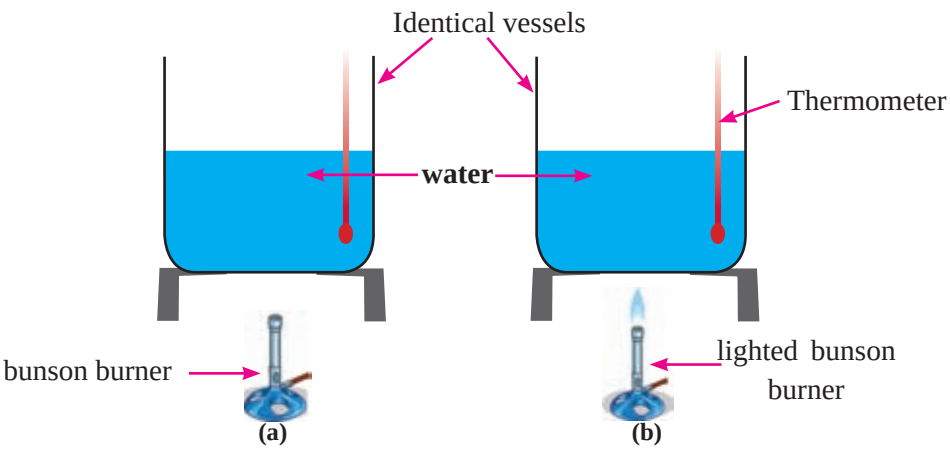


Figure 9.8

The temperature of the water in Figure 9.8(a) remains unchanged. The temperature of the water in Figure 9.8(b) can be seen to increase gradually.

Only the bunson burner in Figure 9.8(b) has been lighted. Therefore the temperature of water in that vessel has increased. From this it is clear that something has transferred from the candle flame to the water and that the temperature of the water has risen as a result of it. Here, heat has transferred to the water.

Therefore, the energy transfers from one object to another as a result of the temperature difference existing between the two objects is known as the **heat**.

For extra knowledge

American national Benjemin Thompson (Count Ramford) (1753 – 1814)has first described heat as a form of energy. In 1798, he experimentally showed that heat is a form of energy and thereafter it was a scientist named James Joule, who experimentally investigated about heat in 1840.

9.2.1 Heat Transfer

Let us investigate what happens when we put a heated piece of iron into a cold water vessel.

Activity 9.1

Apparatus required: A heated block of iron, A thermometer, A stirrer, A vessel with water at room temperature.

- Put a heated piece of iron into a cold water vessel.
- Observe the temperature of the water.

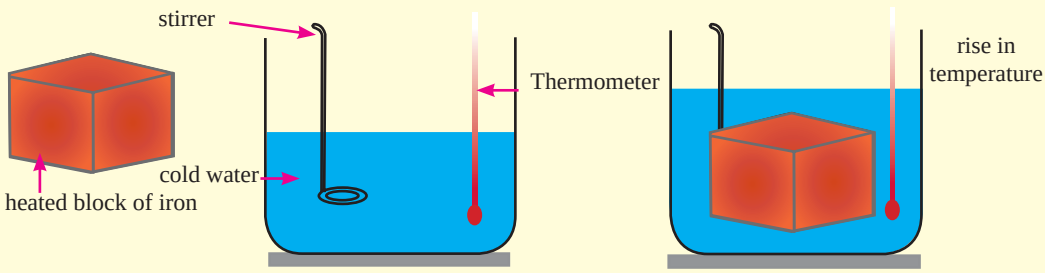


Figure 9.9

You will observe that the temperature of the water rises.

What happens here is the flow of heat from the iron which is at a higher temperature into the water which is at a lower temperature.

As the temperature of the water increases, the vessel also heats up as a result of absorbing heat. As heat flows out from the iron block, its temperature gradually decreases. After a while, the temperatures of the water and the iron block become equal. After reaching this common temperature, heat does not flow to the water from the iron block or to the iron block from the water. This state is known as **thermal equilibrium**. Just as water flows from a higher level to a lower level, heat also flows from a body at a higher temperature to a body at a lower temperature.

Therefore,

- Heat transfers from a body at a higher temperature to a body at a lower temperature.
- Then the temperature of the body at the lower temperature increases.
- At the same time, the temperature of the body at the higher temperature decreases.

Since heat is a form of energy, heat can be measured in Joules (J). The international unit for measuring heat is the Joule. In addition to this, the unit known as the Calorie is also frequently used to measure heat (thermal energy).

9.2.2 Heat Capacity of an Object

Activity 9.2

Apparatus required : Three identical beakers, Water, Coconut oil, Three thermometers, Three bunson burners a stirrer

- Obtain three identical beakers and pour a measured volume of water into one of them.
- Pour an equal volume of coconut oil into another beaker.
- Pour water with a volume equal to twice the initial volume into the third beaker.
- Measure the temperatures of the liquids in all three beakers.
- Now place all three beakers on three identical stands and heat them up for an equal time interval (about 5 minutes) using three identical candles.
- At the end of the time interval measure the temperatures of the liquids.

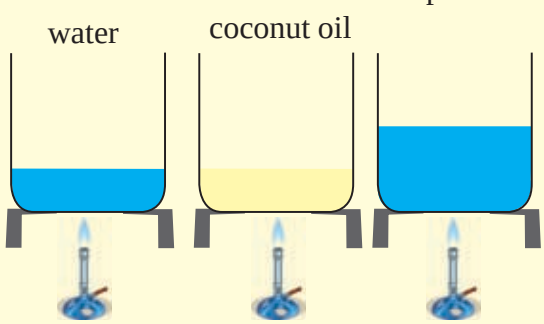


Figure 9.10

Even though there could be minor differences in the candles, we could assume that approximately the same amount of heat was supplied to each of the three beakers. However you will observe that the temperature rise in the three beakers are different.

You will understand from this activity that when the same amount of heat is supplied to different quantities of the same substance or the same quantities of different substances, their temperatures rise in different amounts.

Since the temperature rise in the three beakers of the above activity were not equal although the same amount of heat was supplied to all three beakers, we can conclude that the heat capacities of the substances in the three beakers are different.

The amount of heat required to increase the temperature of an object by one unit is known as the **heat capacity** of the object.

- The international unit for measuring heat capacity is Joules per Kelvin (J K^{-1}).
- Heat capacity can also be expressed in Joules per degree Celsius (J $^{o}C^{-1}$).

The heat capacity of an object depends on the substance that the object is made of and it's mass. Two objects made out of the same substance but with different masses have different heat capacities. Even though the masses are the same, two objects made out of different substances can have different heat capacities. The heat capacity of a substance is indicated by the symbol *C*.

• Specific Heat Capacity

It can be experimentally shown that the heat capacity of different masses of the same substance is proportional to the mass. This means that the heat capacity doubles when the mass is doubled. However the heat capacity of a unit mass of a given substance or the amount of heat required to increase the temperature of a unit mass of the substance by one degree is a property that depends on the substance.

The amount of heat required to increase the temperature of a unit mass of a given substance by one degree is known as the **specific heat capacity** of the substance.

Since the specific heat capacity is the amount of heat that should be supplied to increase the temperature of a unit mass of a given substance by one degree, it can also be described as the heat capacity of a unit mass. Therefore, the heat capacity of an object can be obtained by multiplying the specific heat capacity of an object by its mass.

Heat capacity = Mass × Specific heat capacity

$$C = mc$$

Units of specific heat capacity is J kg^{-1} K^{-1} (Joules per kilogramme per Kelvin) or J kg^{-1} $^{o}C^{-1}$ (Joules per kilogramme per degree Celsius).

The specific heat capacity of a substance is indicated by the symbol *c*.

Specific heat capacities of some substances are given in table 9.1.

Table 9.1 - Specific heat capacities of some substances.

Substance	Specific heat capacity J kg^{-1} K^{-1}	Substance	Specific heat capacity J kg^{-1} K^{-1}
Water	4200	Concrete	3000
Ice	2100	Iron	460
Kerosene oil	2140	Asbestos	820
Coconut oil	2200	Copper	400
Alcohol	2500	Zinc	380
Rubber	1700	Mercury	140
Aluminium	900	Lead	130

• Finding the Quantity of Heat

When a substance absorbs or releases heat its temperature changes. In order to find the quantity of heat flow, the following relation can be established.

If the specific heat capacity of a substance is c,

- Quantity of heat required to increase the temperature of 1 kg by 1 °C $= c$
- Quantity of heat required to increase the temperature of m kg by 1 °C $= mc$
- Quantity of heat required to increase the temperature of m kg by θ °C $= mc\theta$

If the quantity of heat is Q,

$$\text{Quantity of heat } (Q) = \text{mass } (m) \times \text{specific heat capacity } (c) \times \text{temperature change } (\theta)$$

$Q = mc\theta$

Q – quantity of heat (J)
m – mass (kg)
c – specific heat capacity (J kg^{-1} K^{-1} or J kg^{-1} °C^{-1})
θ – temperature difference (K or °C)

This means that the amount of heat required to increase the temperature of a given mass of a substance by a certain amount is equal to the product between the increase in temperature and the heat capacity.

In terms of magnitude, one Kelvin and one degree of Celsius are the same. Therefore, when we consider a temperature range, we can specify it in Celsius instead of using Kelvin, without making any change in the value.

Let us find the amount of heat required to increase the temperature of 6 kg of copper by 20 K. Specific heat capacity of copper is 400 J kg^{-1} K^{-1}.

Heat required to increase the temperature of 1 kg of copper by 1 K = 400 J
Heat required to increase the temperature of 6 kg of copper by 1 K = 6 × 400 J
Heat required to increase the temperature of 6 kg of copper by 20 K = 6 × 400 × 20 J
= 48 000 J

Example 1

Find the amount of heat required to increase the temperature of 2 kg of water by 10 K. Specific heat capacity of water is 4200 J kg^{-1} K^{-1}.

The amount of heat required = $mc\theta$,
= 2 × 4200 × 10 J
= 84 000 J

Example 2

The mass of a block of aluminium is 500 g. Find the amount of heat required to increase the temperature of the block from 30 °C to 50 °C. Specific heat capacity of aluminium is 900 J kg^{-1} $°C^{-1}$.

The amount of heat required = $mc\theta$
= 0.5 × 900 × (50 – 30) J
= 9000 J

Example 3

If 20 000 J of heat is transferred to 2 kg of copper at a temperature of 30 °C, what is the final temperature? (Specific heat capacity of copper is 400 J kg^{-1} K^{-1}).

If the change of temperature is θ,

$$Q = mc\theta$$
$$20\,000 = 2 \times 400 \times \theta$$
$$\theta = \frac{20\,000}{2 \times 400} \text{ °C}$$
$$\theta = 25 \text{ °C}$$

∴ Final temperature of copper = 30 °C + 25 °C
= 55 °C

Example 4

A copper vessel contains 1 kg of water. Mass of the vessel with water is 1.6 kg. The temperature of the water is 25 °C. Find the amount of heat required to heat the water until it boils.

(Specific heat capacity of water is 4200 J kg^{-1} K^{-1}; specific heat capacity of copper is 400 J kg^{-1} K^{-1}.)

Since both the vessel and the water heats up in this case,

Required total quantity of heat = heat absorbed by the vessel + heat absorbed by water

The mass of the copper vessel = total mass – the mass of water
$= 1.6 \text{ kg} - 1.0 \text{ kg} = 0.6 \text{ kg}$

Heat absorbed by the vessel $= mc\theta$
$= 0.6 \times 400 \times (100 - 25)$ J
$= 0.6 \times 400 \times 75$ J
$= 18\,000$ J

Heat absorbed by the water $= mc\theta$
$= 1 \times 4200 \times (100 - 25)$ J
$= 315\,000$ J

Required total quantity of heat $= 18\,000$ J $+ 315\,000$ J
$= 333\,000$ J

Exercise 9.2

(1) Specific heat capacity of iron is 460 J kg^{-1} K^{-1}. Find the quantity of heat required to increase the temperature of 2 kg of iron at a temperature of 25 °C up to 65 °C?

(2) Find the temperature of 0.8 kg of aluminium at a temperature 30 °C when 14 400 J of heat is transferred to it?
(Specific heat capacity of aluminium is 900 J kg^{-1} K^{-1}.)

(3) The mass of a glass vessel is 500 g. It contains 400 g of water at 25 °C temperature. Find the quantity of heat required to boil the water.(Specific heat capacity of glass is 840 J kg^{-1} K^{-1}, specific heat capacity of water is 4200 J kg^{-1} °C^{-1}.)

9.3 Change of State of Matter

You have learnt before that there are three states of matter known as solid, liquid and gas. As an example, when it is being heated ice melts into water and water converts into vapor. By absorbing or releasing heat, water changes from one state to another state.

Figure 9.11

The conversion of the state of a substance from solid, liquid or gas into another state is known as a **change of state**. **Condensation** of a gas, **melting** of a solid, **solidification** of a liquid, **boiling** of a liquid are examples of changes of state.

Melting Point

The temperature at which a solid substance that is being heated changes state from the solid state to the liquid state is known as its **melting point**. The melting point of a given substance depends of the pressure.

Freezing Point

The temperature at which a liquid substance that is being cooled changes state from the liquid state to the solid state is known as its **freezing point**. The freezing point of a given substance depends of the pressure.

The melting point and the freezing point of a given substance have the same value.

Melting points of some solids are given in table 9.2.

Table 9.2 - Melting points of some solids (under the pressure of 1 atmosphere)

Substance	Melting point °C	Substance	Melting point °C
Ice	0	Zinc	410
Paraffin	54	Aluminium	660
Naphthalene	80	Gold	1063
Sulphur	114	Tungsten	5385
Lead	330	Iron	1535

Boiling Point

The temperature at which a liquid starts to boil (i.e. the temperature at which the liquid turns to vapour by forming bubbles inside the liquid) is known as its **boiling point.**

The temperature at which changes of states of matter occur depend on the pressure. Normally, the boiling points and melting points of materials are specified as the temperatures at which boiling or melting occur under the pressure of 1 atmosphere.

Boiling points of some solids are given in table 9.3.

Table 9.3 - Boiling points of some solids (under the pressure of 1 atmosphere)

Substance	Water	Ethanol	Mercury	Zinc	Copper	Iron	Oxygen
Boiling point (°C)	100	78	357	907	2310	2750	-183

9.3.1 Latent Heat

The change of state of a substance takes place as a result of supplying heat to the substance or removing heat from it. Atoms of substances that exist as solids at room temperature possess some amount of kinetic energy. When heat is supplied, this kinetic energy increases gradually and along with it the temperature of the substance increases. When heat is continuously supplied, at a certain point the kinetic energy of the atoms becomes large enough to break the bonds between the atoms and allow the atoms to move freely. This is the point that the substance changes state from the solid state to the liquid state.

At the point that the change of state takes place, the heat supplied is spent on breaking the bonds between molecules and therefore, the temperature of the substance does not increase. When the change of state of all atoms is complete, the heat supplied is spent again on increasing the temperature of the system.

The heat absorbed by the system without changing its temperature while the change of state is taking place is known as the **latent heat**.

Consider an instance when heat is being supplied to a block of ice at a temperature slightly below 0 °C.

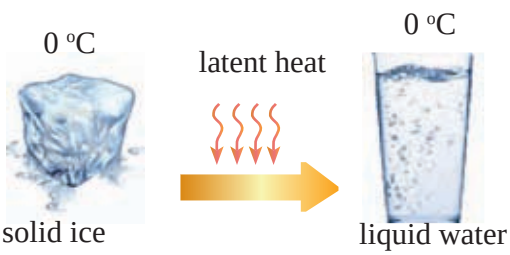


Figure 9.12

At first, its temperature would increase gradually up to 0 °C. Since 0 °C is the melting point of ice, the heat supplied thereafter is spent on doing work against the intermolecular attractive forces between the water molecules and the ice at 0 °C becomes water at 0 °C. If heat is supplied further after the block of ice has completely melted into water, then the heat supplied will be spent on increasing the temperature of the water again.

Conversion of a solid into a liquid is known as **fusion** and the heat absorbed in the conversion of ice at 0 °C into water at 0 °C is known as the **latent heat of fusion**.

Any solid substance that undergoes fusion absorbs latent heat, not only ice. If the fused substance is cooled, it solidifies again, releasing the same amount of heat that it absorbed during fusion. Therefore, when the water mass at 0 °C is cooled, the same quantity of latent heat is released and the water becomes ice.

Now let us consider an instance where heat is supplied to water at 100 °C.

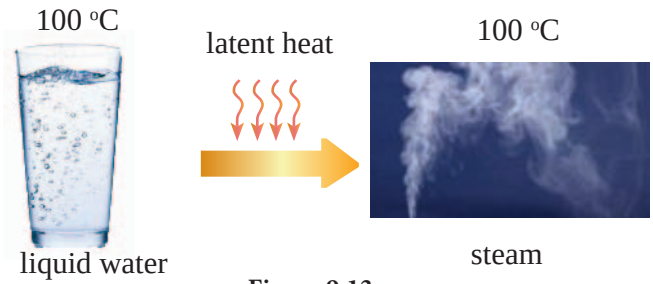


Figure 9.13

Since water is at its boiling point, here too a change of state takes place. Here again, work has to be performed against the intermolecular attractive forces. Therefore, the heat supplied is first spent on doing work against the intermolecular attractive forces and the temperature does not change until all the water at 100 °C becomes steam. The latent heat absorbed in this instance is known as the **latent heat of vaporization**.

Any liquid that vaporizes absorbs latent heat while this vapor releases the same amount of latent heat upon condensation back into the liquid.

• Specific Latent Heat of Fusion

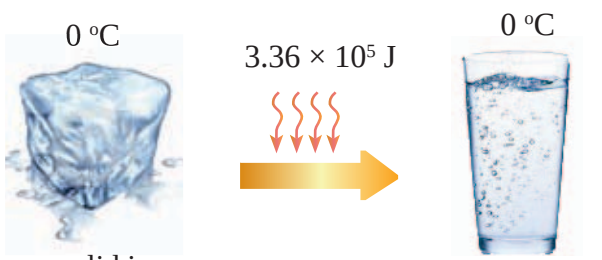
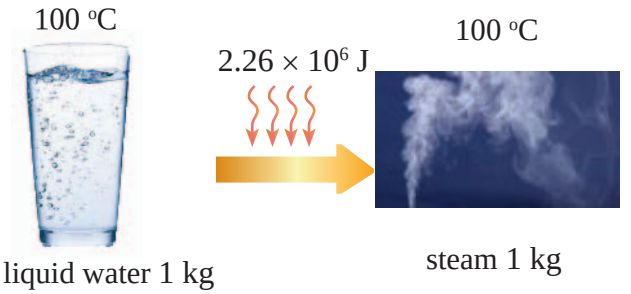


Figure 9.14

The amount of latent heat that has to be supplied in order to convert 1 kg of ice at 0 °C into liquid water at the same temperature is 3.36×10^5 J. This quantity of heat is known as the specific latent heat of fusion of ice.

The amount of heat required to change the state of a unit mass of a solid substance at its melting point into the liquid state is known as the **specific latent heat of fusion** of the substance.

• Specific Latent Heat of Vaporization



The amount of latent heat required in order to convert 1 kg of water at 100 °C into steam at the same temperature is 2.26×10^6 J. This quantity of heat is known as the specific latent heat of vaporization of water.

Figure 9.15

The amount of heat required to change the state of a unit mass of a solid substance at its boiling point into the gas state is known as the **specific latent heat of vaporization** of the substance.

Evaporation and Vaporization

The conversion of a liquid into a gaseous state is called **vaporization**. Liquid into a gaseous can happen in one of two ways. One is the **boiling** that takes place at the boiling point of a liquid when further heat is supplied. The other is the conversion of the liquid into a gas gradually at temperatures below the boiling point. The conversion of a liquid at a temperature below the boiling point is known as **evaporation**.

In vaporization due to either of the processes boiling and evaporation, latent heat is absorbed. Generally, evaporation takes place only at the surface of a liquid exposed to air. However in boiling vaporization takes place even below the liquid surface. This is why bubbles are formed in a boiling liquid.

In drying clothes and in perspiring to regulate our body temperature, evaporation is the process that plays an important role. Since the specific latent heat of vaporization has a fairly large value, in the evaporation of water through the process of perspiration taking place from our skin, a large amount of heat is removed from our body.

9.4 Thermal Expansion

You may have experienced that two glasses washed and one inserted inside the other (*A* inside *B*) are found to be stuck together when you examine them after a few days. At such an instance the two glasses can be separated by pouring cold water into the inner glass and inserting the outer glass in a vessel containing warm water.

Figure 9.16

In this case it becomes possible to separate the two glasses because the glass inserted in warm water expands slightly while the glass into which cold water was poured contracts slightly.

The increase in dimensions of a substance subjected to an increase in temperature is known as **thermal expansion**. That is, the increase in its length, area or volume is called expansion. Similarly, the decrease in dimensions of a substance subjected to a decrease in temperature is known as **contraction**. That is, the decrease in its length, area or volume is called contraction.

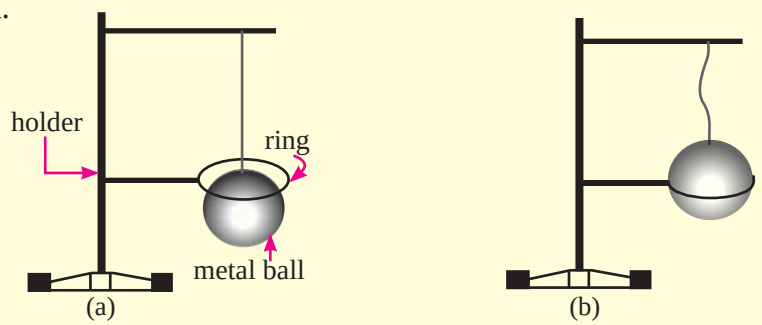
9.4.1 Expansion of Solids

Let us engage in activity 9.3 to demonstrate the expansion of solids.

Activity 9.3

Apparatus required: A metal ball, A holder, A ring through which the iron ball just passes.

- Obtain an iron ball and a ring through which the iron ball just passes.
- Heat up the ball and see if it can be passed through the ring.
- Also observe that the iron ball passes through the ring again after being cooled.



Before heating up the iron ball passes through the ring.

After heating up the iron ball cannot pass through the ring.

Figure 9.17 - Modelling expansion of solids

It will be clear from this activity that solids expand when they are heated up and they contract upon being cooled.

Influences and Applications of Expansion of Solids

- When fitting iron rims to wooden cart wheels, the diameter of the iron rim is chosen to be slightly less than that of the wooden wheel. Then the iron rim is heated and expanded until the wheel can be inserted into it. After inserting the wooden wheel into the iron rim, it is allowed to cool and thus contract, fitting it into the wheel securely.
- In railways, a small gap is left between two rails allowing them to expand when the temperature rises, thus preventing the rails from being deformed due to expansion.

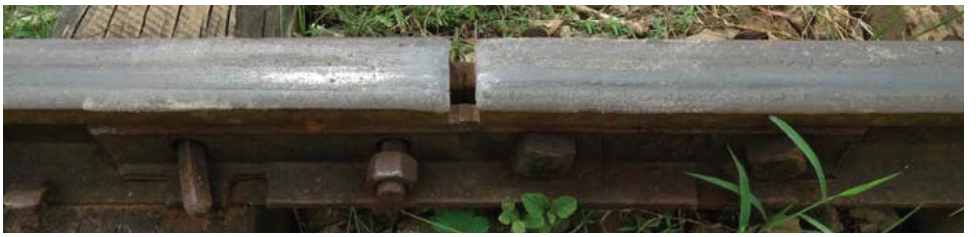


Figure 9.18

- Telephone wires and cables carrying electricity are loosely fitted between posts in order to allow them to contract without breaking the wires when the environmental temperature drops.

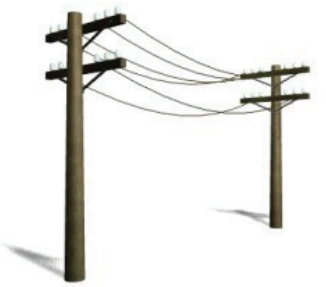


Figure 9.19

- Tight fitting metallic bottle lids can be easily opened by heating them up to expand slightly.

  The reason for this is that the expansion of metals is larger than that of glass making the lid slightly larger than the bottle when they are heated up.

- In electrical appliances such as electric irons and rice cookers, bimetallic strips consisting of two different metals that have different expansions for a given temperature difference are used to regulate the temperature.

Figure 9.20(a) shows such a bimetallic strip. It consists of two metallic strips with inequal expansions rigidly riveted together. One of its ends is rigidly fixed to a piece of metal while the other end remains free. When the temperature of the bipolar strip is increased, one of the strips expands more than the other. Then the two strips bend as shown in figure 9.20(b).

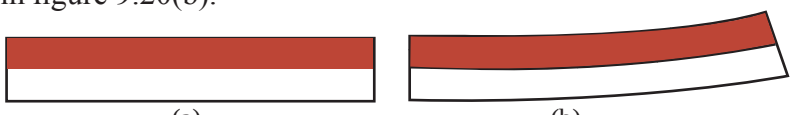


Figure 9.20 –The operation of a bi-metallic strip

By connecting the bipolar strip to an electric circuit as shown in the figure 9.21, power can be disconnected from the circuit when the temperature is increased by supplying power to the heater.

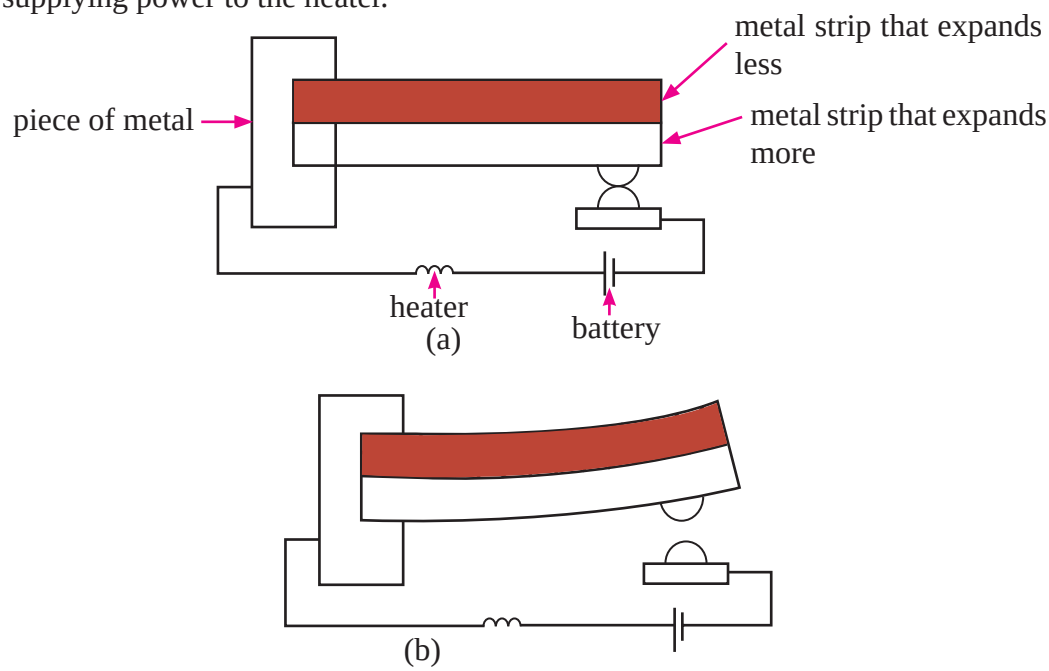


Figure 9.21 – Connecting a bimetallic strip to an electric circuit

Assignment 9.1

Explore other instances where expansion of solids are utilized and record your data.

9.4.2 Expansion of Liquids

Let us engage in activity 9.4 to illustrate the expansion of liquids.

Activity 9.4

Apparatus required: A test tube, Colored water

- Fill a test tube with colored water and fix a rubber stopper with a glass tube to the test tube as shown in the figure 9.22(a).
- Mark the water level on the glass tube
- Insert the glass tube in a warm water vessel for a few minutes and examine it.
- When heating up, the test tube expands and the liquid level goes down to *B* and when the liquid expands, the liquid level rises upto *C*.

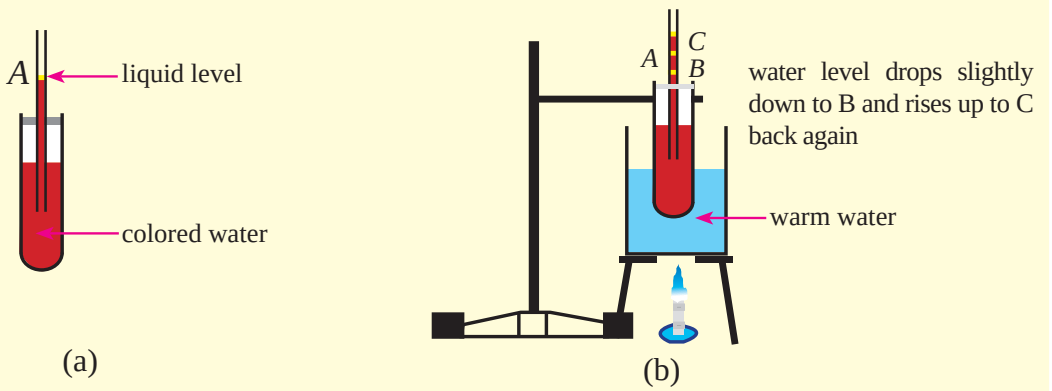


Figure 9.22 - Illustrating expansion of liquids

In this experiment, first the test tube expands when the temperature of the water increases. Then the liquid level drops down slightly. However when the liquid inside the test tubes heats up, the liquid also begins to expand. When the expansion of the liquid exceeds that of glass, the liquid level rises up again. When making thermometers, thermal expansion of liquids is commonly used. In mercury and alcohol thermometers, the expansion of liquid volume is used for measuring temperature.

9.4.3 Expansion of Gases

Let us engage in activity 9.5 to illustrate the expansion of gases.

Activity 9.5

Apparatus required: Ice, An empty plastic bottle, A balloon.

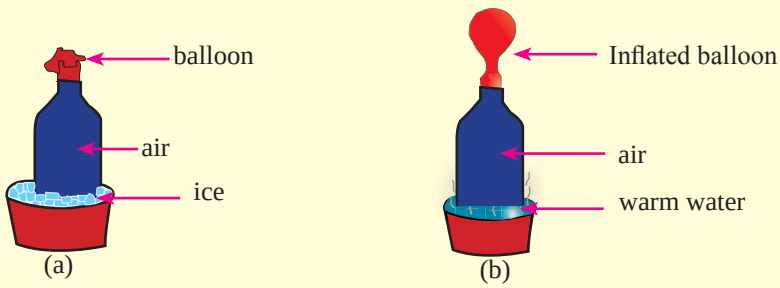


Figure 9.23 - Illustration of expansion of gases

- Place an empty plastic bottle without a lid vertically in a vessel containing ice and water for a short while.
- Then attach a balloon to the opening as shown in Figure 9.23(a).
- Next place the bottle in another empty vessel and pour hot water into the vessel as shown in Figure 9.23(b).
- Observe that the balloon inflates slightly.
- Also observe that the balloon shrinks when left outside for a while.

When the bottle is placed inside the ice vessel, the temperature of the air inside the bottle is close to 0 ^{o}C. When it is placed inside the warm water bottle the temperature of the cool air in the bottle increases close to the room temperature and the air expands. This air cannot leave the bottle because of the balloon attached to it. Instead, the balloon inflates. When the bottle is taken out, the air cools down to the room temperature shrinking again.

From this experiment it is clear that the air inside the bottle expands when it heats up and contracts when the air cools down.

9.5 Heat Transfer

If you touch the far end of a metal spoon inserted in a hot cup of tea you would feel that it gets warmer gradually. Similarly if you hold your hand above a burning fire, you would feel that the hand gets warmer. What has happened in these instances is that heat has transferred along the spoon in the first case and upwards away from the flame in the second. Heat passing from one place to another in this manner is known as **heat transfer**.

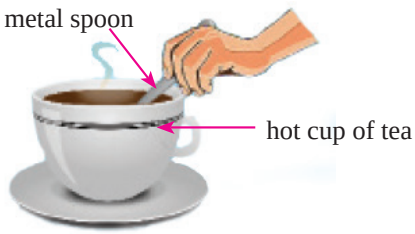


Figure 9.24

Figure 9.25

Heat transfer occurs from the place with the higher temperature to the place with the lower temperature. The energy known as thermal energy (heat) of an object is actually present as the kinetic energy resulting from the random motion of the particles that form the object. This energy can be the translational, rotational or vibrational kinetic energy of the particles. Heat transfer is the spreading of kinetic energy from a region with atoms having a high degree of random motion (with a high temperature) to a region of atoms having a low degree of random motion (with a low temperature).

There are three methods of transferring heat.

(1) Conduction
(2) Convection
(3) Radiation

Let us investigate these methods in a simple way.

9.5.1 Conduction

The handle of a metal spoon held in a hot water soon gets warm. Heat passes along the spoon by conduction.

Some examples where heat transfers by condition are given below.

- Heat flow along a metallic rod in contact with a flame.
- Heat flow from the bottom to the interior of a vessel placed on a cooker.

The main method of heat transfer through solids is conduction.

Since the atoms of a solid are tightly bound to one another, they cannot freely move throughout the volume of the solid. In such substances, heat exists as the vibrational kinetic energy of atoms. In metallic substances, part of the thermal energy exists as kinetic energy of freely moving electrons (free electrons) in addition to this. Conduction is the spreading of the kinetic energy of atoms and electrons throughout the substance due to collisions among these particles.

Substances that conduct heat efficiently are known as **good conductors** and substances that do not conduct heat efficiently are known as **insulators**.

Examples: good conductors – silver, copper, iron, mercury, aluminium

Insulators – wood, plastic, asbestos, clay, wool

Existence of free electrons in metals make metals good conductors.

In liquids, molecules are not very tightly bound. Therefore, conduction of current through liquids is very weak. Water is a very poor thermal conductor.

This Robbin has fluffed out its feathers to trap a layer of air. Air is a poor conductor of heat and so the bird manages to keep warm even in cold weather.

Figure 9.26 - Robbin bird

Seals, spend all of their lives in cold water. They are protected from losing heat by conduction by a very thick layer of fat (blubber) which surrounds their body.

• Conduction through a metal rod

The Figure 9.27 illustrates how heat is conducted through a metal rod that is heated from one end.

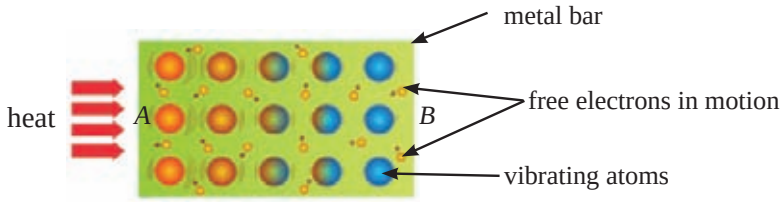


Figure 9.27 – Metal rod heated at one end

Suppose that the metallic rod shown in figure 9.27 is heated by a flame at the end *A*.

Then the atoms at that end begin to vibrate with a large amplitude by receiving thermal energy (heat) from the flame. In addition to this, the free electrons in random motion at that end gain kinetic energy from the flame. As a result of the increased kinetic energy, these atoms collide with adjacent atoms. Due to the collisions, energy transfers to one atom from another increasing the amplitude of vibrations. This process continues through the atoms in the rod from *A* to *B* in succession, transferring thermal energy along the rod. Thermal energy is also transferred by the free electrons in random motion in the rod by receiving thermal energy from the flame.

9.5.2 Convection

The water is heated just under the purple crystal - the crystal colours the water as it dissolves. The heated water expands and becomes less dense than the colder surrounding water, so it floats up to the top of the beaker. Colder water sinks to take its place, and is then heated too.

Figure 9.28

When heat is supplied to liquids or gases they expand and decrease in density and move upwards. In order to fill these gaps, liquids or gases with lower temperatures move downwards. Due to this process, heat flows upwards from the region where heat is supplied. This is known as **convection**.

When a fire is lighted underneath a tree, branches and leaves above the fire tend to swing about and burn as a result of the upward motion of heated up air particles.

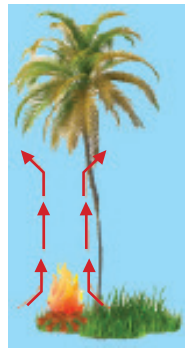


Figure 9.29

Upward motion of heated up particle streams is known as **convection currents**.

Consider the figures below showing an immersion heater used to heat up water.

Figure 9.30 - An immersion heater used to heat up water

Figure 9.30(a) shows a heater partially immersed in water. Here the water near the bottom of the jug warms up slowly but the water near the top warms up fast. This happens since convection currents do not flow downwards.

The immersion heater in Figure 9.30(b) is fully immersed inside the vessel. Then water warms up from bottom to top. Heated up water particles become lighter and move upwards and the water particles that are not heated up move down as their density is higher. When heated up they too move upwards. This process takes place continually heating up the whole jug of water.

• Formation of Sea breeze and Land breeze

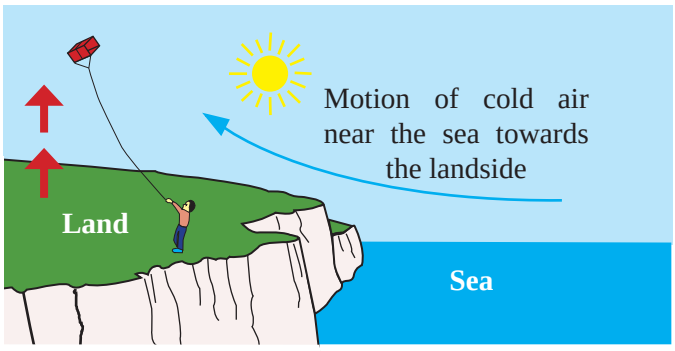


Figure 9.31 - Sea breeze

Specific heat capacity of the earth's surface in the land side is smaller than that of the sea water. Therefore during day time the land surface heats up faster from the sun's heat than the sea water. Then the air near the land surface warms up which decreases the density and the air moves upwards. This reduces the pressure near the ground. Then an air mass flows from the sea to the land side. This is known as **sea breeze.**

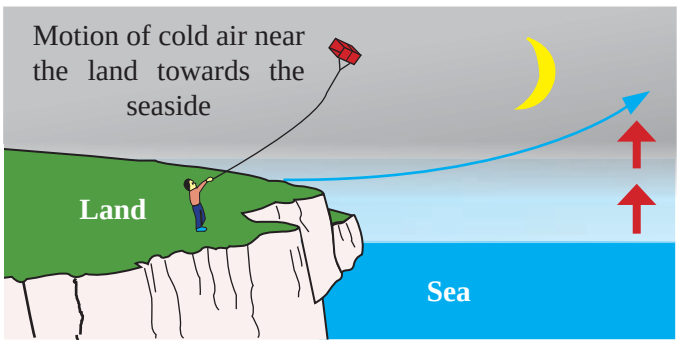


Figure 9.32 - Land breeze

During night time both the land and the sea cool down. The sea cools down slowly while the land cools down fast. Air near the sea water surface is warm while that above is cold. Therefore the air near the sea water moves upwards giving rise to a low pressure region just above the sea. Then wind blows from the land side towards the sea in order to equalize the pressure difference. This is known as **land breeze.**

Think……..
How does a warm cup of tea cool down upon blowing on it?

9.5.3 Thermal Radiation

You will be able understand that it is not due to either conduction or convection that you feel the warmth near a burning fire. Then it must be through another means that heat has transferred. We feel the warmth when thermal rays travel through space in the form of rays (waves) from the flame and reach our bodies.

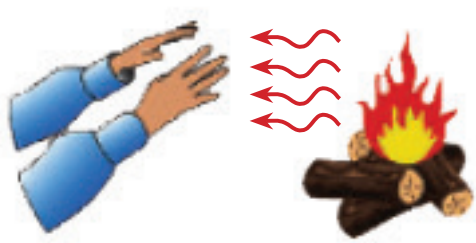


Figure 9.33

The propagation of heat in the form of electromagnetic radiation from a warm body without the aid of matter is known as **thermal radiation**. For heat transfer by radiation, a material medium is not required. However, for heat transfer by conduction or convection, particles of a medium are essential.

Heat from the sun reach the earth through a vacuum of about 150 million kilometres as thermal radiation. Any heated body emits heat as radiation.

• Absorption and Reflection of Thermal Radiation

When thermal radiation is incident on an object, part of the radiation is absorbed by the object while another part is reflected. The surface roughness or the smoothness and the colour of the surface of the object are the factors affecting the amount of thermal radiation absorbed or reflected.

Absorption of thermal radiation is high from darker surfaces and rough surfaces.

Reflection of thermal radiation is high from shining surfaces.

Reflection of heat radiation by polished surfaces and by white surfaces are very high.

Black surfaces absorb a high amount of heat while they reflect a very low amount of heat.

Assignment 9.6

Design an experiment to find out from which out of dark, white and shining surfaces that thermal radiation is most effectively absorbed. Write down the conclusions you can draw based on your observations.

• Situations where thermal radiation is important

When cricketers dress in white during the day time in the presence of sunlight, the absorption of thermal radiation is very low. Then warming up of the body is controlled.

Wearing dark colors inside homes by people in cold climates increase the absorption of thermal radiation. This helps to maintain the body temperature.

If the cooking utensils placed on cookers are black in color, they can absorb thermal radiation efficiently and transfer heat to the vessels fast.

The inner surfaces of thermos flasks are silvered to make them highly reflective. These surfaces reflect heat radiated by the contents inside the bottle or heat radiation coming from outside.

Summary

- Temperature is a measure of the mean kinetic energy of the atoms forming an object.
- The instrument that is used to measure temperature is the thermometer.
- The units used to measure temperature are degrees Celsius (^{o}C), degrees Fahrenheit (^{o}F) and Kelvin (K).
- The international unit of measuring temperature is the Kelvin.
- Heat is the energy transferred from one object to another object due to the temperature difference between them.
- If energy is absorbed by an object where no change of state occurs, then its temperature will definitely rise.
- If energy is released by an object where no change of state occurs, then its temperature will definitely drop.
- Heat capacity (C) of an object is the amount of heat required to increase its temperature by one temperature unit.
- Units of heat capacity are J K^{-1} or J $^{o}C^{-1}$.
- Specific heat capacity (c) of an object is the amount of heat required (or released) to increase (or decrease) the temperature of a unit mass of the object by one temperature unit.
- Units for measuring the specific heat capacity are J kg^{-1} K^{-1} or J kg^{-1} $^{o}C^{-1}$.
- Heat capacity $C = mc$
- Quantity of heat $Q = mc\theta$
- Latent heat is the amount of heat absorbed or released in a change of state of a substance without changing its temperature.
- Specific latent heat capacity of fusion is the heat required to convert a unit mass of a solid at its melting point into a liquid at the same temperature.

- Specific latent heat capacity of vaporization is the heat required to convert a unit mass of a liquid at its boiling point into a vapor at the same temperature.
- The unit of specific latent heat capacity is J kg^{-1}.
- The increase in length, area or volume taking place when an object is heated up is known as thermal expansion.
- Heat transfer is the flow of heat from a point at a higher temperature to a point at a lower temperature.
- The three methods of heat transfer are conduction, convection and radiation.
- Conduction is the forward flow of heat through any material by heating up of the constituent particles one by one in succession.
- Convection is the flow of heat by the upward motion of particles by decreasing the density when liquids or gases are heated up.
- Radiation is the flow of heat from a heated body in the form of electromagnetic waves without the aid of a material medium.

Exercise 9.3

(1) Fill in the blanks of the sentences given below.

(i) The international unit used to measure temperature is ..... and the international unit used to measure the amount of heat is .....

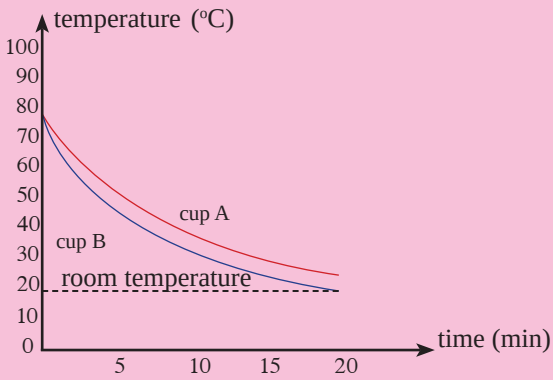
(ii) The absolute zero is equal to ..... Celsius.

(iii) The ..... does not change when absorbing latent heat while the ..... changes.

(iv) The method of transferring heat without the influence of a medium is .....

(v) Bodies having low specific heat capacities increase their temperature ....., bodies with high specific heat capacities increase their temperature .....

(2) Two cups of the same size and shape made out of two different materials are filled with equal amounts of hot tea and are allowed to cool down. Cooling curves plotted by measuring the temperatures of the two cups at definite time intervals are shown below.



(i) What is the temperature of the tea in cup *A* after five minutes?
(ii) What is the time taken for the temperature of the tea in cup *B* to drop by 30 °C?
(iii) What is the difference in the temperatures of the tea in the two cups after 15 minutes?
(iv) Which cup is made out of the material with the lower heat conductivity?
(v) What is the reason for your answer above?
(vi) What is the ultimate temperature of the tea in the two cups?

(3) The figure below shows the cross-section of a thermos flask.

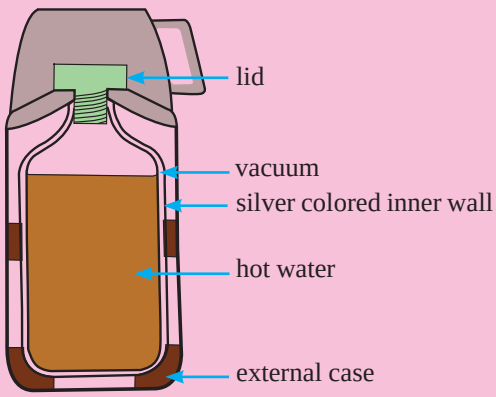


Figure 9.34

(i) There are two situations that a thermos flask can be used. What are they?
(ii) There are 500 ml of water at a temperature of 100 °C inside the flask. In order to keep the water at this temperature, heat loss has to be prevented. What are the techniques used here for this purpose?

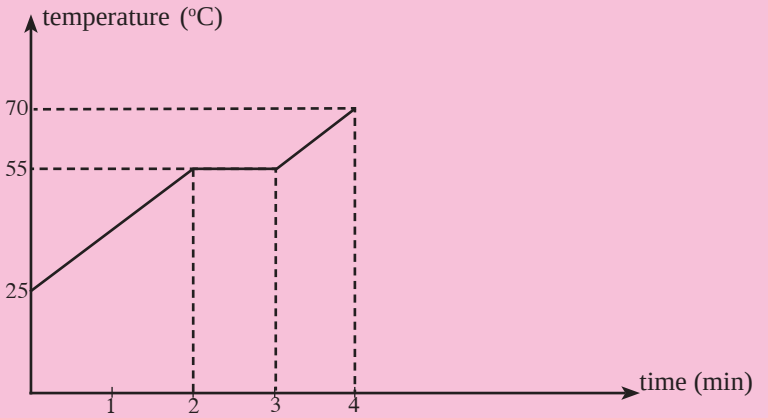
(iii) Calculate the amount of heat loss occurring when 500 ml of water at 100 °C cools down to the room temperature of 25 °C. (Specific heat capacity of water is 4200 J kg^{-1} K^{-1})

(iv) It is not appropriate to remove the hot water from a flask and fill it with cold water immediately. What is the reason for this?

(4) (i) Find the heat released in cooling 10 g of water at 100 °C down to 25 °C.

(ii) A burn caused by steam at 100 °C is more harmful than a burn caused by boiling water at 100 °C. Explain this.

(5) A piece of paraffin is at room temperature. Investigate the changes occurring in it when the temperature is gradually increased and temperature measurements were plotted against time, the following graph was obtained. Answer the questions given below using the graph.



(i) What is the room temperature?

(ii) What is the melting point of paraffin?

(iii) How long after commencing the experiment did the paraffin begin to melt?

(iv) What is the reason for the temperature to remain constant in the time interval between 2 min to 3 min?

(v) If supplying heat to paraffin was stopped at time 4 min, give a rough sketch to show the variation of the temperature of paraffin with time thereafter.

Technical terms

Temperature	- උෂ්ණත්වය	- வெப்பநிலை
Glass-mercury Thermometer	- වීදුරු රසදිය උෂ්ණත්වමානය	- கண்ணாடி இரச வெப்பமானி
Glass-Alcohol Thermometer	- වීදුරු මද්‍යසාර උෂ්ණත්වමානය	- கண்ணாடி அற்கஹோல் வெப்பமானி
Heat Capacity	- තාප ධාරිතාව	- வெப்பக் கொள்ளளவு
Specific Heat Capacity	- විශිෂ්ට තාප ධාරිතාව	- தன்வெப்பக் கொள்ளளவு
Melting Point	- ද්‍රවාංකය	- உருகுநிலை
Freezing Point	- හිමාංකය	- உறைநிலை
Boiling Point	- තාපාංකය	- கொதிநிலை
Latent Heat	- ගුප්ත තාපය	- மறை வெப்பம்
Latent heat of fusion	- විලයනයේ ගුප්ත තාපය	- உருகலின் தன்மறை வெப்பம்
Latent heat of vaporization	- වාෂ්පීකරණයේ ගුප්ත තාපය	- ஆவியாதலின் தன்மறை வெப்பம்
Vaporization	- වාෂ්පීකරණය	- கொதித்து ஆவியாதல்
Evaporation	- වාෂ්පීභවනය	- ஆவியாதல்
Thermal Expansion	- තාප ප්‍රසාරණය	- வெப்பவிரிவு

Physics

10 Power and Energy of Electric Appliances

We use electric energy to do various jobs in our daily lives conveniently. On all these occasions we convert electric energy into another form of energy to suit our requirements. This energy conversion takes place in various electric appliances. The instruments used for these energy conversions are known as electric appliances. The main forms of energy conversions that take place in some electric appliances used in daily life are given in the Figure 10.1.

Figure 10.1 - The main form of energy conversion in some electric appliances

For extra knowledge

In some electric appliances, after the first energy conversion, another energy conversion also takes place and we use that energy. As an example, in a filament bulb, electric energy is initially converted into heat which increases the temperature of the filament resulting in the emission of light. In fluorescent lights electric energy is first converted into ultraviolet radiation which is next converted into visible light.

10.1 Power output of an electric appliance

We know that power is the work done in a unit time.

Just like in mechanical work, power is the rate of doing work in work done by electricity too. **That is, power is the work done in a unit time or the energy consumed in a unit time**.

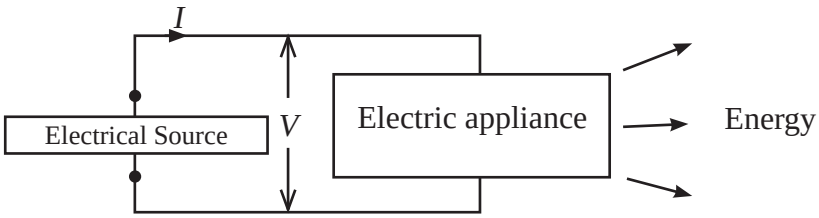


Figure 10.2 - An electric appliance operating with a potential difference *V* and drawing a current *I*

Therefore the rate of energy consumption P by an electric appliance operated with a voltage V and drawing a current I is given by the following equation.

Power = voltage × current

$$P = VI$$

When the voltage, V is measured in Volts (V) and the current, I in Amperes (A) the power, P is given in Watts (W).

Example 1

When a filament bulb is connected across a voltage difference of 12 V, a current of 2 A flows through it. What is the power of the bulb?

Power $P = VI$

$= 12 \times 2$ W

$P = 24$ W

Power of the bulb is 24 W.

Example 2

An electric oven operates under a 230 V power supply. If it has a power output of 2000 W, find the current drawn when the oven is working.

$P = VI$

$\therefore 2000 = 230 \times I$

$$\therefore I = \frac{2000}{230} = 8.69 \text{ A}$$

The current drawn by the oven is 8.69 A.

In the heating coils (heating element) of electric ovens, the energy consumed is converted only into heat. In some other appliances, part of the electric energy is converted into heat due to their internal resistance, while the remaining part is converted into other forms of energy.

10.2 Electric energy consumed by electric appliances

Power is the rate of consumption of energy or the energy consumed in a unit time by an electric appliance. Therefore, the total energy consumed by an electric appliance depends on the time duration that it operates.

If the energy consumed during a unit time interval is P, the total amount of electric energy consumed in a time t is Pt. If the total energy consumed is E,

$$E = Pt$$

When P is measured in Watts (W) and the time t in seconds (s), the electrical energy E is given in Joules (J).

Since $P = VI$, substituting VI for P,

$$E = Pt = VIt$$

Total Energy = voltage × current × time

$$E = VIt$$

In order to find the energy consumed by an electric appliance, the relation $E = VIt$ can also be used.

Example 1

The power of the head light of a motor car is 50 W. Find the energy consumed when this lamp is operated for $1\frac{1}{2}$ hours.

$$E = Pt$$
$$E = 50 \times 1.5 \times 60 \times 60 \text{ J}$$
$$E = 270\,000 \text{ J}$$

The amount of energy consumed is 270 000 J.

Example 2

A 6 V bicycle electric bulb draws a current 0.6 A. What is the power consumed in lighting this bulb for five minutes?

$$E = VIt$$
$$E = 6 \times 0.6 \times 5 \times 60$$
$$E = 1080 \text{ J}$$

Total electric energy consumed is 1080 J.

10.3 Efficiency of electric appliances and conserving power

In many instances, the same purpose can be achieved using various different appliances. In order to get illumination we can use filament bulbs, LED bulbs, fluorescent light tubes or CFL lights (compact fluorescent lights). Choosing a more efficient appliance helps us to save energy. A few different types of bulbs giving the same illumination, their power output and life times are given in Table 10.1 below.

Table 10.1 – Power and life times of various types of bulbs

Light source	Power	Life time
Filament bulbs	60 W	1200 h
Fluorescent tubes	22 W	3000 h
CFL bulbs	11 ~ 13 W	8000 h
LED lights	6 ~ 8 W	50 000 h

According to Table 10.1, it is advantageous to use LED bulbs as light sources. However, the use of LED bulbs in Sri Lanka is limited due to their high initial cost.

Similarly, the efficiencies of cookers used to prepare food are different from one to another due to varying amounts of heat wastage. Old cookers that use heating coils are the lowest in efficiency. Emersion heater is highly efficient for heating water. The reason is that, all the heat generated in the heater is transferred to water when using it. Heaters which contains hot plates such as rice cooker is more efficient because heat loss is less from them. Although microwave ovens cannot be used to cook all types of food, they are very efficient since they produce heat inside the food items. In addition to these, induction cookers with high efficiencies are now available in the market. In these devices, the variable magnetic field emitted by the cooker generates heat only at the bottom of the cooking utensil.

For extra knowledge

The power consumption of television sets that use LCD screens is lower than that of the old televisions that use cathode ray tubes. LCD television sets that use LED lights to illuminate the screen have a very low power consumption and are known as LED televisions in the market.

Similarly, it is more efficient to use table fans to cool houses than ceiling fans. Using the most efficient device suitable for a particular purpose whenever possible would help to minimize the future energy crisis.

If 40% of the energy supplied to a certain electric appliance is lost as heat, then only 60% of the energy would be used for the expected purpose. This means that the efficiency of the electric appliance is 60%. We should try to minimize the loss of electric energy as heat and get the maximum out of the electric energy supplied for a particular purpose. Ironing all clothes required for a week in one occasion is more efficient because it saves electricity used in the initial heating of the iron. All the unwanted lights of the home should be switched off. Also, you have to use more efficient bulbs such as CFL and LED bulbs.

Assignment 10.1

Prepare a list of electric devices used in households and indicate their power usage against them (You may use the specification labels pasted on the device or the instruction sheet provided with the device to do this. Get assistance from an adult when this is not possible.)

10.4 Home Electric Circuits

Electric energy required to operate home electric appliances is obtained from the national electric grid. Electric energy generated by electric power stations are raised to high voltages such as 132 kV or 220 kV using step-up transformers and distributed throughout the island. In distribution sub-centres, these high voltages are lowered to voltages such as 33 kV or 11 kV and ultimately they are lowered down to 230 V before supplying to households. Electricity provided to houses is in the form of an alternating current with a frequency of 50 Hz.

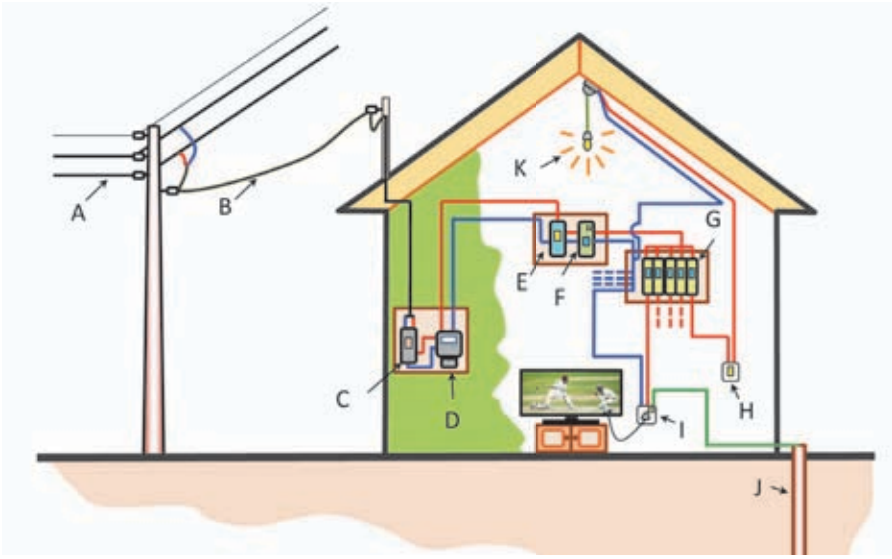


Figure 10.3 – A house connected to the electric grid

A – Distribution wire
B – Supply cable
C – Overload circuit breaker (or Service fuse)
D – Electric meter
E – Isolator (or Main fuse with main switch)
F – Residual current circuit breaker or trip switch (RCCB)
G – miniature circuit breakers or fuses (MCB)
H – Switch
I – plug socket
J – Earth wire
K – Light bulb

Electricity is supplied to houses using a service cable consisting of two wires known as the live wire and the neutral wire. The current flowing through these two wires is provided to the electric appliances through a circuit inside the house.

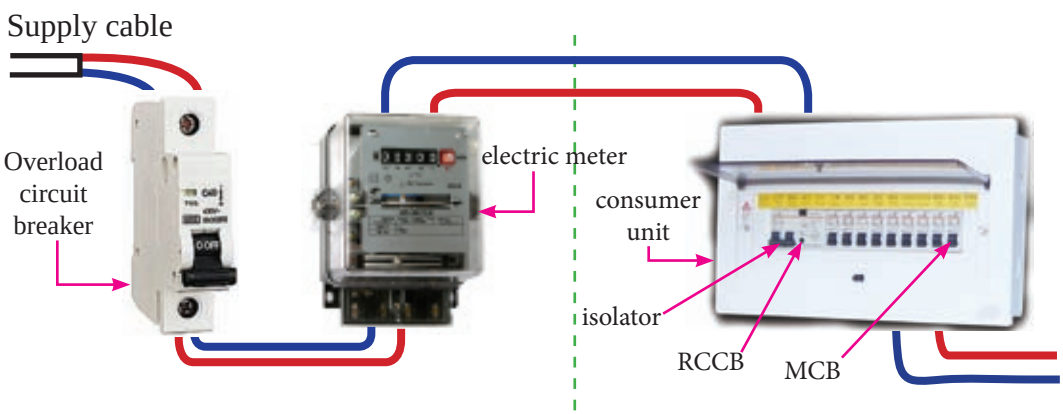


Figure 10.4

Figure 10.5 shows a diagram of a domestic electric circuit.

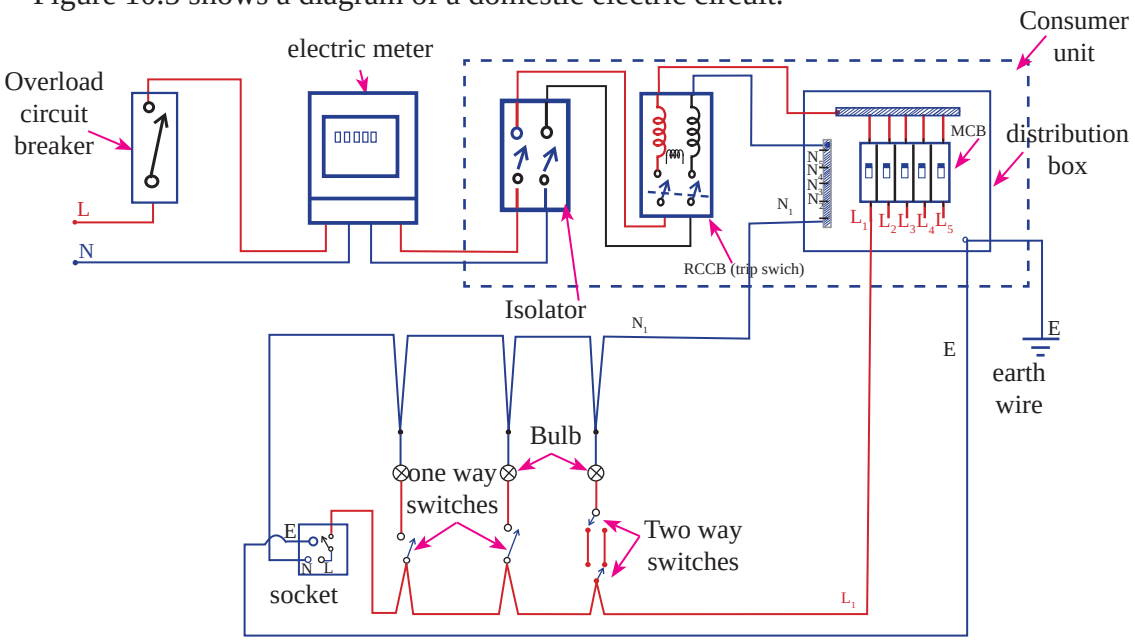


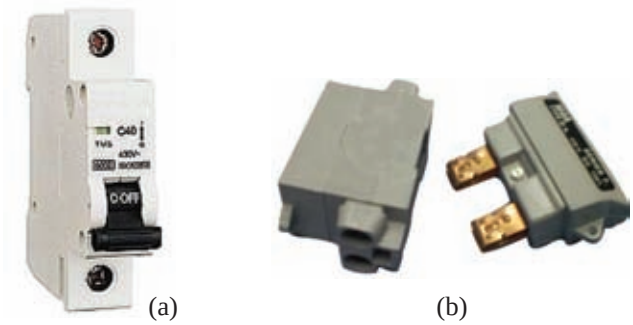
Figure 10.5 – Arrangement of a domestic electric circuit

10.4.1 Components of a Domestic Electric Circuit

• Overload circuit breaker (or Service fuse)

Electricity supplied to household first passes through a fuse connected to the live cable. This fuse is arranged to allow the passage of a maximum current of about 40 A. If a larger current passes through it, the circuit breaker disconnects power to the house. When that happens, the power can be reconnected by moving the lever up, manually. In older houses, a fuse, is used instead of a circuit breaker. When a current above the limit passes through the fuse wire which is made of an alloy consisting of lead and tin, it heats up and melts disconnecting the power supply. The fuse wire is inserted in a ceramic tube or a ceramic mount.

Only the live wire is disconnected by the overload circuit breaker or the service fuse. Figure 10.6(a) shows a overload circuit breaker and Figure 10.6(b) shows a service fuse.



(a) (b)

Figure 10.6 - (a) Overload circuit breaker (b) Service fuse

• Electricity Meter

Consumers are billed according to the amount of electricity they consume. The meter records the electric energy in kilowatt hours (kW h). The live and neutral wires coming through the over load circuit breaker or service fuse are next connected to the electricity meter. These two wires coming from the electricity meter are next connected to the main switch. An electricity meter is shown in Figure 10.7.

Overload circuit breaker and the electricity meter are properties belonging to the service provider (electricity board or electricity company) and any problem with these items should be solved by informing the service provider.

Figure 10.7 - An electricity meter

• Isolator (or Main Switch with Main Fuse)

All items in the domestic circuit beyond the isolator belong to the consumer. After passing through the electric meter, the live wire passes through an isolator that allows the passage of a maximum current of 30 A. Isolator acts as a 30 A high current circuit breaker too. In any instance, by the lowering of the switch levers, it can be disconnected the home hold circuit from power mains (L and N).

In older domestic electrical circuits, a main switch consisting of a 30 A fuse and a dipole switch was used in place of the isolator. The isolator is capable of disconnecting both the live and the neutral wires. Such switches are known as **dual pole switches**. Disconnecting the domestic circuit for any repair purpose can be done by turning off the isolator. Figure 10.8(a) shows the outward appearance of an isolator and Figure 10.8(b) shows the circuit diagram of a main switch.

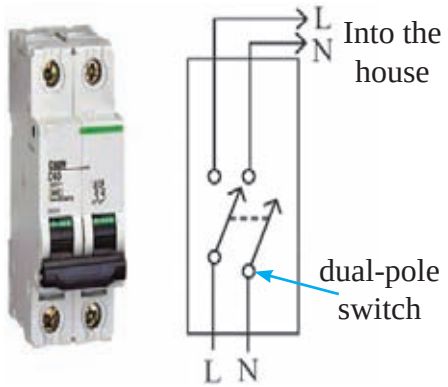


Figure 10.8 (a) - The external view of an isolator and circuit diagram of a isolator

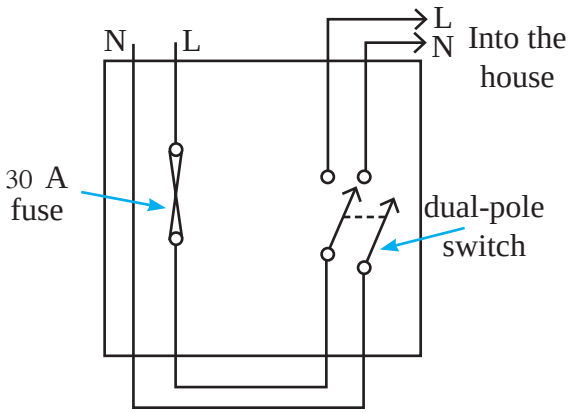


Figure 10.8 (b) - circuit diagram of a main switch

• Residual Current Circuit Breaker - RCCB (or Trip Switch)

After the isolator, the live wire and the neutral wire are connected to a RCCB or a tripped switch. The purpose of connecting to a RCCB is to protect the residents from electric shocks. When there is a current leak to the metal caring of an appliance or to the ground the circuit is automatically disconnect by the RCCB. The RCCB too is a dual pole switch. Outward appearance of a RCCB is shown in Figure 10.9(a) and circuit diagram of a RCCB is shown in Figure 10.9(b).

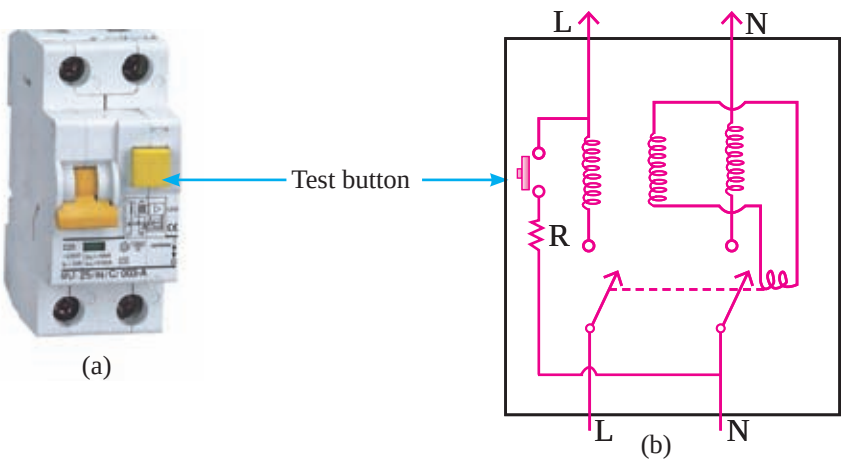


Figure 10.9 – (a) Outward appearance of a RCCB (b) circuit diagram of a RCCB

In a normal switch the switch is on when the lever is turned down. But in this switch it become on when the lever arm is raised.

• Distribution Box

Electricity is distributed for consumption in the household through the distribution box. Electricity is distributed inside the house through lighting circuits and plug circuits. Adequate current to light bulbs in ordinary rooms is supplied by lighting circuits. The maximum current supplied to a lighting circuit is limited to 6 A. Plug circuits are connected to places such as the kitchen that have devices like electric heaters and electric ovens that consume a large amount of electricity. Plug circuits allow the consumption of current upto about 13 A.

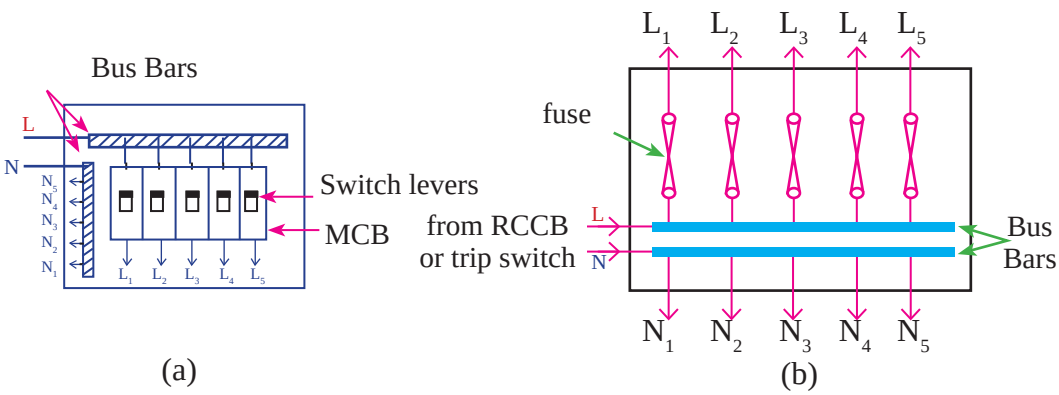
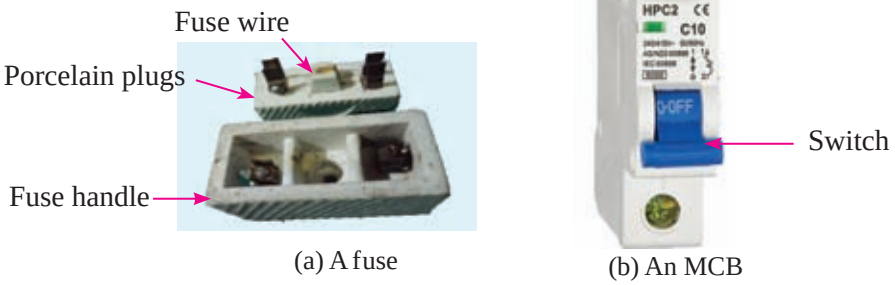


Figure 10.10 – (a) Circuit diagram of a distribution box with MCBs
(b) Circuit diagram of a distribution box with fuses

• Miniature circuit breakers (MCB) and fuses

Miniature circuit breakers (MCB) supplying electricity are connected to each circuit inside the distribution box. When a current larger than the maximum current that can pass through the circuit is drawn, miniature circuit breakers automatically get disconnected and the lever shifts down to the off position. Because of this, the electricity supply gets disconnected only in these circuits and not to the whole household. For lamp circuits, MCBs which can conduct a current of 6 A are used. For socket circuits, MCBs which can conduct a current of 13 A are used.

While bulbs and two 6 A plugs can be connected to a lighting circuit, only plugs can be connected to plug circuits. Figure 10.11 shows the outward appearance of a fuse mount and a miniature circuit breaker.



(a) A fuse (b) An MCB

Figure 10.11 – Outward appearance of a fuse and an MCB

MCBs can be mounted in specially designed distribution boxes. MCBs provide protection against electric shorts and resulting fires due to heated cables only. Since the fuse or the MCB does not operate when a person gets an electric shock, they do not provide any protection to people.

In older domestic circuits, fuses were used instead of MCB. In lighting circuits, 5 A fuses were used instead of 6 A MCBs. Instead of 13 A MCBs, 15 A fuses were used. The use of fuses has declined because replacing fuse wires of blown fuses is inconvenient. When MCBs or fuses are connected, they must always be connected to the live wire.

In modern domestic circuit, isolator, RCCB and the distribution box are included in the same units called **consumer units**. A consumer unit is shown in figure 10.12.

Figure 10.12 - A consumer unit

For extra knowledge

One of the two cables providing electricity to households is earthed near the step down transformer that distributes electricity to the house. Then a potential difference of 230 V is established between the other cable and the earth. Earthed cable maintains a zero potential (Earth is assumed to be at a zero potential).

Now if a person standing on the ground touches the cable that is not grounded, he would receive an electric shock due to the 230 V potential difference across his body (An electric shock is the damage caused to the body by passing an electric current through the body). A 50 mA current passing through the body is considered a major electric shock while a 100 mA current can cause death. Since touching the ungrounded cable causes electric shocks, this cable is known as the "live" cable. Since touching the grounded cable from the ground does not give rise to a potential difference across the body, this cable is known as the neutral cable.

One cable is made to be a live cable in this manner since it is essential for the operation of the RCCB that protects the household from accidents related to electric shocks. If the live wire gets grounded anywhere inside the house, the RCCB automatically disconnects the electricity supply to the house by detecting the large current passing through it. The RCCB operates from electromagnetic induction and if a current of about 35 mA passes through the switch to ground, it automatically turns off. In addition to this, a flow of about 30 A into the house (short circuit) the RCCB operates and disconnects the electricity supply to the house. Although the RCCB sometimes disconnects the electricity supply when there is lightning activity, its protection from lightning damage is not assured.

• Switches and Plug sockets

Switches used to turn on or off power to electric bulbs are major components in domestic circuits. Switches are available as single units or as units consisting of several switches on the same board. Switches are connected to the circuit so as to enable the turning on or off of each bulb separately.

A single switch Four switches

Figure 10. 13 – Switches

Another important component in a domestic circuit is the plug socket. The live cable, the neutral cable and the separately grounded earth cable are connected to these circuit elements. The larger terminal of a three-pin plug socket is connected to the external metal cover of an electric appliance and it connects to the earth wire in the domestic circuit when plugged on. This connection is essential in order to get protection from electric shocks by turning off the trip switch. For some of the modern

Figure 10.14 – A plug socket with switch

electric equipment having a plastic cover that does not leak electricity, two-pin plugs can be used. Two-pin plug sockets are not connected to the earth wire.

Two pin plugs

A three pin plug

Figure 10.15 – Plugs and plug sockets

• Connecting Wires

Copper wires with suitable cross-sectional areas are used as connecting wires for carrying currents. Single cables with a 1 mm^2 cross-sectional area (1.13 mm diameter) are used in order to carry 5 A or 6 A currents while cables consisting of seven wires with a 1.5 mm^2 effective cross-sectional area are used for 15 A or 13 A plug circuits.

A brown PVC cover is used to identify the live wire while a blue PVC cover is used to identify the neutral wire. Previously red and black covers were used to identify live and neutral wires respectively. Green covers are used for the earth wire.

10.4.2 Domestic Electric Circuit

Each bulb and each plug in a domestic circuit is connected in parallel to one another. All switches should be connected to the live wire. Therefore touching a bulb circuit when the switch is in the off position does not cause electric shocks.

Plug circuits are connected using cables that can withstand a current of 13 A. Only plugs are connected in these circuits and this type of circuits are often used in kitchens.

Sometimes plug circuits are connected as ring circuits. Such a ring circuit is shown in Figure 10.16. Cables with smaller diameters can be used in such circuits since each plug receives current through two wires.

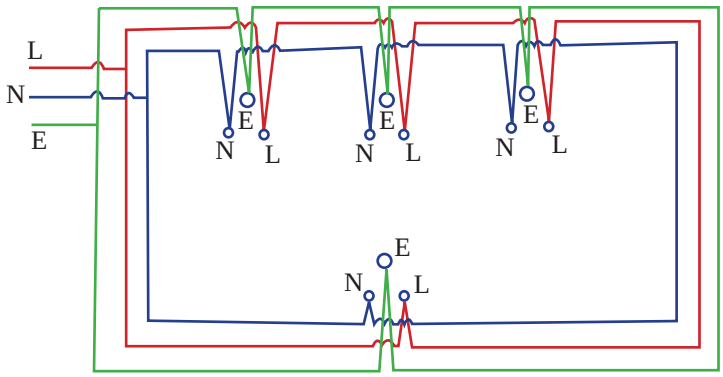


Figure 10.16 – A loop circuit

10.4.3 Protective Measures in Domestic Circuits

Basically there are two protective measures in domestic electric circuits. These are the residual current circuit breaker and the fuse or MCB's.

- **Residual current circuit breaker - RCCB (or Trip Switch)**

In case of a current leakage in the electric appliances or an electric shock, the RCCB disconnects the power supply to the whole house hold. In addition to this, the RCCB also disconnects power if a current greater than 30 A flows through the circuit. This prevents fire arising from over- heated main cables.

- **Fuses or MCB's**

These electrical components prevent large currents flowing through domestic circuits. Fuses or MCB's do not provide protection from accidents due to current leaks or electric shocks.

If there is a power disconnection due to any of the above reasons, the overload circuit breaker should be opened (turned OFF) first. Next, the lever of the RCCB or that of the MCB should be turned upwards (to the ON position) and then close (turn ON) the overload circuit breaker again. If the power supply gets disconnected again, the circuit should be repaired by an electrician.

Further to the above, it is very important to follow the following precautionary measures for safety.

- Only fuses appropriate for 6 A and 13 A currents should be used.
- Many electric appliances that draw a total current exceeding the capacity of the plug socket should not be connected to the plug socket through a multi-plug.
- Only plugs suitable for a plug socket should be inserted into a plug socket. Wires should not be inserted into a plug socket.

- When using an electric iron for ironing clothes, rubber slippers or a rubber carpet underneath the feet should be used. It is good to use a mat in front of a refrigerator for safety.
- Tasks such as changing burnt bulbs in bathrooms should not be done without turning off the overload circuit breaker or the main switch.
- When electric appliances are not in use, their plugs should be disconnected from the socket.
- If there are strong lightning strikes, radio receivers and television sets should be unplugged as much as possible. In such cases it is advisable to refrain from using any unessential electric devices. (RCCBs do not protect the domestic circuit from thunder).
- Electric devices should not be used when the body is wet. Electric switches must not be turned on or off with wet hands.
- During a power failure, switches of electric appliances should not be turned on.
- In case of a fire, the domestic power supply should be disconnected using the overload circuit breaker.
- All maintenance work and installing power extensions should be done by a trained electrician.
- The functioning of the RCCB should be checked every few days by pressing the test button.

10.5 Measuring Electric Energy in kilowatt hours

• Commercial unit of measuring electric energy

Electric energy is measured in kilowatt hours by the domestic electricity meter. One kilowatt hour is the amount of electric energy consumed during one hour by an electric appliance with a power consumption of 1 kW. Although energy is usually measured in Joules, when the consumption is high, energy in Joules gives a large numerical value. Because of this, kilowatt hours (kW h) is used as the measuring unit of electricity. The energy consumed in a second by a device with a 1 Watt power is equal to one Watt second (W s) or one Joule (J).

$$\therefore 1 \text{ kW h} = 1 \text{ kW} \times 1 \text{ h}$$
$$= 1000 \text{ W} \times 1 \times 60 \times 60 \text{ s}$$

$$\mathbf{1 \text{ kW h} = 3\,600\,000 \text{ J} = 3.6 \times 10^6 \text{ J}}$$

This shows that 1 kW h has a large numerical value in Joules.

When the power of domestic electric appliances and the number of hours they are used are known, the amount of electricity consumed by these devices can be easily calculated.

$$\text{Number of kW h} = \frac{\text{number of Watts}}{1000} \times \text{number of hours}$$

Example 1

If four bulbs, each having a power of 100 W are used for 3 hours and 5 bulbs, each with a power of 60 W are used for 4 hours daily, find the electricity consumption during a month.

Energy consumed by 4 bulbs of 100 W power } $= 100 \times 4 \times 3$ W h

Energy consumed by 5 bulbs of 60 W power } $= 60 \times 5 \times 4$ W h

Total energy consumed by all bulbs in a month $= (100 \times 12 + 60 \times 20) \times 30$ W h

Total energy consumed during a month $= (1200 + 1200) \times 30$ W h

$= \frac{2400 \times 30}{1000}$ kW h

Total electricity consumed during a month $= 72$ kWh

Therefore, a total of 72 kW h of electricity is consumed during a month.

Summary

- The power of an electric appliance is the amount of electric energy consumed by it in a unit time.
- When a current I passes through an electric device due to a potential difference V, its power P is given by $P = VI$
- Electric energy E consumed by an electric device over a time period t is given by $E = VIt$
- Domestic electricity meter measures electric energy in kilowatt hours (kW h).
- One kilowatt hour is the energy consumed during one hour by an electric device that has a power of one kW.

  1 kW h = 3 600 000 J

Exercise 10.1

(1) The power of an electric water pump is 750 W.

(a) Calculate the current drawn by the motor, if it is connected to a 230 V supply.

(b) State one type of energy, other than the kinetic energy, generated when the motor is operating.

(2) Specifications of a flash light bulb are given as 2.5 V and 0.3 A.

(a) What is the power of this bulb?

(b) If the efficiency of emitting light from this bulbs is 42% what will happen to the remaining 58%?

(3) The power of the two head lamps of a motor vehicle is 50 W each. There are other two lamps in the rear with 10 W each. If all these bulbs are lighted up for 1/2 h, calculate the quantity of electrical energy spent.

(4) The current flowing through a motor cycle bulb when it is connected to 12 V battery is 2 A. How much electrical energy is spent if this current is flowing for 15 minutes?

(5) (a) Name two instruments that are used in a domestic circuit for the protection of residents.

(b) Mention what is the type of protection provided by each of them.

(c) Explain what is to be done to protect electric equipment in a house when lightning occurs.

(6) (a) Consumers are charged money for the electricity used in houses. What is the unit of electrical energy which is used to make electric bills?

(b) Calculate the amount of energy in Joules equivalent to one commercial unit of electricity.

(c) If the first 60 units are charged at a rate of Rs. 7.50 per unit and the next 30 units are charged Rs. 10.00 per unit, how much will be the electricity bill of a house where the electricity usage is 75 units in a month?

(7) (a) The power of a water heater in a home is 1500 W. This is used for half an hour daily. Three 40 W bulbs are used for 3 hours daily. Two bulbs of 60 W are lighted for 2 hours daily. Calculate the number of units used up in one day.

(b) If electricity is charged according to the above rates given in the question 6 (c), what should be the monthly electricity bill.

(8) (a) A hot plate or immersion heater can be used to heat water. Which one is more efficient out of these two?
(b) Give the reason for this.
(c) What is the reason for using three pin plugs instead of two pin plugs for immersion heaters?
(d) When an electrical appliance is switched on the electrical circuit was disconnected. Give two reasons due to which this can happen.

Technical terms

Power	- ක්ෂමතාව	- வலு
Efficiency	- කාර්යක්ෂමතාව	- திறன்
Hot plate	- තාපන ඵලක	- வெப்பத் தட்டு
Immersion heater	- ගිල්ලුම තාපකය	- அமிழ்ப்பு வெப்பமாக்கி
Microwave oven	- ක්ෂුද්‍ර තරංග උඳුන	- நுணுக்கலைக் கனலி
Induction cooker	- ප්‍රේරක උඳුන	- தூண்டற் சமைகலன்
Live	- සජීවී	- உயிர்
Neutral	- උදාසීන	- நொதுமல்
Fuse	- විලායකය	- உருகி
Residual current circuit breaker (RCCB) or Trip Switch	- ශේෂ ධරා පරිපථ බිඳිනය හෝ පැන්නුම් ස්විචිචය	- இடறு ஆளி / எச்சமான மின் சுற்றுடைப்பான்
Distribution box	- විබෙදුම් පෙට්ටිය	- பரப்பற் பெட்டி
Miniature circuit breaker (MCB)	- සිඟිති පරිපථ බිඳිනය	- சிறு சுற்றுடைப்பான்
Plug socket	- කෙවෙනිය	- குதை
Plug	- පේනුව	- செருகி
Overload circuit breaker	- අධිධාරා පරිපථ බිඳිනය	- பளு சுற்றுடைப்பான்
Isolator	- වෙන්කරණය	- பிரதான ஆளியும் பிரதான உருகியும்

Electronics

Physics 11

11.1 Introduction

Electronics has made a huge impact on our daily lives. We use many electronic devices in our day to day activities. Mobile phone, computers, televisions and radios are some examples for such electronic devices.

Figure 11.1

Materials that conduct electricity are known as electrical **conductors**. Conductors (copper, aluminium, iron, lead etc.) and mixed conductors (brass, nychrome, manganin) are examples of these. Materials that do not conduct electricity (ebonite, polythene, plastic, dry wood, asbestos, glass etc) are known as electrical **insulators**.

The reason behind the ability to conduct electricity is the ability of some of the electrons in the atoms of such materials to move freely within the conductor. Electrons in the outer shells of conductors act in this manner since they are not tightly bound to the nucleus. Since inter-atomic bonds (covalent bonds) between the atoms of insulators are strong, there are very few electrons that are free to move.

Meanwhile, some materials conduct a small amount of electricity. Such materials are known as **semiconductors**. Materials such as silicon (Si) and germanium (Ge) in their crystalline form show such properties. These elements belong to the fourth group in the periodic table and have four electrons in their outermost shell. Such elements form crystal lattice structures by sharing the four electrons in their outermost shell to make covalent bonds with four nearby atoms and thereby acquiring a stable electronic configuration having eight electrons in the outermost shell.

However, these bonds are rather weak and can be broken from the thermal energy available even at room temperature, releasing electrons.

Figure 11.2 shows the covalent bonds of the silicon lattice at 0 K. All the bonds are complete at this temperature. Figure 11.3 shows that some bonds have been broken releasing some free electrons at a temperature higher than 0 K. An electron deficiency can be observed at the positions that the free electrons occupied previously. Such positions with an electron deficiency are known as **holes**. Due to the positively charged protons in the nucleus, a hole gives rise to a positive charge that has not been neutralized (In a neutral atom, the number of protons in the nucleus is equal to the number of and electrons). Therefore a hole is equivalent to a positive charge.

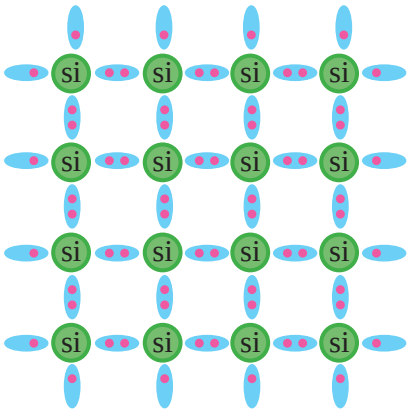


Figure 11.2 - A silicon lattice at 0 K

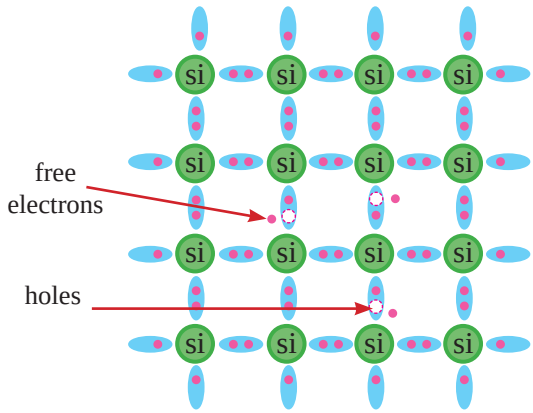


Figure 11.3 - A silicon lattice at temperature above 0 K

In semiconductors, not only electrons contribute to the conduction of electricity. When an electron in an adjacent atom jumps to an atom with a hole having a positive charge, the position of the hole can change. By changing the position of a hole from one atom to another in this manner, holes can move around in the lattice and contribute in conducting a current. Electrons act as negative charge carriers while holes act as positive charge carriers.

Therefore, when an electric potential difference is applied across a semiconductor, holes move from the positive to the negative potential while electrons move from the negative to the positive potential and the (conventional) current flows from the positive to the negative potential.

- In metallic conductors, the charge carriers that conduct electricity are the negatively charged electrons.
- In semiconductors, the negatively charged electrons as well as the positively charged holes act as the charge carriers that contribute in the conduction of electricity.
- Since a hole is generated in the breaking of a bond to release an electron, the number of carrier electrons present in a semiconductor is equal to the number of holes.
- Therefore the semiconductor lattice is electrically neutral.

11.1.1 Intrinsic Semiconductors

Pure semiconductor materials such as silicon (Si) and germanium (Ge) that exist in crystaline form as mentioned above are known as **intrinsic semiconductors**.

• Effect of Temperature on the Conduction of Electricity

Since the random motion of free electrons increases as the temperature is increased, a rise in the temperature inhibits the current flow. Therefore, a temperature rise in conductors causes a decrease in the conductivity (increase in the resistivity). However in semiconductors, a rise in temperature breaks bonds generating more holes and free electrons causing an increase in the conductivity (decrease in the resistivity).

11.1.2 Extrinsic Semiconductors

Let us consider what happens when a minute amount of the element phosphorous (P) is mixed (doped) to an intrinsic semiconductor such as Si. Phosphorous is an element in group V of the periodic table and has five electrons in the outermost shell. A phosphorous atom makes the number of electrons in its outermost shell eight by acquiring four electrons from four nearby silicon atoms around it. In the process, one of the five electrons is left behind without taking part in forming a bond. This electron has the opportunity to move about freely in the lattice.

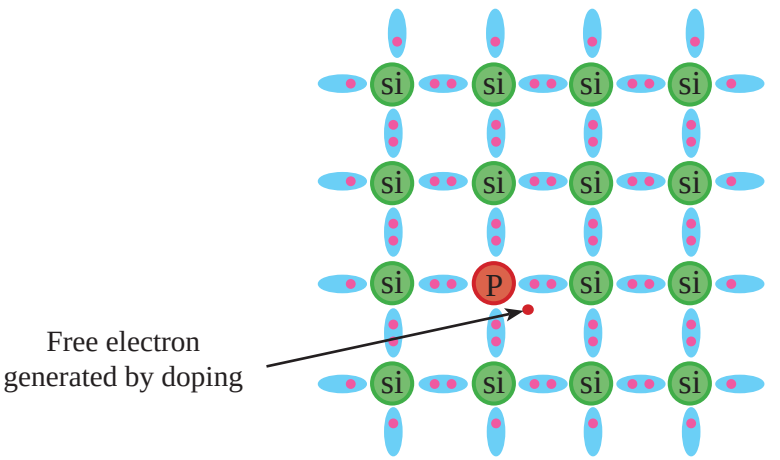


Figure 11.4 - A Si lattice doped by phosphorous

Figure 11.4 shows how a phosphorous atom forms bonds with silicon atoms. The electron left behind increases the conductivity of the lattice. Since negatively charged electrons are introduced to the lattice as charge carriers, the semiconductor is known as a negative type or n-type semiconductor. Semiconductors whose

carriers have been increased by doping it with another element are known as **extrinsic semiconductors**. By doping an intrinsic semiconductor with other elements in group V such as arsenic (As) and antimony (Sb) also, n-type extrinsic semiconductors can be formed. Since electrons are donated to the lattice by group V elements, they are known as **donor atoms**.

If Si which is an intrinsic semiconductor is doped with an element in group III such as boron (B), the boron atom forms bonds with nearby silicon atoms. However, since there are only three electrons in the outermost shell of the boron atom, there is a deficiency of one electron in order to form four bonds. Figure 11.5 shows how the atoms and bonds are configured in this case.

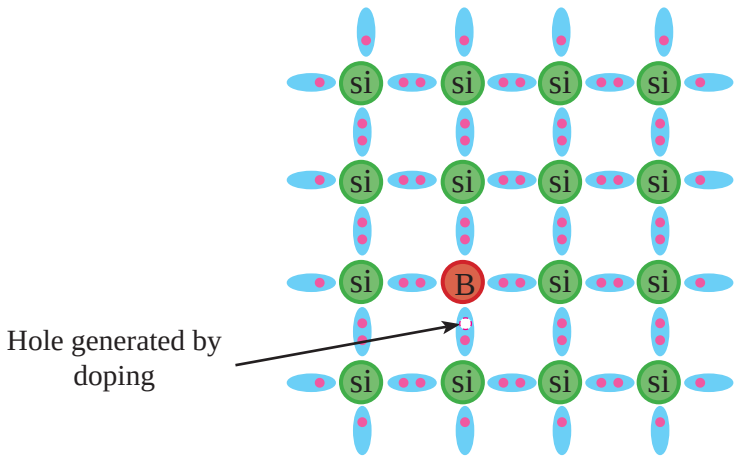


Figure 11.5 - A Si lattice doped by boron

A hole exists at the point where the electron is deficient in the boron atom to form a bond. Since holes can conduct electricity as positive charges, the conductivity of silicon increases. As a hole is equivalent to a positive charge, such extrinsic semiconductors are known as positive or p-type semiconductors. Because the hole concentration in p - type semiconductors is much greater than the electron concentration holes are called majority carriers and electrons are called minority curriers. By doping an intrinsic semiconductor with other elements in group III such as aluminium (Al), gallium (Ga) and indium (In) instead of B also p-type extrinsic semiconductors can be formed. Since holes that can receive electrons are produced by group III elements, they are known as **accepter atoms**.

11.2 p – n Junction

By doping one side of an intrinsic semiconductor such as silicon or germanium with a group III element to form a p-type semiconductor and the other side with a group V element to form an n-type semiconductor, a p-n junction can be formed at the centre of the semiconductor. Such a junction shows an electrical behaviour that is different from normal conductors.

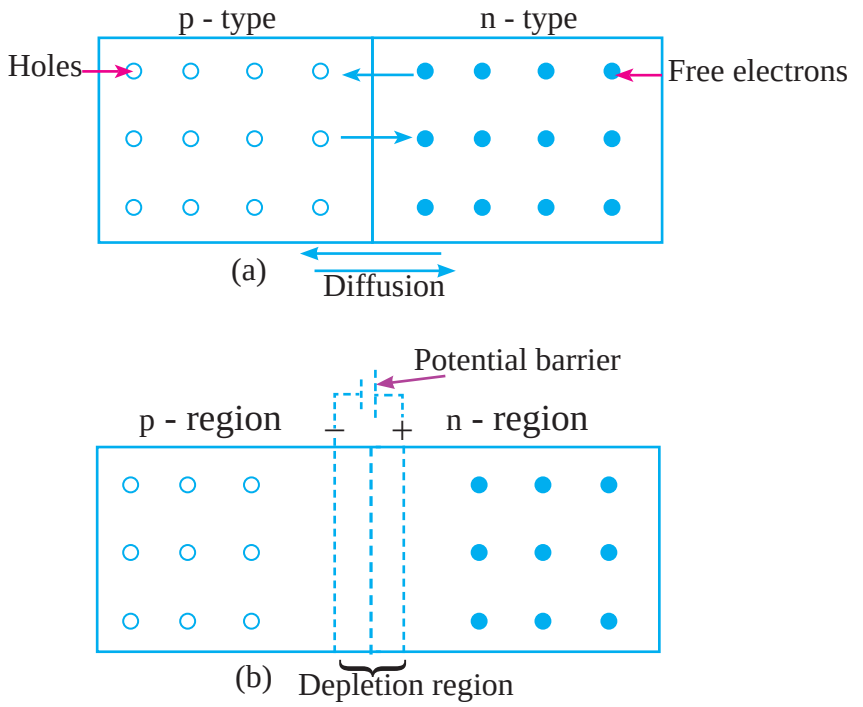


Figure 11.6 – p – n junction

As shown in Figure 11.6(a) as soon as the p–n junction is formed, the free electrons in the n-region diffuse across the junction towards the p-region and the holes in the p-region diffuse towards the n-region. Due to this diffusion, electrons and holes recombine forming a region devoid of charges near the junction. This region is known as the depletion layer or depletion region. As shown in Figure 11.6(b), extra electrons have entered the p-side of the depletion region giving it a negative charge while extra holes have entered the n-side of the depletion region giving it a positive charge generating a voltage difference across the junction. This potential difference repels the charge carriers impeding the diffusion of charge carriers across the junction. Therefore this potential difference is known as a "potential barrier". This potential barrier is represented in the above figure as a hypothetical battery.

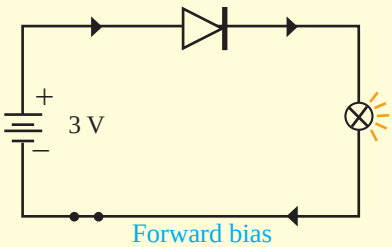
The magnitude of the potential barrier in a p-n junction formed by Si is about 0.7 V while that formed by Ge is about 0.3 V.

11.2.1 Biasing a p-n Junction

Applying a potential difference across the p-n junction using an external electric source is known as biasing. Depending on the direction of the bias voltage across the junction, it behaves in one of two ways. Let us engage in activity 11.1 to demonstrate this.

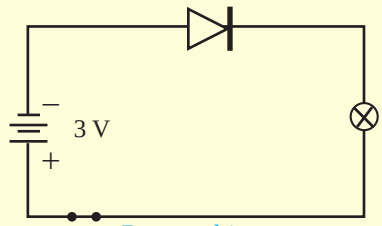
Activity 11.1

Apparatus required : IN 4001 diode, A 2.5 V torch bulb, Two 1.5 V dry cell batteries, A switch, A circuit board, Connecting wires



Forward bias

Figure 11.7(a)



Reverse bias

Figure 11.7(b)

- Connect the circuit on the circuit board (a project board/ bread board is better for this purpose) as shown in the Figure 11.7.
- Turn on the switch and observe the bulb.
- Next, disconnect only the battery and reconnect the battery as shown in Figure 11.8.
- Turn on the switch again. Observe the bulb.

Determine which of the above biasing methods allows a current to pass through the diode. You will observe that the bulb turns on only when the diode is connected as shown in Figure 11.7. According to this, you can use the junction diode when you need the current to flow only in a desired direction in a circuit.

For extra knowledge

- In order for the p-n junction to be forward biased and allow a current to pass through it, a positive potential should be connected to the anode and the potential difference applied should be sufficient to overcome the potential barrier across the junction. (For Si diodes this value should be greater than 0.7 V and for Ge diodes greater than 0.3 V).

• Reverse biased p-n junction

Let us consider what happens when a battery is connected to the junction with its negative terminal connected to the p-type semiconductor and its positive terminal connected to the n-type semiconductor.

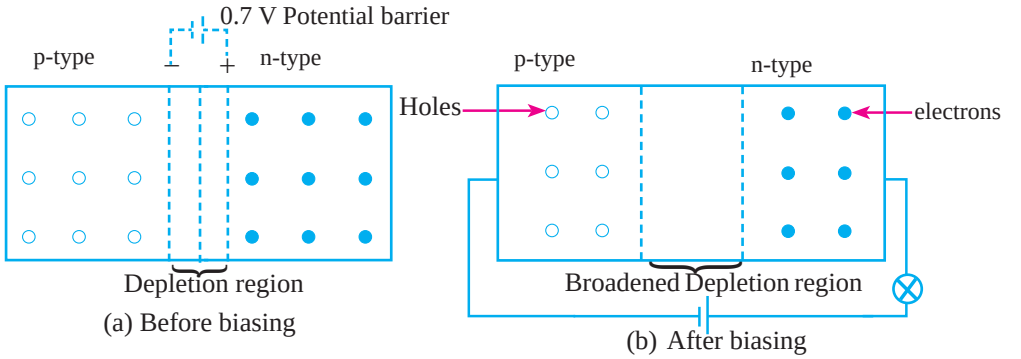


Figure 11.8 – Reverse biased p-n junction

In this case, the free electrons in the n-region are attracted towards the positive potential while the holes are attracted towards the negative potential, broadening the depletion layer. There is no carrier (charge) flow across the junction. Only the depletion region broadens depending on the potential difference of the external source. Since there is no charge flow, connecting the external potential in this manner is known as **reverse bias**. Figure 11.8(a) and (b) shows how the depletion layer behaves when it is reverse biased.

• Forward biased p-n junction

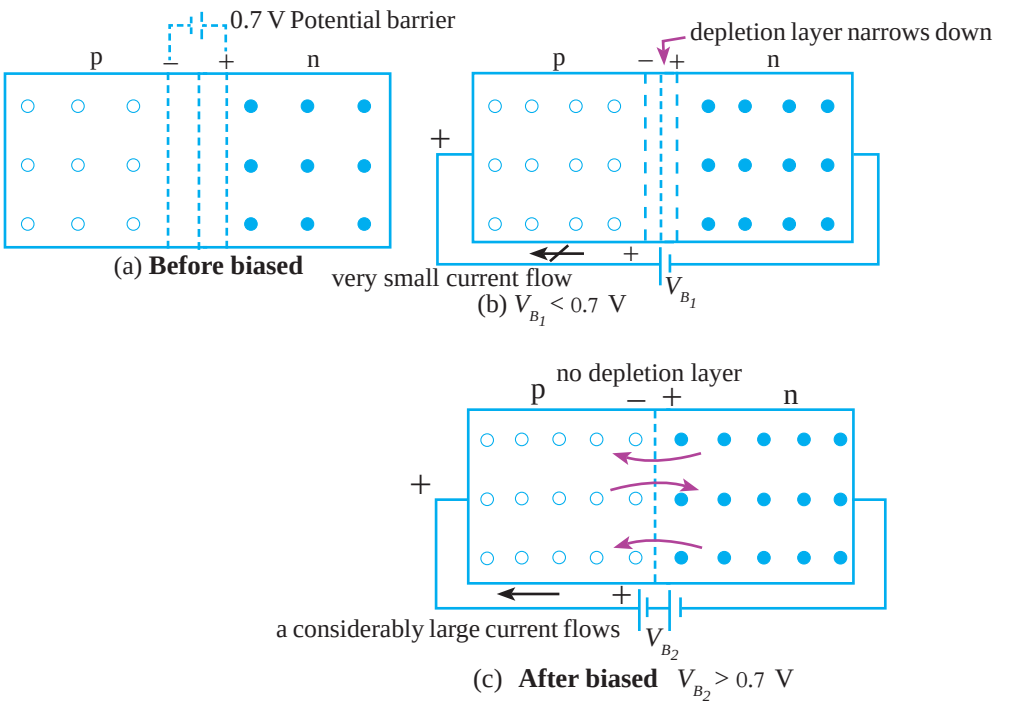


Figure 11.9 – Forward biasing of a p-n junction

In this case the external potential source is connected with the positive potential connected to the p-region and the negative potential connected to the n-region. While the holes in the p-region are repelled by the positive potential towards the junction, electrons in the n-region are repelled by the negative potential towards the junction. The depletion region narrows down due to this and if the externally supplied potential difference exceeds the potential barrier across the junction, carriers flow across the junction. When a high potential than 0.7 V is applied depletion layer is very small and a current is flowing through the p-n junction. Then a current flows across the junction. Therefore, connecting the external voltage in this manner is known as **forward basing**.

11.3 p-n Junction Diode

Now you know that a current flows across a p-n junction only if it is forward biased in the manner described above. A component consisting only of such a p-n junction is known as a junction diode. The arrangement of p and n semiconductors inside a junction diode is illustrated in Figure 11.10(a) and the symbol used for a diode is shown in Figure 11.10(b). Terminal A is known as the anode and terminal K is known as the cathode. Electricity is conducted through the junction only when the anode A is connected to the positive terminal of an external voltage supply and the direction of current through the junction is shown with an arrow head in Figure 11.10(c).

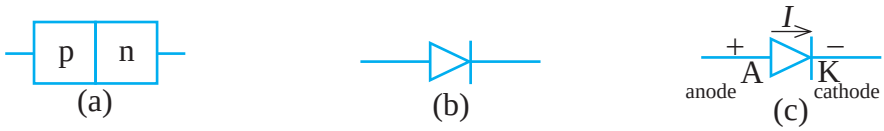


Figure 11.10 – Junction diode

Figure 11.11 - General outward appearance of a junction diode

The general outward appearance of a junction diode is shown in Figure 11.11. It has a cylindrical shape and a black color. The white or silver colored ring shows the terminal of the cathode. There are large numbers of various different types of diodes and a number is printed on the cylinder in order to identify them. But it should be remembered that the external appearance of a diode can vary widely.

11.4 Rectification of Alternating Currents

We know that an alternating current is a current that alternates or changes its direction of flow in a circuit. A direct current is a current that flows only in one

direction. The variation of the current or the voltage with time for direct currents and alternating currents are shown in Figure 11.12. Usually, dynamos produce electricity as alternating currents. However, for operating some electronic devices, direct currents are required. Junction diodes that allow the current to flow in one direction can be used for converting an alternating current to a direct current. The task of converting an alternating current into a direct current that flows only in one direction is known as "**rectification**".

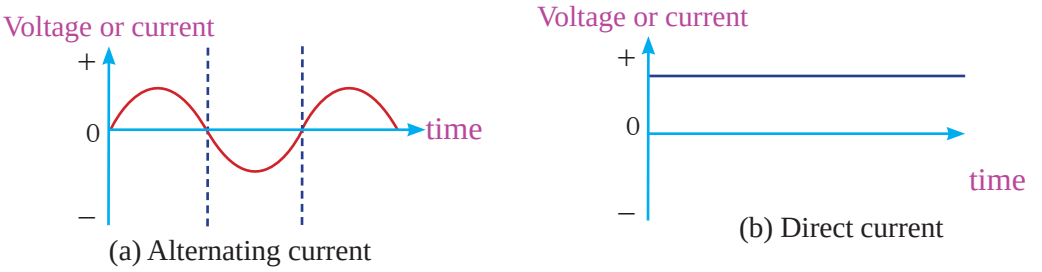


Figure 11.12 – Graphical representation of alternating and direct currents

11.4.1 Half Wave Rectification

Figure 11.13 shows a circuit used for half wave rectification. The main power supply is used to obtain the alternating current.

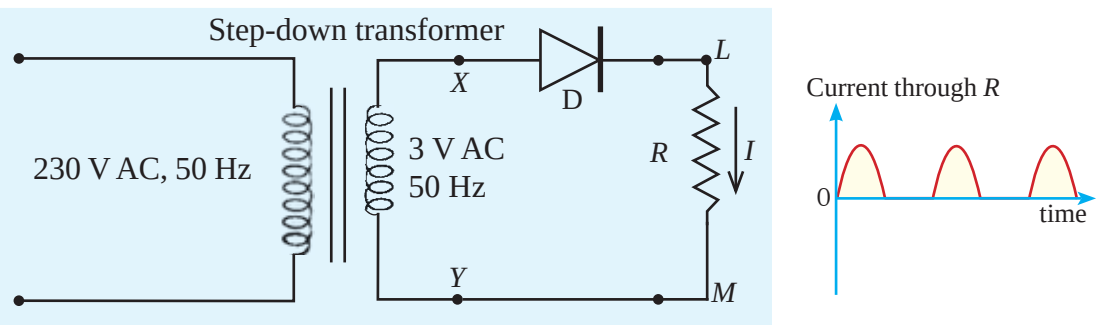


Figure 11.13 – Half wave rectification

First the voltage is lowered to a desired value using the step-down transformer. The lowered alternating potential difference is obtained from the *X*, *Y* terminals of the transformer.

Since the current flow through the diode takes place only in the direction *XL*, the current through the resistance *R* flows only during the positive half cycle of the alternating current. During the negative half cycle, the current through the resistance is zero (Compare this with the way the diode behaved when the batteries were connected in activity 11.1).

Since the output always consists only of half a cycle of the current, this is known as **half wave rectification**.

Exercise 11.1

Plot the current obtained through *R* when only the terminals of the diode in figure 11.13 are changed (so that *X* is connected to the cathode) while all other parts of the circuit remain intact.

11.4.2 Full Wave Rectification

Activity 11.2

Apparatus required : A bicycle dynamo or an alternating current generator available in the laboratory, Four 1N 4001 diodes, A centre zero galvanometer, A 100 Ω rheostat, Lead solder and a soldering iron, Connecting wires

- Solder the four diodes in the form of a bridge so that the anodes and cathodes are correctly connected.
- Connect the rheostat and the centre zero galvanometer as shown in the figure.
- Now connect the terminals of the bicycle dynamo or the alternating power source to the terminals *X* and *Y* and rotate the generator slowly.

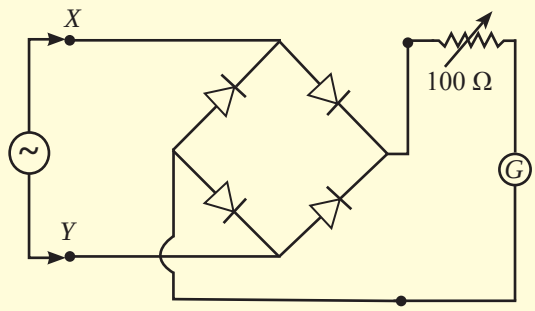


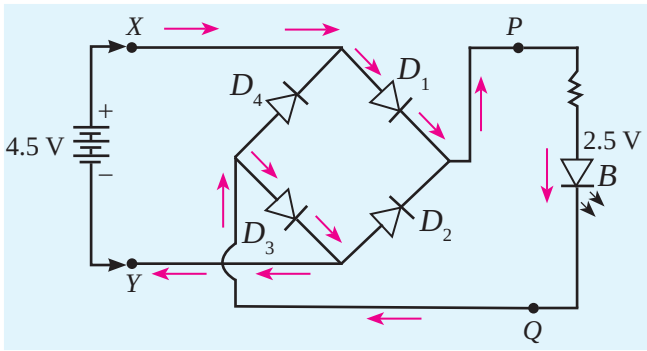
Figure 11.14

- Observe the deflection of the galvanometer. If the deflection is too large adjust the rheostat to lower it.

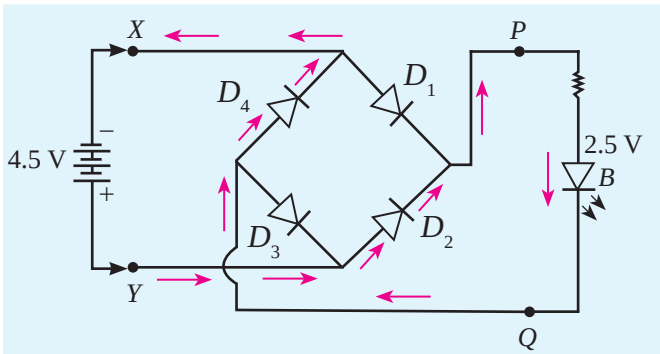
In this activity, you will observe that the deflection in the galvanometers is only in one direction. That means that the current has been converted to a direct current.

If four diodes are used in the form of a bridge in an appropriate manner and an alternating current is passed through it instead of the single diode used earlier, both half cycles of the alternating current can be made to flow in the same direction. Figure 11.15 illustrates such a bridge circuit.

When a 4.5 V battery and a LED bulb is connected as shown in Figure 11.15(a) the bulb lights up with its normal brightness. Here, the LED is used on a lamp that is turned on when the current is flowing in one direction only. When point *X* is positive relative to point *Y*, diodes D_2 and D_4 are reverse biased while diodes D_1 and D_3 are forward biased. Then the current flowing through D_1 passes through the bulb and reaches the negative terminal of the battery after passing through diode D_3.



(a)



(b)

Figure 11.15 - bridge circuit

Now if the circuit is reconnected with the negative terminal of the battery connected to point *X* and the positive terminal connected to point *Y* as shown in Figure 11.15 (b), the bulb would light up with the same brightness. In this case, the diodes D_2 and D_4 are forward biased and D_1 and D_3 are reverse biased. Therefore the current coming from the positive terminal of the battery passes through diode D_2, the bulb and diode D_4 and flows to the negative terminal of the battery. In both cases, the current through the bulb flows in the same direction.

For extra knowledge

In figure 11.15, a 4.5 V battery is used to light a 2.5 V bulb because the current in each case flows through two diodes producing a $2 \times 0.7 = 1.4$ V voltage drop. Due to this drop across the diodes, the available voltage for the bulb is $4.5 - 1.4 = 3.1$ V. If a 3V battery is used instead of the 4.5 V battery, the remaining voltage of 3 - 1.4 = 1.6 V will not be sufficient to light the bulb.

Now if an alternating voltage is connected to the circuit in place of the battery, the current flows through the bulb in the same direction (from *P* to *Q*).

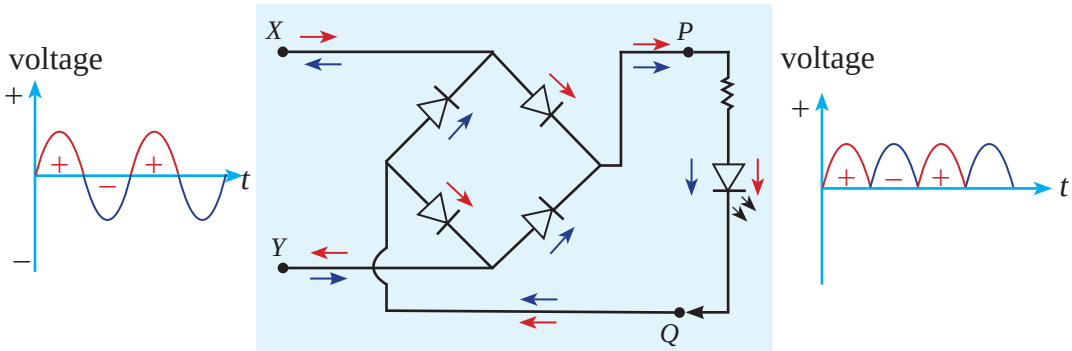


Figure 11.16 – Full wave rectification using a bridge circuit

Figure 11.16 shows the direction of current flow through the diodes in the two half cycles, positive and negative of the input. Since both cycles of the alternating current through the bulb is made to flow in the same direction in the output, this process is known as **full wave rectification**.

Exercise 11.2

Explain the reasons for your observations on the galvanometer in the two instances in activity 11.2 and show the variations of the current with time graphically for the two cases.

11.4.3 Smoothing

A half wave or full wave rectification circuit gives out a current flowing in one direction. However its magnitude (voltage or current) varies between zero and a maximum value.

Time variations of the voltage outputs from a battery, the half wave rectified output and the full wave rectified output from an alternating current are shown in Figure 11.17. For the operation of most electronic devices, a constant voltage similar to that obtained from a battery or a constant direct current is more suitable.

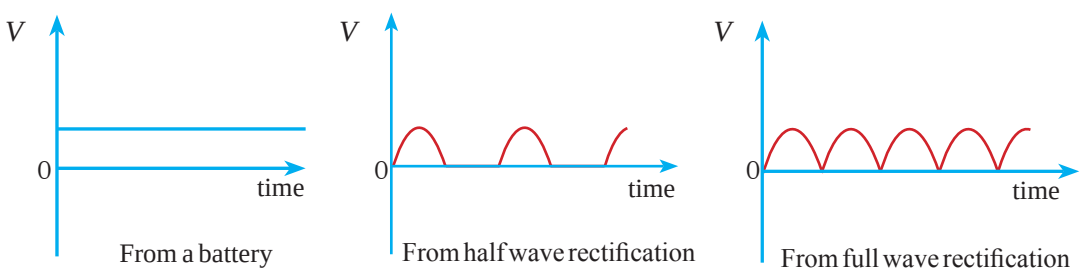
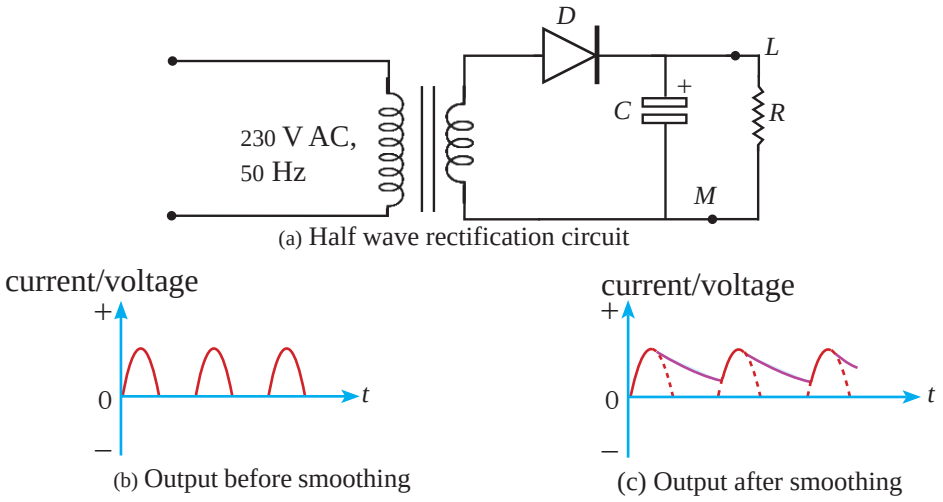


Figure 11.17 – Difference between voltage outputs from a battery and rectification

By connecting a capacitor with a large capacitance in parallel to the output terminals of the rectifier circuit, the variation in rectified voltage can be reduced. This process is known as **smoothing**. Figure 11.18 shows the output of a half wave rectified after smoothing it using a capacitor. Rectifier circuit is shown in the figure (a) and output without the capacitor is shown in (b). The figure (c) shows the output with the capacitor.



(a) Half wave rectification circuit

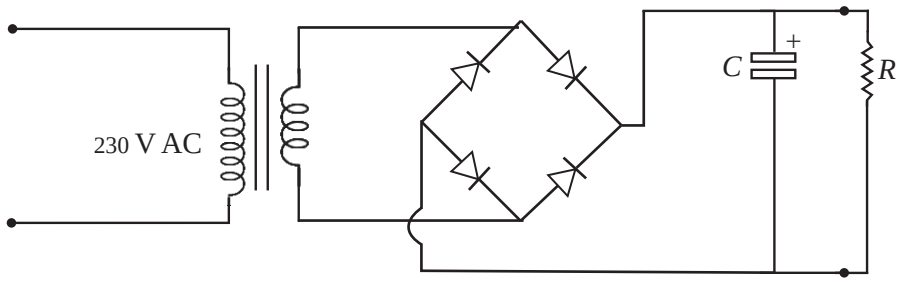
(b) Output before smoothing

(c) Output after smoothing

Figure 11.18 – Smoothing of a half wave rectified

When the voltage supplied by the diode gradually increases from zero, the capacitor gets charged. When the voltage drops back after reaching a maximum value, the charge stored in the capacitor is released. Therefore despite the voltage supplied through the diode being zero, the voltage across the capacitor does not drop down to zero although a small reduction takes place. In addition, because the current across the diode is always in one direction only, the discharge current of the capacitor does not flow through the diode. The time variation of the smoothed output voltage is shown in Figure 11.18(c).

The output from full wave rectification too can be smoothed in the same manner. Figure 11.19 shows the circuit diagram and the time variation of the output voltage for such a rectification.



(a) Circuit diagram of full wave rectification

(b) Before smoothing (without capacitor) **(c) After smoothingq (with capacitor)**

Figure 11.19 – Smoothing of a full wave rectification output

Here the current is even smoother than in a half wave rectification. Capacitors with large capacitances such as 1000 μF, 2000 μF are used for smoothing. Smoothing becomes better with increasing capacitance.

- **Use of a diode in order to prevent the damage caused to a direct current appliance by supplying power with inverted terminals**

A rectifier diode can be used to prevent the damage caused to a direct current appliance by supplying power from the positive and negative terminals incorrectly connected.

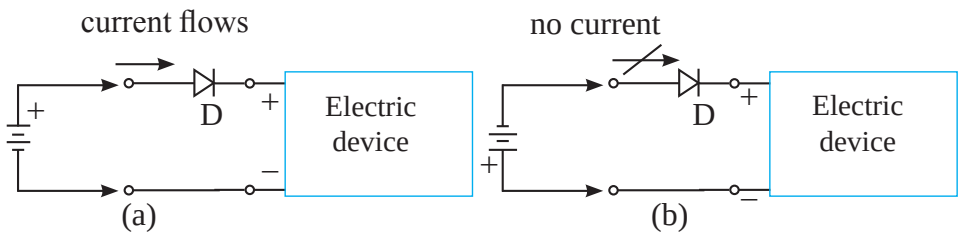


Figure 11.20 - Protecting a device from damage due to incorrectly connected terminals

Figure 11.20(a) shows the circuit with a diode as a circuit protector and the battery connected correctly. Figure 11.20(b) shows the circuit with the battery connected incorrectly. Since the diode is reverse biased in this case there is no current passing through the device. Therefore no damage is caused to the device and it operates only if it is correctly connected to the battery.

For extra knowledge

Try to construct a bridge type rectifier circuit that supplies the voltage correctly to an electronic appliance regardless of how the battery is connected to the circuit.

11.4.5 Light Emitting Diode (LED)

When a p-n junction formed with a semiconductor material such as gallium arsenide (GaAs) is forward biased, light is emitted at the junction. Such diodes that are capable of emitting light are known as **light emitting diodes (LED)**.

Figure 11.21

Various types of diodes are available in the market and Figure 11.22 shows the outward appearance, the symbol and how to identify the terminals of one of the most popular types, the 5 mm LED. The longer terminal of a diode is its anode. Similarly, if the base of the LED is pointed towards us, the terminal near the cut is its cathode. There are also LED's that emit red, yellow, green, blue colors as well as infrared (IR) and ultraviolet (UV) rays in the market.

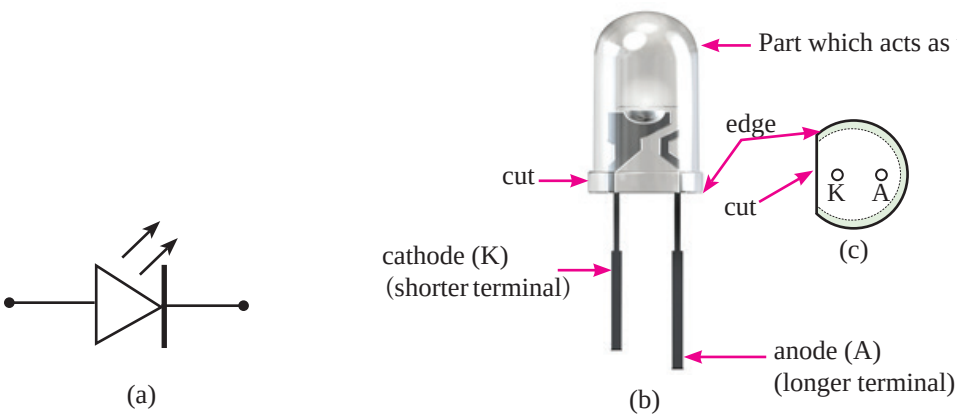


Figure 11.22 – (a) The symbol (b) Outward appearance of a light emitting diode (c) Base diagram cathode (-) is situated at the side with the cut

In the early stages light emitting diodes were mostly used as indicators. At present, light emitting diodes are also used in the construction of large television screens. With the invention of white light LED's, their use is becoming increasingly popular for lighting up homes, streets and in the construction of torches. The very low power consumption, and the long life times of about 50,000 hours are the reasons for the wide usage of light emitting diodes.

For extra knowledge

- Minimum potential required for colour LEDs vary. Minimum potential required for some of them are given below. Current flowing through these is 10 – 20 mA.

Colour	Semiconductor material	Minimum bias voltage
Red	Ga As	1.8 V
Orange	Ga As P	2 V
yellow	Al In Ga P	1.8 V
Green	Ga P	2.2 V
Blue	Ga N	5 V

- Only one colour is given by a LED. The cover is coloured to make it possible to identify its colour when it is not lighted.
- When the current passing through a light emitting diode is increased its brightness also increases. However, the life time decreases with brightness.

11.4.6 Solar Cells

Solar cells are also constructed using p-n junctions. Therefore solar cells are also diodes. They are constructed in such a manner so as to allow light to fall on the junction. When sunlight is incident on these silicon p-n junctions, a small electro motive force (voltage) is generated across the junction. Since such a p-n junction can be used as a source of an electro motive force, they are known as **solar cells**.

By arranging a number of such cells in series and parallel, voltages such as 12 V or 15 V with large currents can be obtained. Such an arrangement is known as a **solar panel**.

Originally such solar panels were developed for the use satellites. They were used instead of batteries to generate electricity. Their cost at that time was very high. Since they can now be produced at a low cost with the development of technology, solar panels are used to light up homes at present.

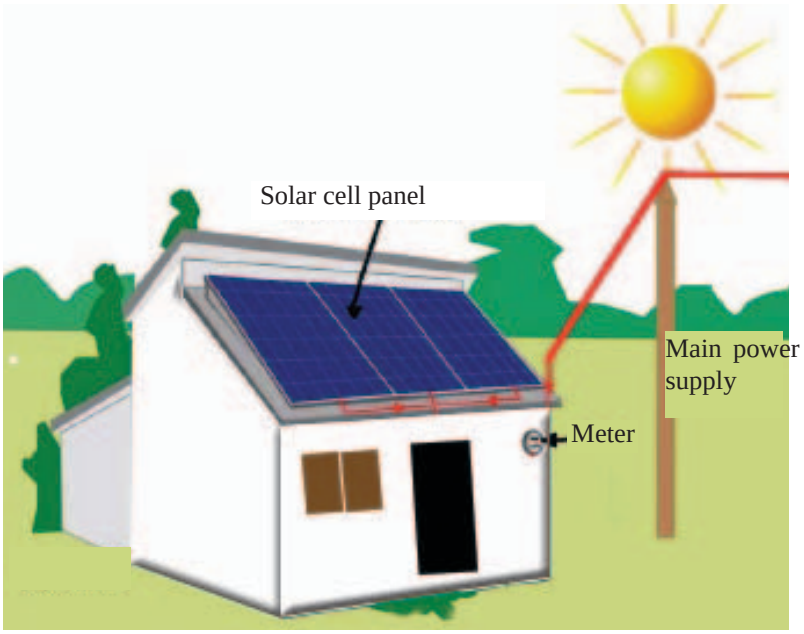


Figure 11.23 - A house with solar panels connected to the mains power supply

Solar cells are considered to be a solution to the future power and energy crisis as they operate with the solar radiation we receive at no cost, as they do not emit any substance that is harmful to the environment and as they have a long lifetime (the solar cells produced initially are still in operation).

Solar cells are presently used to operate clocks and calculators and they are also used in solar powered motor vehicles.

11.5 Transistors

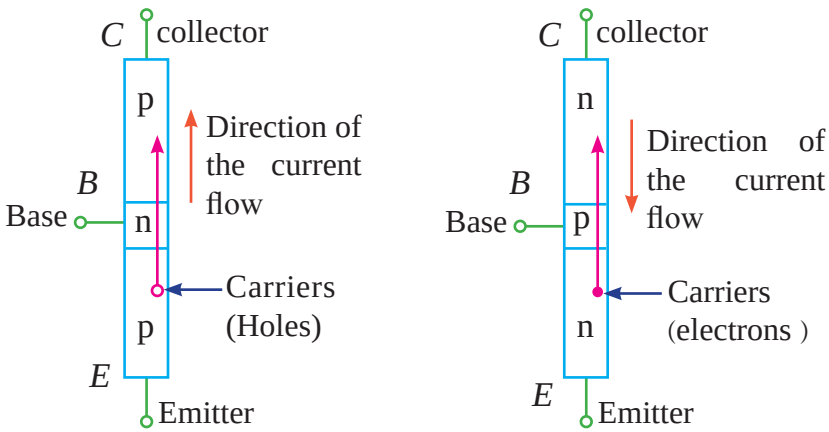
The transistor which is responsible for vast developments in electronics is constructed using two p-n junctions. Three semiconductor regions of type p and n are connected together to form a transistor. There are only two ways in which the three semiconductor regions can be connected in order to form two p-n junctions. Figure 11.24 shows these two ways. They are known as npn and pnp transistors

(a) (b)

Figure 11.24 – (a) structure of pnp transistor (b) structure of npn transistor

Three terminals, one from each of the three semiconductor regions protrude from the transistor. When the transistor is operating, carriers (electrons or holes) are emitted from one of the semiconductor regions at the two ends while the other one collects the carriers. Therefore, the two terminals at the ends are known as the **emitter** and the **collector**. The terminal at the middle can control the carriers flowing from the emitter to the collector and it is known as the **base**.

In figures, the three first letters of the three words *E*, *C* and *B* are used to indicate the respective terminals. Structure of a transistor direction of carries and the direction of current are shown in the figure 11.25(a). The standard symbols used to represent transistors are given in the figure 11.25(b)



(a) Layout of semiconductors

(b) Standard symbols

Figure 11.25 - Layout of semiconductors and symbols of transistors

- An arrow head is used to identify the emitter (*E*).
- The arrow head indicates the direction of current flow from the emitter to the collector of the transistor.

For extra knowledge

- Carriers always flow from the emitter to the collector.
- Since the carriers of a p-type semiconductor are holes (corresponding to a + charge) the current flow in a pnp transistor is from the emitter to the collector (arrow head towards the interior).
- Since the carriers of an n-type semiconductor are electrons, the current flow in an npn transistor is from the collector to the emitter (arrow head towards the exterior).

When using a transistor in a circuit, appropriate voltages must be provided to the terminals. This is known as **biasing a transistor**. The emitter – base junction should be forward biased while the base collector junction should be reverse biased with a higher voltage.

For this a voltage should be supplied to the terminals *C* and *E* in the direction of current shown by the arrow head.

Accordingly, in a npn transistor, *C* should be connected to the positive (+) terminal and *E* should the connected to the negative (–) terminal because current always flow from positive to negative. In a pnp transistor *E* should be connected to the positive terminal while the *C* should be connected to the negative (–) terminal. *B* should be supplied a potential difference in the same direction as *C* but with a smaller magnitude. Then, the base (B) - collector (C) junction becomes reverse biased.

For extra knowledge

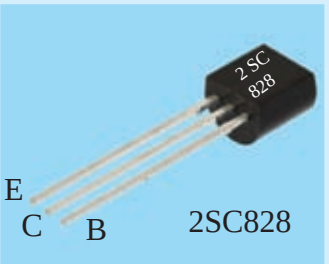
- In all the circuits we discuss in the ordinary level syllabus, we use only npn transistors.

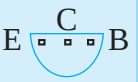
There are a large number of various types of transistors in the market and they are constructed with various different outward appearances. In order to identify these transistors they are coded with numbers.

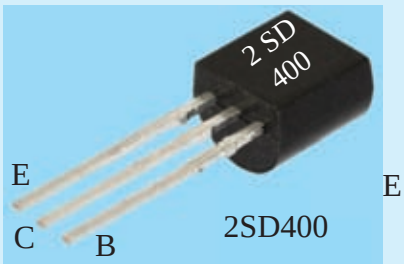
Example – 2SC828 (C828), 2SD400 (D400), 2SC1061 (C1061), 2SD313 (D313)

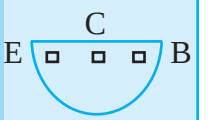
For extra knowledge

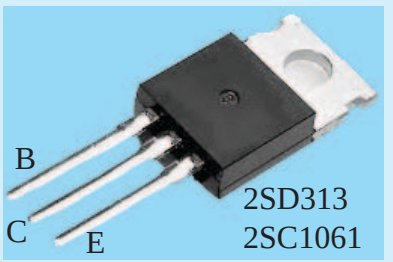
There is no common or standard method of identifing the terminals of a transistor by viewing it externally. Some transistors used in the experiments of the ordinary level syllabus are shown below.











(All these are silicon npn transistors).

As given in data books, when we turn the terminals towards ourselves and view the transistor, the terminals can be identified as shown above (two dimensional figure).

11.5.1 Amplifying Process of a Transistor

- **Current Amplifier**

Basically a transistor is used as a current amplifier. When a small (DC) current is supplied as the input of a current amplifying transistor circuit, a large current can be obtained as the output of the amplifier.

Activity 11.3

Apparatus required : A 2SD400 (D400) transistor, Two 2.5 V torch bulbs, Two 3 V battery covers, six 1.5 V dry cells, Two switches (button switches are more suitable), A 10 kΩ volume controller, A circuit board

- Construct the circuit given in the figure on the circuit board.
- Attach a pair of dry cells to each of the battery covers before connecting them to the circuit. Terminals of the volume controller (variable resistance) and the transistor are indicated in the circuit.

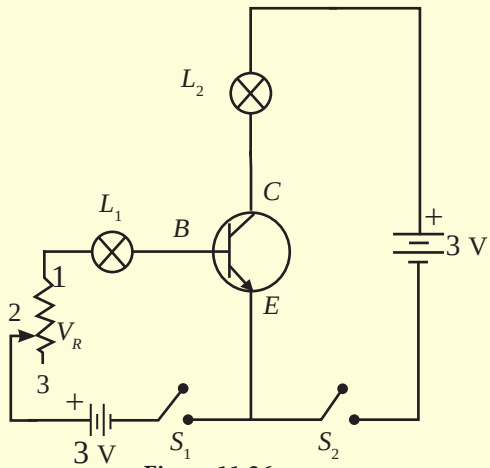


Figure 11.26

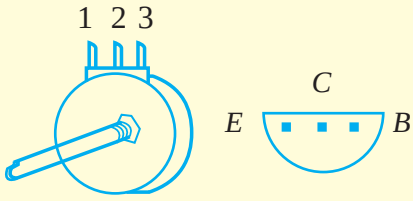


Figure 11.27

Switch S_1, the 3 V battery, the volume controller V_R, and the bulb L_1 are in the input circuit while the second 6 V battery, switch S_2, and the bulb L_2 are in the output circuit. The batteries should be correctly connected while the switches S_1 and S_2 are in the off positions.

- First turn S_1 on (close) and adjust the resistance of V_R until the bulb L_1 just begins to light up. Now turn off (open) switch S_1.
- Open and close the switches S_1 and S_2 as indicated in the table below and observe the brightness of the bulbs and fill in the table.

S_1	S_2	Bulb L_1		Bulb L_2	
		Lighting up	Brightness	Lighting up	Brightness
off	off	×	–	×	–
on	off	✓	less	×	–
off	on				
on	on				

(In order to clarify how to record your observations in the table, the first and second columns have been filled with the expected observations). You may assume that the

current flow is small if the brightness of the bulbs are low and that the current flow is large if the brightness of the bulbs are high.

We can draw the following conclusions from the activity above.

- A current flows in the output circuit only when a current flows in the input circuit.
- Even when a voltage is given to the output circuit, a current does not flow in the output circuit unless there is a current flowing in the input circuit.
- When a small current flows in the input (when L_1 lights up with a low brightness) a large current flows in the output (L_2 lights up with a higher brightness). (The input current is known as the base current I_B and the output current is known as the collector current I_C).
- A small current I_B in the input can be amplified into a large current I_C in the output using a transistor. This is the process known as current amplification.

• Signal Amplifier

The transistor is frequently used not only as a current amplifier but also as a signal amplifier. How a transistor can be used to amplify an audio frequency signal is illustrated in the activity 11.4.

Activity 11.4

Apparatus required : A 2SD400 transistor, A 22 kΩ carbon resistor, A 8Ω speaker, A 0.1 µF capacitor, A 3 V battery cover, Two 1.5 V dry cells, A circuit board and connecting wires, Audio frequency generator (found in the laboratory)

- Construct the circuit shown in the figure on the circuit board.
- First connect only the AF signal generator to the speaker and adjust the output so that a sound could be just heard.
- Connect a small signal from an audio frequency (AF) signal generator to the points *A* and *B*.
- Now you will hear an amplified output of the sound generated by the audio frequency generator.
- 0.1 µF capacitor has been connected to give only the alternating signal to the base. Base needs a forward biasing voltage of 0.7 V. This is supplied through the 22 kΩ resistor.

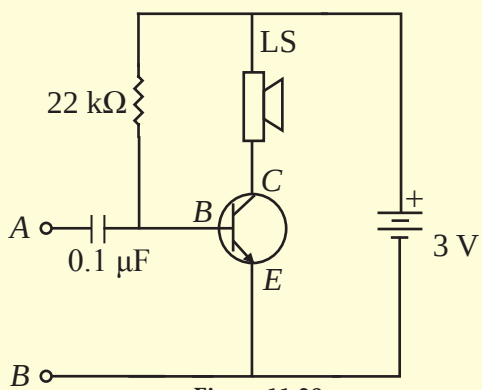
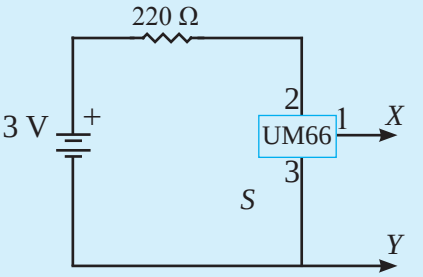


Figure 11.28

For extra knowledge

Apparatus required : A UM66 integrated circuit, 220 Ω carbon resistor, A 3 V battery cover, Two 1.5V dry cells, A circuit board and connecting wires

A circuit that can produce a "musical" audio frequency wave using an integrated circuit is shown below. This circuit can be constructed on the circuit board to produce a signal for the audio frequency amplifier above.



1 - signal
2 - positive supply
3 - negative supply

The signal can be given to the amplifier by connecting the X, Y terminals to the points A and B of the amplifier circuit.

11.5.2 Switching action of a transistor

Instead of a mechanical switch, the transistor can be used as an electronic switch that operates according to a certain sensation.

In electronics, when digital circuits are constructed, the transistor is often used as a switch.

Activity 11.5

Apparatus required : A 2SD313 transistor, A multimeter, A 2.5 V bulb, A 3 V battery cover, Two 1.5 dry cells, A 10 kΩ volume controller (V_R), A 10 kΩ resistor, A circuit board, A switch (S)

- Construct the above circuit on the circuit board. Rotate the volume controller to the extreme right so as to have the minimum resistance.
- Connect batteries while keeping switch *S* in the off position.
- Select the multimeter range 2.5 V (DC) and connect it between the base and emitter of the transistor. (Its positive probe must be connected to the base.)

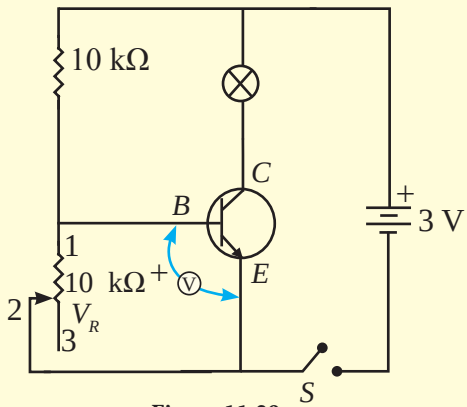


Figure 11.29

- Now open switch S. Observe the voltmeter reading and the lighting up and brightness of the bulb.
- Turn the volume controller gradually to the left so as to increase the resistance while observing the voltmeter reading and the bulb.
- Observe that the bulb begins to light up when the voltmeter reading is about 0.7 V and the bulb has the maximum brightness when the voltage is about 0.8 V.

We can draw the following conclusions from the above activity.

- When the voltage difference between the emitter and the base is less than 0.7 V, there is no collector current Ic.
- When the voltage difference between the emitter and the base is about 0.7 V, the collector current begins to flow.
- When the voltage difference between the emitter and the base exceeds 0.7 V, (about 0.8 V), the collector current reaches a maximum.
- Therefore, when the voltage difference between *B*-*E* terminals is less than 0.7 V, the transistor acts as an open switch (off) and the voltage difference between the *B*-*E* terminals exceeds 0.7 V, it acts as a closed switch (on).

Let us engage in activity 11.6 to demonstrate how to design a switch circuit that automatically lights up when darkness falls using the above principle.

Here we will use a light dependent resistor (LDR) as the light sensor. When light is incident on its front surface, its resistance becomes very low (of the order of 1 Ω) while in the dark it has a very high resistance (of the order of 100 kΩ).

Activity 11.6

Apparatus required : A D400 transistor, An LDR, A 10 kΩ volume controller (V_R), A 2.5 V bulb, A 3 V battery cover, Circuit board and connecting wires

- Cover the top surface of the LDR (from light) with your finger tip and adjust the resistance of the V_R until the bulb lights up.
- Remove your finger tip and allow light to fall on the LDR.

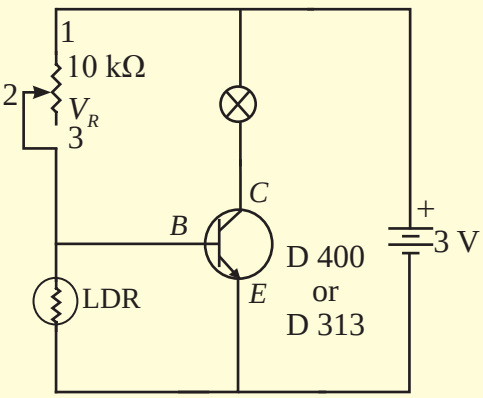
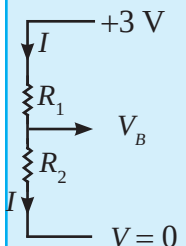


Figure 11.30

Then the light will go out (Adjust the V_R until the bulb lights up upon reducing the amount of incident light).

For extra knowledge

- In the activity 11.6, the V_R acts as a variable resistor and the LDR as a potential divider. (In the activity 11.5, 10 kΩ resistor and 10 kΩ variable resistor).
- The total potential drop across the two resistors is 3 V.



$V = IR$ from Ohm's law

$3 = I\,(R_1 + R_2)$

$\therefore I = \dfrac{3}{R_1 + R_2}$

If the potential at B is V_B, the potential difference across R_2 is V_B,

$V_B = R_2 I$

$V_B = R_2 \times \dfrac{3}{R_1 + R_2}$

- By keeping R_1 constant and varying R_2, any potential from 0 to 3 V can be given to that point.
- If $R = 10$ kΩ, the value of R_2 in order that $V = 0.7$ V:

$$0.7 = \frac{3 \times R_2}{10{,}000 + R_2}$$

$$7000 + 0.7\,R_2 = 3 \times R_2$$

$$7000 = 3 \times R_2 - 0.7\,R_2 = 2.3\,R_2$$

$$\therefore R_2 = \frac{7000}{2.3} = 3043\ \Omega$$

Therefore when R_2 is 3043 Ω, the potential at B becomes 0.7 V.

- When the resistance of the LDR increases upto 3043 Ω by decreasing the light incident on it, the bulb dimly lights up and when the light is further decreased, the potential increases upto 0.7 V and the current I_c increases to a maximum (Switch opens).

Summary

- The charge carriers that conduct electricity in metallic conductors are the negatively charged electrons.
- In semiconductors, both electrons and holes (corresponding to a positive charge) act as carriers that conduct electricity.
- Since a hole is formed in a semiconductor when a bond breaks releasing an electron, the number of free carrier electrons in the semiconductor is equal the number of holes in it.
- Therefore when a potential difference is applied across a semiconductor, holes move from the positive to the negative potential while the electrons move from the negative to the positive potential and the (standard) current flows from the positive to the negative potential.
- An n-type extrinsic semiconductor can be formed by doping an intrinsic semiconductor with a group V element.
- A p-type extrinsic semiconductor can be formed by doping an intrinsic semiconductor with a group III element.
- When an external potential difference is applied across a p-n junction so as to make the p region negative, the depletion region broadens and no current flows across the junction. This is known as "reverse bias".
- When an external potential difference is applied across a p-n junction so as to make the p region positive, the depletion region thins down if the external potential difference is sufficiently large to mate the potential barrier, then a current flows across the junction. This is known as "forward bias".
- Diodes can be used for the rectification of an alternating current.
- The potential barrier across a p-n junction for a Si junction is about 0.7 V and for a Ge junction about 0.3 V.
- Since charge carriers in a p-type semiconductor are holes (corresponding to a positive charge), in a pnp transistor, the current flows from the emitter to the collector (inward arrow head).
- Since charge carriers in a n-type semiconductor are electrons, in a npn transistor, the current flows from the collector to the emitter (outward arrow head).
- Always, carriers flow from the emitter to the collector.
- A transistor can be used as a simple current amplifier, signal (ac) amplifier and a switch.

Exercise 11.1

(1) (i) Explain briefly, how metals and semiconductors conduct electricity.
(ii) How does the increase of temperature affects the conduction of electricity?

(2) (i) A LED is not lighted up by one dry cell, but it is lighted when two dry cells are used. Explain why.
(ii) Give examples for three instances where we use LEDs in day to day life.
(iii) The use of LEDs which give white light, instead of filament bulls is increasing now. Give reasons for this.

(3) It has been stated in the activity, 11.6 that a transistor can be used as a switch to light a bull in the dark. A student plans to modify the above circuit to open the garage door automatically when the head lights of a car falls on it.

Design a circuit for building a small model of this system for the school exhibition. Draw the circuit and Name all the components. The student hopes to use a 3 V motor to open the door. And also, indicate to which place that this motor is connected.

(4) The following figure shows a circuit made to study about the rectifier bridge in a school exhibition. All the diodes need in the circuit are 1.8V LEDs.

(i) Which LEDs are lighted – up, when a 6 V battery is connected to the terminal X and Y?

(ii) Mark the direction of current drawing arrows near the LEDs.

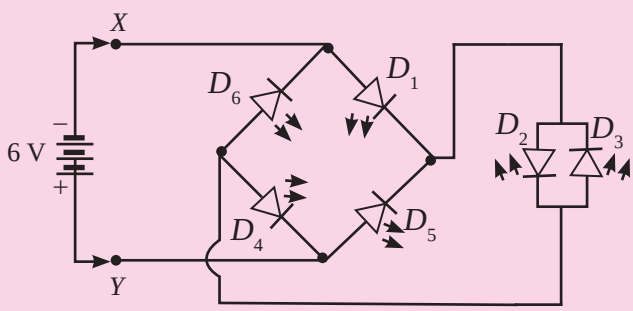


Figure 11.31

(iii) What will happen if the battery is connected to X and Y in the opposite direction?

(iv) What would happen if a 3 V battery is used to supply current instead of a 6 V battery? Give reasons for the above.

Technical terms

Semiconductors	- අර්ධ සන්නායක	- குறை கடத்திகள்
Intrinsic Semiconductors	- නිසග අර්ධ සන්නායක	- உள்ளீட்டு
Extrinsic Semiconductors	- බාහ්‍ය අර්ධ සන්නායක	- வெளியீட்டு
Charge carriers	- ආරෝපණ වාහක	- ஏற்றக்காவிகள்
Holes	- කුහර	- துளை
Doping	- මාත්‍රණය	- மாசூட்டல்
Donor atom	- දායක පරමාණුව	- தாளி அணு
Acceptor atom	- ප්‍රතිග්‍රාහක පරමාණුව	- ஏற்பான் அணு
Depletion layer	- හායිත පෙදෙස (හීන ස්ථරය)	- வறிதாக்கல் பகுதி
Rectifier diode	- ඍජුකාරක ඩයෝඩය	- சீராக்கும் இருவாயி
Bridge Rectifier	- ඍජුකාරක සේතුව	- பால சீராக்கம்
Light Emitting Diode	- ආලෝක විමෝචක ඩයෝඩය	- ஒளிகாலும் இருவாயி
Transistor	- ට්‍රාන්සිස්ටරය	- திரான்சிற்றர்
Collector	- සංග්‍රාහකය	- சேகரிப்பான்
Emitter	- විමෝචකය	- காவி
Base	- පාදම	- அடி
Current amplifier	- ධාරා වර්ධකය	- ஓட்ட விரியலாக்கி
Signal amplifier	- සංඥා වර්ධකය	- அறிகுறி விரியலாக்கி
Forward bias	- පෙර නැඹුරුව	- முன்முககோடல்
Reverse bias	- පසු නැඹුරුව	- பின்முக கோடல்

Electrochemistry

Chemistry 12

12.1 Electrochemical cells

In our everyday life, we frequently use equipment powered by domestic electricity as well as appliances operated by electrochemical cells or batteries. Toy cars, electric torches, calculators, computers and mobile phones are a few examples for equipment that are powered by electrochemical cells.

A toy car powered by batteries

An electric torch

A mobile phone

A calculator

A computer

Figure 12.1.1 - Equipment powered by electrochemical cells

The electrochemical cells or batteries used in the examples given above are small in size. A battery used to start a car is large in size. Such a battery is a collection of several electrochemical cells.

Figure 12.1.2 - Different types of cells and batteries

In your former grades you have learnt about electrochemical cells. In those cells, the chemical energy stored in the chemicals they contain is converted to electrical energy. In this section, we study further the reactions occurring in electrochemical cells and the action of those cells.

For this, let us do the activity 12.1.1 described below.

Activity 12.1.1

Materials required :- A small beaker, dilute sulphuric acid, a zinc metal sheet

Method :-

- Add dilute sulphuric acid to the small beaker. Place a strip of zinc metal sheet in the beaker so that a part of it dips in the sulphuric acid solution as shown in the figure 12.1.3 Record your observations.

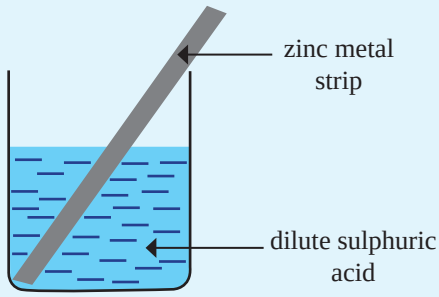


Figure 12.1.3

Here, it can be observed that, gas bubbles are liberated near the zinc strip and the zinc strip dissolves gradually. Let us find the reasons for those observations.

Zinc atoms (Zn) go into the solution as zinc ions (Zn^{2+}) leaving electrons on the metal. Electrons get accumulated on the zinc strip. This process can be shown as follows using chemical symbols.

$$Zn\,(s) \longrightarrow Zn^{2+}(aq) + 2e \ldots\ldots (1)$$

Sulphuric acid dissociates into hydrogen ions (H^+) and sulphate ions (SO_4^{2-}) in water. This can be illustrated as follows.

$$H_2SO_4\,(aq) \longrightarrow 2H^+(aq) + SO_4^{2-}(aq)$$

The H^+ ions in the solution are attracted towards the zinc strip to capture the electrons on it. Hydrogen ions, after receiving the electrons become hydrogen gas (H_2). Using chemical symbols, this can be written as follows.

$$2H^+(aq) + 2e \longrightarrow H_2\,(g) \ldots\ldots (2)$$

The reactions written as (1) and (2) above, depicting the conversion of one chemical species into another, either by removing or accepting electrons, are called 'half reactions'. By adding two half reactions appropriately, the balanced ionic equation can be obtained.

$$Zn(s) \longrightarrow Zn^{2+}\,(aq) + 2e \quad \text{—} (1)$$
$$2H^+(aq) + 2e \longrightarrow H_2(g) \quad \text{—} (2)$$

$$(1) + (2) \quad Zn(s) + 2H^+\,(aq) + \cancel{2e} \longrightarrow Zn^{2+}(aq) + \cancel{2e} + H_2\,(g)$$

$$Zn(s) + 2H^{+}(aq) \longrightarrow Zn^{2+}(aq) + H_2(g)$$

Next, let us consider how this reaction can be represented by a balanced chemical equation. The hydrogen ions (H^+) were added to the solution by the dissociation of sulphuric acid (H_2SO_4). When sulphuric acid dissociates sulphate ions (SO_4^{2-}) are also added to the medium in addition to H^+ ions. But sulphate ions do not undergo any change during the reaction. So, we add SO^{2-}_4 to both sides.

$$\underbrace{Zn(s) + 2H^{+}(aq) + SO_4^{2-}(aq)}_{H_2SO_4} \longrightarrow \underbrace{Zn^{2+}(aq) + SO_4^{2-}(aq)}_{ZnSO4} + H_2(g)$$

$$Zn(s) + H_2SO_4(aq) \longrightarrow ZnSO_4(aq) + H_2(g)$$

Given above is the complete reaction for which zinc metal reacts with dilute sulphuric acid. If the exchange of electrons taking place between the zinc metal and H^+ ions during the above process occurs through an external conductor, we can produce an electric current.

Let us do the following activity to see whether this can be done.

Activity 12.1.2

Materials required :- A beaker, zinc and copper strips, dilute sulphuric acid, connecting wire, Ammeter.

Method :- ● Connect the zinc strip and the copper strip to the Ammeter using connecting wires as shown in the Figure 12.1.4. Then immerse the two metal strips in the beaker containing dilute sulphuric acid. Record your observations.

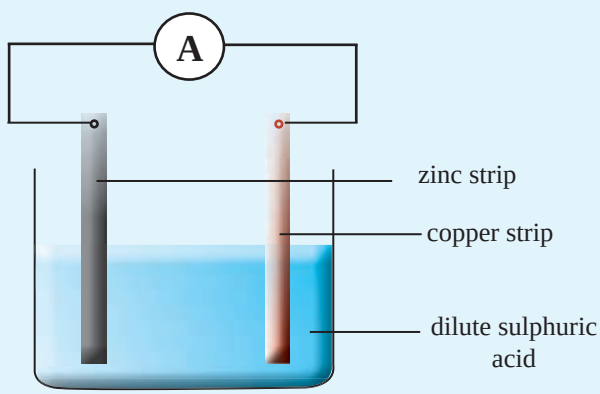


Figure 12.1.4

In this, it can be observed that the Ammeter pointer is deflected, zinc strip is dissolved and gas bubbles are evolved at the copper strip.

Let us explore the reasons for these observations.

Here too, zinc atoms become zinc ions (Zn^{2+}) leaving electrons on the metal. Therefore, the zinc strip dissolves.

The electrons accumulated on the zinc strip, flow towards the copper strip through an external wire. This flow of electrons is considered an electric current. Deflection of the Ammeter shows that an electric current flows through the circuit. Hence in this set up, H^+ ions in the solution move toward the copper strip and receive electrons from it. Therefore, hydrogen gas bubbles are liberated at the copper strip.

Reaction at the zinc strip

$$Zn\ (s) \longrightarrow Zn^{2+}(aq) + 2e \ldots\ldots (1)$$

Reaction at the copper strip

$$2H^+(aq) + 2e \longrightarrow H_2\ (g) \ldots\ldots (2)$$

In the above reaction it was confirmed that an electron current flows from zinc to copper in the external wire. A current of electrons means an electric current. In this, a chemical reaction has generated an electric current. A set up of this kind used to generate electricity by a chemical reaction is known as an electrochemical cell. The conducting substances dipped in the electrolyte here are called electrodes.

In the above cell, zinc strip and copper strip act as electrodes. The balanced ionic equation obtained by adding the half reactions (1) and (2) above is the electrochemical reaction taking place in the cell.

$$(1) + (2) \qquad Zn\ (s) + 2H^+(aq) \longrightarrow Zn^{2+}(aq) + H_2\ (g)$$

Let us further consider the reaction occurring at the zinc electrode in the above cell.

$$Zn\ (s) \longrightarrow Zn^{2+}(aq) + 2e \ldots\ldots (1)$$

Loss of electrons from a given species (atoms, molecules or ions) is referred to as oxidation. Therefore, what is happening at the zinc strip is **oxidation**. If oxidation occurs at a certain electrode, that electrode is defined as the **anode**. Accordingly, the zinc strip is the anode of the above cell. Equation (1) represents the **oxidation half reaction** taking place at the anode. Since zinc atoms dissolve into the solution leaving electrons on the zinc plate, the zinc plate gets negatively charged relative to the copper plate. Therefore, zinc electrode is the **negative terminal** of the cell.

Next let us consider the reaction occurring at the copper strip.

$$2H^+(aq) + 2e \longrightarrow H_2(g) \ldots\ldots (2)$$

The hydrogen ions (H^+) gaining electrons turn into hydrogen gas molecules (H_2). Gaining electrons by a given species (atoms, molecules, ions) is described as a **reduction**. Since gaining of electrons or a reduction occurs at the copper electrode, reaction (2) is the **reduction half reaction.**

If reduction occurs at a certain electrode, it is defined as the **cathode**. Therefore, copper strip is the cathode of the cell. Since electrons flow to the copper strip, it is positively charged relative to the zinc strip. Therefore, copper electrode is the positive terminal of the cell.

The electrochemical reaction of the cell can be obtained by adding the reactions (1) and (2).

At the zinc electrode/negative terminal:

$$Zn\ (s) \longrightarrow Zn^{2+}(aq) + 2e^- \quad (1)\ \text{Anodic reaction}$$

At the copper electrode/positive terminal:

$$2\ H^+(aq) + 2e^- \longrightarrow H_2(g) \quad (2)\ \text{Cathodic reaction}$$

(1) + (2)

$$Zn(s) + 2H^+(aq) \longrightarrow Zn^{2+}(aq) + H_2\ (g) \quad \text{Overall cell reaction}$$

The following comparisons would be important for you to identify the anode and cathode of a given electrochemical cell.

- The metal placed higher in the activity series acts as the anode and the metal placed lower in the activity series acts as the cathode.
- Oxidation occurs at the anode and reduction occurs at the cathode.
- Anode becomes the negative terminal of the cell while cathode becomes the positive terminal of the cell.

Note

In a cell, electrons flow from the negative terminal to the positive terminal. But, according to the conventions in physics, the conventional current is marked as flowing from the positive terminal to the negative terminal.

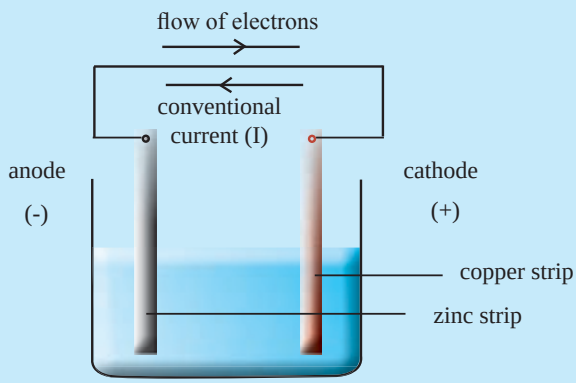


Figure 12.1.5

Next, let us consider a cell constructed using iron and copper electrodes.

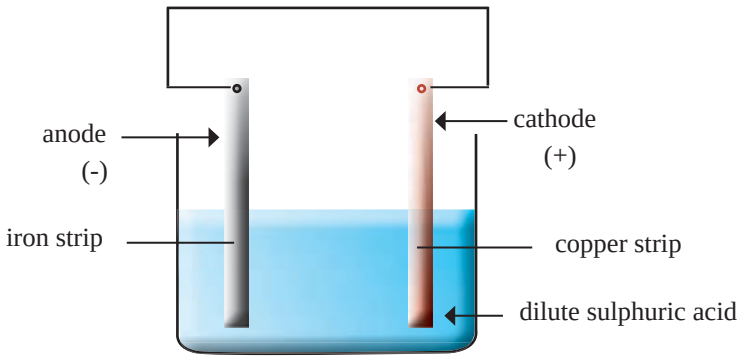


Figure 12.1.6

In the activity series, iron lies above copper. Therefore, what is subjected to **oxidation** and acts as the **anode** is the more reactive metal, iron.

$$Fe\ (s) \longrightarrow Fe^{2+}(aq) + 2e \ldots\ldots (4)$$

Since iron atoms dissolve into the solution leaving electrons on the iron strip, it is negatively charged relative to copper. Thus, iron electrode is the **negative terminal** of the cell.

In this cell also, the following reduction half reaction occurs at the less reactive copper metal. Therefore, copper electrode acts as the cathode of this cell.

$$2H^{+}\ (aq) + 2e \longrightarrow H_2\ (g) \ldots\ldots (5)$$

Electrons flow to the copper electrode across the external wire. Therefore, copper electrode is the **positive terminal** of the cell.

The overall ionic reaction of the cell can be obtained by adding the two half reactions (4) and (5) .

$$Fe\ (s) + 2H^{+}(aq) \longrightarrow Fe^{2+}(aq) + H_2\ (g)$$

When a current is drawn from this cell it can be observed that the iron electrode dissolves and gas bubbles evolve at the copper electrode.

Consider the following cell constructed using zinc and iron electrodes.

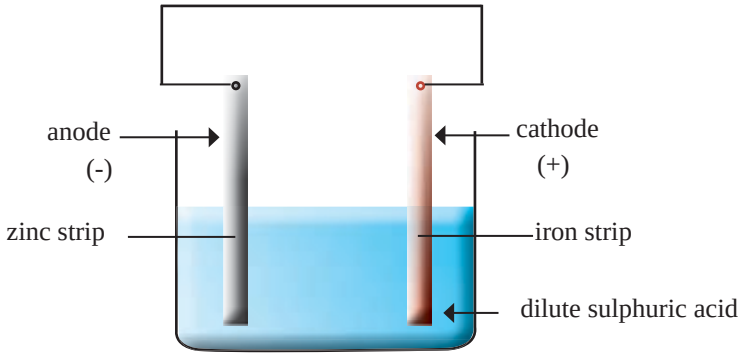


Figure 12.1.7

In the activity series, zinc metal is placed above iron. Therefore, zinc which is the more reactive metal, undergoes oxidation and acts as the anode.

Reaction at the zinc electrode/anode

$$Zn\,(s) \longrightarrow Zn^{2+}(aq) + 2e \quad \ldots\ldots (6)$$

Here too, as the zinc atoms dissolve into the solution leaving electrons on the zinc electrode, zinc becomes negatively charged relative to iron. For this reason, zinc electrode becomes the **negative terminal** of the cell.

Reaction at the iron electrode/cathode

$$2H^{+}(aq) + 2e \longrightarrow H_2\,(g) \quad \ldots\ldots (7)$$

Because reduction occurs at iron, it acts as the **cathode**.

Electrons flow towards the iron electrode along the connecting wire. Hence iron electrode is the **positive terminal** of the cell.

The overall ionic reaction of the cell can be obtained by adding the reactions (6) and (7).

$$Zn\,(s) + 2H^{+}(aq) \longrightarrow Zn^{2+}(aq) + H_2\,(g)$$

When this cell operates, we will be able to see that the zinc electrode dissolves and gas bubbles evolve at the iron electrode.

12.2 Electrolysis

You would have seen the goldsmiths burnishing gold/silver jewellery near the jewellery shops in town.

If you have not seen such a person, make it a point to observe well the equipment he has, when you meet such a person next time. You may be able to see a battery supplying electricity, wires connected to it and a vessel filled with a certain solution. He uses a narrow gold foil as one electrode and the piece of jewellery that needs to be polished as the other electrode. What he does with these equipment is the application of gold on the piece of jewellery.

Using the above process, he deposits gold on various jewellery. He lets an electric current to pass through the solution.

The chemical changes brought about by passing electricity through a solution/liquid which conduct electricity are called electrolytic processes. This chapter discusses about electrolysis. For this, let us first do the following activity to find out about the liquids/solutions which conduct electricity.

Activity 12.2.1

Materials required :-

Carbon electrodes, two torch cells (1.5v), connecting wires, a ammeter, beakers, coconut oil, kerosene, distilled water, acidified water, salt solution, ethanol

Method :-

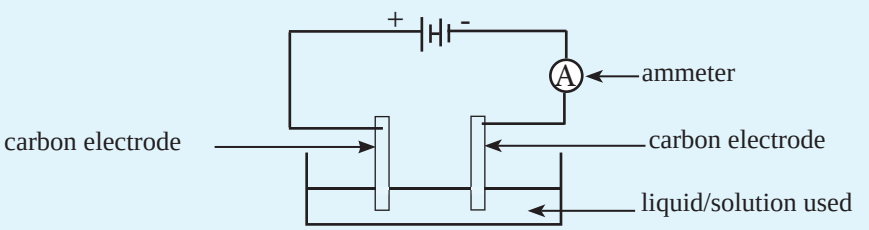


Figure 12.2.1

- Dip the carbon electrodes in the above liquids/solutions and see whether there is a deflection in the Ammeter.
- Record your observations.

A deflection in the ammeter could be observed only when acidified water and the salt solution are used in the above set up. That means, those solutions conduct electricity.

- The liquids/solutions conducting electricity are referred to as electrolytes. Some examples for electrolytes are given below.

» Aqueous solutions of ionic compounds

e.g. aqueous sodium chloride, aqueous copper sulphate

» Molten (fused) liquids of ionic compounds

e.g. fused sodium chloride

» Solutions of acids

e.g. aqueous hydrochloric acid, aqueous sulphuric acid

» Solutions of bases

e.g. aqueous sodium hydroxide

- The liquids/solutions that are not conducting electricity are non-electrolytes. Some examples for non-electrolytes are:
  - » Pure water (distilled water)
  - » Organic liquids
    e.g. petrol, kerosene, paraffin, hexane

For your memory file

The solid ionic crystals formed by the oppositely charged ions do not contain mobile ions. Therefore they cannot conduct electricity. But, when they are dissolved in water or fused (heated till the solid melts) its ions become mobile. For this reason, aqueous solutions or molten liquids of ionic compounds conduct electricity. The hydrocarbons such as petrol, kerosene and paraffin are compounds with covalent bonds, so they do not conduct electricity. Pure water is also covalent and there are almost no ions. Therefore, pure water does not conduct electricity. In aqueous solution, the covalent bonds in acids such as hydroiodic acid (HI), hydrochloric acid (HCl) and sulphuric acid (H_2SO_4) break to form ions. Therefore the solutions of acids such as these conduct electricity.

$$HCl \xrightarrow{water} H^+(aq) + Cl^-(aq)$$

$$H_2SO_4 \xrightarrow{water} 2H^+(aq) + SO_4^{2-}(aq)$$

An apparatus set up to conduct electricity through an electrolyte is shown in the following figure. A set up such as this is called an electrolytic cell. An electrolytic cell comprises of a source of electricity, an electrolyte, two electrodes and connecting wires.

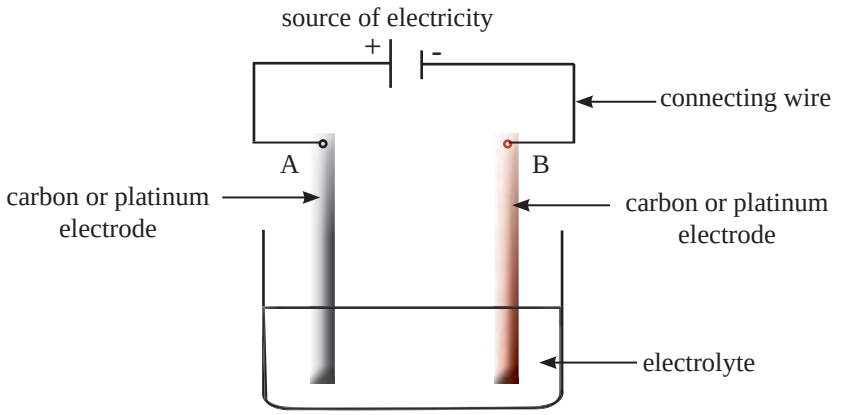


Figure 12.2.2 - An electrolytic cell.

Let us consider the supply of electricity to an electrolytic cell containing an aqueous solution of sodium chloride as the electrolyte. Liberation of gas bubbles can be seen at the carbon electrodes. This indicates that a chemical change has taken place in the aqueous solution.

Bringing about a generally non-spontaneous chemical reaction such as the one given above by supplying electricity is known as electrolysis.

• Conventions adopted in electrolysis

(1) The electrode connected to the positive terminal of the external electrical supply (battery) is the positive electrode whereas the electrode connected to the negative terminal is the negative electrode.

(2) The positive ions in the solution/liquid migrate towards the negative electrode while the negative ions are attracted by the positive electrode.

(3) The positive ions moving towards the negative electrode receive electrons and undergo reduction. If there are several positive ions in the solution, generally, the cations (positive ions) formed by the elements further down in the activity series has a higher tendency to undergo reduction.

For example, if there are Na^+ and H^+ ions in the solution, the H^+ ions formed by hydrogen which is below sodium in the activity series receive electrons and get reduced.

If there are Cu^{2+} and H^+ ions in the solution electrons are gained by the Cu^{2+} ions formed by copper which is placed below hydrogen in the activity series.

(4) Since a **reduction half reaction** occurs at the negative electrode, negative electrode is the **cathode**.

(5) The anions (negative ions) in the solution move towards the positive electrode and lose electrons. That means, they undergo oxidation.

For example, the Cl^- ions in the solution become Cl_2 molecules releasing electrons.

$$2Cl^-(aq) \longrightarrow Cl_2(g) + 2e$$

(When there are several negative ions in the solution, which ion oxidizes first is decided by several factors. Since these facts are beyond the scope of your subject they are not discussed here).

(6) **Oxidation** occurs at the positive electrode, so positive electrode is the **anode**.

(7) If a metal (except platinum) is used as the anode, metal atoms get oxidized losing electrons instead of the oxidation of negative ions.

For example, if the anode is a silver rod, the oxidation reaction

$Ag(s) \longrightarrow Ag^+(aq) + e$ takes place at the positive electrode.

Based on the above conventions, let us predict the reactions taking place during the following electrolysis reactions.

- Electrolysis of fused sodium chloride using carbon electrodes

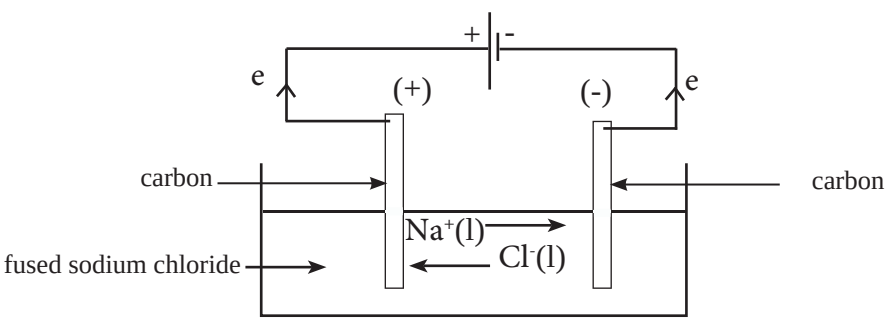


Figure 12.2.3

- **Reaction occurring at the negative electrode**

The only positive ions present in the fused (molten) liquid, Na^+ ions, are attracted by the negative electrode. At this electrode Na^+ ions receive electrons and become sodium atoms (Na).

$$Na^+(l) + e \longrightarrow Na(l) \quad \ldots\ldots\ldots\ldots (1)$$

Since Na^+ ions are reduced by gaining electrons, this is the cathodic reaction. Accordingly, the negative electrode is the cathode.

- **Reaction occurring at the positive electrode**

Chloride ions (Cl^-), the only negative ions present in the liquid, migrate towards the positive electrode. At this electrode, Cl^- ions get converted to chlorine molecules (Cl_2) by removing electrons.

$$2Cl^-(l) \longrightarrow Cl_2(g) + 2e \quad \ldots\ldots\ldots\ldots (2)$$

Since chloride ions are oxidized by losing electrons, this is the anodic reaction. Hence, positive electrode is the anode.

The overall electrolytic reaction can be obtained by adding the half reactions (1) and (2) appropriately.

(1) × 2, $\quad 2Na^+(l) + 2e \longrightarrow 2Na(l) \quad \ldots\ldots\ldots\ldots (3)$

(2) + (3) $\quad \cancel{2e} + 2Na^+(l) + 2Cl^-(l) \longrightarrow 2Na(l) + Cl_2(g) + \cancel{2e}$

$$2Na^+(l) + 2Cl^-(l) \longrightarrow 2Na(l) + Cl_2(g)$$

The electrolytic reaction discussed above is the reaction happening in the Downs cell to extract sodium metal industrially. This method, you will study later in more detail. Later you will study this method in more detail.

- Electrolysis of aqueous solutions

Now let us engage in the following activities to study the changes taking place during the electrolysis of aqueous solutions.

- Electrolysis of aqueous sodium chloride

Activity 12.2.2

Materials required :- A solution of sodium chloride, carbon rods, conducting wires, a 9 V battery

Method :- ● Connect the two carbon rods to the terminals of the battery using wires. Then immerse those two electrodes in the aqueous sodium chloride solution and observe. Record the observations.

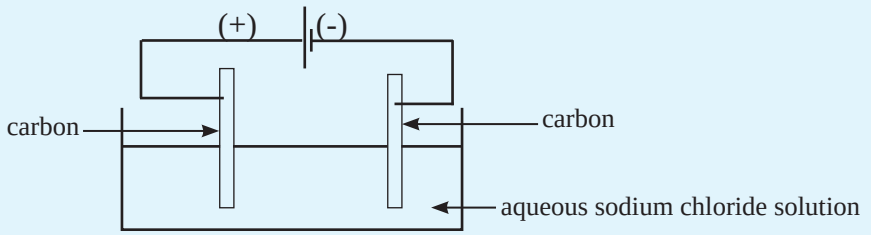


Figure 12.2.4

Liberation of gas bubbles can be observed at the electrodes. In order to explain these observations, let us understand the reactions occurring in the above experiment.

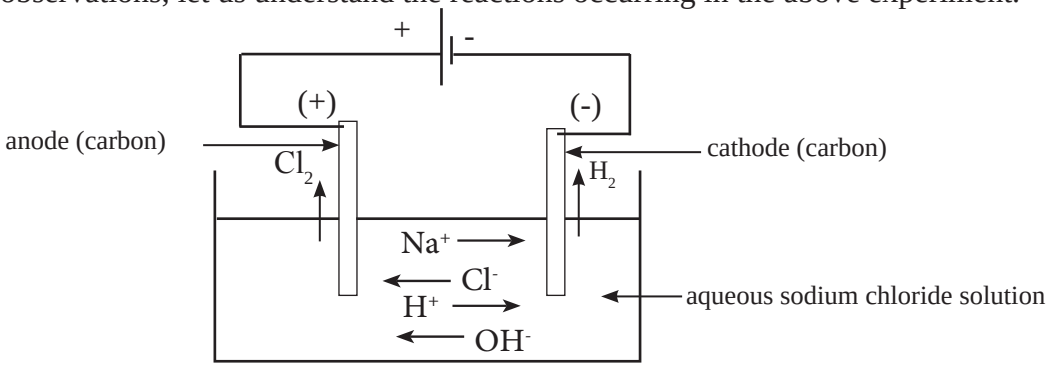


Figure 12.2.5

The solution mainly contains Na^+ and Cl^- ions. In addition to these, there is a small amount of H^+ and OH^- ions formed by the poor ionization of water molecules.

For your memory file

Water is a molecule with covalent bonds. But even in pure water it has been found that a very small amount of water molecules dissociate into H^+ and OH^- ions. In pure water, H^+ and OH^- concentrations at 25 ^{0}C are 1.0 x 10^{-7} mol dm^{-3}.

- **Reaction at the negative electrode (cathodic reaction)**

Na^+ and H^+ ions in the solution migrate towards the negative electrode.
As hydrogen is below sodium in the activity series, it is the H^+ ions that are reduced here.

$$2H^+ (aq) + 2e \longrightarrow H_2 (g) \quad \text{.....} (1)$$

As this is a reduction occurring with the gain of electrons, the negative electrode is the cathode.
Therefore reaction (1) is the cathodic reaction. Hence gas bubbles of hydrogen (H_2) are evolved at the negative terminal.

- **Reaction at the positive electrode (anodic reaction)**

The positive terminal attract Cl^- and OH^- ions in the solution. Of them, Cl^- ions have a greater tendency to oxidize.

$$2Cl^- (aq) \longrightarrow Cl_2 (g) + 2e \quad \text{.....} (2)$$

As this is an oxidation (because it involves loss of electrons) reaction (2) is the anodic reaction.
Hence chlorine gas bubbles (Cl_2) evolve at the positive electrode.
The overall electrolytic reaction can be obtained from the reactions (1) and (2)

$$(1) + (2) \quad \cancel{2e} + 2H^+ (aq) + 2Cl^- (aq) \longrightarrow H_2 (g) + Cl_2 (g) + \cancel{2e}$$
$$2 H^+ (aq) + 2Cl^- (aq) \longrightarrow H_2 (g) + Cl_2 (g)$$

Initially the ions Na^+, H^+, Cl^- and OH^- were present in the solution. Of these, the ions H^+ and Cl^- are removed by the conversion into H_2 and Cl_2 molecules. Hence Na^+ and OH^- ions are left in the solution. Because of this you may understand that this reaction can be used to produce sodium hydroxide (NaOH).

- Electrolysis of an aqueous copper sulphate solution

Activity 12.2.3

Materials required :- An aqueous solution of copper sulphate, carbon rods, connecting wires, a 9V battery

Method :- ● Connect the electrodes to the battery as follows. Then, dip the two electrodes in the copper sulphate solution and observe. Record your observations.

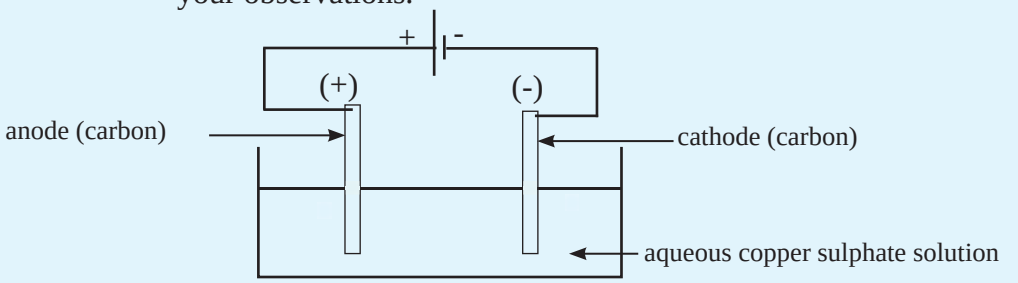


Figure 12.2.6

In this activity, it can be observed that gas bubbles evolve at the positive terminal (anode) and copper gets deposited on the negative terminal (cathode). The blue colour of the solution gradually diminishes.

In order to understand these observations, let us consider the reactions involved in here.

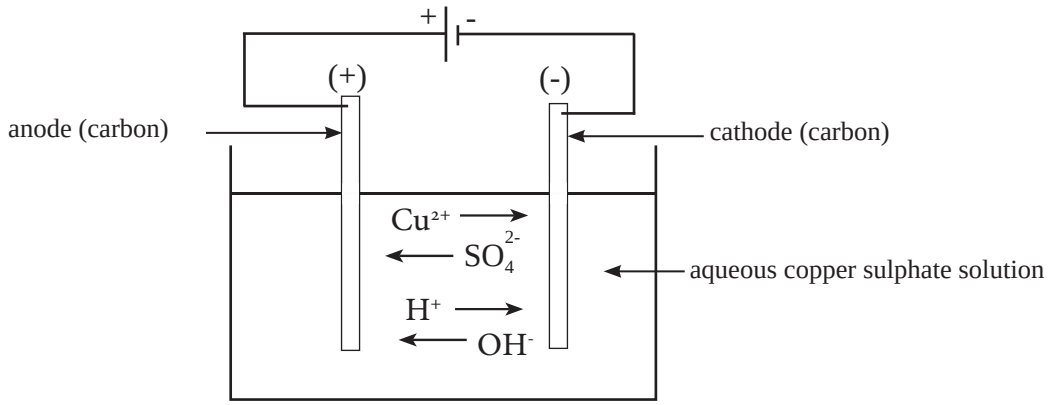


Figure 12.2.7

The solution mainly contains Cu^{2+} and SO_4^{2-} ions formed by the ionization of copper sulphate. In addition to these, a very small amount of H^+ and OH^- ions formed by the slight ionization of water molecules are also present.

- **Reaction at the negative electrode**

(cathodic reaction)

Both Cu^{2+} and H^+ ions migrate towards the negative electrode. As copper lies below hydrogen in the activity series, Cu^{2+} ions have a greater tendency to get reduced.

$$Cu^{2+}(aq) + 2e \longrightarrow Cu(s) \quad \cdots\cdots\cdots\cdots (1)$$

Hence, copper is deposited on the cathode. As this is a reduction, reaction (1) is the cathodic reaction. Thus, negative electrode is the cathode. As Cu^{2+} ions responsible for the blue colour of the solution are removed from the solution, the intensity of the blue colour of the solution decreases.

- **Reaction at the positive electrode**

(anodic reaction)

SO_4^{2-} and OH^- ions in the solution are attracted towards the positive electrode. Of these, OH^- ions have a greater tendency to be oxidized.

$$4\,OH^-(aq) \longrightarrow O_2(g) + 2H_2O(l) + 4\,e \quad \cdots\cdots\cdots\cdots (2)$$

Therefore, oxygen gas bubbles evolve at the anode.

Reaction (2) is an oxidation, so it is the anodic reaction. Hence, positive electrode is the anode.

For your memory file

- Since the amount of H^+ ions in water is negligible, sometimes the reaction
  $2H_2O(l) + 2e \longrightarrow 2OH^-(aq) + H_2(g)$
  is considered the more fitting cathodic reaction than
  $2H^+(aq) + 2e \longrightarrow H_2(g)$
- Similarly the anodic reaction $2H_2O(l) \longrightarrow O_2(g) + 4H^+(aq) + 4e$ is more appropriately used in place of $4OH^-(aq) \longrightarrow O_2(g) + 2H_2O(l) + 4e$

- Electrolysis of acidulated water

Now let us pay attention to the electrolysis of acidulated water using carbon electrodes.

Activity 12.2.4

Materials required :- Distilled water to which a little dilute sulphuric acid is added, carbon rods, a 9 V battery, connecting wires, a plastic cup

Method :-

- Pierce the bottom of the plastic cup and fix the carbon rods as shown in the figure. Seal any spaces around the rods with a substance such as molten wax or PVC so that water does not leak (silicone sealer may also be used). Add acidulated water to the cup. Introduce the two carbon rods into two inverted test tubes filled with water as shown in the figure 12.2. Supply electricity to the two carbon electrodes
- Record you observations.

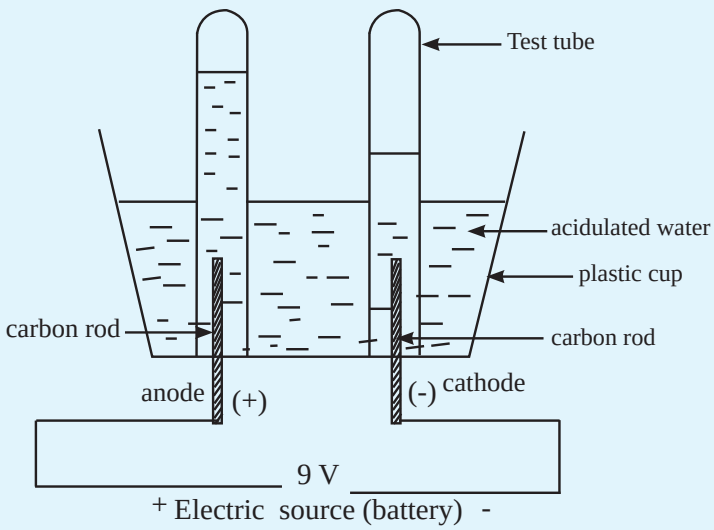


Figure 12.2.8

Here, we will be able to see gases collecting in the test tubes. Also, we can observe that the volume of gas liberated by the cathode is greater than that liberated by the anode. Let us investigate into the reactions taking place in this set up.

Acidulated water contains H^+ and SO_4^{2-} ions provided by the ionization of dilute sulphuric acid and H^+ and OH^- given by the dissociation of water.

- **Reaction at the negative electrode**

(cathodic reaction)

Which ions in the solution migrate towards the negative electrode? The positively charged H^+ ions in the solution migrate towards the negative electrode and get reduced receiving electrons.

$$2\,H^+(aq) + 2e \longrightarrow H_2(g) \ldots\ldots\ldots\ldots (1)$$

As this is a reduction, this is the cathodic reaction.

Hence hydrogen is liberated at the cathode.

- **Reaction at the positive electrode**

(anodic reaction)

The positive terminal attracts SO_4^{2-} and OH^- ions in the solution. Of these, the OH^- ions tend to undergo oxidation preferentially.

$$4OH^-(aq) \longrightarrow O_2(g) + 2H_2O(g) + 4e \ldots\ldots\ldots\ldots (2)$$

Because this is an oxidation, reaction (2) is the anodic reaction. Thus positive electrode is the anode.

Oxygen gas bubbles are liberated at the anode.

Electrolysis of water, on the whole can be represented by the following equation.

$$2H_2O(l) \longrightarrow 2H_2(g) + O_2(g)$$

Industrial applications of electrolysis

Electrolysis process is frequently used in the manufacturing of various industrial products. Some examples are given below.

(1) Extraction of metals

Example :- (i) Extracting sodium metal by electrolysing fused sodium chloride

(ii) Extracting aluminium metal from bauxite

(2) Metal refining

Example :- When copper is produced from the copper ores, the copper obtained first is impure. It is purified by an electrolytic process.

(3) Electroplating (coating an object with a metal)

Example :- (i) Applying gold on silver jewellery

(ii) Applying nickel or chromium on steel

(4) Industrial production of sodium hydroxide (Diaphragm cell method)

• Industrial production of sodium metal

We have already studied the electrode reactions occurring when fused sodium chloride is electrolyzed using carbon electrodes. The following reaction occurs at the cathode, in this process.

$$Na^+(l) + e \longrightarrow Na(l) \quad \text{.....} (1)$$

The reaction occurring at the anode is as follows.

$$2Cl^-(l) \longrightarrow Cl_2(g) + 2e \quad \text{.....} (2)$$

The overall reaction is:

(1) × 2 + (2) ;

$$2Na^+(l) + 2Cl^-(l) \longrightarrow 2Na(s) + Cl_2(g)$$

The above reaction is used to produce sodium metal industrially on large scale. For this a special type of electrolytic cell illustrated below is used. This is named the Downs cell.

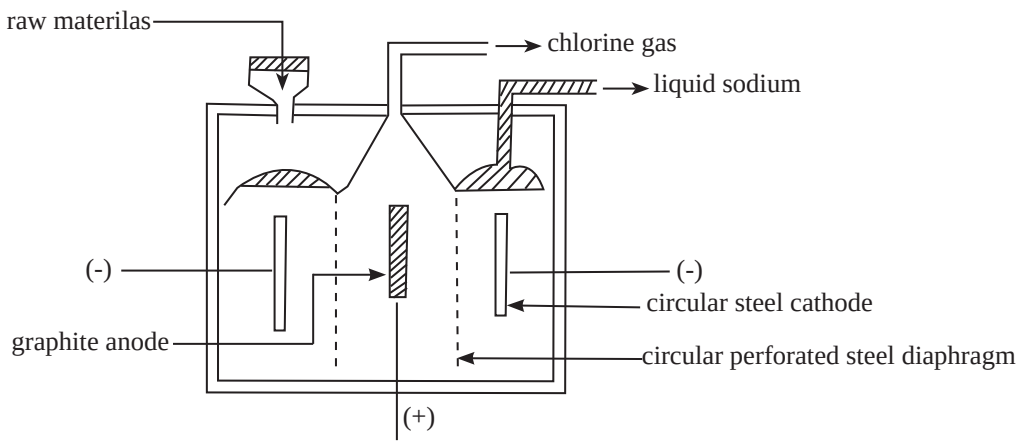


Figure 12.2.9 Downs cell

Fused sodium chloride is used as the raw material. The melting temperature of solid sodium chloride is as high as 840 ^{0}C. By adding about 40% calcium chloride to sodium chloride, the meling temperature of the mixture is decreased to about 600 ^{0}C.

What will happen is chlorine gas produced at the anode comes into contact with the sodium discharged at the cathode. Sodium and chlorine would react giving sodium chloride again. To prevent this, the anode and cathode are separated by a steel mesh diaphragm. It prevents the reaction between sodium and chlorine to form sodium chloride.

In this production process, chlorine gas is obtained as a by - product. Chlorine gas can also be used as a raw material for various products.

Uses of sodium

- Used in sodium vapour lamps which emit a yellow light.
- Used as a coolant in nuclear reactors in power houses producing nuclear energy
- It is a requirement for laboratory experiments

Uses of chlorine

- Chlorine is bubbled through water to destroy bacteria in potable water.
- Used to bleach (decolourise) paper, pulp, and cloth
- Production of hydrochloric acid by reacting with hydrogen
- Used to produce plastics such as PVC

Electroplating

At the beginning of this lesson, it was stated that electroplating is used to coat jewellery with gold. In addition to that, think about the ornamental objects used to decorate houses. In many items such as vases, trays and door locks that shine with golden or silvery colour, the metallic lustre is given by a metal coating deposited on them.

Applying a thin metallic layer on a given surface using electrolysis is referred to as electroplating.

Generally the coating is a less reactive metal such as tin, copper, silver or chromium. The metal that is plated needs to have a certain special property which is absent

for the surface that is plated. Resistance for rusting, attractive colour, chemical inertness and lustrous nature are some of such properties.

When electroplating objects, it is important to know the following.

- The object to be plated should be used as the cathode.
- A solution of a salt of the metal that is used for plating should be used as the electrolyte.
- The anode should be a plate/ rod made of the metal that is plated.
- In order to have a plating of high quality, the concentration of the electrolyte should be low. Then, the rate of the reaction decreases, so the plating is effected better.

Suppose you need to coat an iron spoon with copper. What do you use as the anode and cathode of the electrolytic cell which you construct for this? What is the electrolyte you employ?

The object to be plated, that is the iron spoon has to be used as the cathode. A copper rod can be used as the anode. A solution of copper sulphate can be used as the electrolyte.

Activity 12.2.5

Materials required :- An iron spoon, a copper plate, connecting wires, an aqueous solution of copper sulphate, a 9 V battery

Method :-
- Connect the iron spoon and the copper plate to the cell by connecting wires and immerse them at once in the copper sulphate solution.
- Record the observations.

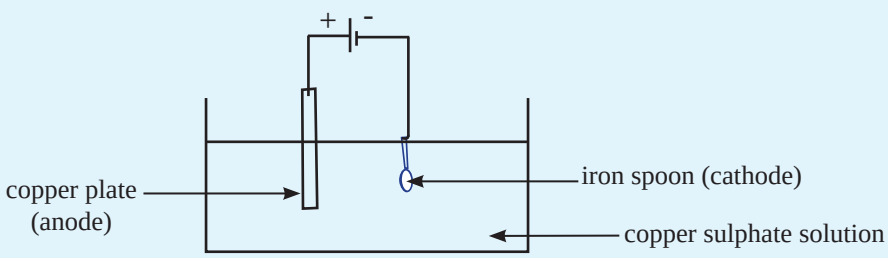


Figure 12.2.10

- **Anodic (positive electrode) reaction**

SO_4^{2-} and OH^- ions in the solution migrate towards the anode. Of them OH^- ions preferentially tend to undergo oxidation. Therefore, it can be anticipated that the reaction $4\ OH^-\ (aq) \longrightarrow 2H_2O\ (l) + O_2\ (g) + 4e$ occurs at the anode. However, it does not occur at the anode. As the anode is a metal, oxidation of metal atoms into metal ions is more feasible. Hence, the anodic reaction is

$$Cu\ (s) \longrightarrow Cu^{2+}\ (aq) + 2e$$

That means, the anode dissolves gradually.

- **Cathodic (negative electrode) reaction**

The solution contains Cu^{2+} ions and a little amount of H^+ ions produced by the dissociation of water. Of these, Cu^{2+} ion which is less in reactivity shows a greater tendency to be reduced. Therefore, the cathodic reaction is the following.

$$Cu^{2+}\ (aq) + 2e \longrightarrow Cu\ (s)$$

As a result, the cathode (iron spoon) gets coated with copper.

12.3 Corrosion of metals

Think about various metal objects that are used at home. With time, most of them are subjected to changes such as tarnishing, surface turning ditted and colour change. Subjecting metals to changes such as these when exposed to air is known as **corrosion** of metals.

Try to remind an instance where you relocated a lost item such as a knife or a mammoty blade after a long time in the garden. You would have observed that they are discoloured and decayed. Such objects are made of iron or steel. Corrosion of iron or steel exposed to air is specifically known as **rusting**.

12.3.1 Rusting of iron

Iron is the metal mostly used by humans. Therefore, it is the metal produced in the largest quantity. Iron manufactured is largley used to produce steel. Iron and steel are used to make vehicles, ships, bridges, machinery and many other products. Hence, rusting of iron is an economically disadvantageous process.

What kind of a process occurs when iron rusts ?

Why do the equipment made up of iron rust more easily outdoors rather than when they are indoors? Do the following activity to investigate into this

• Finding out whether air is essential for rusting

Activity 12.3.1

Materials required :- Two boiling tubes, ordinary cold water, coconut oil, two iron nails, burner, dilute hydrochloric acid

Method :-

- The iron nails available in the market has a zinc coating on them. To remove this, keep the two nails immersed in dilute hydrochloric acid for about 10 minutes and then wash with water. (Always use this procedure for experiment used the iron nail)
- Add cold water about half the height of the two boiling tubes.
- Boil the water in one of the boiling tube for about five minutes. Immerse the cleaned nails one each in the two boiling tubes. Add a little amount of coconut oil to the boiling tube with hot water to prevent the entry of atmospheric air. Allow the boiling tubes to stand for about two days and observe. Note down the observations.

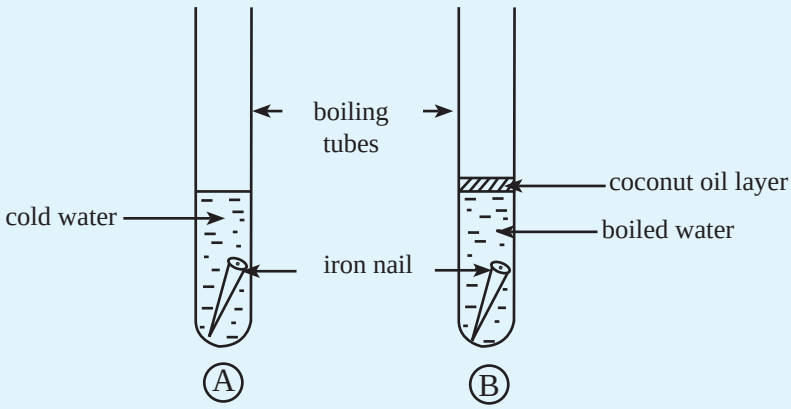


Figure 12.3.1

The nails in the above two tubes are in contact with water. But, as the water in the tube (B) is boiled, air dissolved in it has been removed. Because of the coconut oil layer, water in tube (B) does not come into contact with air, so the nail in (B) doesn't receive air. The nail in tube (A) received air (dissolved in water). All the other factors are common to the two settings.

It can be observed that the nail in tube (A) has rusted but the nail in tube (B) has not rusted. This confirms that air is essential for rusting.

Next, let us investigate which components in air are essential for rusting.

- **Examining which components in air are essential for rusting**

Activity 12.3.2

Materials required :- Two boiling tubes, iron wool, a basin of water

Method :-

- In one of the boiling tubes, trap a lump of iron wool and keep it inverted in the basin of water as shown in the figure.
- Keep the other empty tube also inverted in the basin of water.
- Observe after a few days.

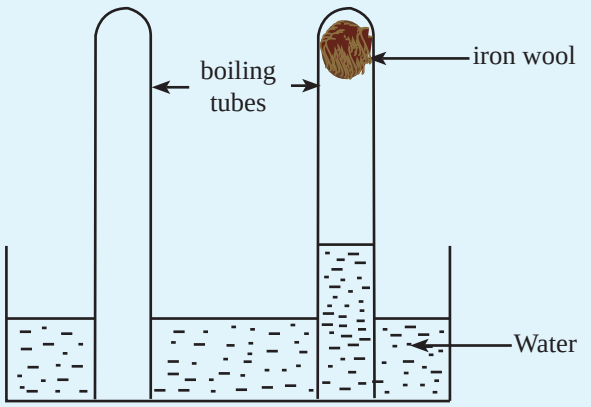


Figure 12.3.2

You can notice that the water level in the tube with iron wool has risen approximately up to $1/5^{th}$ of the total volume of air inside the tube. Hence a part of air has been used for rusting. By composition, $1/5^{th}$ of the volume of air is oxygen. Thus it can be concluded that it is the oxygen gas in air that is required for rusting. The gas required for rusting is oxygen.

• Examining whether water is essential for rusting

Activity 12.3.3

Materials required :- Four cleaned iron nails, two boiling tubes and two stoppers, anhydrous calcium chloride ($CaCl_2$) or silica gel

Method :-

- Fix two cleaned iron nails to each of the rubber stopper as shown in the figure.
- Fix one of the stoppers with nails to an empty boiling tube and the other to a boiling tube with anhydrous calcium chloride or silica gel
- Observe after a few days. Record your observations.

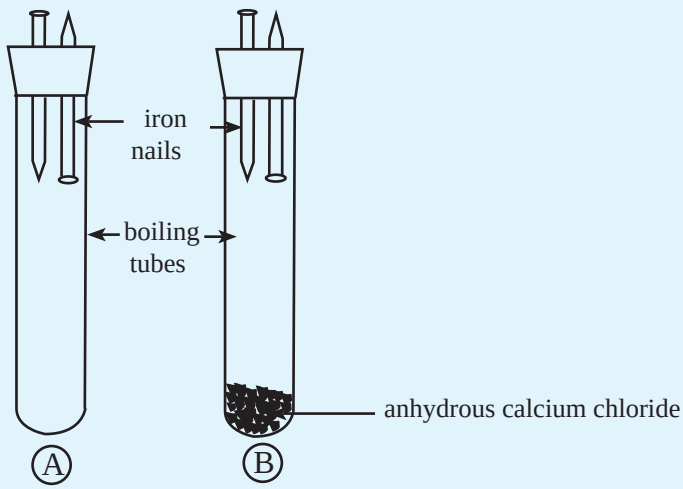


Figure 12.3.3

anhydrous calcium chloride can absorb water vapour in air.

In the above experiment, it can be observed that in the two nails in tube (A), the parts inside and outside the tube have rusted. However, in the case of (B), in the two nails, only the parts of the nails which are outside the tube have undergone rusting. As regards the tubes (A) and (B) are compared we note that tube (B) does not have water vapour in it. Other factors are common to both tubes. This shows that water is a requirement for rusting.

Next let us get on to the process taking place during rusting.

Iron atoms form positive ions by losing electrons. This means that they get oxidised. It can be represented by an equation as follows.

$$Fe\,(s) \longrightarrow Fe^{2+}\,(aq) + 2e$$

Metal atoms oxidise as above only when there is another species which can accept electrons.

When oxygen gas in the atmosphere and water/ water vapour are together, they get reduced accepting electrons as indicated below.

$$2H_2O\,(l) + O_2\,(g) + 4e \longrightarrow 4OH^-\,(aq)$$

Accordingly, the half reactions occuring when iron rusts can be given as follows.

$$Fe\,(s) \longrightarrow Fe^{2+}\,(aq) + 2e \quad \ldots\ldots\ldots\ldots (1)$$

$$2H_2O\,(l) + O_2\,(g) + 4e \longrightarrow 4OH^-\,(aq) \quad \ldots\ldots\ldots\ldots (2)$$

The number of electrons lost by reactions (1) should be balanced by the number of electrons gained in reaction (2).

$$(1) \times 2\ ;\ 2Fe\,(s) \longrightarrow 2Fe^{2+}\,(aq) + 4e \quad \ldots\ldots\ldots\ldots (3)$$

$$(2) + (3)\ ;\ 2H_2O\,(l) + O_2\,(g) + 2Fe\,(s) \longrightarrow \underbrace{2Fe^{2+}\,(aq)\ 4OH^-\,(aq)}_{2\,Fe(OH)_2}$$

Therefore, it is clear that what occurs in rusting also is an electrochemical process similar to what you studied in the sub-unit 2.6. It can be stated that reaction (1) is the anodic reaction (because oxidation occurs) and reaction (2) is cathodic reaction (because reduction occurs).

$Fe(OH)_2$, formed above further reacts with air to form hydrated ferric oxide ($Fe_2O_3 . H_2O$)

$$4Fe\,(OH)_2\,(s) + O_2\,(g) \longrightarrow 2(Fe_2O_3 . H_2O)\,(s) + 2H_2O\,(l)$$

Hydrated ferric oxide is reddish brown in colour. As the number of water molecules combining with ferric oxide during hydration may vary, the formula of rust can be more appropriately given as $Fe_2O_3 . xH_2O$.

Perhaps you would have observed that if a knife used to cut a lime was left unwashed for about a day, the part of the blade smeared with lime juice becomes rusty. Let us do the following activity to find out how acidity affects rusting.

• Examining how acids affect rusting

Activity 12.3.4

Materials required :- Three boiling tubes, water, lime juice,dilute hydrochloric acid (HCl)

Method :-

- Put an iron nail each to three boiling tubes.
- Add ordinary cold water to the first boiling tube, water mixed with lime juice to the second and water mixed with dilute hydrochloric acid to the third.
- Allow to stand for about one day and observe. Record your observations.

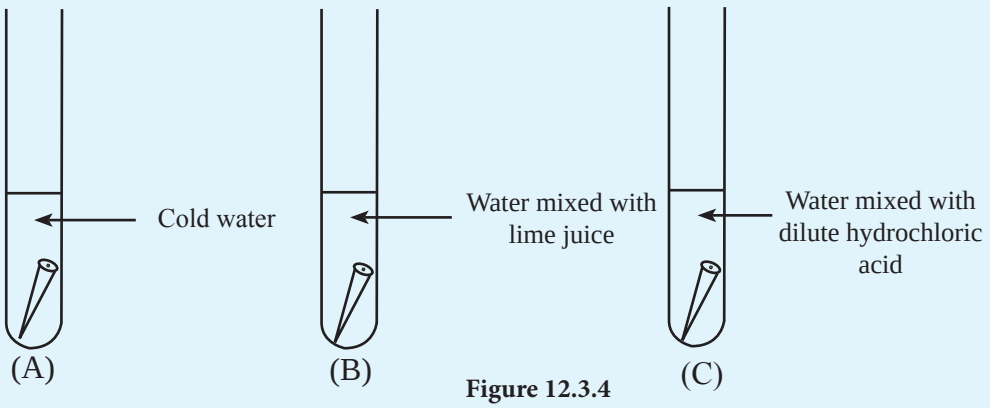


Figure 12.3.4

It can be observed that the nails in the tubes B and C have rusted more than the nail in tube A.

From this, it can be inferred that **acidity is a factor that accelerates rusting.**

Have you heard that the items made from iron used in houses in coastal areas rust faster compared to the iron objects used in other areas? In order to investigate into this, let us do the following activity.

• Investigating the effect of salt (sodium chloride) on rusting

Activity 12.3.5

Materials required :- Cleaned iron nails, boiling tubes, solid sodium chloride

Method :-

- Clean two new iron nails.
- Put the two nails separately to the two boiling tubes and into one of them add water mixed with some sodium chloride and to the other tube, add ordinary cold water.
- Allow to stand for about a day and observe. Record your observations

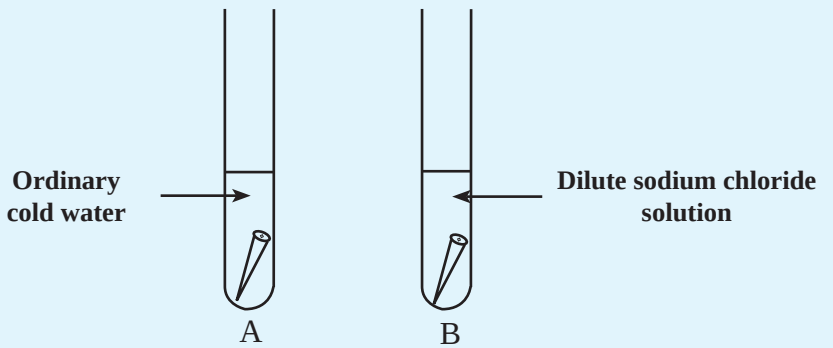


Figure 12.3.5

The nail in tube B rusts more than that in tube A. This indicates that sodium chloride has accelerated the rusting of iron. Sodium chloride is a salt. Many salts accelerate rusting. The salt concentration in coastal areas is high. Therefore, the iron objects used in those areas rust relatively faster.

We learnt that acids accelerate rusting. Next, let us do the following activity to explore how bases affect rusting.

- **Examining how bases affect rusting**

Activity 12.3.6

Materials required :- Two boiling tubes, two cleaned iron nails, sodium hydroxide (NaOH) solution

Method :-

- Put the two cleaned nails to the two boiling tubes seperately. Add equal volumes of ordinary cold water to one tube and sodium hydroxide solution to the other tube.
- Allow to stand for about a day and observe.

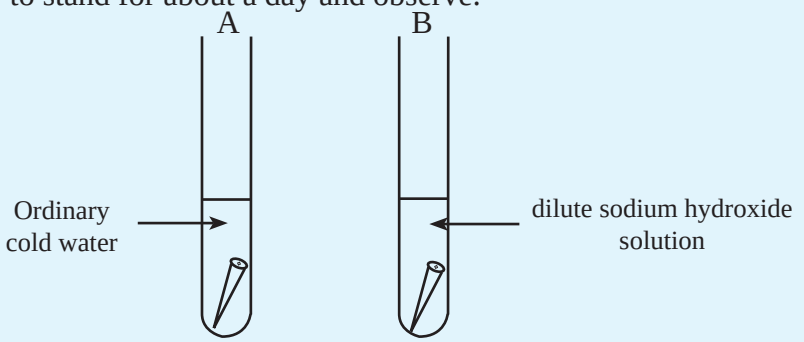


Figure 12.3.6

It can be observed that the nail in the tube with ordinary water has rusted and relative to this, the nail in sodium hydroxide solution has not rusted much. This confirms that bases decrease the speed of rusting.

The speedy corrosion of iron which is a very useful metal is a disadvantage. Therefore, steps must be taken to control the corrosion of objects made of iron.

12.3.2 Control of rusting of iron

What are the methods you suggest to prevent the corrosion of iron? In order to protect iron from corrosion you may propose that it is appropriate to prevent iron from coming into contact with the essential factors for rusting. In fact, if oxygen and water are kept away from iron, rusting can be prevented.

For this, following measures can be adopted.

1) Applying paint, grease or oil on iron

This prevents iron from coming into contact with oxygen and water (moisture)

2) Coating iron with tin

This too prevents impinging of oxygen and water (moisture) on iron.

In both instances above, the coating acts as a protective film.

Let us do the following activity to inquire into the effect of other metals on corrosion of iron.

• Effect of other metals on corrosion of iron

Activity 12.3.7

You will need :- Five cleaned iron nails, agar jelly, sodium chloride, phenolpthalein indicator, potassium ferricyanide, petri dishes, strips of magnesium, Zinc, copper and lead, water.

Method:-

- To approximately 250 cm^3 of water add a small amount a few of sodium chloride, phenolphthalein and potassium ferricyanide. Boil the solution and add about one tea spoonful of agar jelly to it and stir well.

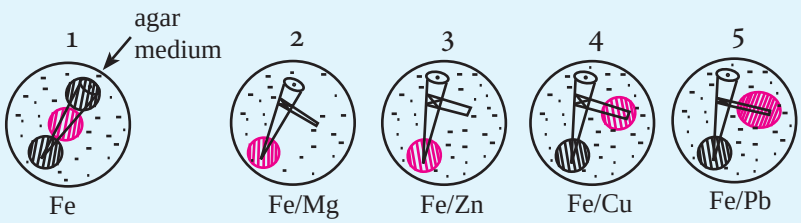


Figure 12.3.7

- Take five petri dishes. Place only an iron nail into the first petri dash. Keep the strips of magnesium, zinc, copper and lead in good contact with the other four nails. In each of the other four petri dishes, as shown in the figure. Then add the hot gel medium to all the five dishes so that the nail in each is fully covered. Allow to cool and observe after about one hour. Record the observations.

★ In the presence of OH^- ions, phenolphthalein indicator turns pink.

★ Fe^{2+} ions indicate a blue colour with potassium ferricyanide.

In the petri dishes 2 and 3 above pink colour is seen around the iron nails. That means, OH^- ions are formed near the iron nail. Absence of blue colour show that Fe^{2+} ions have not formed. In the petri dishes 2 and 3, the iron nails are in contact with magnesium and zinc which are more reactive than iron. Hence, cathodic reaction has occured at the iron nails.

$$2H_2O\,(l) + O_2\,(g) + 4e \longrightarrow 4OH^-\,(aq)$$

Here, the metals of higher reactivity, magnesium and zinc, act as the anode. At these metals oxidation occurs.

$$Mg\ (s) \longrightarrow Mg^{2+}\ (aq) + 2e$$

$$Zn\ (s) \longrightarrow Zn^{2+}\ (aq) + 2e$$

The Mg^{2+} and Zn^{2+} ions formed do not give a colour with potassium ferricyanide in the medium.

Appearnce of blue colour around the iron nails in the petri dishes 4 and 5 indicates the formation of Fe^{2+} ions. This shows that the iron nails in them have corroded. In these set ups, iron acts as the anode and is subjected to oxidation as follows.

$$Fe\ (s) \longrightarrow Fe^{2+}\ (aq) + 2e$$

Copper and lead are placed below iron in the activity series. When iron is in contact with such a metal, iron rusts faster. Areas around copper and lead strips turning pink indicates the formation of OH^- ions closer to them. Therefore, the following reaction should have occured at copper or lead.

$$2H_2O\ (l) + O_2\ (g) + 4e \longrightarrow 4\ OH^-\ (aq)$$

According to the above observations it would be clear to you that in order to protect iron from corrosion, a metal above iron in the activity series can be kept in contact with iron. Then, iron acts as the cathode and is protected from corrosion. Protecting iron by making it the cathode of an electrochemical cell is known as the cathodic protection or sacrificial protection.

Instances where cathode protection is used:

- Coating iron objects with zinc (galvanizing)- buckets, barbed wire, roofing sheets, GI pipes
- Welding blocks of magnesium and zinc to the hulls of the ships sailing in the sea (These blocks of magnesium and zinc should be replaced from time to time)

Summary

- Electrochemical cells are used to convert chemical energy to electrical energy.
- A simple cell can be made by connecting two different metal rods by conducting wires and immersing them in an acid solution.
- In a simple electrochemical cell, the more reactive metal acts as the anode and the less reactive metal acts as the cathode.
- An oxidation half reaction occurs at the anode while a reduction half reaction occurs at the cathode.
- Anode is the negative terminal and cathode is the positive terminal of an electrochemical cell.
- Along the external wire, electrons flow from the anode to cathode.
- The conventional current is considered to flow from the positive terminal (cathode) to negative terminal (anode).
- Electrolysis causes chemical changes in matter by passing an electric current through a solution or a liquid.
- In electrolysis, electricity is passed through the solution or a liquid by immersing two carbon or metal electrodes in it, to which an external electrical supply is connected.
- The solution /liquid through which electricity is passed is called the electrolyte. To conduct electricity there should be mobile ions in the electrolyte.
- Since the positive terminal of the electrolytic cell acts as the anode, an oxidation half reaction occurs at the positive terminal.
- Manufacturing of useful substances from the products discharged at the electrodes is an industrial application of electrolysis.
- Industrially, sodium metal is obtained by the electrolysis of fused sodium chloride. Hydrogen and chlorine gases obtained as by-products of this are also useful chemicals.
- Subjecting the surface of a metal to chemcial changes when it is exposed to atomsphere and moisture is known as the corrosion of the metal.
- Subjecting iron and steel to corrosion as above is specifically known as rusting.
- Oxygen gas and moisture are indispensable for the rusting of iron.
- Corrosion of iron is an electrochemical process.
- The anodic reaction of this process is

$$Fe\ (s) \longrightarrow Fe^{2+}\ (aq) + 2e$$

- The cathodic reaction is
  $2\ H_2O\ (l) + O_2\ (g) + 4\ e \longrightarrow 4\ OH^-\ (aq)$
- The overall corrosion reaction can be obtained by the above anodic and cathodic reactions.
  $2\ H_2O\ (l) + O_2\ (g) + 2\ Fe\ (S) \longrightarrow 2\ Fe\ (OH)_2\ (s)$
- By further oxidation of $Fe(OH)_2$, hydrated ferric oxide ($Fe_2O_3 . x\ H_2O$) or rust is formed.
- Salts such as sodium chloride and acids speed up rusting.
- Bases decrease the rate of rusting.
- Rusting can be prevented by keeping iron without coming into contact with oxygen and moisture, the essential conditions for rusting.
- For this, iron can be coated with a protective layer of paint, grease or tin metal.
- When a metal more reactive than iron is in contact with iron, rusting is reduced because the reactive metal acts as the anode and iron acts as the cathode. This is called sacrificial protection or cathodic protection.
- Galvanizing iron is an example for sacrifical protection.

Exercises

Multiple choice questions

1. Consider a cell constructed using a zinc metal plate, an iron metal plate and dilute sulphuric acid. Which of the following statement is true about it?
   1. The conventional current of the cell flows from zinc to iron through the wire.
   2. Gas bubbles evolve at the iron electrode.
   3. Iron electrode decays.
   4. Iron electrode is the negative terminal of the cell.

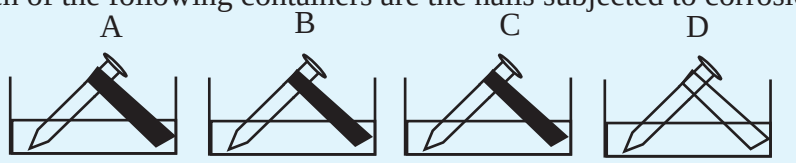
2. Consider the cell constructed by immersing iron and copper electrodes in dilute sulphuric acid. Which of the following is the anodic reaction of this cell?

   1. $Cu\ (s) \longrightarrow Cu^{2+}\ (aq) + 2\ e$
   2. $Fe^{2+}\ (aq) + 2\ e \longrightarrow Fe\ (s)$
   3. $Fe\ (s) \longrightarrow Fe^{2+}\ (aq) + 2\ e$
   4. $2\ H^+\ (aq) + 2\ e \longrightarrow H_2\ (g)$

3. Which of the following is an essential factor for corrosion of iron?
   1. water 2. atomospheric carbon dioxide gas
   3. acids 4. bases

4. Which of the following is a factor that accelerates corrosion of iron?
   1. atmospheric moisture
   2. atmospheric carbon dioxide gas
   3. limewater
   4. grease

5. In which of the following containers are the nails subjected to corrosion?



   1. A and B 2. B and C
   3. A and C 4. B and C

6. Which of the following statements is not true?
   1. In an iron spoon the part smeared with vinegar rusts more.
   2. Galvanized wire rusts when the coating is scratched.
   3. A tin-coated vessel rusts when the coating is scratched.
   4. Rusting of iron can be prevented by coating it with magnesium.

7. When an aqueous solution of sodium chloride is electrolysed using carbon electrodes
   1. hydrogen gas is liberated at the positive terminal.
   2. sodium hydroxide is formed in the solution.
   3. chlorine gas is liberated at the cathode.
   4. anode dissolves.

8. When a solution of copper sulphate is electrolysed using carbon electrodes
   1. copper is deposited on the cathode.
   2. copper is deposited on the anode.
   3. oxygen gas bubbles are formed at the negative electrode.
   4. the blue colour of the solution remains unchanged.

9. Which of the following is not a conductor of electricity?
   1. aqueous sodium hydroxide
   2. acidified water
   3. solid sodium chloride
   4. aqueous sodium chloride

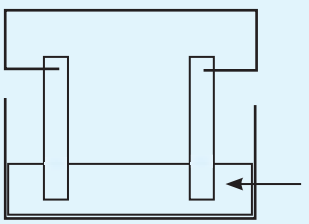
10. During the electrolysis of acidulated water using carbon electrodes
    1. hydrogen gas is evolved at the anode.
    2. oxygen gas is evolved at the cathode.
    3. hydroxide ions are genarated at the anode.
    4. anode dissolves.

11. Which of the following is an occasion where electrolysis is not used industrially?
    1. coating an iron spoon with nickel.
    2. extraction of aluminium metal.
    3. galvanizing iron nails.
    4. extraction of sodium from fused sodium chloride.

Essay questions

1.Write balanced half equations for the following chemical processes. State whether the half reactions you write are oxidation or reduction.
    i. magnesium metal (Mg) turning into magnesium ions (Mg^{2+})
    ii. aluminium metal (Al) turning into aluminium ions (Al^{3+})
    iii. sodium metal (Na) turning into sodium ions (Na^{+})
    iv. hydrogen ions (H^{+}) turning into hydrogen molecules (H_2)

2. Consider the following electrochemical cell constructed using zinc and lead metals.



i. Name the anode and cathode of this cell.
ii. Name the positive terminal and negative terminal of this cell.
iii. Write the anodic and cathodic reactions of this cell.
iv. Name the electrode reactions corresponding to oxidation and reduction.
v. Write the overall cell reaction.
vi Write the changes that can be observed at the electrodes.

Technical terms

Electrolysis	-	විද්‍යුත්විච්ඡේදනය	-	மின்பகுப்பு
Electrolyte	-	විද්‍යුත් විච්ඡේද්‍යය	-	மின்பகுபொருள்
Non-electrolyte	-	විද්‍යුත් අවිච්ඡේද්‍යය	-	மின்பகாப்பொருள்
Electrolytic cell	-	විද්‍යුත් - විච්ඡේදන කෝෂය	-	மின்பகுப்புக் கலம்
Spontaneous	-	ස්වයංසිද්ධ	-	சுயாதீனமான
Activity series	-	සක්‍රියතා ශ්‍රේණිය	-	தாக்கவீதத் தொடர்
Bleaching	-	විරංජනය	-	வெளிற்றல்
Electroplating	-	විද්‍යුත් ලෝහාලේපනය	-	மின் உலோக முலாமிடல்
Anode	-	ඇනෝඩය	-	அனோட்டு
Cathode	-	කැතෝඩය	-	கதோட்டு
Electrochemical cell	-	විද්‍යුත් - රසායනික කෝෂය	-	மின் இரசாயன கலம்
Electrode	-	ඉලෙක්ට්‍රෝඩ	-	மின்வாய்
Half reactions	-	අර්ධ ප්‍රතික්‍රියා	-	அரை அயன் தாக்கம்
Flow of electrons	-	ඉලෙක්ට්‍රෝන ධාරාව	-	இலத்திரன் பாய்ச்சல்
conventional current	-	සම්මත ධාරාව	-	நியம மின்னோட்டம்
Galvanometer	-	ගැල්වනෝමීටරය	-	கல்வனோமானி
Oxidation	-	ඔක්සිකරණය	-	ஒட்சியேற்றம்
Reduction	-	ඔක්සිහරණය	-	தாழ்த்தல்
Negative terminal	-	ඍණ අග්‍රය	-	மறை முனை
Positive terminal	-	ධන අග්‍රය	-	நேர் முனை
Oxidation half reaction	-	ඔක්සිකරණ අර්ධ ප්‍රතික්‍රියාව	-	ஒட்சியேற்ற அரை அயன் தாக்கம்
Reduction half reaction	-	ඔක්සිහරණ අර්ධ ප්‍රතික්‍රියාව	-	தாழ்த்தல் அரை அயன் தாக்கம்
Anodic reaction	-	ඇනෝඩ ප්‍රතික්‍රියාව	-	அனோட்டுத் தாக்கம்
Cathodic reaction	-	කැතෝඩ ප්‍රතික්‍රියාව	-	கதோட்டுத் தாக்கம்
Cell reaction	-	කෝෂ ප්‍රතික්‍රියාව	-	கலத் தாக்கம்
Corrosion	-	ලෝහ විඛාදනය	-	உலோக அரிப்பு
Rusting	-	මල බැඳීම	-	துருப்பித்தல்
Bimetal effect	-	ද්වි ලෝහ ආචරණය	-	ஈருலோகச் சட்டம்
Sacrificial protection	-	කැප කිරීමේ ආරක්ෂණ ක්‍රමය	-	தியாகப் பாதுகாப்பு முறை
Cathodic protection	-	කැතෝඩීය ආරක්ෂණ ක්‍රමය	-	கதோட்டுப் பாதுகாப்பு முறை

Electromagnetism and Electromagnetic Induction

Physics 13

13.1 Magnetism

Figure 13.1 shows the use of a large electromagnet to lift and remove scrap iron and steel. Since iron and steel pieces are attracted towards this strong electromagnet, it is easy to move them using this method.

Figure 13.1 – Use of an electromagnet to remove scrap iron and steel

There are two main types of magnets known as **electromagnets** and **permanent magnets**. In electromagnets, magnetism exists only while a current is passing through the coil of the electromagnet. In permanent magnets, magnetism is a characteristic of the material of the magnet and it remains in the magnet permanently.

Both types of magnets are used in many instruments for various purposes. Magnets are used in controlling most domestic appliances and robots by electric motors, in applications involving magnetic cards, in medical equipment such as MRI machines and in various other scientific and technological instruments. Therefore, it is useful to have a good knowledge about the behaviour, operation and applications of magnets.

Figure 13.2

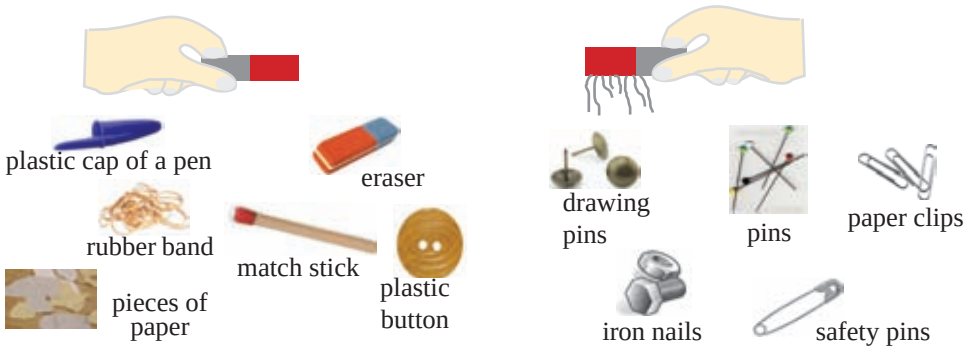


Figure 13.3 (a) - Objects which are not attracted (b) - attracted by magnets

Objects made of magnetic materials such as iron, steel, nickel are attracted by magnets. Objects made of materials such as plastic, wood, paper and rubber are not attracted by magnets.

13.1.1 Magnetic Field

Around any magnet, there is a region within which the magnet has an influence. This region is known as the **magnetic field**. A magnetic field is not perceptible to the eye. Therefore we cannot see a magnetic field. However, it can influence another magnet or a moving charge. It has been found that some animals such as birds use the earth's magnetic field for navigation.

One way of determining whether there is a magnetic field in a certain region is to use a compass. A compass is a small light-weight magnet mounted on a pivot in such way that it could rotate freely around the pivot. In the absence of any magnetic influence other than the earth's magnetic field, a compass aligns along the north-south direction. Let us engage in activity 13.1 to investigate the field near to a bar magnet.

Activity 13.1

Apparatus required: A compass, a piece of glass, A piece of iron, A magnet, A piece of plastic, a piece of brass

- Place the compass on a table and observe the deflection of its indicator by bringing close to it, a piece of glass, a piece of iron, a magnet, a piece of plastic and a piece of brass one at a time.

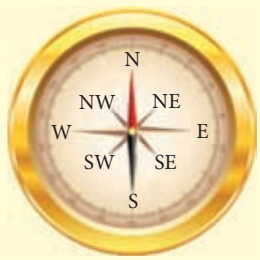


Figure 13.4

You will observe that the indicator of the compass deflects only when a magnet is brought close to it. From this we can conclude that the magnet gives rise to a magnetic field in its vicinity.

For extra knowledge

Naturally occurring magnets have been known to man as far back as thousands of years. The compass was invented by Chinese in the eleventh century AD.

When a compass is placed at a point in a region where a magnetic field exists, the direction of the compass needle shows the direction of the magnetic field at that point. This direction can vary from point to point. In addition, the strength of the magnetic field can also vary from point to point. Therefore, a magnetic field is a physical quantity with a magnitude and a direction.

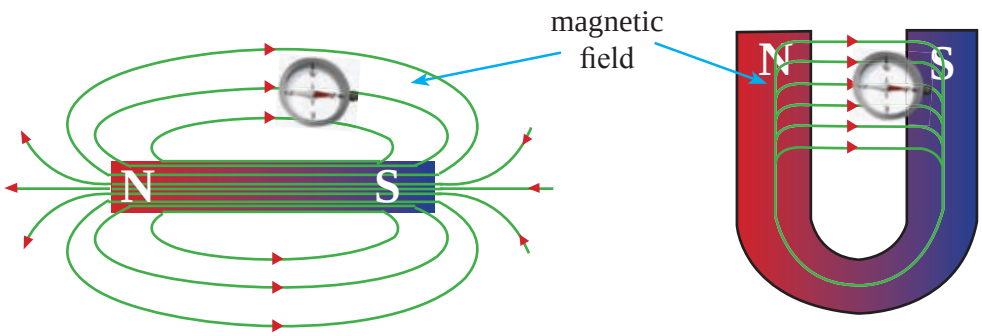


Figure 13.5 – Finding the direction of a magnetic field using a compass

13.2 Magnetic Effect of a Current

When an electric current flows through an electric conductor, a magnetic field is created in the vicinity of the conductor. Danish scientist Hans Christine Oersted was the first to observe a magnetic effect in the vicinity of a current carrying conductor.

Figure 13.6 - Hans Christine Oersted

Let us now engage in activity 13.2 to observe a magnetic effect (field) due to a straight conductor carrying a current.

Activity 13.2

Apparatus required: a compass, a straight copper wire, a few batteries, connecting wires and a switch

- Place the compass on the table with its indicator along the north-south direction and next place the copper wire *AB* above the compass and along the north-south direction.

Figure 13.7

- Connect a battery and a switch to *AB* using connecting wires.
- Close the switch S and allow a current to pass through *AB*. The compass indicator will show a deflection towards the left hand sides.
- Stop the current flow by opening switch S and observe the compass needle. You will observe that the indicator returns to its original position.

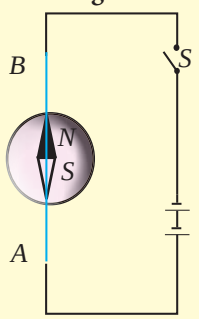


Figure 13.8

- Now place the compass horizontally above the wire *AB* and observe what happens when a current flows through *AB*. You will observe that the indicator deflects in the opposite direction.
- Now change the terminals of the battery and allow a current to flow in the opposite direction (*BA*). Place the compass below the wire *AB*. You will observe that the compass needle deflects towards the right hand side.
- Now place the compass above the wire and allow the current to pass in the direction *BA*. You will be able to observe that the compass indicator deflects in the opposite direction.

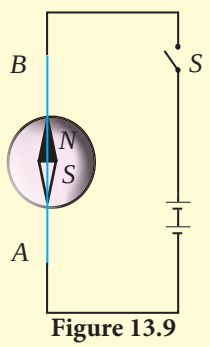


Figure 13.9

The indicator deflects only when it is subjected to the influence of a magnetic effect. That is, in the presence of a magnetic field. This activity would show you that a magnetic field is created when a current flows through a conductor.

It will be clear to you from the above activity that the direction of the magnetic field in the vicinity of a current carrying conductor depends on the direction of the current flow.

13.2.1 Direction of the Magnetic Field due to a Current through a Straight Conductor

Let us now investigate about two rules that could be used to find the direction of the magnetic field due to a current flowing through a straight conductor.

- **Maxwell's corkscrew rule**

Maxwell's corkscrew rule can be used to find the direction of the magnetic field due to a current flowing through a conductor.

When a corkscrew is rotated in such a way that its tip moves in the direction of current flow, then the magnetic field lines produced by the current are in the direction of rotation of the corkscrew.

A corkscrew is an instrument used to open bottles with cork lids. Normal screws show the same behavior as corkscrews.

(a) According to Figure 13.10 (a), when a current flows from *A* to *B*, the direction of the resulting magnetic field is anti-clockwise.

(b) According to Figure 13.10 (b), when a current flows from *B* to *A*, the direction of the resulting magnetic field is clockwise.

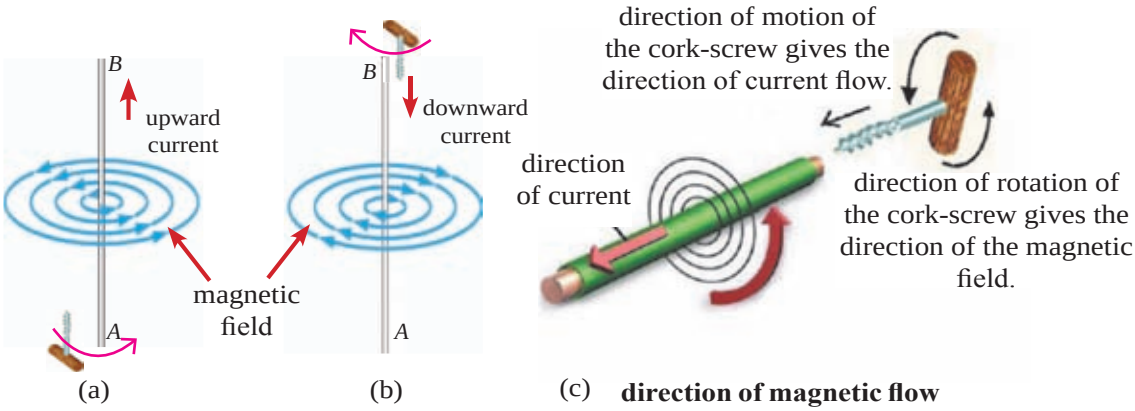


Figure 13.10 – Magnetic field around a current carrying conductor

- **Right hand grip rule**

Right hand grip rule is another simple rule for finding the direction of the magnetic field due to a current carrying conductor.

If the conductor is held with the right hand in such a way that the thumb is directed towards the direction of current flow, then the direction of the other four fingers around the conductor indicates the direction of the magnetic field.

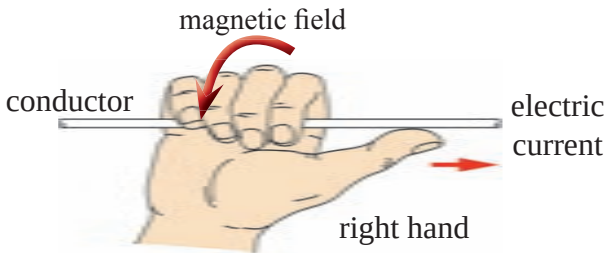


Figure 13.11 – Finding the direction of magnetic field from the direction of current flow

Figure 13.12 shows how the direction of the magnetic field due to a current carrying conductor is marked in a diagram.

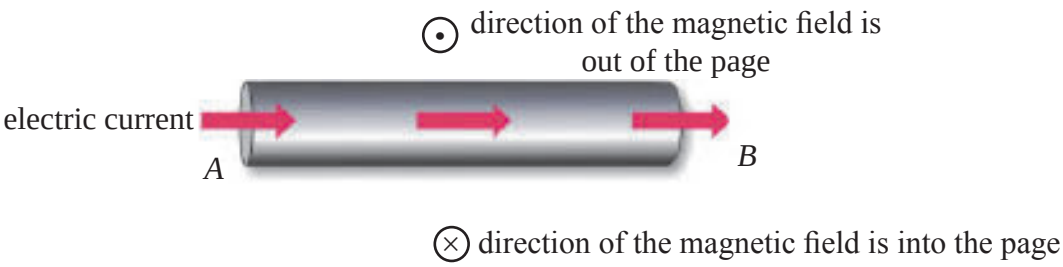


Figure 13.12 – Indicating the magnetic fields perpendicular to the plane of the page directed into and directed out of the page in a diagram

Suppose that a current flows through the conductor in Figure 13.12 along the direction *AB*. Then, according to the right hand rule, the magnetic field is directed towards you (from the page) in the region above the conductor while it is directed away from you (into the page) in the region below the conductor. A dot inside a circle (⊙) is used to indicate a magnetic field coming out of the page while a cross inside a circle (⊗) is used to indicate a magnetic field going into the page.

13.2.2 Force Acting on a Current Carrying Conductor Placed in a Magnetic Field

You have learnt that a magnetic field is established in the vicinity of a conductor that carries a current. Let us now engage in Activity 13.3 in order to find out whether a force acts on a current carrying conductor placed in a magnetic field.

Activity 13.3

Apparatus required: A U-magnet, a piece of conductor, two brass or some other conducting rods, two dry cells

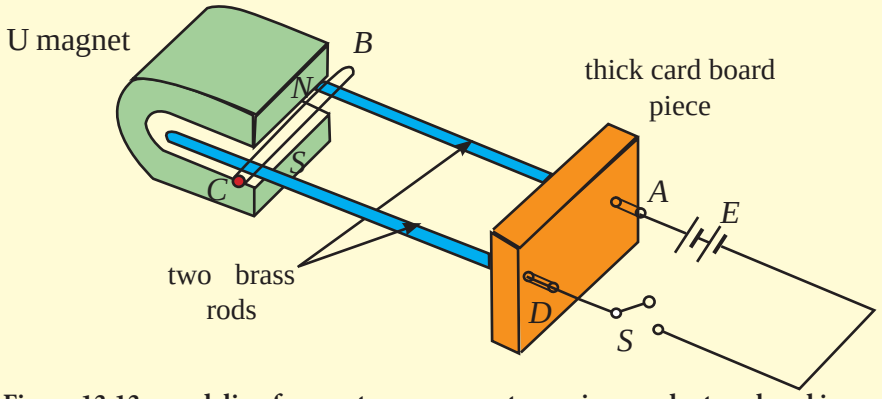


Figure 13.13 - modeling force acts on a current carrying conductor placed in a magnetic field

- Place the U-magnet on a table and place the two brass rods as shown in the figure by inserting them through two holes pierced in the thick card board. Connect the two dry cells and the switch *S* to the ends *A* and *D* of the brass rods.
- Next place the conductor *BC* on the two brass rods between the north and south poles of the magnet.
- Allow a current to flow by closing the switch *S*. Then a current flows from the cells through the brass rods along the direction *AB* and through the conductor in the direction *BC* and reaches the cell from the direction *CD*.
- When the current flows, you will observe that the conductor *BC* moves along the brass rods away from the magnet (to the right hand side).
- Now repeat the above step by changing the cell terminals to change the direction of the current. Now you will observe that the conductor *BC* moves along the brass rods towards the magnet (to the left hand side).
- Repeat the above step after changing the top and bottom poles of the magnet. You will observe that the direction of motion of the conductor *BC* is opposite to that of the above steps.

A conductor placed in a magnetic field moves when a current flows through the conductor as a result of a force acting on it. The direction of the force is indicated by the direction of motion of the conductor.

In the activity above, the direction of the magnetic field and the direction of the current through the conductor have been arranged to be perpendicular to each other.

You will be able to observe that the motion of the conductor takes place in a direction perpendicular to both of the above directions.

The magnitude of the resulting force depends on the following three factors.

- The magnitude of the current through the conductor
- The length of the conductor between the rods
- The strength of the magnetic field

The force increases as the above three factors are increased and it decreases when the above three factors are decreased. That is, the force is directly proportional to the three factors given above.

• Fleming's left hand rule

Fleming's left hand rule can be used to find the direction of the force acting on a conductor placed in a magnetic field when a current flows through the conductor.

Keep the thumb, index finger and the middle finger of the left hand perpendicular to one another and point the middle finger in the direction of the current flow and the index finger along the direction of the magnetic field. Then the direction pointed by the thumb will be the direction of the force acting on the conductor.

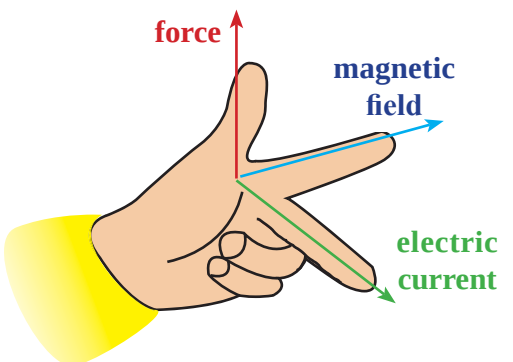
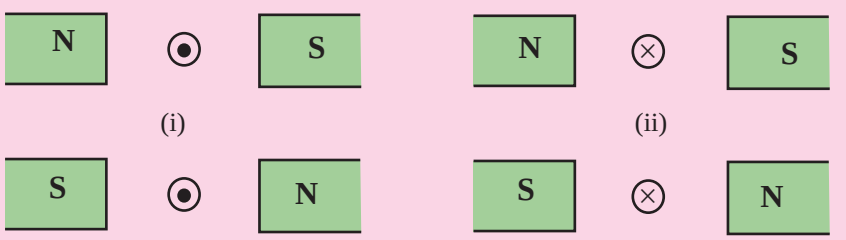


Figure 13.14 – Finding the direction of the force on the conductor based on the directions of the current and the magnetic field

Exercise 13.1

(1) Find and mark the direction of the force acting on the conductor using Fleming's left hand rule in each of the figures given below for the magnetic fields and currents indicated.



The action of a force on a current carrying conductor placed in a magnetic field is a very useful phenomenon in our daily lives. Electric motors, loud speakers, galvanometers, voltmeters and ammeters (analog) are some of the instruments constructed based on this phenomenon.

13.2.3 Loud Speaker

Figure 13.15 shows the outward appearance and the cross section of a loud speaker. A loud speaker generates a sound when a current that varies according to the wave form of the sound is allowed to pass through the coil in the loud speaker.

The main components of a loud speaker are a light-weight cardboard cone, a conducting coil and a ring-magnet. The end of the cone with the larger diameter and the magnet are fixed to a supporting metal frame as shown in Figure 13.15(b).

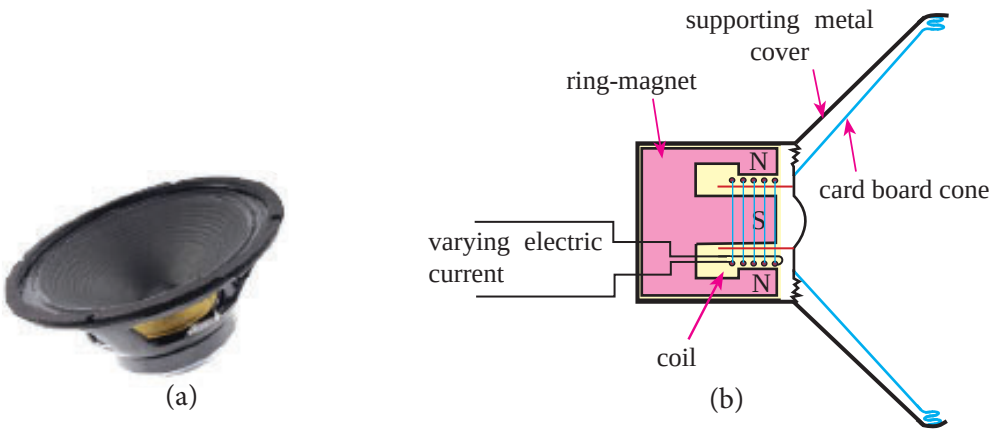


Figure 13.15 (a) – A loud speaker (b) A cross section of a loud speaker

The coil is connected to the end of the cone with the smaller diameter in such a way as to allow the coil to freely move forward and backward in the region between the poles of the magnet. When a time-varying current flows through the coil, the force exerted on the conductor by the magnet vibrates the coil forward and backward according the variation of the current and the cone too vibrates accordingly, generating sound waves.

13.2.4 Direct Current Motor (DC Motor)

Toy motor cars, hybrid cars, electric cars and electric trains are operated using DC motors.

A hybrid car

An electric car

An electric train

Figure 13.16

Let us engage in activity 13.4 to construct a DC motor.

Activity 13.4

Apparatus required: A dry cell, insulated copper wires, two needles with large holes, some clay, cello tape, A knife for cutting wires, A small (ring) magnet.

- First construct the magnetic coil. In order to do this, wrap about 30 windings of the copper wire around a cylindrical object such as a somewhat large pen, starting from the middle of the wire. Wind the free ends of the wire several times around the coil to prevent it from unwinding.
- Use the knife to remove the insulation of the wire as shown in figure 18 near the free ends. Removal of the insulation should only be done in about half of the wire and on the same side at each end.
- Next, pass the two ends through the needle holes and mount the coil on the needles horizontally as shown in figure 3.

- Fix the needles on to the terminals of the dry cell using cello tape as show in the figure 4.
- Use clay to fix the dry cell rigidly.
- Finally attach the circular magnet on the cell using clay.

You will be able to observe the copper wire rotating. If it does not rotate, give it a slight push with your hand. Then it will start rotating.

figure 1

figure 2

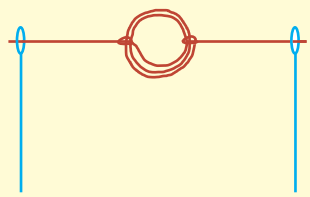


figure 3

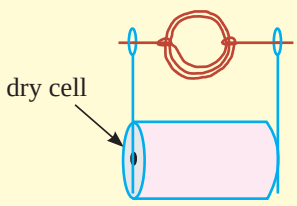


figure 4

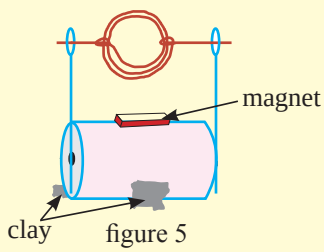


figure 5

In this case too, the magnetic field exerts a force on the conductor when a current flows through it. Since the conductor in this case is a coil, two forces act on the coil in two opposite directions (a couple) as shown in figure 6 causing it to rotate.

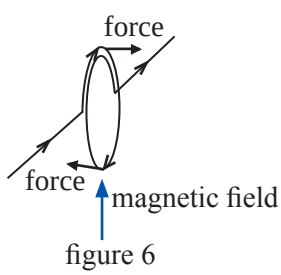


figure 6

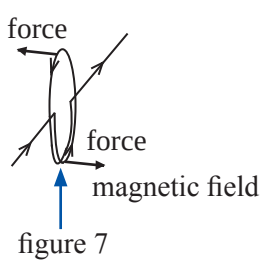


figure 7

The reason for removing the insulation in only one side of the coil at the two ends is to prevent a current from flowing through the coil in the second half a cycle (after the first half cycle). Otherwise, the couple will act in the opposite direction in the second half cycle as shown in figure 7 and the coil will tend to rotate in the opposite direction. If however the current is prevented from flowing in the second half cycle, the coil will continue to rotate in the same direction during the second half cycle too in the first half cycle.

• Main parts of the DC motor

Armature

In normal DC motors, there is a coil much like the coil you used in the previous activity. Since a motor is used to rotate some load, the coil of a DC motor must be strong enough to withstand an external load. Therefore the coil is wrapped around a steel or iron core as shown in the figure 13.17. This coil, together with the core, is known as the **armature.**

Figure 13.17 - Armature

The function of the armature is to give rise to a rotation by generating a couple when a current is passing through it.

Magnetic Poles

A magnetic field is required to exert a force on a coil when a current flows through the coil. In normal DC motors this magnetic field is obtained by poles of a permanent magnet arranged around the armature as shown in the figure 13.18.

Figure 13.18- Magnetic Poles

Commutator

In the motor you constructed, the insulation was removed only on one side of the wire near the ends. That was because the coil would rotate in two opposite directions if the insulation is completely removed. Therefore, in your motor, the current flows through the coil only in one half of each cycle. When the current flows only during half a cycle, the load that the motor can rotate is restricted. Therefore a more suitable way for the current to flow would be to let the current to flow in one direction during half of a rotation cycle and to let the current to flow in the opposite direction in the next half cycle. A **commutator** is used to alternate the direction of current flow in this manner.

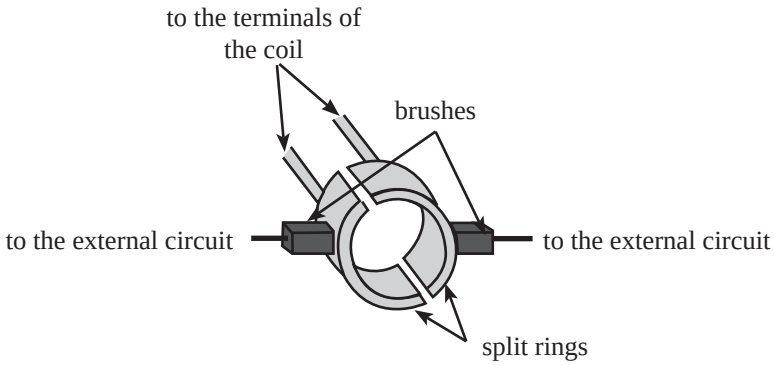


Figure 13.19 - Commutator

The commutator consists of two metallic split rings and two parts known as brushes that can be adjusted to brush against the split rings as shown in the figure 13.19. The two ends of the coil are connected to the two split rings and they rotate with the armature. The two brushes maintain contact with the split rings without rotating themselves. These two brushes are connected to the external circuit that provides current to the motor.

• Operation of a DC Motor

Figure 13.20 shows the appearance of a motor with all of the above components assembled together. Figure 13.21 shows a simplified figure that can be used to understand the operation of the motor easily. In the Figure 13.21 the coil of the motor is shown by a single loop *ABCD*. This coil is placed between two magnetic poles. The coil is connected to the split rings *X* and *Y* while the brushes *P* and *Q* are connected to the battery *S*.

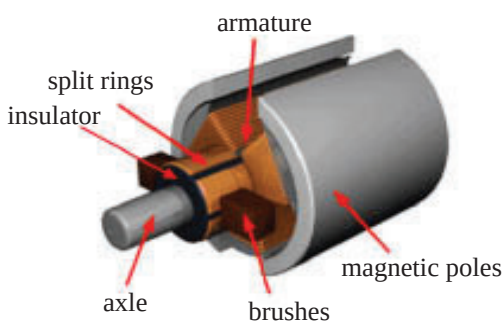


Figure 13.20 – Main parts of a dc motor

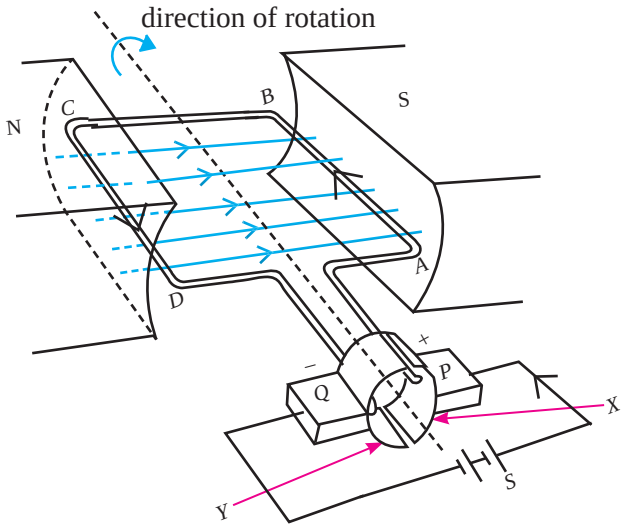


Figure 13.21 – Modeling the operation of a DC motor

- When a current is made to flow through the motor, the current enters the split ring *X* through the brush *P* and flows through the wire loop *ABCD*, reaches the split ring *Y* and passes to the external circuit through the brush *Q*.
- The current passes through the loop placed in the magnetic field along the directions *AB* and *CD*.
- Find the direction of the force acting on *AB* and *CD* by applying Fleming's left hand rule. You will find that the force on *AB* acts downwards while that on *CD* acts upwards. The armature will rotate clockwise due to the resulting couple.
- Let us now consider what happens when the coil and the two split rings have rotated by 180^{o} and their positions are inverted. This position is shown in Figure 13.22.
- At this point, brush *P* is in contact with split ring *Y* while brush *Q* is in contact with split ring *X*. Then the current enters from brush P to split ring *Y*, flows in the direction *DCBA* and reaches split ring *X* and leaves from brush *Q*.

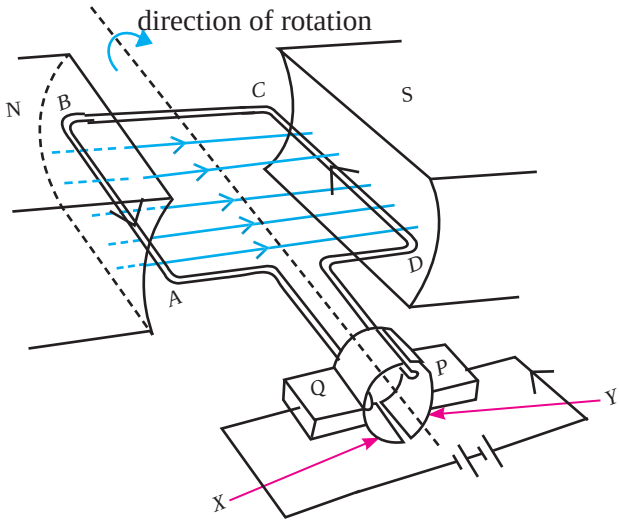


Figure 13.22 – Modeling the operation of a DC motor

- In this situation, current flows along the directions *DC* and *BA* in the coil.
- When Fleming's left hand rule is applied it will be clear that the motion of *AB* is upwards while that of *CD* is downwards. The resulting couple rotates the armature further in the clockwise direction.
- If the direction of the current is changed by changing the battery terminals, the directions of the forces also change to the opposite directions and the direction of rotation of the armature will be in the anti-clockwise direction.
- In the operation of the DC motor, the electric energy given to the motor is converted to mechanical energy.

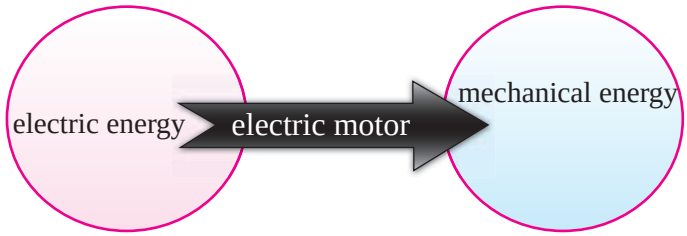
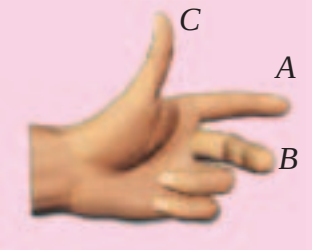


Figure 13.23 – Energy transformation in electric motor

Exercise 13.2

(1) The figure below shows how a student used his left hand in order to apply Fleming's left hand rule.

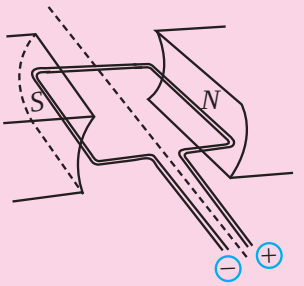


(i) For what purpose is Fleming's left hand rule used?

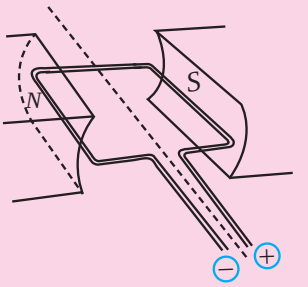
(ii) Directions of what physical quantities are represented by the fingers *A*, *B* and *C* in the above figure?

(iii) Write down what happens to the wire in the following cases using Fleming's left hand rule.

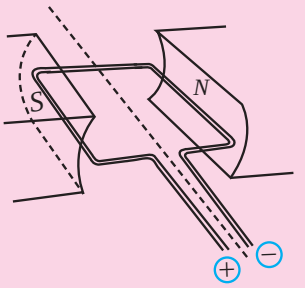
(a)



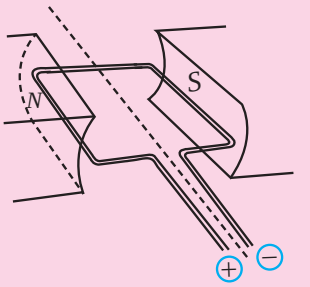
(b)



(c)



(d)



(2) The figure below shows the cross section of a loud speaker.

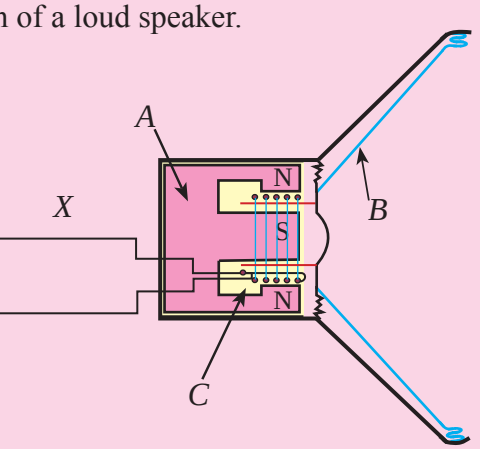
(i) Label parts *A*, *B* and *C* of the figure.

(ii) Write down a special characteristic of the current entering from the terminal *X*.

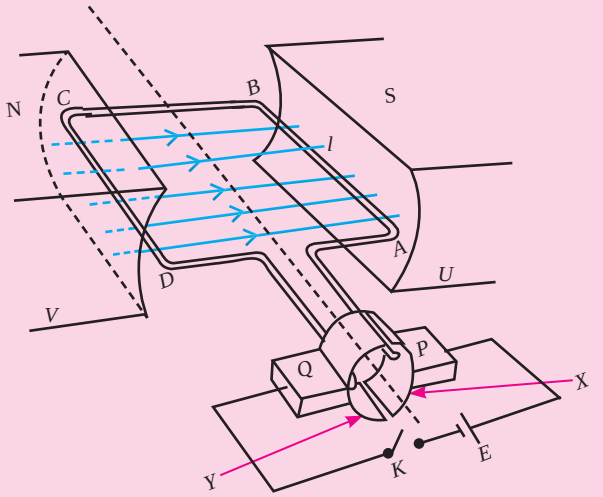
(iii) Explain the operation of the loud speaker.

(iv) Write down the energy transformation taking place in a loud speaker.

(v) Write down the functions of each of the parts *A*, *B* and *C*.



(03) The figure below shows the main parts of a DC motor.



(i) Label parts P, Q of the above figure.

(ii) What are the components labeled X and Y?

(iii) Indicate the direction of current flow in terms of the letters given when the switch K is closed.

(iv) What is the direction of rotation of the motor when switch K is closed?

(v) Write down the functions of each of the components given below in the motor above.

(a) V and U (b) E (c) P and Q (c) X and Y

(vi) Write down the changes that take place in the operation of the motor under each of the changes given below.

(a) Interchanging the battery terminals
(b) Increasing the strength of the magnet

13.3 Electromagnetic Induction

We studied the motion caused by electricity in the previous section. We will next focus on producing an electric current by a conductor that is moving in a magnetic field.

When there is a current flow through a conductor placed in a magnetic field, a force is exerted on the conductor causing it to move. Electromagnetic induction is the inverse of this. That is, if a conductor placed in a magnetic field is set in motion, then an electromotive force is created between the terminals of the conductor.

The generation of an electromotive force between the terminals of a conductor when the conductor is kept at rest in a changing magnetic field or when the conductor is moving in a constant magnetic field is known as **electromagnetic induction**.

Electromagnetic induction was first introduced to the world by Michael Faraday. An important law known as Faraday's law regarding this was presented by him in 1831.

Figure 13.24 – Michael Faraday (1791 - 1867)

The phenomenon of electromagnetic induction is used in magnetic cards used to enter shops and offices by employees, and the magnetic cards (credit and debit cards) used to make payments. Electricity, essential for the daily activities of the modern world, is mainly generated by converting the energy produced from sources such as oil, coal and nuclear power into electric energy through electromagnetic induction.

Figure 13.25

Let us now demonstrate electromagnetic induction by a simple activity.

Activity 13.5

Apparatus required: A bar magnet, The inner tube from a reel of thread, About one metre length of gauge 28 copper wire, A center zero galvanometer

- Form a coil by winding the copper wire around the thread reel and connect its two ends to a center zero galvanometer.
- Now do the movements given in the table below and fill the table by observing whether there is a deflection in the galvanometer or not.
- Observe the relative magnitudes of the deflections in steps 8 and 9.

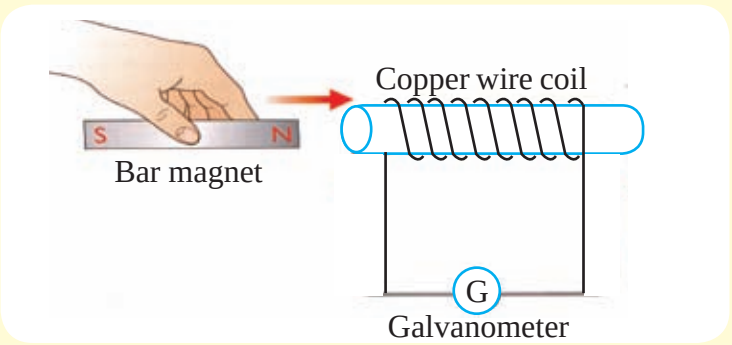


Figure 13.26 – Demonstrating electromagnetic induction

Motion of the magnet	Motion of the coil	Whether there is a deflection in the galvanometer or not
Towards the coil	Stationary	
Stationary near the coil	Stationary	
Away from the coil	Stationary	
Stationary	Towards the magnet	
Stationary	Away from the magnet	
Away from the coil	Away from the magnet	
Towards the coil	Away from the magnet (without changing gap)	
Rapidly towards the coil	Stationary	
Slowly towards the coil	Stationary	

It can be seen from the above activity that there is a deflection in the galvanometer for every motion where there is a change in the relative distance between the coil and the magnet.

- The galvanometer produces a deflection when there is a current passing through it. In order to create a current, there must be a source of electromotive force in the circuit. However there is no such source in the circuit above.
- In this case, an electromotive force has been created by the relative motion between the coil and the magnet. Such an electromotive force is known as an **induced electromotive force**.
- When the magnet and the coil get closer to each other or further away from each other, the magnetic field lines linked to the coil either increase or decrease. Since a deflection is observed in the galvanometer only at such instances, one can conclude that there must be a variation in the magnetic field lines linked to the coil in order to induce an electromotive force.

- A larger deflection is observed in the galvanometer when the magnet is moved rapidly than when it is moved slowly because the electromotive force induced in the coil is directly proportional to the rate of change of the magnetic field lines.

There are several factors affecting the magnitude of the induced electromotive force. Faraday's experiments showed these factors as,

(i) the number of turns (windings) in the coil,
(ii) strength of the magnet, and
(iii) speed of motion of the magnet or coil.

13.3.1 Direction of the current induced in a straight conductor placed in a magnetic field and connected to a closed circuit

When a straight conductor is placed in a magnetic field perpendicular to the field and moved in a direction perpendicular to both the magnetic field and the conductor, an electromotive force is induced across the ends of the conductor. If the conductor is connected to a closed circuit, a current flows through the conductor due to the induced electromotive force. The direction of current flow can be found using Fleming's right hand rule.

- **Fleming's right hand rule**

When the first three fingers of the right hand are oriented perpendicular to one another and the thumb is pointed in the direction of motion of the conductor and the index finger along the direction of the magnetic field that intersects the conductor, the middle finger shows the direction of the current flowing through the conductor.

Figure 13.27 illustrates the right hand rule.

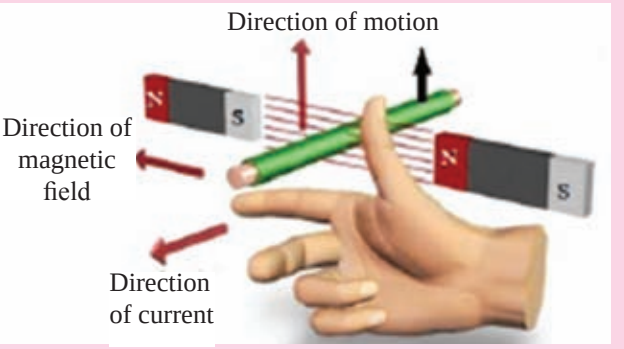
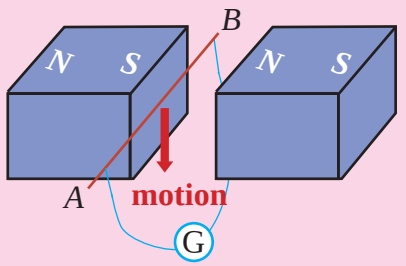


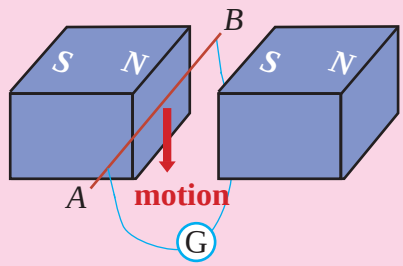
Figure 13.27 – Illustrating Fleming's right hand rule

Exercise 13.3

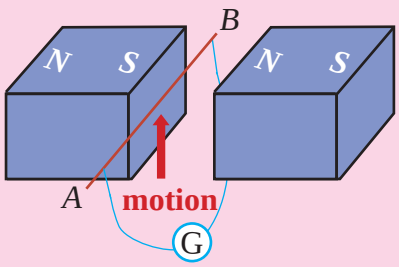
(01) Find and mark the direction of induced current flow using Fleming's right hand rule in each of the instances given below.



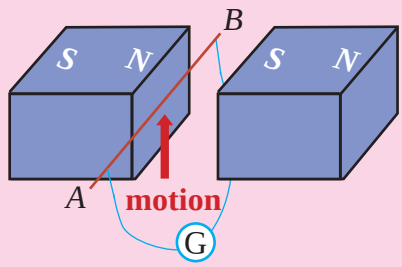
(i)



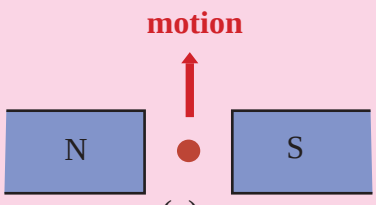
(ii)



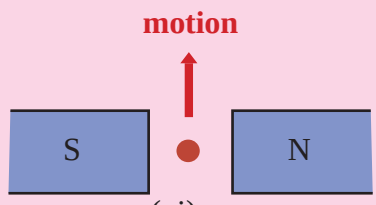
(iii)



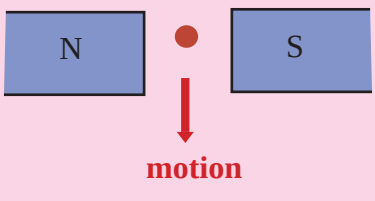
(iv)



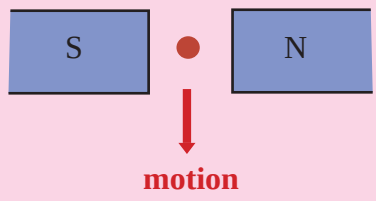
(v)



(vi)



(vii)



(viii)

13.3.2 Applications of Electromagnetic Induction

• Alternating current dynamo

Figure 13.28 shows an alternating current dynamo. A rectangular coil *ABCD* consisting of a number of turns of an insulated copper wire wound around it is connected to an axle that can be rotated around its axis. A strong magnetic field is applied across the coil using a north and a south pole placed on either side of the coil as shown in the figure. Terminal *A* of the coil *ABCD* is fixed to a coaxial copper ring *P* and the other terminal *D* is fixed to another identical copper ring *Q*. *P* and *Q* are known as brushing rings.

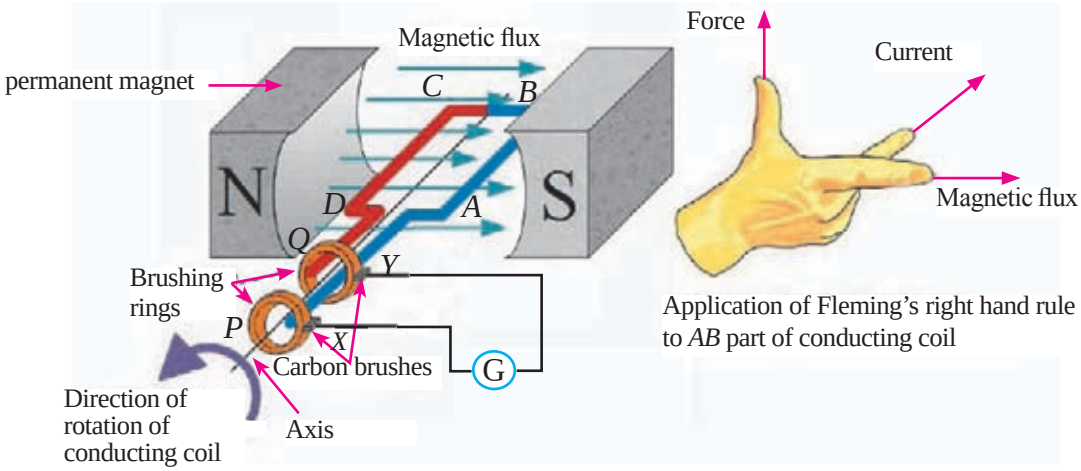


Figure 13.28 – Induced current in a conducting loop rotating in a magnetic field

Two brushes *X* and *Y* made of carbon are mounted in such a way that they brush against the brushing rings. The coil is connected to the external circuit which consists of a center zero galvanometer through the brushes *X* and *Y*. The part consisting of the coil *ABCD*, brushing rings and the axle is known as **the armature**.

Since the arms *AB* and *CD* of the coil intersect the magnetic field across the coil when the coil is rotating, an electromotive force is induced across these arms. Since the circuit is closed, a current passes through the arms *AB* and *CD* of the circuit and the direction of this induced current can be found using Fleming's right hand rule. If the coil is rotated in an anticlockwise direction as shown in the figure, according to Fleming's right hand rule the induced current flows from *A* to *B* since the arm *AB* is moving up and from *C* to *D* since the arm *CD* is moving down. Since both currents through the arms *AB* and *CD* are induced in the same cyclic direction, a current flows through the coil in the direction *ABCD*. The current flow across the galvanometer in the external circuit is from *Y* to *X*. Then the galvanometer indicator deflects to the left.

Figure 13.29 shows how the induced voltage in the coil varies with time when the *ABCD* coil shown in Figure 13.28 is rotated anti-clockwise in the magnetic field.

The upper part of the figure 13.29 shows how the coil (armature) rotates in the magnetic field.

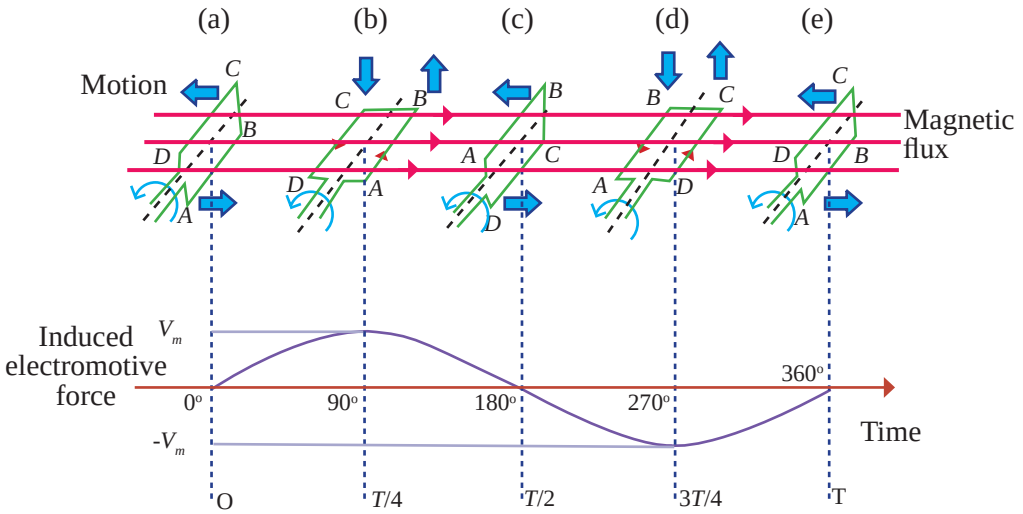


Figure 13.29 – Production of an alternating current

- Since the arms *AB* and *CD* are moving parallel to the magnetic field when the rotating coil is in position (a), the conductors do not intersect the magnetic field lines. Therefore an electromotive force is not induced in the arms *AB* and *CD*. Therefore the galvanometer does not show a deflection.
- While the coil is rotating from position (a) to position (b), the rate at which the field lines are intersected by the coil increases. Therefore, the galvanometer deflection increases accordingly.
- Position (b) is the position of the coil after the coil has rotated by 90° from position (a). At this position, the field lines are intersected perpendicularly by the coil in the upward motion of *AB* and downward motion of *CD*. Then a current flows in the direction *ABCD* as described above causing a deflection to the left of the galvanometer.
- While the coil is moving from position (b) to position (c), the coil is rotating from 90° to 180° and the electromotive force during this period keeps decreasing and becomes zero at position (c). When the coil rotates from position (c) to (d), the coil is rotating from 180° to 270°. During this time *AB* moves down and *CD* moves up intersecting the field lines. Using Fleming's right hand rule one can find that the induced currents flow from *D* to *C* and *B* to *A*. Therefore, the induced current flows through the coil in the direction *DCBA*. This causes a deflection to the right hand side of the galvanometer in the external circuit.

Since the induced electromotive force becomes maximum in the horizontal positions of the coil when the field lines are intersected perpendicularly (in positions (b) and (d) when plane *ABCD* of the coil is parallel to the magnetic field), the current flow becomes maximum at those positions. The induced electromotive force becomes zero for vertical positions of the coil (positions (a), (c) and (e)).

When the coil rotates continuously in this manner, it can be seen that the current flow in the external circuit alternates its direction. We can see that the direction of current flow oscillates periodically since the galvanometer deflects to the left in (b), becomes zero in (a), (c) and (e) and deflects to the right in (d) repetitively. That is, the current changes its direction in each half cycle during one complete cycle of rotation of the coil. The variation of this alternating current or the induced electromotive force with time can be represented by a sinusoidal wave as shown in Figure 13.28.

When the plane of the coil is parallel to magnetic field, the EMF becomes a maximum in + or – direction. when the plane of the coil is perpendicular to the magnetic field, EMF becomes zero.

• Moving coil magnetic microphone

Figure 13.30 shows a diagram of a moving coil magnetic microphone. When a sound reaches the diaphragm of the microphone, the diaphragm vibrates in and out. Then the light coil attached to it also vibrates accordingly. Since the coil vibrates in a magnetic field, the magnetic flux linked to the coil changes inducing an electromotive force in the coil. Since the coil moves in both directions, the direction of the electromotive force alternates. This generates a small alternating current (flowing in both directions) in the microphone that varies corresponding to the variations of the sound reaching the diaphragm.

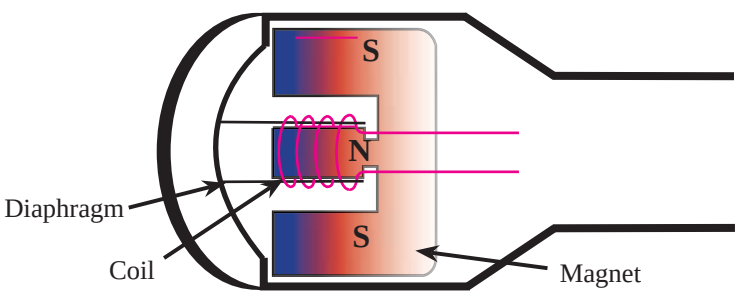


Figure 13.30 – Cross section of a moving coil microphone

• Bicycle Dynamo

Figure 13.31 shows the internal components of a bicycle dynamo. When its rough head is arranged to touch a tire of a bicycle, it rotates fast when the tire is rotating.

Then the cylindrical magnet connected to the rough head also rotates. Since the magnetic field linked to the coil wound around the soft iron changes now, an electromotive force is induced in the coil.

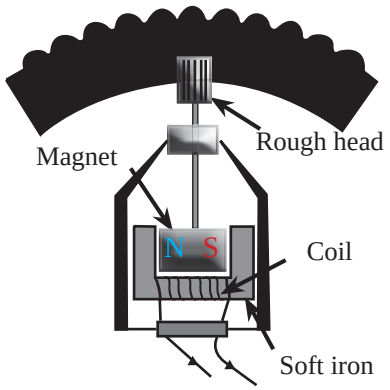


Figure 13.31 – A bicycle dynamo

As a result of winding the dynamo coil around a soft iron it is possible to link most of the magnetic field lines through the coil which increases the induced electromotive force.

Since the direction of the magnetic field alternates when the magnet rotates, the direction of the induced current also alternates its direction. Therefore the output from a bicycle dynamo is an alternating current.

When the bicycle is ridden fast, the speed of the wheels increases. Then the head of the dynamo which is in contact with the tire also rotates fast increasing the rotation speed of the magnet. The increased rate of change of the magnetic field linked to the coil increases the induced electromotive force which gives rise to a larger current. Therefore, the brightness of the bicycle lamp increase with the speed of the bicycle.

An energy transformation takes place in a dynamo. In order to generate electricity, the dynamo has to be rotated. Therefore in a dynamo, the energy is converted from mechanical energy to electric energy.

13.3.3 Direct Currents and Alternating Currents

Figure 13.32(a) shows a circuit connecting a battery, a resistor and a center-zero galvanometer in series. (The resistor prevents a large current from passing through the galvanometer). The constant deflection of the galvanometer will show that the current in the circuit is constant. When the current is plotted against time, a straight line can be obtained as shown in figure 13.32(b).

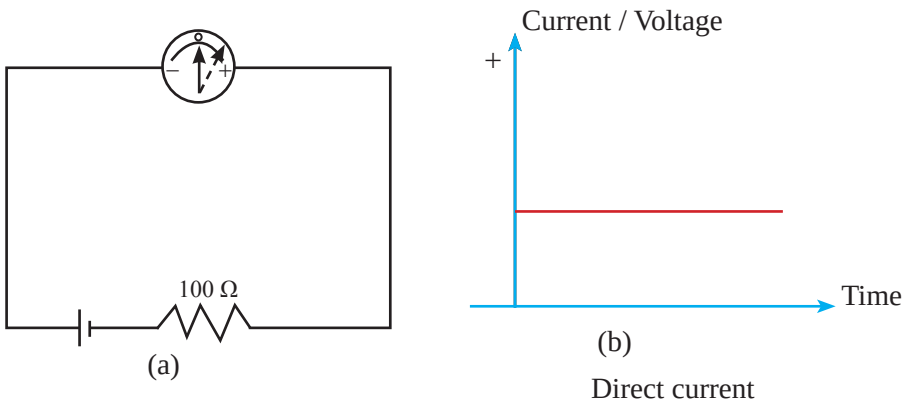


Figure 13.32 – A DC current circuit

If we connect a resistor and a center zero galvanometer in series to the alternating current dynamo discussed above as shown in Figure 13.33(a) and slowly rotate the armature of the dynamo, you will observe that the galvanometer indicator would oscillate in the positive and negative directions around the zero. Therefore when the current (or voltage) is plotted against time, a curve such as that shown in Figure 13.33(b) will be obtained.

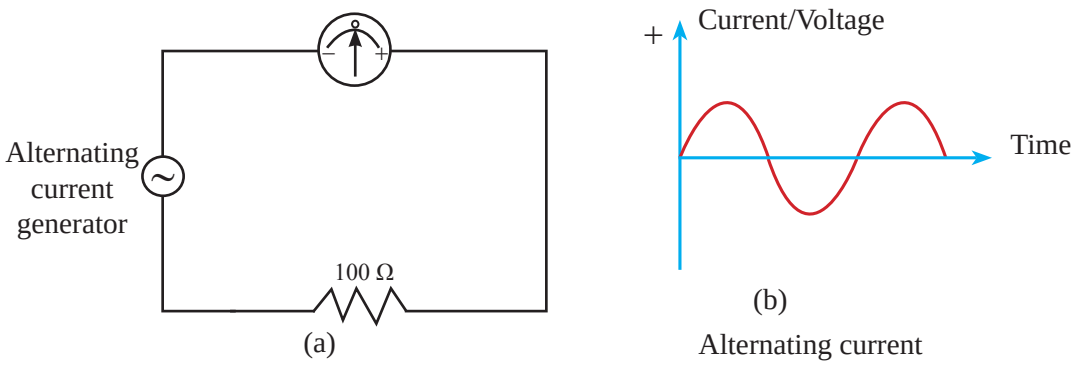


Figure 13.33 – An alternating current circuit arrangement

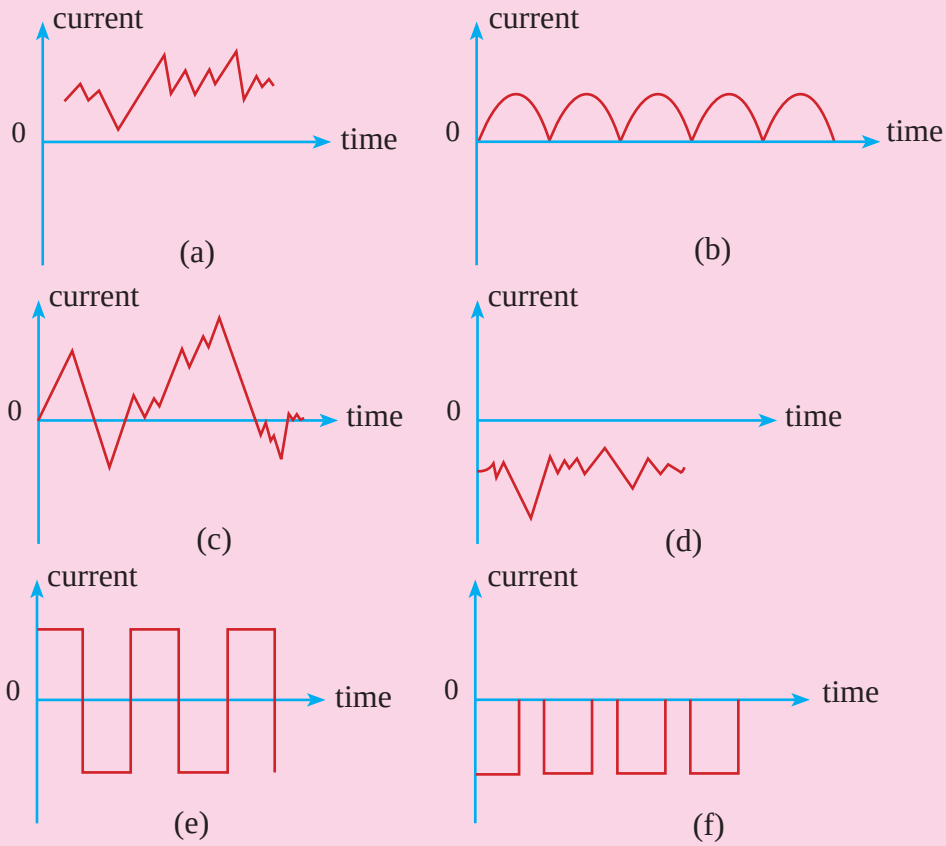
In the first case (Figure 13.39) the direction of current flow does not vary with time. Such currents whose direction does not vary with time are known as **direct currents**.

In the second case (Figure 13.33) the direction of current flow varies with time and such currents whose direction varies with time are known as **alternating currents**.

Exercise 13.4

(1) Write down some instances where alternating currents and direct currents are used.

(2) Several graphs showing the variation of current with time are given below. Indicate which type of current is represented by each of them giving reasons for your answer.



13.3.4 Transformers

Transformers are useful because they allow you to change the voltage of a supply. Transformers are used in power packs and in electric appliances such as computers and radios.

Figure 13.34

Activity 13.6

Apparatus required: about two meters of copper wire of gauge 28, a bundle of soft iron wires, two dry cells, a center zero galvanometer, a switch

- Wrap about 100 turns of insulated copper wire around the bundle of soft iron wires in order to form a coil as shown in the figure.
- Now form another similar coil on the same soft iron wire rope at about a distance of one centimeter from the first.

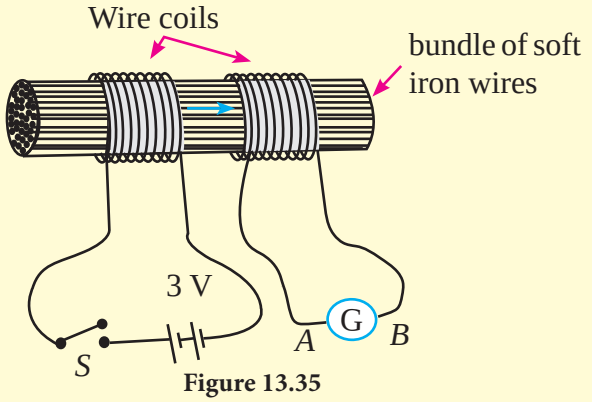


Figure 13.35

- Connect a switch and two 1.5 V dry cells in series to one of the two coils above. Connect the other coil to a center zero galvanometer.
- Now observe the deflection of the galvanometer by turning the switch *S* on and off and fill the table given below by crossing off the incorrect words.

Switch *S*	Galvanometer deflection	Conclusion
Turned on	Deflects to the right/left	A current flows in the second circuit from A to B/B to A.
Turned on continuously	There is a/no deflection	A current flows/does not flow.
Turned off	Deflects in the opposite direction (to the left/ right)	A current flows/does not flow in the opposite direction.
Turned off continuously	There is a/no deflection	A current flows/does not flow.

You will be able to draw the following conclusions from the above activity.

- A current is induced in the second circuit at the instant that a current starts to flow in the first circuit.

- When the current in the first circuit is flowing continuously, the current in the second circuit ceases to flow.
- At the instant that the current flow through the first circuit is turned off, a current is induced in the second circuit in a direction opposite to the direction of current flow before.
- When the current flow in the first circuit ceases, the induced current in the second circuit becomes zero.

In this activity there is no magnetic field through the coils before a current passes through the first coil. A magnetic field is generated when a current begins to flow through the first coil. This magnetic field also passes across the second coil through the soft iron wires. As a result of this change in the magnetic field through the second coil, an electromotive force is induced in it which causes a current to flow through the galvanometer giving rise to a deflection in the galvanometer.

When a current is continuously flowing through the first circuit, the magnetic field remains constant and there is no variation in the magnetic field through the second coil. Therefore an electromotive force is not induced in it. Then the galvanometer deflection is zero.

When the switch in the first circuit is opened, the current flow is terminated. The magnetic field caused by the current too diminishes together with the current. As a result of the diminished magnetic field, the magnetic field through the second coil changes and therefore an electromotive force is induced in the second coil. This induced electromotive force has a direction opposite to that of the previous occasion. Therefore the galvanometer deflection occurs in the opposite direction.

When there is no current flow through the first coil, an electromotive force is not induced in the second coil as there is no variation in the magnetic field. Therefore the galvanometer deflection is zero. Therefore we can conclude that an electromotive force is induced in the second coil whenever there is a "change" caused by the first coil in the magnetic field through the second coil.

If we connect an alternating voltage to the first coil, instead of a battery, then as the magnetic field varies continuously, a similar alternating voltage difference is induced in the second coil too. Such a combination of coils linked by a magnetic field is known as a **transformer**. Transformers only work with ac currents and ac voltages. They will not work with dc currents and dc voltages. Transformers work with alternating currents or voltages and with changing direct currents only. They do not work with cons that direct currents.

The figure below shows the symbol used to represent a transformer in circuit diagrams.

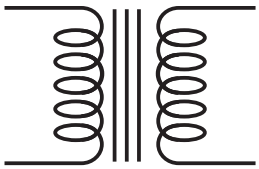


Figure 13.36

The straight lines between the two coils represent the soft iron core.

• Construction of a Transformer

Figure 13.37 shows a simple arrangement of a transformer. It has two insulated copper coils wrapped around a soft iron ring.

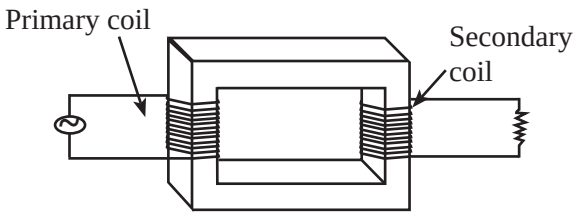


Figure 13.37 – A Simple transformer

Primary coil	Secondary coil
Number of turns N_P	Number of turns N_S
Electromotive force V_P	Induced electromotive force V_S

Normally one coil of a transformer is connected to an alternating power supply while the other is connected to a load (a resistor or an electric appliance operated with an alternating power supply). The first coil that supplies power to the transformer is known as the primary coil or the "**input**". The second coil from which power is taken out of the transformer is known as the **secondary coil** or the "**output**". The voltage supplied to the primary is denoted by V_P and the voltage given out by the secondary is denoted by V_S.

The alternating voltage V_P applied to the primary gives rise to an alternating current flow in the primary circuit which in turn gives rise to an alternating magnetic field. This alternating magnetic field is linked to the secondary coil by the soft iron core and this varying magnetic field induces an alternating voltage V_S in the secondary coil.

The relation between the voltages and the number of turns of a transformer can be expressed as follows.

$$\frac{\text{Number of turns in the primary}}{\text{Number of turns in the secondary}} = \frac{\text{Voltage difference in the primary coil}}{\text{Voltage difference in the secondary coil}}$$

$$\frac{N_P}{N_S} = \frac{V_P}{V_S}$$

According to this relationship, by varying the ratio between the number of turns N_P in the primary and the number of turns N_S in the secondary, an output voltage larger than or smaller than the input voltage can be obtained.

- **Step-up Transformers and Step-down Transformers**

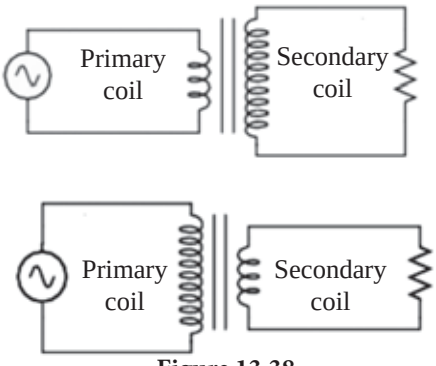


Figure 13.38

Transformers that give an output voltage larger than the input voltage are called **step-up transformers**. They have a larger number of turns in the secondary coil than that in the primary coil.

Transformers that give an output voltage smaller than the input voltage are called **step-down transformers**. They have a smaller number of turns in the secondary coil than that in the primary coil.

- **Applications of transformers**

- Alternating current electricity generated in electric power stations are stepped up to high voltages such as 132 000 V (132 kV) or 220 000 V (220 kV) using step-up transformers before supplying to the national power grid.
- Step-down transformers are used in power substations that distribute power obtained from main power transmission stations to homes.

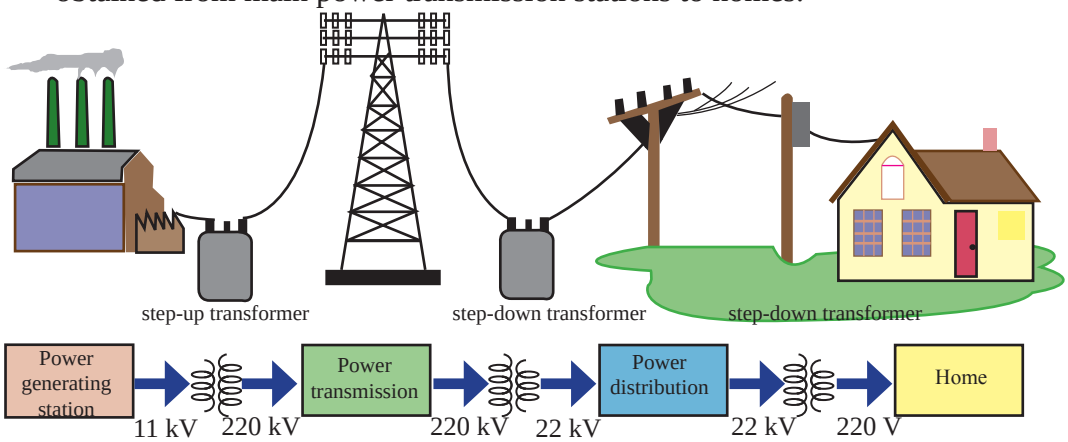


Figure 13.39

- In order to obtain high voltages used in microwave ovens and X ray tubes, step-up transformers are used.
- They are also used in power packs and in electric appliances such as computers and radios.

• Energy Relation in a Transformer

The efficiency of any instrument is not 100% as they produce other forms of energy (such as heat) apart from what they are intended for. In transformers too, all the energy supplied to the primary cannot be obtained from the secondary. However we will assume here that there is no energy loss in the transformer. Then according the law of energy conservation, efficiency will be 100%. Then the power of the primary coil is equal to the power of the secondary coil.

Power = Potential difference × Current

Therefore following relationship is obtained.

Energy supplied to the primary = Energy obtained from the secondary

In this equation,

$\therefore\ V_P I_P = V_S I_S$

I_p = current in the primary coil
I_s = current in the secondary coil
V_p = Voltage in the primary coil
V_s = Voltage in the secondary coil.

Example

A certain transformer has 500 turns in its primary coil and 5000 turns in its secondary coil. A voltage difference of 12 V is supplied to the primary coil.

(i) Find the voltage difference of the secondary coil.
(ii) If a 2 A current passes through the primary. calculate the current in the secondary coil.
(iii) Which type of a transformer is this?

(i) $N_p = 500,\ N_s = 5000,\ V_p = 12\ V,\ V_s = ?$

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

$$V_s = \frac{V_p N_s}{N_p}$$

$$V_s = \frac{12\ V \times 5000}{500}$$

$$V_s = 120\ V$$

(ii) $V_p = 12\ V,\quad V_s = 120\ V,$
$I_p = 2\ A,\quad I_s = ?$

From $V_p I_p = V_s I_s$

$$I_s = \frac{V_p I_p}{V_s}$$

$$I_s = \frac{12\ V \times 2}{120\ V} A$$

$$I_s = \frac{2}{10}\ A$$

$$I_s = 0.2\ A$$

(iii) This is a step-up transformer.

Summary

- The direction of the magnetic field existing in the vicinity of a current carrying conductor can be found using the corkscrew rule.
- When a corkscrew is rotated in such way that it moves in the direction of current flow, then the direction of rotation gives the direction of the magnetic field lines.
- A force acts on a current carrying conductor placed in a magnetic field.
- This force is directly proportional to three factors; current flowing through the conductor, length of the conductor and the strength of the magnetic field.
- Fleming's left hand rule can be used to find the direction of the force acting on the conductor.
- According to Fleming's left hand rule, when the thumb, index finger and the middle finger of the left hand are oriented perpendicular to one another so that the middle finger points in the direction of current flow and the index finger is pointed in the direction of the magnetic field, the thumb is pointed in the direction of the force acting on the conductor.
- The operation of instruments such as the DC motor and the loud speaker are based on the force acting on a current carrying conductor placed in a magnetic field.
- In the operation of a motor, electric energy is converted into mechanical energy.
- The generation of an electromotive force in a closed circuit due to a variable magnetic field is known as electromagnetic induction.
- The magnitude of the induced electromotive force depends on the number of turns in the coil, the strength of the magnetic field and the speed of the moving magnet.
- In order to find the direction of current flow due to the induced electromotive force in a straight conductor, Fleming's right hand rule can be used.
- According to Fleming's right hand rule, when the thumb, index finger and the middle finger of the right hand are oriented perpendicular to one another so that the index finger is pointed in the direction of the magnetic field, the thumb is pointed in the direction of motion, then the middle finger points in the direction of current flow through the conductor.
- Bicycle dynamo, moving coil microphone and the transformer are instruments whose operations are based on electromagnetic induction.

- A current whose direction does not depend on time is a direct current.
- A current whose direction depends on time is an alternating current.
- Dry cells and solar cells produce direct currents while the alternating current dynamo produces an alternating current.
- Using a transformer, an alternating voltage can be changed from one value to another value.
- Relations between the primary and secondary coils of a transformer is given by

$$\frac{V_s}{V_p} = \frac{N_s}{N_p} \qquad V_p I_p = V_s I_s$$

Exercise 13.5

(1) The primary coil of a transformer has 1000 turns while its secondary coil has 100 turns. An alternating current with a voltage difference of 230 V is supplied to the primary coil. Find the following, assuming that there is no energy loss in the transformer.

(i) The maximum voltage that can be obtained from the secondary.
(ii) Current output of the secondary if the current input of the primary is 5 A.

(2) In a certain transformer the number of turns in the primary coil is 5000 and that in the secondary coil is 500. A voltage difference of 230 V is supplied to the primary coil. If the efficiency of the transformer is 100%,

(i) Find the output voltage of the secondary.
(ii) Find the current input of the primary if the current output of the secondary is 10 A.

(3) The ratio between the number of turns in the primary coil and the secondary coil in a certain transformer is 1:10. An alternating current with a voltage difference of 6 V is supplied to the primary coil. An output current of 20 A is required from the secondary. Find the following assuming that the efficiency of the transformer is 100%.

(i) Voltage output of the secondary.
(ii) Current input to the primary.
(iii) Ratio between the primary voltage and the secondary voltage.
(iv) Ratio between the primary current and the secondary current.

(4) There are many useful applications for electromagnetic induction. The following figure shows a set up used to model the phenomenon of electromagnetic induction.

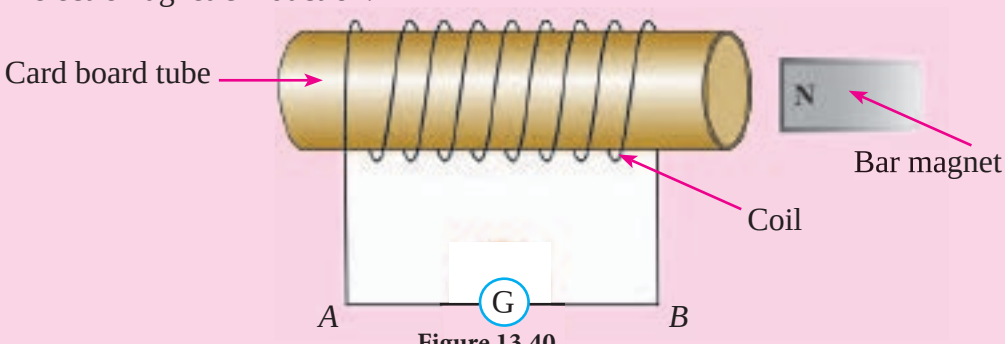


Figure 13.40

(i) Describe electromagnetic induction in a simple manner.

(ii) When the north pole of the bar magnet was brought towards the coil rapidly, a deflection was observed to the right hand side in the center zero galvanometer (G). Is the current flowing through the galvanometer from *A* to *B* or *B* to *A*?

(iii) What is the direction of deflection of the galvanometer when the bar magnet is moved away from the coil?

(iv) What is the direction of deflection of the galvanometer if the South pole of the bar magnet is moved towards the coil?

(v) Write down three factors that the strength of the current flowing through the galvanometer depends on.

(5) The internal components of a bicycle dynamo are shown in the figure below.

(i) Label the parts *A*, *B*, *C* and *D*.

(ii) What is the principle that the operation of a dynamo is based on?

(iii) Describe the operation of the dynamo.

(iv) Is the current output of a dynamo a direct current or an alternating current?

(v) Draw a rough sketch to show the variation of the voltage output of this current with time.

(vi) The brightness of a bicycle lamp depends on the speed at which the bicycle is being ridden. Explain how this happens.

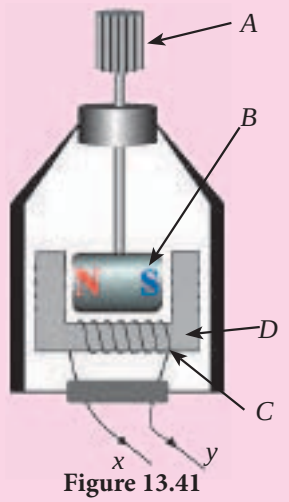


Figure 13.41

(vii) Write down the energy transformation that takes place when a bicycle lamp is lit up using the bicycle dynamo.

(6) The figure below shows a moving coil galvanometer. Name the components labeled as *A*, *B*, *C* and *D* and describe the function of each of them.

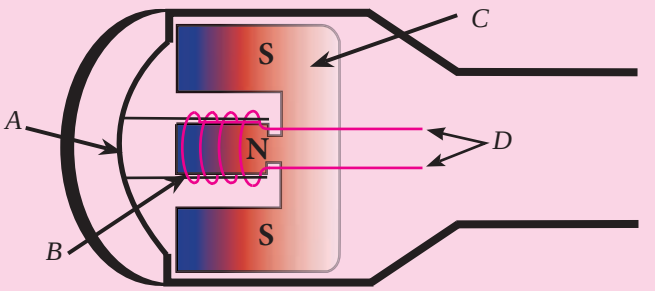


Figure 13.42

Technical terms

Magnetic field	- චුම්බක ක්ෂේත්‍රය	- காந்தப்புலம்
Step - up transformer	- අධිකර පරිණාමකය	- படிகூட்டு நிலைமாற்றி
Step - down transformer	- අවකර පරිණාමකය	- படி குறை நிலைமாற்றி
Magnet	- චුම්බකය	- காந்தம்
Power	- ජවය	- வலு
Coil	- දඟරය	- சுருள்
Transformer	- පරිණාමකය	- விரியலாக்கி
Alternating current	- ප්‍රත්‍යාවර්තක ධාරාව	- ஆடலோட்டம்
Electro magnetic induction	- විද්‍යුත් චුම්බක ප්‍රේරණය	- மின்காந்த தூண்டல்
Induced current	- ප්‍රේරිත ධාරාව	- தூண்டல் மின்னோட்டம்
Electromotive force	- විද්‍යුත්ගාමක බලය	- மின்னியக்கவிசை

Hydrocarbons and Their Derivatives

Chemistry 14

14.1 Hydrocarbons

Figure 14.1 shows some items that we use in our day to day life.


Plastic goods


Food items


Tyres


Clothes


Paints


Cosmetics


Agro-chemicals

Figure 14.1

When considering the composition of all of the above materials, presence of carbon as a component element seems to be a common feature. Carbon is also abundant in the plants and animals that we find in our environment and all the materials obtained from those sources.

Elements combine with one another in different ways to create a very large number of compounds. Quite a majority of them are compounds formed by the combination of carbon with other elements.

Because of the abundance of carbon containing compounds and the special chemical characteristics shown by those compounds, carbon chemistry (organic chemistry) is studied as a separate section under chemistry.

The compounds contaning carbon are commonly referred to as organic compounds [But, the oxides of carbon, namely carbon dioxide (CO_2) and carbon monoxide (CO)

and carbonates and bicarbonates such as sodium carbonate (Na_2CO_3) and sodium bicarbonate ($NaHCO_3$) are not considered organic]. Organic compounds necessarily contain carbon and in addition, they may contain elements like hydrogen, oxygen, nitrogen, halogen, phosphorus and sulphur.

For the convenience of study, organic compounds are classified in various ways. One method is classifying on the basis of the component elements in the organic compound. On this basis, the simplest group of organic compounds are hydrocarbons which contain carbon and hydrogen only.

Assignment 14.1

List several types of fuels that are used in day to day life. Investigate into the chemical composition (the elements they contain) of those fuels.

Compare the list you prepared with the following table.

Table 14.1

Fuel	Elements present
Wax	C, H
Petrol	C, H
Methane	C, H
L.P. gas	C, H
Kerosene	C, H
Diesel	C, H
Firewood	C, H O, N

It is seen that every fuel in the above table contain carbon and hydrogen.

Let us do the following activity to examine whether wax contains carbon and hydrogen.

Activity 14.1

Confirming the pressure of carbon and hydrogen in candle wax

Materials required :- connecting tubes, beaker, aspirator, Lime water, copper sulphate, U - tube, test tube.

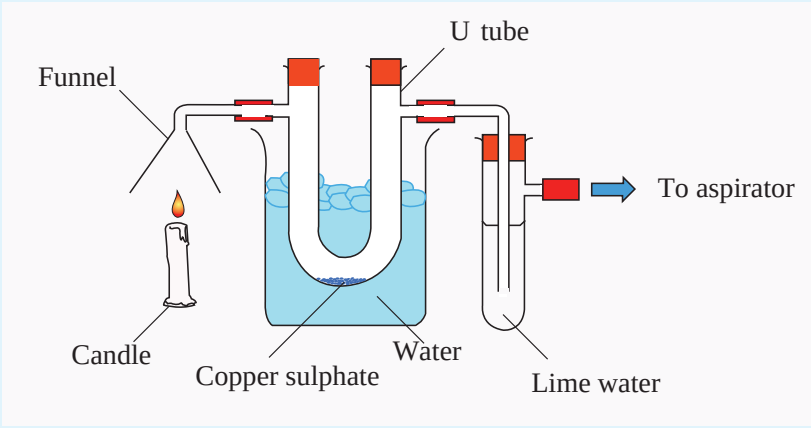


Figure 14.2

Set the apparatus as shown in figure 14.2, light the candle, connect the apparatus to the aspirator and make air pass through.

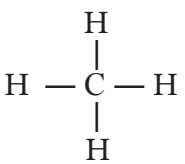
It will be seen that, the anhydrous copper sulphate contained in the U tube turns from white to blue. This change in colour was brought about by the water produced during the burning of the candle. Hydrogen required to produce that water was supplied by candle wax. This verifies the presence of hydrogen in wax.

Also, it can be observed that the limewater contained in the test tube on the right hand side turns milky. Therefore, carbon dioxide gas has been produced during the burning of the candle. The source of carbon in that carbon dioxide is wax.

This confirms the presence of carbon (C) and hydrogen (H) in candle wax.

All the countries in the world meets their energy requirements by using petroleum fuels produced by the distillation of crude oil. All compounds in those fuels are hydrocarbons. Based on the structure, hydrocarbons are classified as alkanes, alkenes and alkynes.

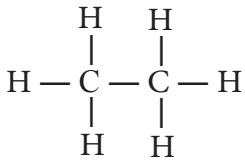
• Alkanes



Have you heard that bio gas produced using the waste disposed from poultry farms is used as a fuel? The main component of it which is important as a fuel is methane gas. This gas is also present in the marsh gas produced when organic matter decays in marshes.

This is the simplest hydrocarbon and has the formula CH_4. Its structure is shown in the figure.

During the mining of mineral oils, the gas ethane comes out from oil wells. Ethane is also a hydrocarbon. Its formula is C_2H_6. The structure corresponding to this formula is as follows.



Consider the methane and ethane molecules described above. Bonds between carbon atoms and hydrogen atoms (only) are present in the methane molecule. But in the ethane molecule there are bonds between carbon and carbon atoms. The hydrocarbons which have only single bonds between carbon atoms are referred to as alkanes.

Alkanes are a series of compounds. This series has several common characteristics. One of those is that all the compounds in that series can be represented by a common formula.

The common formula of the alkane set is C_nH_{2n+2}. In this, 'n' is the number of carbon atoms in a molecule of the compound. According to the above formula, the formula of the simplest alkane methane can be obtained as follows.

For methane n = 1. Hence the formula of methane is,

$$C_1H_{1 \times 2 + 2} = CH_4$$

In ethane ⟶ n = 2. Hence the formula of ethane is

$$C_2H_{2 \times 2 + 2} = C_2H_6$$

Assignment 14.2

Using the common formula, derive the formulae of alkanes that contain carbon atoms from 1 to 5.

Listed in Table 14.2 are the formulae and names of the alkanes of which the number of carbon atoms varies from 1 to 5.

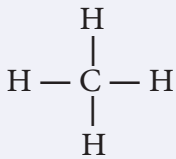
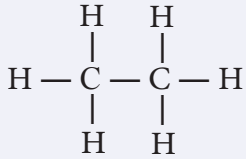
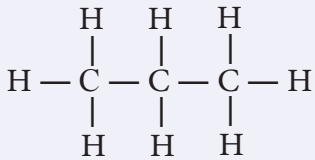
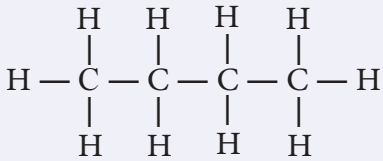
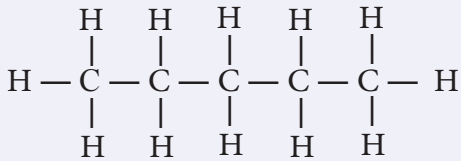
The fuel petrol (gasoline) is a mixture of alkanes. The most abundant alkane in it is octane represented by the formula C_8H_{18}. L.P. gas, another mixture of alkanes/ mainly contain alkanes propane (C_3H_8) and butane (C_4H_{10}).

Table 14.3 presents the molecular formulae and structural formulae of the alkanes with carbon atoms 1 - 5.

Table 14.2

Molecular formula	Name of the alkane
CH_4	Methane
C_2H_6	Ethane
C_3H_8	Propane
C_4H_{10}	Butane
C_5H_{12}	Pentane

Table 14.3

Molecular formula	Structural formula
CH_4	
C_2H_6	
C_3H_8	
C_4H_{10}	
C_5H_{12}	

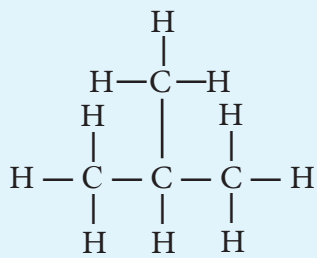
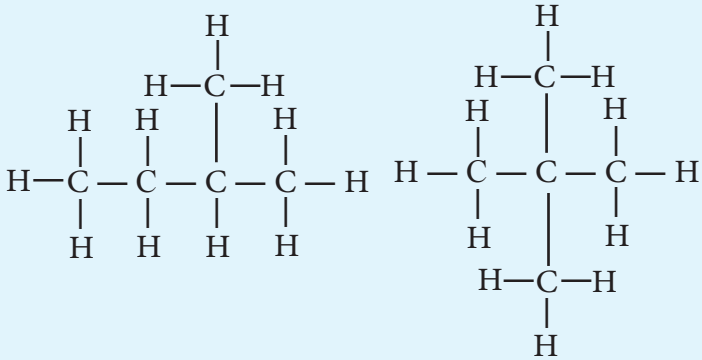
Activity 14.2

Make models of the alkanes with carbon atoms 1 - 5 with the help of your teacher, using suitable materials.

Extra knowledge

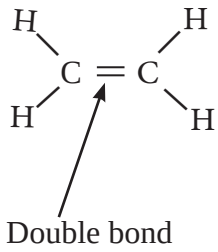
For C_4H_{10} and C_5H_{12}, the following structures are also correct in addition to the structures given in Table 14.3

Table 14.4

Molecular formula	Structural formula
C_4H_{10}	
C_5H_{12}	

• Alkenes

In alkanes there are only single bonds between carbon - carbon atoms. Also, there are hydrocarbons having double bonds between carbon - carbon atoms. The hydrocarbons of this type with one or more double bonds between carbon - carbon atoms are classified as alkenes. The molecular formula of the simplest alkene ethene is C_2H_4. Its structural formula is given below.

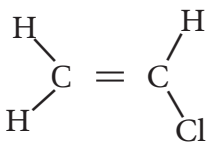


Due to the presence of double bonds between the carbon atoms, alkenes are more reactive than alkanes.

14.2 Derivatives of ethene

• Chloroethene

The compound derived by the displacement of a hydrogen atom in ethene by a chlorine atom is called chloroethene. The formula of chloroethene is C_2H_3Cl and its structure is given below.



• Tetrafluoroethene

The compound derived by the displacement of the four hydrogen atoms in ethene by four fluorine (F) atoms is known as tetrafluoroethene. Its formula is C_2F_4 and the structure is as follows.

C_2F_4

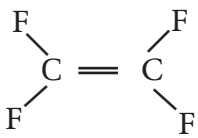
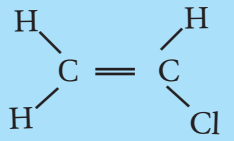
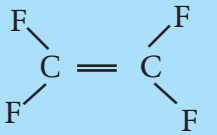


Table 14.4 - Derivatives of ethene

Chloroethene C_2H_3Cl	
Tetrafluoroethene C_2F_4	

Ethene and derivatives of ethene are used to produce the polymers that we use in our day to day life such as polythene, styrofoam and teflon

14.3 Polymers

Pay your attention to the following pictures.

Plastic goods

Clothes

Toys

Figure 14.3

Let us inquire into the chemical nature of the materials shown in the above pictures that we use frequently in our daily life.

At molecular level, they all have a common special feature. That is, they all are made up of large molecules arranged in the form of long chains. Another speciality is that most of those long chain molecules are composed of repeating small molecular units. Thus, the molecules from which they are made are called polymers. In this lesson, let us discuss about polymers.

Large molecules formed by the joining of a large number of small molecules with one another are known as polymers.

The process of forming polymers is called polymerization. The small molecules forming polymers are known as monomers and the large molecules formed by the polymerization of monomers are referred to as polymers. Pay your attention to the chain formed by joining some paper clips together.

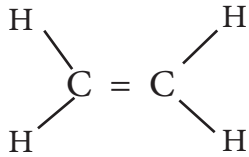
Figure 14.4

The single paper clips used to form the above chain are analogous to monomers and the chain of clips is equivalent to the polymer. The basic structural units contained in the chain after the formation of the polymer are referred to as repeating units. The molecular mass of monomers is relatively low. However, the relative molecular mass of polymers formed by the polymerization of a large numbers of monomers has a very high value.

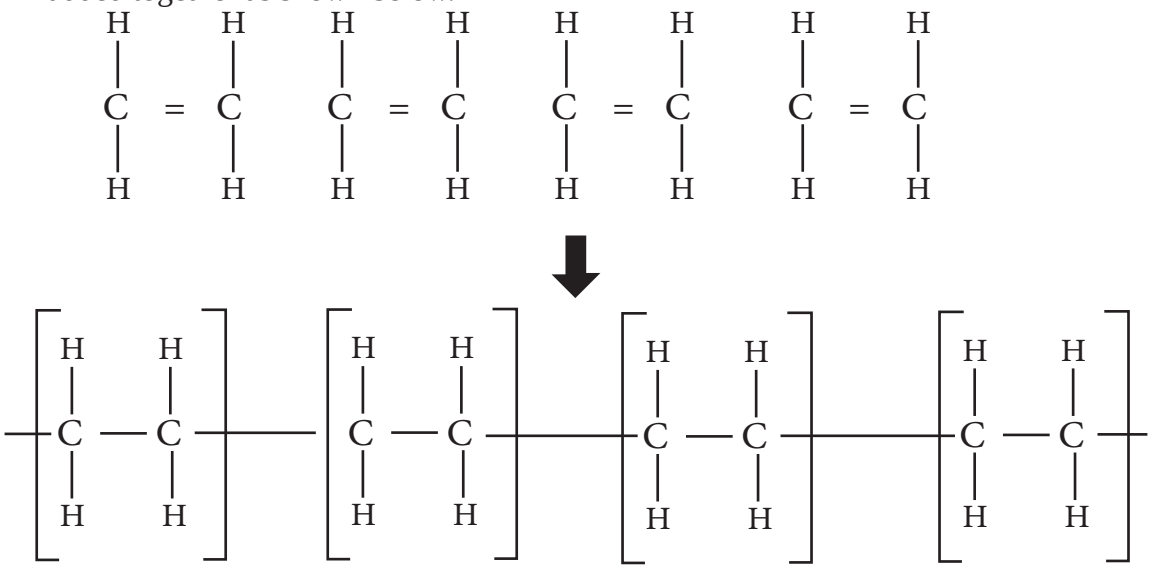
Now, let us investigate into some common polymers.

- **Polythene (Polyethene)**

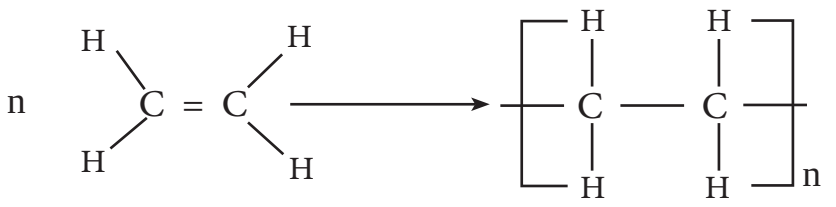
Consider the ethene molecule we learnt earlier.



Polythene is produced by the polymerization of ethene molecules. What happens here? Of the double bond, one bond breaks and thousands of ethene molecules are added together as shown below.



The above polymerization process may be summarized and indicated as follows.

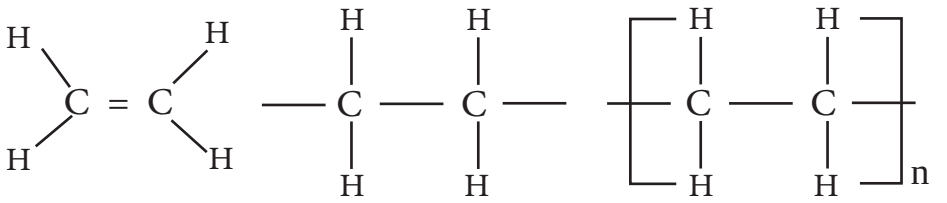


This means that 'n' number of ethene molecules link with one another and create a polythene molecule with 'n' number of – CH_2 – CH_2 – repeating units.

Assignment 14.3

Make a polythene polymer molecule linking appropriately the models of the ethane molecules you have made in assignment 14.2.

Hence, it may be clear to you that polythene is a macromolecule formed by the linking of a large number of ethene molecules in a specific pattern.
The polymer, monomer and the repeating unit of polythene are given below.

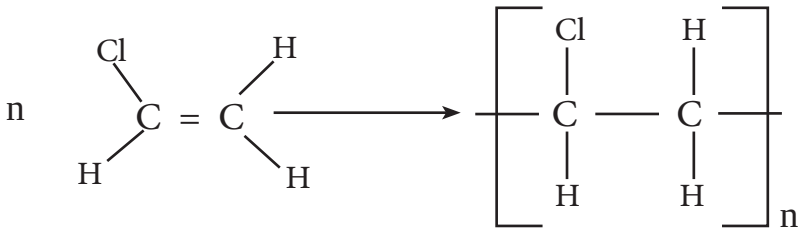


Monomer Repeating unit Polymer

Polymers - Very large molecules formed from linking together, a large number of small molecules are named polymers.
Monomers - Small molecules contributing to form polymers are called monomers.
Repeating unit - The basic structural units contained in a polymer are known as repeating units.

- **Polychloroethene (Polyvinyl chloride)**

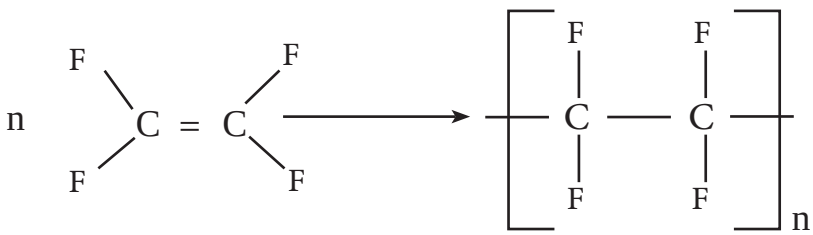
Polymerization of chloroethene gives polychloroethene. This can be summarized as follows.



Try to identify the monomer, repeating unit and the polymer of polychloroethene.

- **Polytetrafluoroethene (Teflon)**

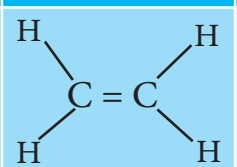
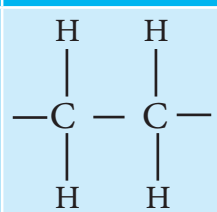
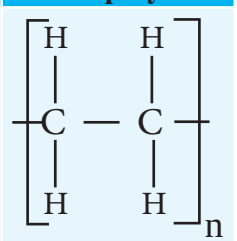
Polytetrafluoroethene is formed by the polymerization of tetrafluroethene. This can be illustrated as follows.

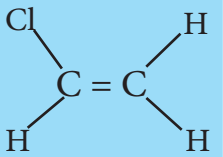
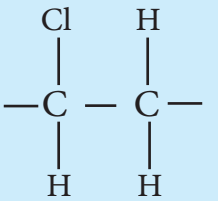
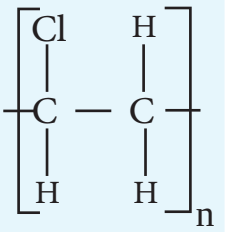
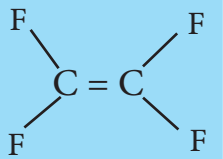
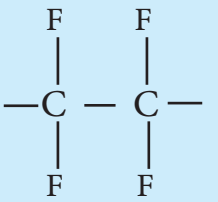
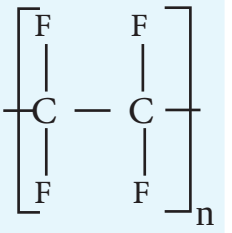


Identify the monomer, repeating unit and the polymer of tetrafluoroethene.

A summary of the polymers you studied is present in Table 14.6

Table 14.6

Polymer	Monomer	Repeating unit	Representation of the polymer
Polythene			

Polychloroethene (PVC)			
Polytetrafluoroethene			

Given in Table 14.6 are the special properties and uses of the polymers which we discussed above.

Table 14.7

Polymer	Special properties	Uses
Polyethene	Electrical insulator, impervious to water and air, light and can withstand tensions, durable	Making plastic bottles, toys, polythene tissues, polythene bags, garbage bins, hard plastic fibers
Polychloroethene (Polyvinyl chloride PVC)	Resistant to fire, electrical insulator, impervious to water, light	Making gutters, water pipes, conduits and flexible pipes
Polytetrafluoroethene (TEFLON)	resistant to heat, electrical insulator	Making non - stick cooking pans, snow shoes

• Classification of polymers based on origin

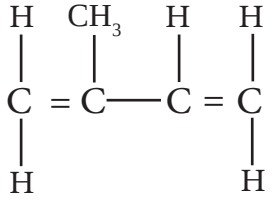
Recall the polymers you studied earlier. All of them are artificially synthesized polymers. Have you heard about natural polymers Pay attention to the bio - molecules you learnt in grade 10. Molecules like proteins, starch, cellulose and DNA are polymers. They belong to the category of natural polymers. Therefore, by origin, polymers can be classified into two types as natural and artificial. Rubber which is frequently used for technical purposes is also a natural polymer. Table 14.7 lists some examples of natural and artificial polymers.

Table 14.8

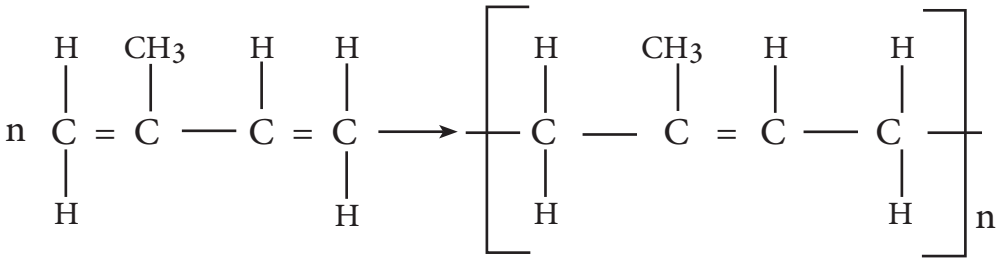
Natural polymers	Artificial polymers
Rubber	Polythene
Protein	Polychloroethene
DNA	Teflon
Starch	Polyester
Cellulose	Nylon
RNA	Terylene
	polystyrene
	Bakelite

• Rubber

Rubber is a natural polymer formed by the polymerization of a monomer called isoprene. The structure of an isoprene molecule is given below.



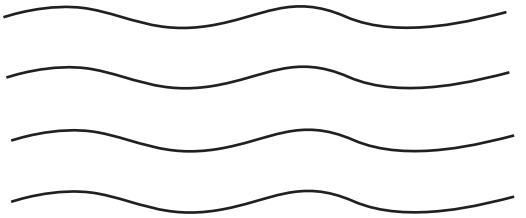
The process leading to the formation of the polymer can be illustrated as follows.



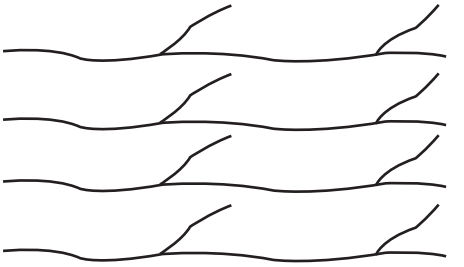
• Classification of polymers based on structure

All the polymers so far discussed are made of linear chains. However, all polymers are structurally not linear polymers. By joining polymer molecules laterally to the principle chain of the linear polymers of the type described above, branched polymers are produced.

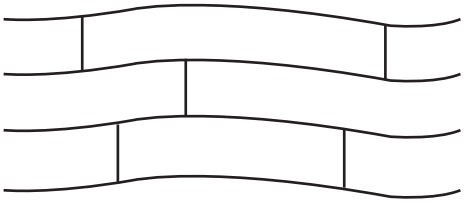
The polymers in which the linear chains are cross-linked are known as cross-linked polymers. Therefore, the polymers can be classified as follows according to the structure.



Linear polymers
Figure 14.5

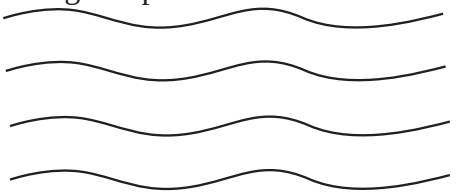


Polymers with side chains
Figure 14.6

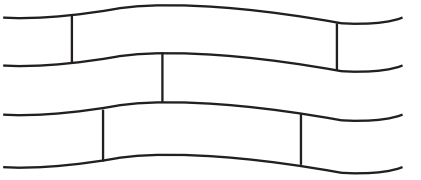


Polymers with cross links
Figure 14.7

Have you heard about vulcanized rubber? Because of the elastic property of rubber, it is difficult to be used in some applications. By vulcanization, rubber can be made harder while decreasing its elasticity. During vulcanization natural rubber is reacted with sulphur. Then, cross links are formed among the linear chains of rubber through sulphur.



Rubber
Figure 14.8



Vulcanized rubber
Figure 14.9

Vulcanized rubber is used to make tyres, tubes and battery cases.

• Importance of polymers

When taking lunch away from home, natural materials such as a banana leaf or a "Kolapatha" was used for wrapping in the past. But today, what we use for this purpose is a type of polythene which is a synthetic polymer. Like this, at present, artificial polymers are being used as substitutes for materials. Properties such as the ability to synthesize with required characteristics, ease of usage, ability to produce in various shapes, ability to make colourful with any required colour and cheapness have made the items produced with polymers popular.

Assignment 14.4

List the products made of polymers that are of domestic use.

Most of the artificial polymers are not subjected to biodegradation. That is, they do not decay through biological process. Therefore they get collected in the environment. This is a big environmental problem. Since the combustion of artificial polymers release poisonous gases, burning is not suitable. Chemists are making attempts to find a solution for this problem by producing degradable polymers. At present, production of biodegradable and photodegradable polymers and water-soluble polymers are underway.

The clothes produced with artificial polymers such as nylon, terylene and polyester do not absorb sweat and cause discomfort to the body. This can be minimized by mixing natural polymers such as cotton and wool with artificial polymers.

Summary

- Organic compounds only made up of carbon and hydrogen are called hydrocarbons.
- In some hydrocarbon molecules, carbon atoms are bound only by single covalent bonds. Such hydrocarbons are named alkanes.
- Crude oil is a mixture of alkanes. The common formula of the alkane family is $C_n H_{2n+2}$.
- In addition to alkanes, there are hydrocarbons in nature with double or triple bonds between carbon atoms.
- Joining of other atoms or atomic groups in place of hydrogen atoms in hydrocarbons gives rise to other organic compounds.
- The macromolecules formed by linking together of a large number of simple molecules are known as polymers.
- The polymers present in natural animal parts or plant parts are called natural polymers. The artificially synthesized polymers are artificial polymers.
- Artificial polymers are generally referred to as plastics.
- The shape of some polymers can be changed by heat whereas in some the shape cannot be changed by heat.
- Since artificial polymers do not decay, there are both advantages and disadvantages in them.
- If the management of plastic wastes is not carried out properly, many environmental problems may arise

Exercises

01. L.P. gas is a mixture of propane and butane.

i. Write the molecular formulae of propane and butane.

ii. Draw the structures of propane and butane.

iii. If only carbon dioxide and water are formed during the combustion of the above compounds, write balanced chemical equations for their combustion separately.

iv. Is the use of L.P. gas as a fuel more environment friendly than using firewood? Present your ideas.

02. Octane is the most abundant alkane contained in petrol

i. What would be released if petrol completely burns in a combustion engine?

ii. State two unfavorable substances released to the environment during the incomplete combustion of petrol.

iii. How do you know that the L.P gases burn incompletely in the gas cooker used at home?

03. Polythene is a commonly used artificial polymer.

i) What is the chemical name of polythene?

ii) Draw the structure of the monomer that forms polythene and write its name

iii) State two advantages and two disadvantages of polythene.

04. It is more suitable to use PVC pipes as water pipes rather than iron pipes.

i) Give three reasons to support this statement.

What is the name of the monomer that is used to make the polymer PVC?

ii) Draw the structure of that monomer.

05. Name three natural polymers of your choice.

Technical terms

Organic compound	-	කාබනික සංයෝග	-	சேதன சேர்வைகள்
Hydrocarbon	-	හයිඩ්‍රොකාබන	-	ஐதரோகாபன்
Alkanes	-	ඇල්කේන	-	அற்கேன்
Alkenes	-	ඇල්කීන	-	அற்கீன்
Polymers	-	බහුඅවයවක	-	பல்பகுதியம்
Monomer	-	ඒකඅවයවකය	-	ஒருபகுதியம்
Repeating unit	-	පුනරාවර්තන ඒකකය	-	மீண்டுவரும் அலகு

Biosphere 15

15.1 Organizational levels and interactions of biosphere

15.1.1 Environmental equilibrium/Ecological balance

The physical and the biological components in which interactions take place for the existence of organisms is environment. Soil, water and air come under the physical component and all the organisms that is plants, animals and micro organisms are included in the biological component or the biotic component. Other than that temperature, rainfall, humidity and sunlight come under environmental conditions.

The organisms and the physical environment have a balanced relationship. This favourable relationship is referred to as the **environmental equilibrium.** Even a small change in the environment can affect its existence. Then it has an ability to restore its conditions. But today this equilibrium is affected due to complicated human activities.

15.1.2 Organizational levels in the biosphere

Biosphere is organized from the simplest level to complex level. This organization can be shown in the following flow chart.

Individual → Population → Community → Ecosystem → Biosphere

Observe the organizational levels of the biosphere in the diagram given below.

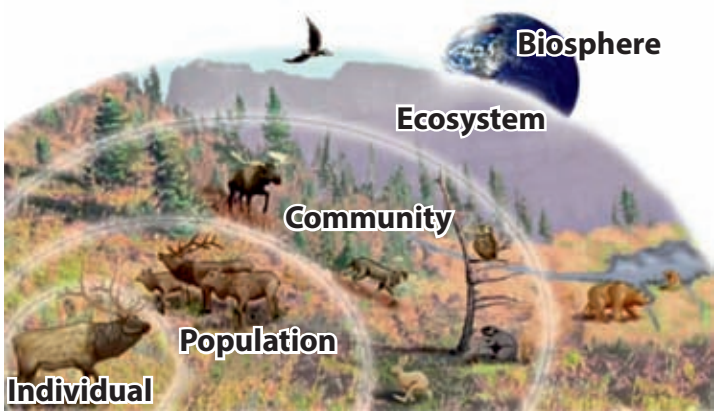


Figure 15.1 - Organizational levels in biosphere

- **Individual**

A single organism belongs to a particular species and lives in the environment is referred to as an individual.

E.g. - Coconut plant, Elephant

A species is a group of similar organisms who can interbreed naturally to produce fertile offsprings.

Assignment 15.1

Name different species found in a particular location of your home garden or school premises.

- **Population**

A group of organisms belong to the same species in a particular geographical location during a specific time period is called a population.

E.g. - The number of elephants lived in Yala national park in year 2011 is 5,879
Human population in Sri Lanka in year 2014 is 21,899,445

- **Community**

A group of different populations, interact with each other in a particular area is reffered to as community

E.g. - Animal community in Yala national park
Mangrove plant community in Negombo lagoon area

- **Ecosystem**

All the communities and the non living component with which they interact in a particular area is called an ecosystem.

E.g. - A pond, A decaying log, A forest
A beach with rocks and cliffs

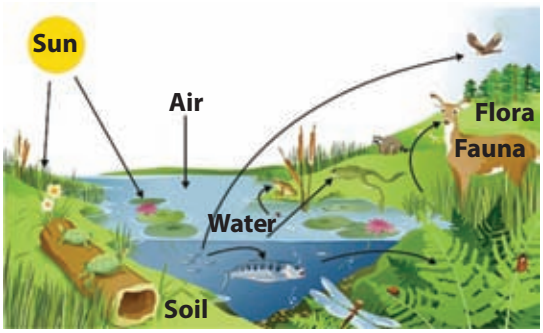


Figure 15.2 shows the interactions of the living organisms with the non living component in a pond eco system.

Figure 15.2 - Interactions in a pond ecosystem

- **Biosphere**

The part of the earth and its atmosphere that is inhabited by living things is called biosphere. The biosphere is composed of three components.

- Lithosphere - The crust and the upper mantle of the earth.
- Hydrosphere - The region that includes all the oceans and fresh water bodies. 70% of the earth surface is covered with water.
- Atmosphere - The region that contains air around the earth.

15.1.3 Growth of population and growth curves

The number of organisms of a species, living in a unit area of a selected habitat is called the population density.

E.g. - Human population density of Sri Lanka in year 2014 is 329.12 km^{-2}

The size of a natural population varies with time. There are four factors that affect the population density.

- Births (Number of new born organisms added to the population)
- Deaths (Number of organisms die in the population)
- Immigration (Number of organisms add to the population from outside)
- Emigration (Number of organisms leave the population)

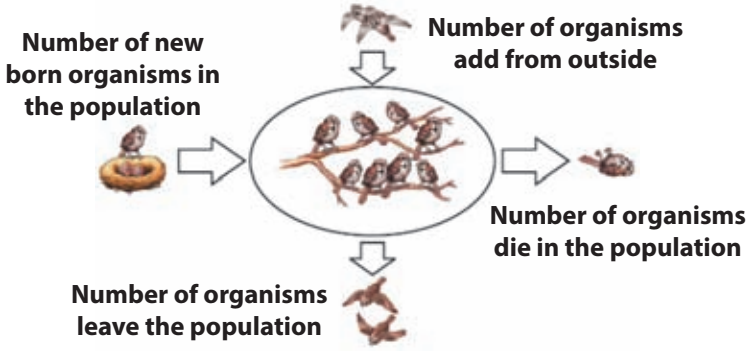


Figure 15.3 - Factors affecting population density in biosphere

Typical growth curve of population

The number of organisms in a natural population changes with time according to a particular pattern. When this pattern is expressed in a graph it will be a sigmoid shaped growth curve. There are four main phases in it.

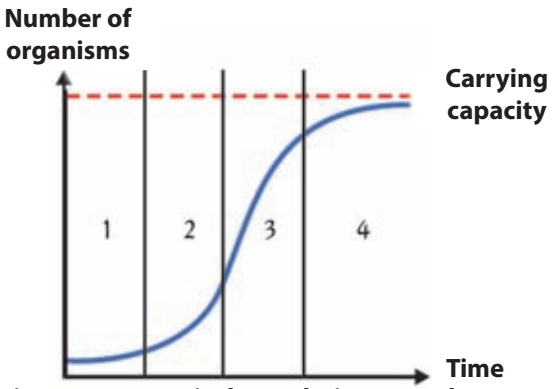


Figure 15.4 - Typical population growth curve

Phase 1 - Slow growth phase (Lag phase)

During this phase population growth increases as reproduction gets underway. Often starts slowly because intially there is a shortage of reproducing individuals which may widely dispersed.

Phase 2 - High growth phase (Exponential phase/ Log phase)

This phase represents the maximum growth rate as organisms are well adapted to the environment and the number of organisms that reproduce is high. Presence of favourable environmental conditions and abundance of food increases the growth rate of organisms rapidly. Birth rate exceeds death rate.

Phase 3 - Deceleration phase

Due to the competition for resources, food shortage, spreading of diseases, predation and parasitism, the growth rate of population decreases.

Phase 4 - Stationary phase/ Stabilizing phase

The number of organisms in a population increases till it has a population adapted to environmental conditions which the environment can bear. Once it reaches its carrying capacity the population achieves the dynamic equilibrium. During dynamic equilibrium birth and death rates balance. Hence the growth of the population is considered as zero. When it comes to this balanced situation the number of organisms in the population is called as the carrying capacity.

- **Growth curve of human population**

Although the growth curve of a natural population is **S** shaped, it takes **J** shape for human population. That means the human population is still in exponential phase.

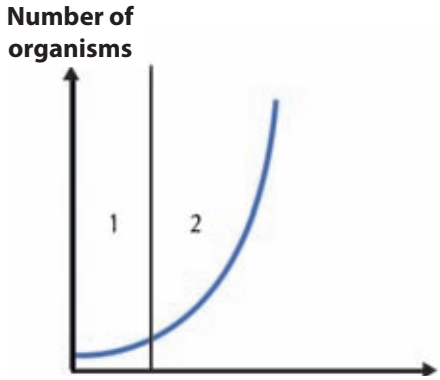


Figure 15.5 - Growth curve of human population

It has taken 300,000 years for the human population to become, one billion. But it has taken only 130 years for it to become two billions and 15 years for it to become four billions. There are two reasons for this rapid growth.

- Increase of birth rate
- Decrease of death rate

The development of technology, progress in medical field and high rate of food production are some of the reasons for high population growth.

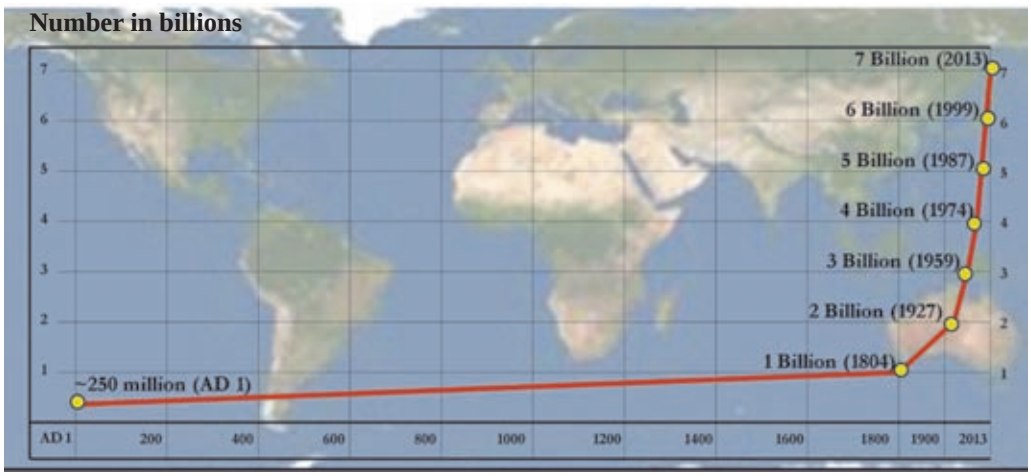


Figure 15.6 - Growth curve of human population from 1 AD to year 2013

Assignment 15.2

According to the graph, predict the time that would take for the world human population to become twice as it was in 2013.

15.2 Mechanisms involve in maintaining the equilibrium of ecosystems

15.2.1 Flow of energy and nutrients

The energy source of all ecosystems in the biosphere is the sun. Flow of energy and nutrients among ecosystms is essential for the existence of the biosphere.

- **Food web**

The mutual relationships for food among organisms is referred to as food webs. Different trophic levels of many food chains are inter-connected in a web like structure in the biosphere. Due to this relationship an organism is free to depend on different types of food. This helps to avoid bioaccumulation of organisms. An example for a food web is given in figure 15.7

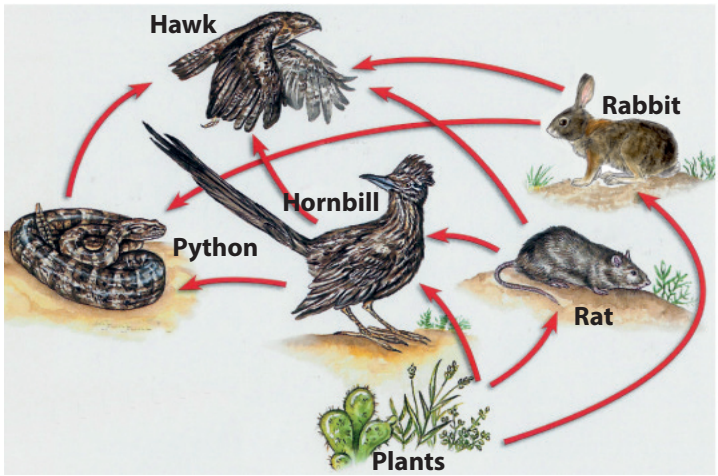


Figure 15.7 - An example for a food web

Assignment 15.3

Build up a food web in a pond ecosystem.

- **Food chains**

The sequence of energy and materials flow from producer to consumers such as primary consumer and then to the secondary consumer is referred to as a food chain. This can be shown in a linear diagram as follows.

E.g. :-

Grass ⟶ Grass hopper ⟶ Toad ⟶ Cobra ⟶ Hawk

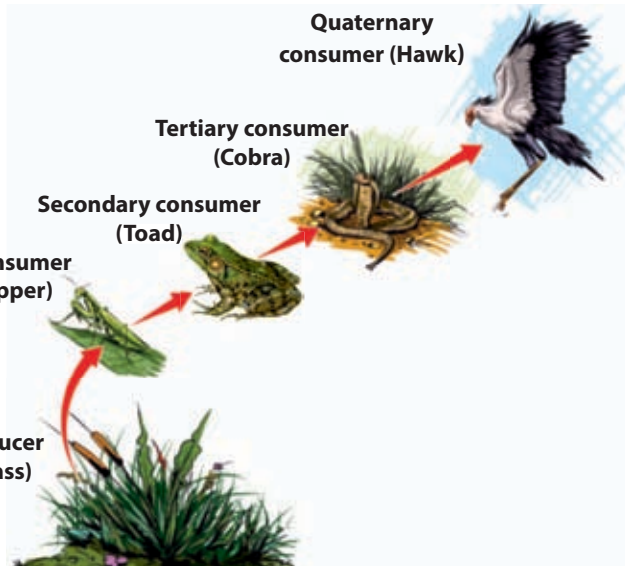


Figure 15.8 - An example for a food chain

Assignment 15.4

Observe different modes of nutrition consumed by different organisms in the environment. Write down their relationships for food.

Trophic level

Every organism belongs to a certain trophic level according to their mode of nutrition. The links of a food chain are known as trophic levels. The number of trophic levels of a food chain cannot be exactly predicted. Most often it is less than five links. Somehow the organisms belong to last trophic level would be carnivorous predators.

All organisms can be divided into three groups on the basis of their mode of nutrition.

- Autotrophs
- Heterotrophs
- Decomposers

Autotrophs

Organisms such as green plants, algae and some bacteria which can transform simple inorganic compounds into organic compounds to fulfill their nutrition requirement are called autotrophs.

According to the energy source used to produce their food, autotrophs can be divided into two groups, as photo-autotrophs and chemo-autrotrophs. Green plants are photo-autotrophs and some bacteria are chemo-autotrophs.

Heterotrophs

The animals that cannot produce their own food are known as heterotrophs. They depend on food produced by other organisms. Therefore they are known as consumers. The consumers are further divided as follows,

1. Primary consumers : They are herbivores. Feed on producers.
2. Secondary consumers : They are carnivores. They can be omnivores too. Feed on primary consumers.
3. Tertiary consumers : They are carnivores.

Decomposers

Organisms feed on bodies of dead organisms and organic waste products by converting complex organic compounds into simple compounds are known as decomposers. Saphrophytes like bacteria and fungi belong to this group. This process is called decomposition.

Figure 15.9 - Stages of decomposition process of a dead body

• Ecological pyramids

Ecological pyramids can be built up using number of organisms, biomass and energy relationships in different trophic levels of an ecosystem.

The base of the pyramid represents, producers, and the rest of the rows represent consumers in different trophic levels respectively.

There are three types of Ecological pyramids.

- Number pyramid
- Biomass pyramid
- Energy pyramid

Number pyramid

The graphical representation of number of organisms in different trophic levels is called the number pyramid. It is expressed as the number of organisms per square meter (1 m^2).

The number of organisms in a particular trophic level can be greater or lesser than the number of organisms in the upper trophic level. Therefore upright and inverted number pyramids can be seen.

An upright number pyramid is shown in Figure 15.10.

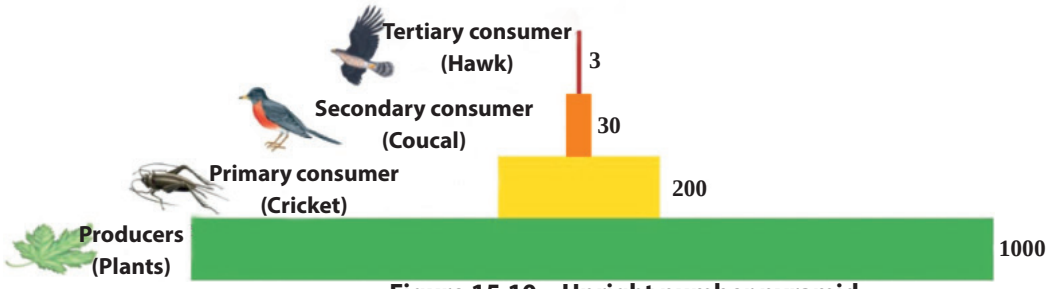


Figure 15.10 - Upright number pyramid

An inverted number pyramid is shown in figure 15.11.

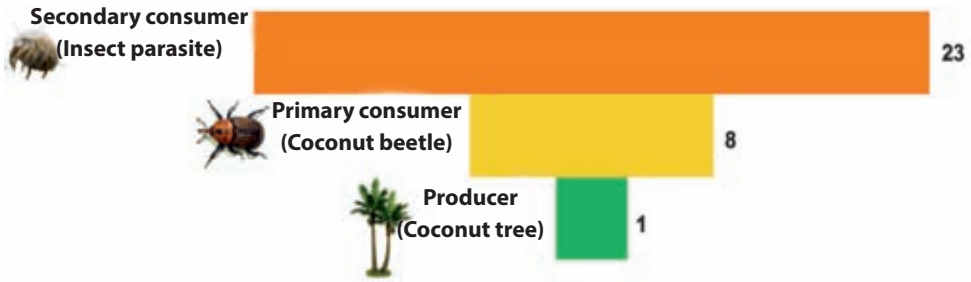


Figure 15.11 - Inverted number pyramid

Biomass pyramid

The graphical representation that shows the total amount of organic matter present in different trophic levels is called biomass pyramid. By considering the dry mass of organisms it is expressed as grammes per square meter per year ($g\ m^{-2}\ yr^{-1}$)

Mostly the biomass of consumers is less than the producers. Therefore most of the time the biomass pyramids are upright. But rarely, the biomass of consumers in aquatic environment is greater than that of producers. Then the biomass pyramid is an inverted one.

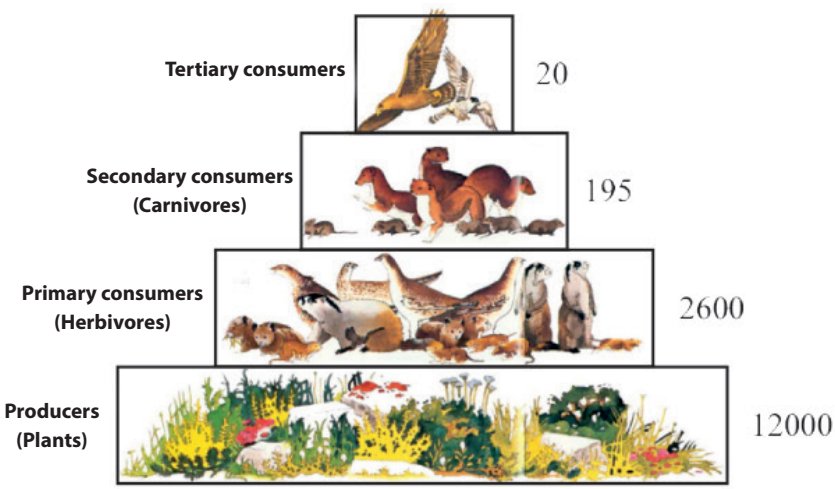


Figure 15.12 - A biomass pyramid

Energy pyramid

The graphical representation that shows the amount of energy, flows through different trophic levels is called the energy pyramid. It is expressed as kilo joules per square meters per year (kJ m^{-2} yr^{-1}).

Only 10% of energy in a trophic level passes to the upper trophic level. 90% of the energy is dissipated to the environment. Therefore the energy in the upper trophic levels is less than the lower trophic levels. So the energy pyramids are always upright. The number of links in a food chain is less than five levels due to this loss of energy.

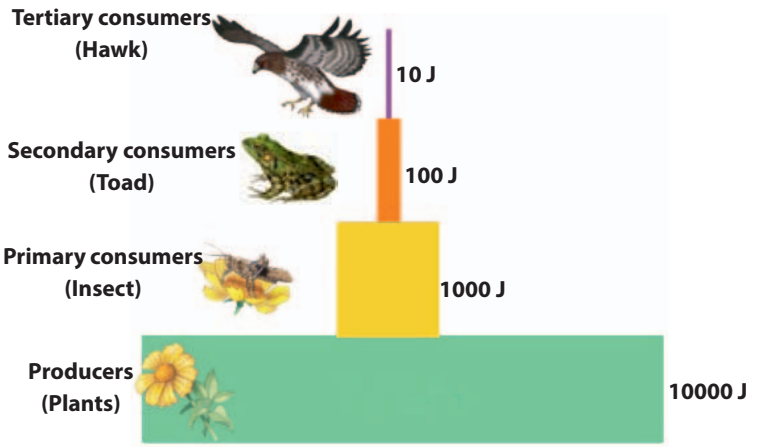


Figure 15.13 - An energy pyramid

• Flow of energy through ecosystem

The main energy source of the biosphere is the sun. Green plants absorb sunlight, and use CO_2 and water as raw materials to produce glucose. This process of fixing energy of sunlight is called photosynthesis.

The energy fixed by producers passes from organism to organism along trophic levels. Only 10% of the energy of lower trophic levels passes to the upper trophic levels. 90% of energy is lost in each trophic level as heat.

Energy dissipation

The loss of energy during transferring energy from one trophic level to the next, is called energy dissipation.

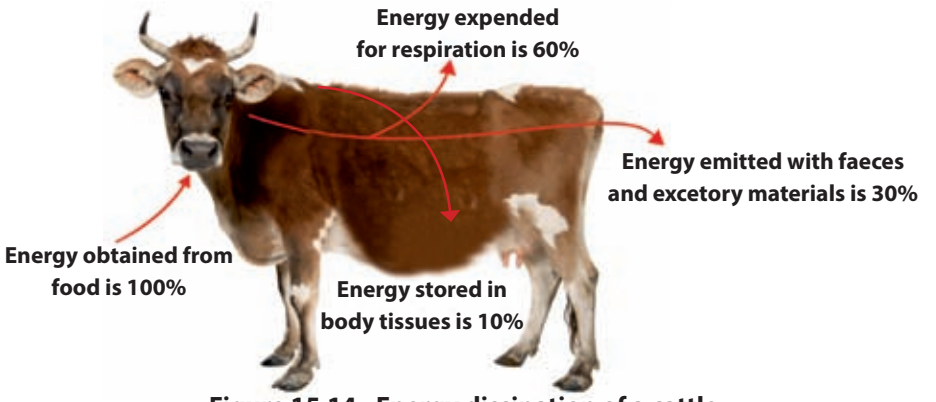


Figure 15.14 - Energy dissipation of a cattle

As a considerable amount of energy is lost during the flow of energy from one trophic level to the next, the shorter food chains are efficient than longer food chains.

Figure 15.15 - A long food chain

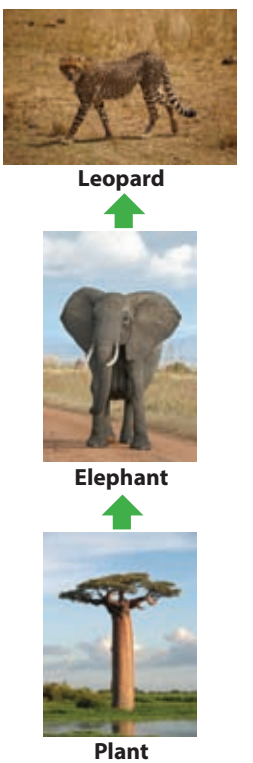


Figure 15.16 - A short food chain

15.2.2 Biogeochemical cycle

The process of cyclic circulation of essential chemical components through atmosphere, hydrosphere and lithosphere of biosphere is called Biogeochemical cycle.

Cyclic circulation of water, carbon, nitrogen, oxygen and phosphorous takes place in the biosphere. The natural environmental balance is maintained by these Biogeochemical cycles.

A few such Biogeochemical cycles are given below.

- Carbon Cycle
- Nitrogen Cycle
- Phosphorous Cycle

Among the above Biogeochemical cycles carbon and nitrogen cycles are discussed in details.

• Carbon cycle

The main method of fixing carbon in an ecosystem is photosynthesis. Animals depend on green plants and they receive carbon through those food. Decomposers obtain carbon by digesting dead organisms. All organisms release carbon as CO_2 during respiration. When decomposers are absent, carbon in dead plants and animals convert in to fossil fuels. This process needs millions of years to be completed. During combustion of fossil fuels carbon releases. Micro organisms play a major role in carbon cycle. They release carbon in dead matter rapidly to the atmosphere. Carbon cycle is represented in the diagram 15.17.

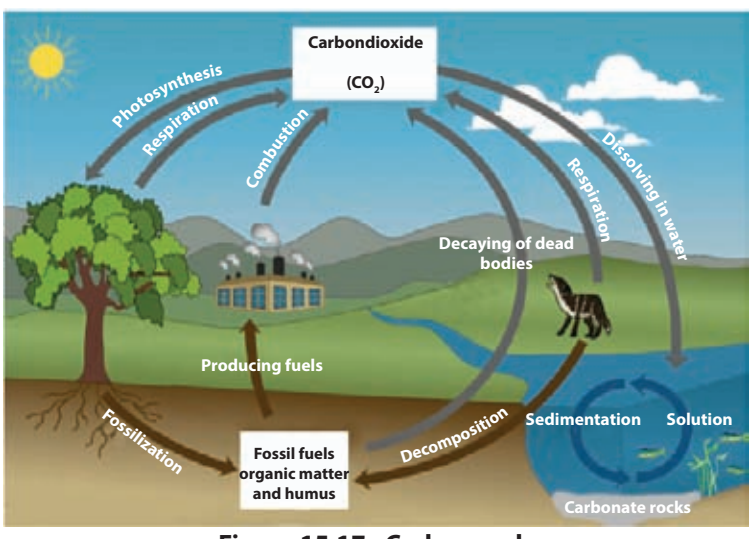


Figure 15.17 - Carbon cycle

• Nitrogen cycle

The main source of nitrogen of earth is the atmosphere.

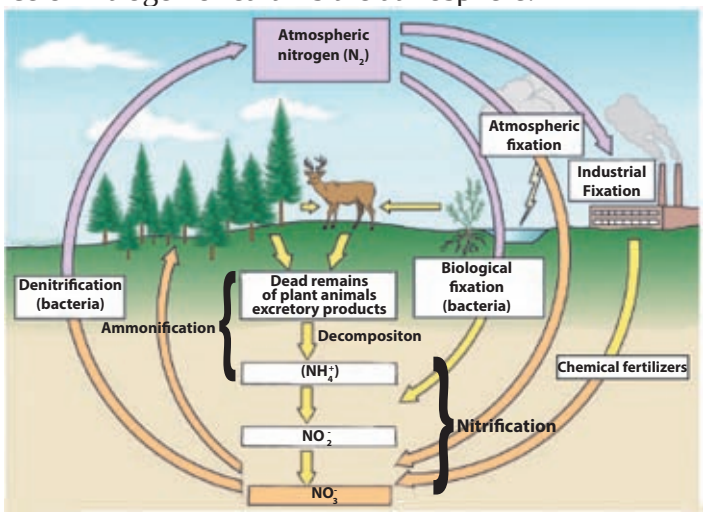


Figure 15.18 - Nitrogen cycle

The fixation of atmospheric nitrogen takes place in three main methods.

- **Biological fixation**

Free living bacteria in soil (*Azotobacter*) and symbiotic bacteria like *Rhizobium* live inside root nodules of leguminous plants that can convert atmospheric nitrogen into NH_4^+.

- **Atmospheric fixation**

During lightning atmospheric nitrogen is converted to nitric oxide and nitrogen dioxide.

- **Industrial fixation**

Atmospheric nitrogen converts to nitrate during industrial production of chemical fertilizers.

Nitrifying bacteria like *Nitrosomonas* first convert Ammonium compounds into nitrites and then *Nitrobacter* bacteria convert nitrite to nitrates. These nitrates are absorbed by plants and used to synthesise proteins. These plant proteins pass into animals through food chains.

Due to microbial activity on dead bodies of organisms, the nitrogenous compounds convert to ammonium compounds known as ammonification and collect into soil. The denitrifying bacteria like *Pseudomonas* and *Thiobacillus* convert nitrates back to atmospheric nitrogen.

Assignment 15.5

Prepare a creative exhibit board to display the nitrogen or carbon cycle.

15.3 Different environmental pollutants and their effects

Disposal of different effluents by the rapid growing population, affects the environmental balance. Let us discuss about the effects of these waste materials.

15.3.1 Environmental pollution

Discharge of pollutants, which cause deleterious effects on natural environment is called environmental pollution.

Environmental pollution are of three types.

- Soil pollution
- Water pollution
- Air pollution

15.3.2 Factors affecting environmental pollution

There are many factors which cause pollution. Let's do the activity 15.1 to identify those pollutants.

Activity 15.1

Materials required :- Different waste materials found in environment

Method :-

- Make a list of pollutants found in the school premises after a field trip.
- Classify them according to the methods given below.

Method I

Method II

- If you are asked to place different waste disposal bins in your school premises decide what type of bins to be placed mostly after analyzing the amount of different waste materials.

There are different types of waste materials involved in environmental pollution. We have to be aware of them to reduce their usage.

These different types of wastes are,

- Agro chemical waste
- Industrial waste
- Greenhouse gases
- Heavy metals
- Particulate matter
- Domestic waste
- Electronic waste
- Nuclear waste

• Excessive usage of agro chemicals

The artificially synthesised chemicals for agricultural practices are called agro chemicals. Mainly agrochemicals include chemical fertilizers, weedicides, insecticides, and fungicides. They are used to get short term benefits, but they cause many ill effects on the environment and hazardous to health.

Weedicides, insecticides and fungicides are commonly known as pesticides. The dose of a pesticide required to kill 50% of a population of a particular pest species is defined as lethal dose (LD_{50}).

Assignment 15.6

List out the agro chemicals that are used for a specific crop from its planting to harvesting. Avoid touching those agro chemicals.

The gazette announcement issued on 23rd of December 2014 by the government has banned selling and usage of chemicals such as Glyphosate, Propanil, Carbaryl, Choloropyrifos and Carbofuran.

Figure 15.19 - Different types of chemical substances sold at market

• Discharge of industrial effluents to the environment

The waste materials that discharge after the production process which cannot be used again are called industrial wastes. The discharge of these industrial wastes to the environment causes harmful impacts on the environment. Industrial waste are as follows.

Hydrocarbons

The compounds formed by combination of carbon and hydrogen only in different ratio are called hydrocarbons.

Methods of releasing hydrocarbons to the environment

- Release of CH_4 (methane the simplest hydrocarbon) due to bacterial activity on garbage and dead plant and animal matter in marshy lands.
- During usage of liquid petroleum (LP gas), petrol, diesel, kerosene as fuel that are obtained by fractional distillation of crude oil.
- During usage of lubrication oil and greese which are products of fractional distillation of crude oil.

Emission of greenhouse gases

The temperature of the earth is fixed by a steady state balance between the energy received from the sun and the energy radiated back by the earth. Carbondioxide, water vapour, methane, ozone and CFC absorb radiation given out from the earth and some of it re-radiates back to the earth's surface. This re-radiation helps to warm the earth and maintains a climate that will support life. This is called greenhouse effect and these gases are called greenhouse gases.

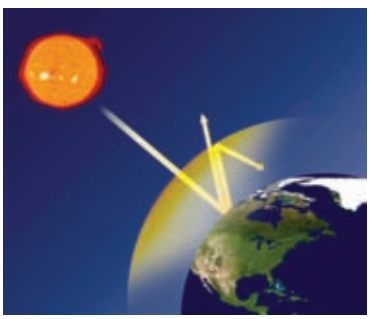


Figure 15.20 - Greenhouse effect

Types of greenhouse gases

Carbondioxide	(CO_2)
Sulphurdioxide	(SO_2)
Oxides of Nitrogen	(NO_x)
Methane	(CH_4)
Chloro Fluoro Carbon	(CFC)
Water vapour	(H_2O)

Due to emission of greenhouse gases enormously, global warming increases.

Ways by which greenhouse gases released to the environment

- Release of CO_2 due to excessive combustion of fossil fuels.
- Sulphur dioxide is released instead of CO_2 due to combustion of fossil fuels and eruption of volcanos.
- Release of CH_4 due to anaerobic decomposition of dead plant and animal matter in marshy lands and garbage.
- CFC is released when using refrigerators and air conditioned appliances.

Accumulation of heavy metals in the environment

The metals with high density and higher relative molecular mass are called heavy metals. Discarded metal items, instruments and parts of vehicles that contain heavy metals accumulate in the environment. Some heavy metals are naturally present in the soil of some areas.

Figure 15.21 - Soil containing heavy metals

Types of heavy metals

Mercury	(Hg)
Arsenic	(As)
Chromium	(Cr)
Cadmium	(Cd)
Lead	(Pb)
Copper	(Cu)
Manganese	(Mn)
Zinc	(Zn)

Methods by which the heavy metals released into the environment

- Release of industrial wastes, wastes of zinc mines, electro plating and cadmium (Cd) released during production of orange coloured pigments.
- Due to excessive usage of agro chemicals, arsenic (As) is released to the environment.
- Release of lead (Pb) from lead mixed petrol.
- Due to excessive usage of coal, discard of damaged thermometers, barometers, CFL bulbs, the paints used to apply on ships and industrial wastes release mercury (Hg).
- Chromium (Cr) is released by paints, cement, paper and rubber. Chromium is used as a pigment to colour them.

Assignment 15.7

- List out the materials and appliances that is utilized at home. Discuss the ill effects caused by different types of heavy metals in them.

Particulate matter

There are two types of particulate matter accumulated in air. They are solid particulate matter and liquid particulate matter.

Solid particles	Liquid particles
• Carbon particles • Heavy metal particles • Ash • Dust • Asbestoes	• Water droplets • Liquid organic particles • Mercury droplets

Figure 15.22 - Particulate matter of asbestoes

Sulphurdioxide

A colourless gas with a pungent smell. When it releases to the environment it causes a big impact on the atmosphere.

Methods of releasing SO_2 to the environment

- When using coal as a fuel
- During combustion of petroleum
- During combustion of vulcanized rubber products
- During bacterial activity on organic matter
- During eruption of volcanoes

Oxides of nitrogen (NO_x)

Oxides of nitrogen (NO, NO_2) cause a big impact on the environment once they are released to the atmosphere.

Methods of releasing oxides of nitrogen to the environment

- During lightning, the reaction between N_2 and O_2 form oxides of nitrogen.
- During combustion inside the engines of vehicle N_2 and O_2 react together to form oxides of nitrogen.

Acid rain

Naturally rain is little bit acidic due to dissolution of carbondioxide and nitrogendioxide (NO_2). The pH is about 5.6 of natural rain water. Sometimes this pH decreases, that is acidity of rain increases. The reason for the increase of acidity in rain is due to increase of sulphurdioxide, sulphurtrioxide and nitrogendioxide in the atmosphere.

Sulphurdioxide is water soluble and then it makes sulphurous acid (H_2SO_3) with water. This sulphurous acid further oxidizes to make sulphuric acid (H_2SO_4). Sulphuric acid is formed due to dissolution of sulphurtrioxide too. Nitrogendioxide helps in increasing acidic nature of rain. It forms nitric acid with water. Water mixing with above acids to form rain is known as acid rain.

Adverse effects of acid rain

Figure 15.23 - Acid rain

- Destruction of forests and crops.
- Destruction of aquatic organisms due to increase of acidity in water.
- Affect the aborption of minerals by plants.
- Dissolving of limestones and other rocks.
- Destruction of metalic buildings, statues, and other ruins.
- Some poisonous heavy metals dissolve in water and the concentration increases in reservoirs.

Activity 15.2

- Ditect the acidity of normal rain and the rain after drought period using indicators.

Domestic waste

Figure 15.24 - Domestic-waste

Food scraps, spoiled food, plastic and polythene wastes, discarded clothes, glass and porcelain items, garden wastes and human excretory matter belong to domestic wastes. These are added to the environment continuously.

Electronic waste

Figure 15.25 - Electronic waste

The electrical and electronic accessories which are stopped permenantly from reselling, and selling are called e-waste.

Electronic wastes due to the modern technology are added to the environment at a higher rate.

The materials released as e- waste

- Lead - Battery, circuit boards, cathode ray tubes of computers and televisions
- Mercury - Thermometers, florescent lamps
- Cadmium - Battery, cellular phones
- Berilium - Computers, telephone, automatic electronic apparatus
- Arsenic - Light emitting diodes (LED)
- Polyvinylchloride (PVC) - Computer casings, wires, etc.

Nuclear-waste

The radio active and high toxic materials discarded by nuclear preparation centres and nuclear weapons are known as nuclear wastes. Uranium and plutonium are the main elements used as nuclear fuels. The radioactivity of them can exist for a longer period of time. Therefore, they are deposited in deep sea or ground after covering by thick concrete or metal casing.

• Domestic chemical-waste

Figure 15.26 - Domestic chemical - waste

With the industrial development, the usage of chemicals for domestic purposes instead of natural materials has become popular. In present days there are many such chemicals that are used for domestic purposes. Food additives, cleaning agents, medicine, paints and cosmetics are the main chemicals that come under domestic chemical waste.

Food additives

The substances that are added to food to enhance the taste, odour, appearence nutrification and shelf - life are called food additives.

E-number

E-number is a code given by European union to indicate that the food additive is experimentally proven to assure that it is safe for human consumption. Though it is given by an E- number, reliability of some additives is not 100% assured.

Activity 15.3

Identify E-numbers of food items that is brought home. What are the substances denoted by those numbers? What is the purpose of adding such things? What are the adverse effects of them.

Activity 15.4

- Do an investigation about the substances such as colourings and flavours which are used for the fast foods. Fill the table using those information

Food type	Ingredients	Defects

Extra knowledge

Materials added and the objective	Substances contained	Adverse effects
Pigments (Attractive colour)	FDSC Blue No 1, FDSC Red No - 40 Beta carotene	Allergies, Deformities in children
Sweeteners (Enhance sweetness)	Sucrose, Glucose, Fructose	Obesity, Diabetes, Belly protrude outwards
Taste Enhancer (Enhance the taste of food)	Monosodium Glutamate (MSG)	Headache, Chest pain, Weakening of taste buds, Heart attack
Preservatives (Preserve food without spoilage)	Ascorbic acid, BHA, BHT, EDTA, Sodium Bensoate, Calcium Proponate, Sodium Nitrate ($NaNO_3$)	Allergies, Vomitting, Nausea, Stomachache, Infertility, Cancers, Mutations, Disorders in liver and kidney
Stabilizers (Enhance the texture)	Gelatine, Pectin	Diarrhoea
Leavening agent (Make porous)	Sodium bicarbonate (Baking soda) Calcium carbonate Monocalcium phosphate	Stomachache, Cancers
Bleaching agents	Sulphurdioxide SO_2	Breathing difficulties
Nutrients (Addition of nutrients that are destroyed during production)	Thyamine hydrochloride Riboflavin Folic acid Ascorbic acid	Nausea, Vomitting

Diseases caused by food additives

- Wheezing
- Kidney disorders
- Diabetes
- Cardiac diseases
- Cancers (Digestive tract, Lungs, Liver, Thyroid gland)
- Allergies (Skin diseases)
- Disorders associated with nutrition
- Diseases of nervous system
- Hyperactivity of children
- Mental disorders
- Diseases associated with digestive tract.

Cleaning agents

Soap or different types of shampoo are used to cleanse skin and hair. Soap or detergents are used to wash clothes and different types of cleaning agents are used to clean floors and walls. Cleaning agents are important to do the cleaning activities which cannot be done with water, better. The basic raw materials of soap are plant oil or animal fat and a strong base like sodium hydroxide or potassium hydroxide. Coconut oil and other plant oils are often used for this purpose.

Figure 15.27 - Detergent swans

Soap bubbles are formed less in dense water. Artificial detergents are used as a solution to this. These are produced with a mixture of artificially synthesized chemicals. When both these types are added to water, it is harmful to the aquatic organisms. Furthermore, there is a threat of coral reefs being destroyed in the marine areas near hotels and it also affects to reduce the bio diversity of fresh water sources.

The harmful effects of the excessive use of artificial detergents are detergent swans which can be seen on the surface of water systems.

Medicines

In the past, man had a sound knowledge of popular indigenous medicines and they used natural medicines. At present there are different kinds of medicines at home that are used without prescription to ease simple ailments. Examples are using anodynes for fever, using different creams for pains and itching and using antacids for gastro acidity. Moreover, when there are cuts and bruises, antiseptics like spirit is used. Antiseptics is a chemical which is applied on living tissues which destroy microorganisms or prevent their growth. When they are used, the correct dosage should be taken on the correct time. It is very dangerous to use medicine without the advice of the doctors for a long period of time. In the past, margosa, turmeric liquid and salt water were used as disinfectants and at present artificial disinfectants are used to clean the floor, kitchen, toilets and bathrooms. Disinfectants destroy microorganisms and it is not safe for them to come into contact with living tissues. Many side effects can be resulted due to their excessive use and they should be used moderately. By using disinfectants often and excessively in the toilet, the microorganisms that decompose faeces are destroyed.

The following grid contains examples for medicines, disinfectants and antiseptics that are used in homes.

Medicines	Disinfectants	Antiseptics
Magnesium carbonate	Phenol	Iodine
Aluminum hydroxide gel	Chlorine	Surgical spirit
Aqueous magnesium hydroxide (milk of magnesia)	Alcohol	Boric acid

Cosmetics

For cleanliness, beauty, health and pleasantness, people have used natural plant extracts like sandalwood, turmeric and types of clay as cosmetics for thousands of years in the history.

At present, perfumes, bleaching creams, talc, hair colourants and bleaches, deodorants and lipsticks are used as cosmetics. There are naturally or artificially synthesized oils, colourings, fragrant substances, distilled substances and preservatives contained in them. Most of them are complex carbonic substances. In perfumes and deodorants, there are alcohol, esters and distilled substances. When these are used excessively, some diseases are caused in some people. Sometimes, headaches, vomiting and breathing difficulties can occur. In most of the lipsticks, there is led and the excessive usage can cause dryness and cracks on lips.

Mercury is present in some cream. In some other creams, carbon compound that controls the formation of melanin colourant is present. This will destroy the natural protection that protects the skin from ultraviolet rays and poses the risk of skin cancer. It gets into the skin and harms the connective tissues. The use of cream for a long period of time can cause defects in skin. Sometimes, this can harm the brain, liver and kidneys. Some hair colourings and compounds with bleaches cause allergies in some people. This causes itching in the scalp, skin rashes, swelling, cancers and even death.

Paints

A material that is applied on sufaces to protect the surface having a desired colour are called paints. Paints contain three components.

- Pigment - They are produced mainly by metal oxides or metal salts. Bronze, gold, zinc and alminium metals are prepared into a fine powder and used as pigments.
- Binder or non volatile substance
- Vehicle or solvent - Volatile hydrocarbonic substance such as turpentine is used as vehicle. water is used as the vehicle for water soluble binders.

• Cumbustion of fossil fuel and waste matter

Combustion of fossil fuel enormously in factories, automobiles, petroleum power stations results in emitting a large amount of carbonmonoxide (CO), carbondioxide (CO_2) and sulphurdioxide (SO_2). Burning of plastics and polythene too emits dioxin and other gases.

• Persistent Organic Pollutants - POPs

Some toxic, hazardous organic substances have been identified as persistent organic pollutants. They are released to the environment from different sources. These pollutants have certain specific features as follows.

- Persist in the environment for a long of time period
- Accumulate in the body of organisms along food chains
- Widely dispersed in the environment
- Highly toxic

Twelve organic pollutants have been identified as dirty dozen which can pose effective threat to the earth.

Extra knowledge

Dirty dozen

Chemicals associated with factories	Industrial and cumbustive byproducts	Pesticide
◘ Hexacholoro benzene ◘ Polychlorinated biphenyls / PCBs	◘ Dioxin ◘ Furan	◘ Aldrin ◘ Chlordane ◘ DDT ◘ Deildrin ◘ Endrin ◘ Heptachlor ◘ Mirex ◘ Toxaphene

Other than those, some other compounds belong to persistent organic pollutants. These POPs cause certain adverse effects as follows,

- Inborn defects
- Cancers
- Mental defects
- Weakness of the immunity and function of reproductive system.

15.3.3. Adverse effects of environmental pollution

• Direct effects of environmental pollution

Acid rain

It is mentioned in page 184 about acid rain. Acid rain has been described as a harmful condition caused by the industrial wastes such as oxides of nitrogen and sulphur.

Global warming

Greenhouse effect occurs in the atmosphere with the high concentration of the polyatomic molecules of greenhouse gases such as carbondioxide, methane, CFC etc. High amount of energy received from sun is refracted away from the earth when the greenhouse gases exceed their permissible level. Hence, the temperature of the atmosphere increases. This is called global warming. Changes that occur due to global warming are shown in Figure 15.28

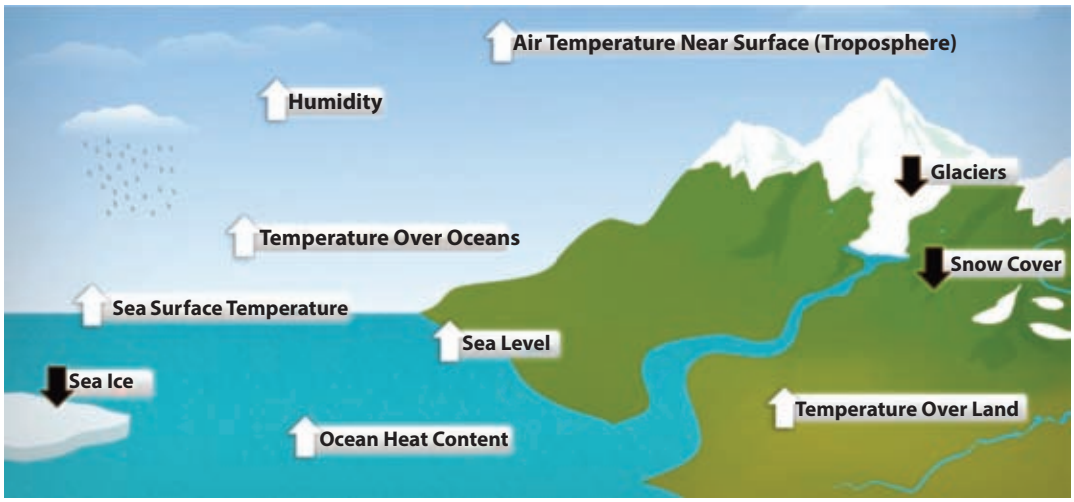


Figure 15.28 - Changes that occur due to global warming

Ill effects of greenhouse effect

- Melting of polar Glaciers due to global warming
- Rising of sea level and small islands will be submerged
- Change of global climatic patterns

Depletion of ozane layer

Ozone is a trimetric molecule of oxygen. This is a thin layer found at 25 km away from the earth surface. At higher atmosphere oxygen absorbs Ultra Violet radiation and forms atomic oxygen.This atomic oxygen is highly reactive. They react with O_2 to form O_3. This O_3 is converted back to O_2 and natural equilibrium is maintained. This ozone layer acts as a protective shield to prevent the entry of harmful UV radiation to the earth surface. But gases like CFC and nitric oxide (NO) destroy ozone layer by detaching O_2. CFC at higher atmosphere obtain solar radiation and is converted to atomic chlorine. This atomic chlorin reacts with O_3 and breaksdown ozone molecules**.** Similarly nitric oxide also reacts with ozone to destroy them.

Due to the depletion of ozone layer, holes appear in it. As a result, radiation with high energy reaches the earth surface.

Ill effects of ozone layer depletion

- Cause cataracts
- Cause mutations
- Reduce body immunity
- Affect photosynthesis and reduce crop yield

Photo chemical smog

It is a yellow coloured mist that is formed due to reaction, resulted between sunlight and the chemicals in vehicle emission, which causes eye irritation and vision impairment.

Extra knowledge

The oxides of nitrogen released due to combustion of fossil fuel and unburnt hydrocarbons transforms into ozone aldehyde, Peroxy Acetyl Nitrate (PAN), Peroxy Benzyl Nitrate (PBN) at 15^0C in the presence of sunlight. Due to these secondary pollutants, photochemical smog is formed.

Figure 15.29 - Photochemical SMOG

Adverse effects of photochemical SMOG

- Cause respiratory tract disorders like cough, wheezing etc.
- Toxic to plants. So plant growth and food production is affected.
- Vision is affected due to turbidity.
- The quality of rubber and clothes reduces due to bleaching.

Biomagnification

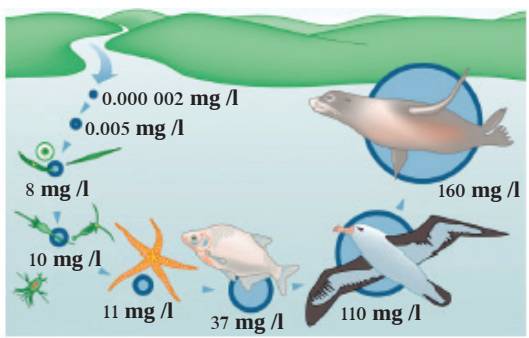


Figure 15.30 - Biomagnification

Collection of toxic chemical pollutants along with food chains from one trophic level to the other is called biomagnification.

Extra knowledge

Dichloro Diphenyl Trichloro Ethane (DDT), Poly Chlorinated Biphenyl (PCB), Mercury, Copper (heavy metals) accumulate in the body of organisms.

Features of bioaccumulated substances

- These substances do not degrade easily and retain for a longer period of time
- Can pass from one organism to the other
- Soluble in lipids
- Become active as biochemicals

These substances enter into lower trophic levels in micro amounts. But they get concentrated along higher trophic levels.

Eutrophication

Figure 15.31 - Eutrophicated reservoir

Phosphate and nitrate concentration in reservoirs increases due to waste materials from industries, agrochemicals, faecal matter and detergents. As a result algae grow excessively and form a green coloured foamy layer. This incident is known as eutrification. The over populated algae die due to competition and anaerobic bacteria act on these dead matter and emit gases such as hydrogen sulphide (H_2S) ammonia (NH_3), methane (CH_4)which result an unpleasant odour.

Ill effects of eutrofication

- Loss of transparency of water
- Unable to utilize water
- Reduction of bio diversity due to death of aquatic plants and animals
- Loss of beauty of reservoirs

Increase of radiation level

Exposure to radiation increases day by day. These radiations are released by natural sources and due to human activities. Especially destruction of ozone layer and accidents in nuclear power stations are the reasons for this situation.

E.g. :- Fukushima power station in Japan, Churnobill power station in Russia

Figure 15.32 - Accidents in nuclear power stations

• Indirect effects of environmental pollution

Loss of habitats of organisms

The natural environment where a plant or an animal lives is known as a habitat. These habitats are lost due to environmental pollution. Wild elephants tempt to destroy villages and agricultural lands due to the loss of their habitat. That is a result of environmental pollution.

Desertification

The change of the ground condition making unsuitable for the plant growth is called desertification. Deforestation, greenhouse effect, salination and natural causes such as weather changes are the reasons for desertification. Irregular monsoon rains causing droughts is a result of this.

Reduction of crop yield

When the conditions required for photosynthesis are not present in optimum levels the productivity of plants is affected. Therefore, the yield is reduced. Lands become infirtile due to their constant use for agriculture. The productivity of plants decreases through water, land and air pollution.

Constructions and degradation of natural environment

Metal statues, buildings, ruins and marble buildings are eroded by acid rains. Natural limestones also degrade due to acid rains. As temperature of the environment increases wall plasters and paintings of Taj Mahal is at a risk of deterioration.

Health issues

As environment is polluted, the infectious (contagious) and non - infectious (non-contagious) diseases spread rapidly in the environment. Due to improper disposal of garbage, diseases like Dengue spread.

Reduction of biodiversity

Reduction of number of species in a unit area of biosphere is known as reduction of biodiversity. When pruning some plants used in landscaping some parts are removed. When ornamental fish like catfish grow in size they are released to the natural water bodies. These organisms become a threat to other organisms in the natural environment and affect the biodiversity.

Introduction of invasive species

Invasive species are results of the changes in the environment. These species can tolerate the conditions and therefore invade the habitats of native species.

E.g. - Giant Mimosa, Trout, Andara, Lantana

Assignment 15.8

Prepare a report about invasive plants and animal species of Sri Lanka.

Economical losses

An extra amount of financial input and effort is needed to revise the environment and maintain it.

15.4 The factors that affect the life style of human and the problems created

15.4.1 Factors that affects the life style of human

Several factors on earth affect the life style of human. Industrialization, urbanization, commercial agriculture and irrigation systems are some of them.

- **Industrialization**

The process by which a country transforms primarily from an agricultural society to a society that produces goods and services is called industrialization. The industrialization initiated from Western Europe in AD 1800 with the technological development and insufficiency of small scale production.

- **Urbanization**

Aggregation of people in areas with abundant resources with the growth of human population is called urbanization. People migrate to cities in search for employments and comfortable life style. As a result, urbanization takes place.

Figure 15.33 - View of an urban area

- **Commercial agriculture**

Large scale agriculture which exceeds the subsistance food production and commercial intentions are called as commercial agriculture. Here, use of modified varieties to obtain productive harvest, agrochemicals and machinary are taken into consideration.

- **Irrigation systems**

Instead of depending on direct rain water, man constructed tanks, ponds, reservoirs, canals, dams and tunnels to obtain water for agricultural purposes. They are considered as irrigation systems.

- **Utilizing materials and energy abundantly and differently**

Due to technological development and complex needs of life, materials harmful to environment in a great extent are being used while minimum labour is spent whereas machinery is used consuming energy.

15.4.2 Problems that arise due to changes in life style

- **Growth of non contagious diseases and dissabilities**

Diseases which are not spread from one person to the other are called as non contagious diseases. According to data of World Health Organization (WHO) annually 38 million people die due to these type of diseases. Most comman contagious diseases are cancers, pulmonary diseases and diabetes Excessive consumption of tobacco and liquor, wrong food habits and lack of physical exercises are the causes for these diseases. Non contagious diseases have

become a major problem in Sri Lanka today. Out of the deaths occured due to diseases, 60% had occured due to non contagious diseases. Out of them several diseases are given below.

Chronic Kidney Disease /CKD

Chronic Kidney Disease or renal failure is spreading gradually in agricultural areas in Sri Lanka. Gradual loss of kidney functions including the urine production is known as renal failure.There are two main forms of renal failure as follows,

1. Acute renal failure

Loss of kidney function temporarily for a few hours or days is a feature of acute renal failure. It is often reversible with immediate treatment.

2. Chronic renal failure

Chronic renal disease causes gradual loss of kidney function which is not reversible.

Other causes for renal failure are,

- Diabetes
- High blood pressure
- Constant urine infections
- Calculi in bladder
- Urinary tract Infections
- Intoxication (snake,wasp, hornet venum, agrochemicals)
- Allergies

Symptoms of renal failure

- Urinary urgancy may occur frequently at night
- Little or no urine output
- Pain in the back
- Swelling of feet and ankle
- Weakness, pale skin
- Urine contain protein
- Rashes on palm and soles

Figure 15.34 - Patches due to clinical kidney disease

Speciality of the kidney disease

- Though acute renal failure occurs due to uncontrolled diabetes or high blood pressure people might have chronic kidney disease without any prior disease.
- Most of the people who have the disease are engaged in agriculture. Tendency of people who spray the agrochemicals having the disease is high.
- The first patient was reported from Padaviya Govi Janapadaya in 1994. Though at the beginning farmers of 50-60 years of age were seen to have the disease, later people of 25-30 years of age have got the disease at present.
- Delayed symptoms keep the patient ignorant about this disease. Sometimes when the patient realizes, he is affected by the disease and 40-60% of the kidney has lost its function.
- Most of the people affected are identified to be drinking hard water

Factors that have been identified to be contrtibuting to CKD

- Toxic elements emmited by blue green algae.
- Absorption of agrochemical into body.
- Absolutely heavy metals such as Cd, Pb, As
- Drinking water with floride
- Dehydration
- Using drugs without any control
- Consumption of liquor

Measures that can be taken to avoid CKD

- Refraining from using agrochemicals, and food for which agrochemicals are used
- Maintaining a wholesome life style to control and prevent diabetes and high blood pressure
- Minimizing the frequent urine infections during childhood or which adults are affected from
- An adult drinking 3.5-4.5 litres or 5-6 bottles of clean water a day
- Receiving medical treatment for skin allergies immediately
- Refrain from improper use of pain killers
- Refrain from liquor consumption and smoking

Diabetes

Increase of blood glucose level above the normal level is known as diabetes. Normally, insuline converts the excess glucose in the blood into glycogen and allows it to store in the liver. Failing of the secretion of insulin due to dysfunction or inborn absence of beta cells in the Islets of Langerhans which is located in the

pancreas, secretion of insulin fail. When diabetes is not controlled kidney weakens and gradual blindness occurs. Due to busy life style, consumption of food items made of wheat floor and polished rice which are digested instantly, abstaining from exercising and mental stress are some of the causes of diabetes.

Cancer

Cancer is a disease caused by an uncontrolled division of abnormal cells in a part of the body. With the industrialization, harmful radiation, chemical and heavy metals are abundant in the environment. Frequent exposure to radiation and intake of heavy metals to the body, increase the possibility of a cancer.

Heart diseases

Narrowed or blocked blood vessels, heart muscles, valves or rythem not functioning properly lead to heart diseases. Chest pain, heart attack, strokes, thrombosis are some forms of heart diseases. The main cause of heart diseases is the changes in the human life style. With the industrialization, activities of human have become more convenienced, lack of physical exercises, rest and mental stress cause these diseases.

Pulmonary diseases

An unhealthy condition which affects the organs or tissues which involves in the respiration such as trachea, bronchi, bronchioles, alveoli and other nerves and muscles may cause pulmonary diseases. Harmful gases emitted from vehicles and factories also contribute to this.

Wheezing

The air ways are obstructed by the mucus produced due to allergies in trachea, bronchi, bronchioles and alveoli of the respiratory system. Harmful gases and dust particles (Air pollutants and irritants) remain as causes.

Gastritis

Inflammation and swelling in the lining of the stomach due to increasing acidity is the main symptom of this disease. Not taking meals on time because of busy life style, frequent consumption of food containing excessive oil and acids, mental stress caused because of living under a competitive condition are the causes of this disease.

Cataracts

Due to the change in the nature of proteins in the lens of the eye, the transparency of the lens ceases. It is known as the cataract. Here, light does not enter the eye and the eye sight is weakened. Due to the emission of harmful gases from factories, the ozone layer becomes depleted. Thus, ultraviolet rays fall on earth. The exposure to these rays is a cause for this disease.

15.5 Sustainable development and environmental management

Sustainable development is the smart use of the natural resources by safeguarding the balance of the environment in such a manner that the future generations can use them in the future.

Environmental management is the maintenance of natural resources by using them in an environmental friendly manner to fulfill the needs of man.

15.5.1 Sustainable agricultural uses

A sustainable development could be expected by reforestation, use of traditional knowledge and technology, carbon foot print, minimizing food miles, waste management and energy management.

- **Multiple cropping**

Cultivation of different crops in one land area instead of mono cropping in large scale is called multiple cropping. Multiple cropping avoids the risk of destroying the cultivation with a disease and also reduce pests with high resistance.

Figure 15.35 - Mono cropping

Figure 15.36 - Multiple cropping

- **Biological pest control**

The biological pest control is the use of another plant, animal or a microorganism which do not harm the cultivation in order to destroy pests. Coconut catepillar *Promecotheca cumingii* was a major coconut pest which was successfully controlled, using a larval parasitoid *Dimokia javanica.*

- **Use of organic fertilizer**

It is environmental friendly to use substances made by transforming complex organic compounds found in animals and plant parts to simple compounds as fertilizers. Organic fertilizers are the decomposed plant and animal matter which help to improve, soil structure and porosity to enhance the activity of soil organisms.

Assignment 15.9

Engage in a discussion about the advantages caused to the environment by using the above mentioned agricultural uses.

- **Reforestation for environmental balance**

Environmental management is the maintenance of natural resources by using them in an environmental friendly manner to fulfill the needs of man.

As a result of changing the environment by man according to his necessity, the forest cover gradually decreased. Specially, paddy cultivation, vegetable cultivation, tea cultivation, rubber cultivation and large scale development projects were the reasons for this situation.

At present, we experience the harmful effects of the decrease of the natural forest cover. Therefore, in order to reestablish the environmental balance, it is necessary to do reforestation in suitable areas.

Figure 15.37 - Reforestation

15.5.2 Traditional knowledge and use of technology

- **Agriculture**

It is mentioned that during the rule of King Parakramabahu the Great, our country was self sufficient with rice and rice had even been exported. But, at present, we are unable to achieve such heights although machines and agricultural chemicals are excessively used. Therefore, instead of seeds and agricultural chemicals purchased from multinational companies, it is the high time to use traditional agricultural methods such as local seeds and cultivation methods.

Extra knowledge

Some important information of traditional varieties of paddy

Type of paddy	Function
'Kuruluthuda'	• Induce spermatogenesis • Make body strength • Reduce joint pain • Increase immunity • Act on excretory system readily
'Kahawanu'	• Facilitate digestion of food • Facilitate absorption of sugar • Prevent carcinogenic properties
'Rathhal'	• Activate excretory system • Make the body comfortable • Cure lung diseases and fever • Heal abdominal disorders • Clean urine and bile
'Madathawalu'	• Removal of toxic metals from body • Prevent diabetes • Avoid gene mutations • Enhance immunity • Growth and repair of tissues • Cooling of body
'Suwadal'	• Control eye diseases • Induce nerve activities and control diseases • Aids in spermatogenesis • Reduce oedema • Anti-diabetic properties
'Mavee'	• Anti-diabetic properties • Reduce burning sensation, Thridosha and prevent constipation • Improve skin condition
'Kaluheenati'	• Prevent constipation • Anti cancerous properties or carcinogenic properties • Body warming • Aids in spermatogenesis

• The technology of irrigation

Sri Lankan irrigation system is one of the unique water management systems in the world. Historical large tank can be identified as a great technical attempt with a very complex scientific knowledge.

Figure 15.38 - An ancient tank bund

The reservoir constructed across a river, canal or a branch of it with the aim of collecting sufficient water for agricultural activities is known as a tank.

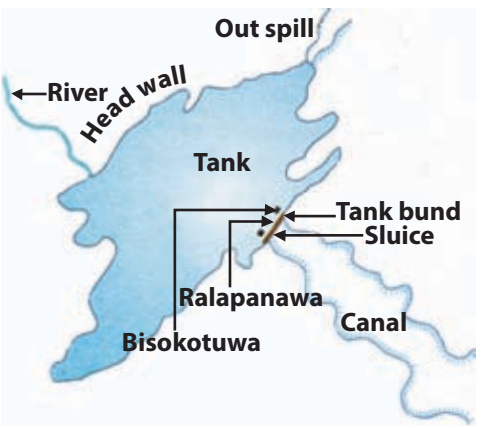


Figure 15.39 - Major parts of a tank

The large tanks distributed in the dry zone of Sri Lanka hold a huge water capacity. Major factor that should be paid attention to constructing such large scale tanks is, keeping the collected water for a long time. Also by controlling the pressure caused by its colossal capacity of collected water and controlling the power caused by its extremely destructive pressure when the water is taken out for use.

There are several functions done by tank bund, sluice, Bisokotuwa (Sluice gate), Ralapanawa and canal, which are considered as the major parts of a tank. The tank bund was built with soil connecting the hills from either side.

The robustness is essential if the stability of the tank bund and needs to be protected. To maintain this situation a systematic methodology has been applied. Tank bund had been constructed of several soil layers. It had been made of several thoroughly beaten layers such as, a layer of clay, soil, gravel and clay (Kirimeti) layer, kept one on one.

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Figure 15.40 - A sluice gate

When water in large tanks is taken out a huge pressure is exerted and the magnitude of pressure increases with the height of water column. The sluice was built at a specific level on the tank bund using huge pieces of stones in a way that it began from the area where water is filled in the tank bund and going under the tank bund or piercing it. A slab of stone, connected to the sluice vertically was used to release water. There are more than one sluice made in tanks with a high bund.

Bisokotuwa is also a part of the sluice. It means that the rectangular space made of stones, from which water flows out from the tank. Its purpose is to take water out with less pressure level after releasing water at different pressure levels. The mud sluice is at the bottom level of a tank bund. This mud sluice was used to remove alluvial collected after a rainy season.

When a tank is filled with water, waves occur on its surface, and the waves can erode the bund. The Ralapanawa is made by keeping stones on the interior slope of the tank bund. A brink **(Isweti)** is built to avoid collecting water with eroded mud, sand and gravel, to the tank water.

The small sized water tanks built in the upper part of tank collect water first and next the large tank.

The upper part of tank that is Head wall **(Wew Ismaththa)** is the water catchment area. Clearing forest, cultivation and building of houses is strickly prohibited in this area.

The surrounding area parellel to the water level is known as **wew thawulla** and this is rich with natural habitats of flora and fauna.

Accordingly, tank is a marvellous human creation that is compatible with nature.

Assignment 15.10

Make a scientific investigation about the technology of irrigation system of Sri Lanka, and prepare a report.

• Conventional food patterns

Food comprises of a collection of nutrition, healthyness, culture, tradition, environment, creation, folk tales, literature, technology, etc. The traditional food patterns improved the quality of life of our people. But consumption of oily, starchy

food, flavourings and bad food habits cause number of issues in public health. This condition has influenced the tendency of non-contagious diseases like high blood pressure and diabetes.

Important facts about natural flavourings

- The most reactive parts of a food
- Improve the colour, taste, odour and appetite of food.
- Contain bactericidal properties
- Minimize, harmful effects caused by food
- Has unique taste and quality, which cannot be obtained by artificial flavourings.

E.g. :- Cinnamon - Control the blood glucose level.
Reduce diseases caused by phlegm
Has anticancer properties

Clove - Give pleasant odour to mouth
Relieve pain
Destroy microorganism (Detergent property)

Pepper - Stimulate digestion of food
Relieve abdominal disorders

• Indegeneous medical science

This field consists of Aurveda, **Siddha, Unani** and native medicinal fields, which has history of thousands of years. Ayurveda is one of the important medical fields, descended from India. It is a perfect science with two traditions.

1. Clinical medicine (Kayachikithsa)

2. Surgical science

According to Ayurveda there are three types of reaction that take place in human body. Those three factors are known as **Va, Pith and Kapha.**

'Va' - Air

'Pith' - Bile

'Kapha' - Phlegm

Imbalance of these three factors cause diseases according to Ayurveda. Ayurveda field of medicine, use plants, or parts of plants to treat patients.

Treatments are given in three ways

1. Medicine 2. Food 3. Exercises

In Ayurvedic medicine, treatments are done to the cause or root to the disease. Body activity is not controlled artificially by giving medicine (drugs) externally. Therefore side effects are not resulted.

Food is also a significant factor to cure diseases. It should be consumed to balance Va, Pith and kapha the three factors.

Its main target is not only curing diseases, but also maintaining physically and mentally fit healthy life.

15.5.3 Carbon footprint and minimization of food mile

• Carbon footprint

The amount of carbondioxide released into the atmosphere as a result of the activities of a particular individual, organization or community is a carbon footprint. Total carbonfoot print cannot be calculated as CO_2 is naturally produced whereas it needs more data.

• Water footprint

The amount of fresh water utilized in the production or supply of the goods and services used by a particular person or group.

Figure 15.41 - Water footprints of several foods

• Food mile

The distance over which a food item is transported during the journey from producer to consumer, is known as food mile.

The food mile changes according to the quantity of food and the place it is produced.

E.g. - Food mile of some of the foods that you take for your breakfast can be calculated as follows. Suppose you are in kurunegala.

(1)

Rice	1 mile	(Taken from your paddy)
Potato curry	100 miles	(Taken from Welimada area)
Coconut	0 mile	(Taken from your coconut trees)
Eggs	10 miles	(Taken from a poultry farm of your area)
Summation	111 miles	

(2)

String hoppers made up of rice floor	85 miles	(Rice taken from Polonnaruwa)
Dhal curry	925 miles	(Taken from Misur area of India)
Coconuts	0 mile	(Taken from your home garden)
Coconut sambol	185 miles	(Taken from Jaffna)
Summation	1195 miles	

(3)

Bread		(Wheat flour taken from America)
Fish curry	9340 miles	(Taken from Negombo)
Coconuts	44 miles	(Taken from your home garden)
Coconut sambol	0 mile	(Taken from Chennai, India)
	800 miles	
Summation	10184 miles	

As long as the food mile is short, sustainability and environmental friendliness is high. Therefore we should take actions to shorten the magnitude of food mile.

15.5.4 Waste management

Consumption of substances becomes greater with the increase of human population. Eventhough natural waste materials deteriorate gradually, they get collected to the environment rapidly. Odour of such waste spreads in urban areas, rather than in villages. Non deteriorative materials such as polythene, plastic, electrical cells, electronic waste, electric bulbs and, printed coloured newspapers get collected in the environment continuously. When burning these waste materials gases such as dioxine emits. When these waste materials are burried, soil gets polluted and heavy metals get collected into soil. Public is unaware of the danger of them. It is very important to be knowledgeable that gradual disposal of the tiny piece of plastic, battery of a mobile phone CFL bulb be catostrophic. It is our responsibility to collect waste matter separately and forward it to the process of recycling.

The waste handling technique named 4R is practised in waste management

Reuse - Use as many items as possible again and again.
E.g. Polythene

Reduce - Unnecessary items should be avoided or minimized.
E.g. - Avoid taking antibiotics and vitamins unnecessarily

Replace - Use of eco friendly substances instead of incompatible materials with nature.

E.g. - Use of organic fertilizer instead of chemical fertilizer.

Recycle - Process to convert different raw materials, animal dung and dead bodies into new products to prevent waste of potentially useful materials.

E.g. - Production of bio gas using animal excretory matter, dung and dead matter.

Recyling polythene and plastic in order to produce fuel.

15.5.5 Energy management

Consumer is provided with an opportunity to utilize energy with the aim of conservation of energy and minimization of cost. Planning and monitoring of energy production and consumption is required for sustainable utilization and then fulfil the needs of the consumer. This process is referred to as energy management.

• Energy crisis and technological issues

Drastic increase of price of economically important energy resources due to their constricted supply is referred to as energy crisis. Fuel oil crisis, electiricity crisis and dearth of energy resources also indicate this problem. Energy crisis occurs as a result of the great demand for the supply of limited natural energy resources.

Reasons for energy crisis

- Drastic growth of human population
- Increase of the number of industries
- Over consumption of energy
- Wasting energy
- Non investigation of renewable energy resources
- War activities
- Political problems

Technical problems arise during the management of available energy. Technology for extraction of energy resources, methodology of purifying energy resources are some of them.

Assignment 15.11

List out the steps you follow to utilize energy with minimum wastage.

• Monitoring of daily energy consumption

It is necessary to be aware and compare the energy consumption by measuring it daily. Then wastage can be minimized.

- **Energy auditing**

The purpose of monitoring is to visit different institutions, and make recommendations and advise based on the results of the respective energy audits and make the authorities aware related to energy consumption.

In this context making the public enthusiastic on reduction of energy consumption and improving energy efficiency are ensured.

- **Energy efficiency**

Energy efficiency is defined as utilization of minimum quantity of energy for a particular service through effective management of energy consumption.

It is possible to improve energy management and control through energy efficiency. It also enables to provide an enhanced service by utilizing minimum energy. However this does not mean that the service is withheld or controlled.

Assignment 15.12

Investigate the electrical appliances at your home and record their wattage (power). Hence compare their level of energy consumption.

- **Sustainable energy use**

In sustainable use maintenance of a certain aspect at a desired status/level is expected. Due to technical reasons, utilization of most renewable energy resources still remains at a lower level.

E.g. Solor energy, Wind energy, Biomass

Importance of utilizing natural energy in architecture

In constucting a house some steps need to be taken in order to maintain good indoor air circulation. When natural sunlight incidents upon the surfaces the temperature of indoor environment increases. Hence it is not desirable to place fenestrations (windows) on East and West walls of the house. Especially since heat transfer from the western side is high, it is not done. By placing windows on North and South directions good air circulation and natural cooling can be maintained within the house. Electrical energy consumption for air conditioning can be minimized to a great extent by means of natural ventilation. Day light harvesting can be utilized for reducing electrical energy consumption due to artificial lighting. This enables a substantial reduction of operational cost of a building. Using thick curtains can also lead to reduction of heat transfer in air conditioned spaces. This considerably reduces energy consumption for air conditioning. Rain water harvesting can be applied as an energy conservation measure. In boiler systems exhaust gases discharged through the chimney stack contain high temperature waste heat which can be extracted to heat boiler feed water and as an air pre-heater. With the utilization

of eco-friendly natural energy sources it is possible to minimize the adverse effects on the environment.

Different Conventions, Legislations and Acts are in function at international and national level for the management and sustainable use of the environment.

Several examples for international conventions are given below.

- Montreal protocol to control the gases which harm the ozone layer
- Kyoto protocol to minimize the emission of greenhouse gases

State institutions under the Ministry of Environment, Central Environment Authority, Marine Environment Protection Authority, Geological Survey and Mines Bureau, State Timber Corporation, National Gem and Jewellery Authority implement law, rules and regulations related to environmental management.

Assignment 15.13

Prepare a booklet on renewable energy sources.

Summary

- There is a natural balance among living organisms, physical component and the environmental conditions in the biosphere. This balanced relationship is known as the environmental equilibrium.
- The increasing human population and their activities cause the breakdown of the ecological balance.
- The simple organizational level that is individual, organize to form population, community, ecosystem and finally forms the biosphere.
- The flow of energy and natural minerals among organisms is essential to maintain the ecological balance.
- The flow of energy and nutrient among organisms occur through food chains, food webs and bio geo-chemical cycles.
- Environmental pollution is the breakdown of ecological balance due to the waste materials released to the environment by man.
- Agro chemicals, industrialized waste, greenhouse gases, heavy metals, particulate matter, food additives, cleaning agents medicine, detergents and perfumes are the main causative agents of environmental pollution.
- Man is experiencing direct and indirect effects of environmental pollution at present.
- Usage of indegenous knowledge and technology, indegenous medicines waste management and energy management are some of the effective ways for sustainable development.

Exercise

(01)

(i) What is the organizational level which includes abiotic component in the biosphere

i. Individual ii. Population iii. Community iv. Ecosystem

(ii) Select the answer with all the descriptions about the population

i. Species name, living period
ii. Species name, location
iii. Living period, locaton
iv. Species name, living period, location

(iii) Which of the following is not a causative gas for acid rain

i. Nitrogendioxide ii. Carbondioxide
iii. Sulphurdioxide iv. Sulphurtrioxide

(iv) The main gas which cause greenhouse effect is,

i. Carbondioxide ii. Methane
iii. Chloro Fluoro Carbon iv. Oxides of nitrogen

(v) The bacteria which involves in fixation of atmospheric nitrogen as ammonium is,

i. *Rhizobium* ii. *Nitrosomonas*
iii. *Nitrobacter* iv. *Pseudomonas*

(02)

(1) There are many ecosystems found in the biosphere.

1. Name two relationships present in an ecosystem.
   ---
2. Name two biological communities identified in a pond ecosystem.
   ---
3. Name two causes for the breakdown of ecological balance.
   ---
4. What is the main method of fixation of carbon in an ecosystem ?
   ---
5. The flora in Singharaja forest are naturally well-grown than the crops in an agricultural land. Justify this statement.

   ---

(3)

1. Name two applications in sustainable agriculture.
   ---------- ----------
2. State two fields where indigeneous knowledge and technology can be applied.
   ---------- ----------
3. What is known as **food mile** ?
   ---------- ----------
4. Name two ways to shorten the food mile.
   ---------- ----------

Technical terms

Biosphere	- ජෛවගෝලය	- உயிர்க்கோளம்
Bio geo - chemical cycles	- ජෛව භූ රසායනික චක්‍ර	- உயிர்ப்புவி இரசாயனச் சக்கரம்
Industrialization	- කාර්මීකරණය	- கைத்தொழில் மயமாக்கம்
Urbanization	- නාගරීකරණය	- நகரமயமாக்கம்
Non - contagious diseases	- බෝ නොවන රෝග	- தொற்றாத நோய்கள்
Food chain	- ආහාර දාමය	- உணவுச் சங்கிலி
Food web	- ආහාර ජාලය	- உணவு வலை
Energy pyramid	- ශක්ති පිරමීඩය	- சக்திக் கூம்பகம்
Number pyramid	- සංඛ්‍යා පිරමීඩය	- எண்ணிக்கைக் கூம்பகம்
Biomass	- ජෛව ස්කන්ධ	- உயிர்த்திணிவு
Sustainable development	- තිරසාර සංවර්ධනය	- தொடர்ச்சியான அபிவிருத்தி
Environmental management	- පරිසර කළමනාකරණය	- சூழலில் முகாமைத்துவம்
Energy management	- ශක්ති කළමනාකරණය	- சக்தி முகாமைத்துவம்
Waste management	- අපද්‍රව්‍ය කළමනාකරණය	- கழிவு முகாமைத்துவம்
Carbon food print	- කාබන් පියසටහන	- காபன் அடிச்சுவடு
Food mile	- ආහාර සැතපුම	- உணவின் மைல் பெறுமானம்

Introduction

This textbook was compiled by the Educational Publications Department in accordance with the syllabus prepared by the National Institute of Education for the use of Grade 11 students in the Sri Lankan school system with effect from 2016. An effort has made here to arrange the subject content to suit the national educational goals, common national competencies, the objectives of teaching science and the content of the syllabus.

The subject of science directs the student towards a more active learning process in a manner as to develop knowledge, skills and attitudes needed for a developmental scientific thought.

Each chapter is compiled based on the three main subject areas that comprise the Science subject; Biology, Chemistry and Physics. Pictures, charts, graphs, activities and assignments are included to enable the easy understanding of the related concepts of the subject.

At the end of each chapter, a summary was included and it provides the opportunity to identify the basic concepts of each chapter and to revise the subject matter. Furthermore, there is a series of exercises at the end of each chapter. It will contribute to measure the expected learning outcomes through a self evaluation.

Activities, self evaluative questions, solved examples, assignments and exercises are planned in a manner as to develop the higher order skills such as it enables the students to develop knowledge as well as the higher order skills such as comprehension, application, analysis, synthesis and evaluation.

For the purpose of directing the student to study further about the subject matter, more information is included in the "For extra knowledge". It is given only to broaden the subject area of the child and certainly not to ask questions at term tests.

Some of the activities mentioned in the textbook could be performed at home and some of them should be performed in the science laboratory of the school. Activity based learning helps to create a liking towards learning science in the students and it will easily establish the concepts.

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