6.1.3 How are these Tissues protected?

A delicate organ like the brain, which is so important for a variety of activities, needs to be carefully protected. For this, the body is designed so that the brain sits inside a bony box. Inside the box, the brain is contained in a fluid-filled balloon which provides further shock absorption. If you run your hand down the middle of your back, you will feel a hard, bumpy structure. This is the vertebral column or backbone which protects the spinal cord.

6.1.4 How does the Nervous Tissue cause Action?

So far, we have been talking about nervous tissue, and how it collects information, sends it around the body, processes information, makes decisions based on information, and conveys decisions to muscles for action. In other words, when the action or movement is to be performed, muscle tissue will do the final job. How do animal muscles move? When a nerve impulse reaches the muscle, the muscle fibre must move. How does a muscle cell move? The simplest notion of movement at the cellular level is that muscle cells will move by changing their shape so that they shorten. So the next question is, how do muscle cells change their shape? The answer must lie in the chemistry of cellular components. Muscle cells have special proteins that change both their shape and their arrangement in the cell in response to nervous electrical impulses. When this happens, new arrangements of these proteins give the muscle cells a shorter form. Remember when we talked about muscle tissue in Class IX, there were different kinds of muscles, such as voluntary muscles and involuntary muscles. Based on what we have discussed so far, what do you think the differences between these would be?

QUESTIONS

1. What is the difference between a reflex action and walking?
2. What happens at the synapse between two neurons?
3. Which part of the brain maintains posture and equilibrium of the body?
4. How do we detect the smell of an *agarbatti* (incense stick)?
5. What is the role of the brain in reflex action?

6.2 COORDINATION IN PLANTS

Animals have a nervous system for controlling and coordinating the activities of the body. But plants have neither a nervous system nor muscles. So, how do they respond to stimuli? When we touch the leaves of a *chhui-mui* (the 'sensitive' or 'touch-me-not' plant of the Mimosa family), they begin to fold up and droop. When a seed germinates, the root goes down, the stem comes up into the air. What happens? Firstly, the leaves of the sensitive plant move very quickly in response to touch.

There is no growth involved in this movement. On the other hand, the directional movement of a seedling is caused by growth. If it is prevented from growing, it will not show any movement. So plants show two different types of movement – one dependent on growth and the other independent of growth.

6.2.1 Immediate Response to Stimulus

Let us think about the first kind of movement, such as that of the sensitive plant. Since no growth is involved, the plant must actually move its leaves in response to touch. But there is no nervous tissue, nor any muscle tissue. How does the plant detect the touch, and how do the leaves move in response?

Figure 6.4 *The sensitive plant*

If we think about where exactly the plant is touched, and what part of the plant actually moves, it is apparent that movement happens at a point different from the point of touch. So, information that a touch has occurred must be communicated. The plants also use electrical-chemical means to convey this information from cell to cell, but unlike in animals, there is no specialised tissue in plants for the conduction of information. Finally, again as in animals, some cells must change shape in order for movement to happen. Instead of the specialised proteins found in animal muscle cells, plant cells change shape by changing the amount of water in them, resulting in swelling or shrinking, and therefore in changing shapes (Fig. 6.4).

6.2.2 Movement Due to Growth

Some plants like the pea plant climb up other plants or fences by means of tendrils. These tendrils are sensitive to touch. When they come in contact with any support, the part of the tendril in contact with the object does not grow as rapidly as the part of the tendril away from the object. This causes the tendril to circle around the object and thus cling to it. More commonly, plants respond to stimuli slowly by growing in a particular direction. Because this growth is directional, it appears as if the plant is moving. Let us understand this type of movement with the help of an example.

Activity 6.2

- Fill a conical flask with water.
- Cover the neck of the flask with a wire mesh.
- Keep two or three freshly germinated bean seeds on the wire mesh.
- Take a cardboard box which is open from one side.
- Keep the flask in the box in such a manner that the open side of the box faces light coming from a window (Fig. 6.5).
- After two or three days, you will notice that the shoots bend towards light and roots away from light.
- Now turn the flask so that the shoots are away from light and the roots towards light. Leave it undisturbed in this condition for a few days.
- Have the old parts of the shoot and root changed direction?
- Are there differences in the direction of the new growth?
- What can we conclude from this activity?

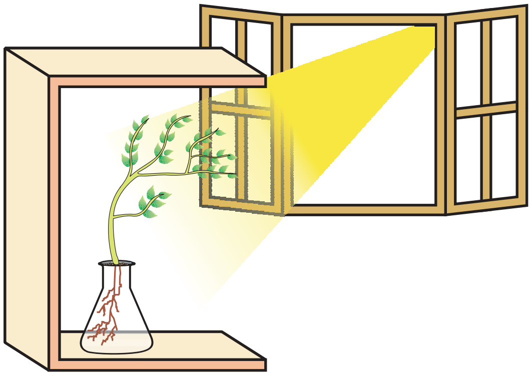

Figure 6.5
Response of the plant to the direction of light

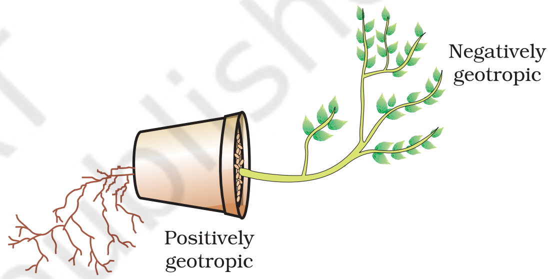

Figure 6.6 *Plant showing geotropism*

Environmental triggers such as light, or gravity will change the directions that plant parts grow in. These directional, or tropic, movements can be either towards the stimulus, or away from it. So, in two different kinds of phototropic movement, shoots respond by bending towards light while roots respond by bending away from it. How does this help the plant?

Plants show tropism in response to other stimuli as well. The roots of a plant always grow downwards while the shoots usually grow upwards and away from the earth. This upward and downward growth of shoots and roots, respectively, in response to the pull of earth or gravity is, obviously, geotropism (Fig. 6.6). If 'hydro' means water and 'chemo' refers to chemicals, what would 'hydrotropism' and 'chemotropism' mean? Can we think of examples of these kinds of directional growth movements? One example of chemotropism is the growth of pollen tubes towards ovules, about which we will learn more when we examine the reproductive processes of living organisms.

Let us now once again think about how information is communicated in the bodies of multicellular organisms. The movement of the sensitive plant in response to touch is very quick. The movement of sunflowers in response to day or night, on the other hand, is quite slow. Growth-related movement of plants will be even slower.

Even in animal bodies, there are carefully controlled directions to growth. Our arms and fingers grow in certain directions, not haphazardly. So controlled movements can be either slow or fast. If fast responses to stimuli are to be made, information transfer must happen very quickly. For this, the medium of transmission must be able to move rapidly.

Electrical impulses are an excellent means for this. But there are limitations to the use of electrical impulses. Firstly, they will reach only those cells that are connected by nervous tissue, not each and every cell in the animal body. Secondly, once an electrical impulse is generated in a cell and transmitted, the cell will take some time to reset its mechanisms before it can generate and transmit a new impulse. In other words, cells cannot continually create and transmit electrical impulses. It is thus no wonder that most multicellular organisms use another means of communication between cells, namely, chemical communication.

If, instead of generating an electrical impulse, stimulated cells release a chemical compound, this compound would diffuse all around the original cell. If other cells around have the means to detect this compound using special molecules on their surfaces, then they would be able to recognise information, and even transmit it. This will be slower, of course, but it can potentially reach all cells of the body, regardless of nervous connections, and it can be done steadily and persistently. These compounds, or hormones used by multicellular organisms for control and coordination show a great deal of diversity, as we would expect. Different plant hormones help to coordinate growth, development and responses to the environment. They are synthesised at places away from where they act and simply diffuse to the area of action.

Let us take an example that we have worked with earlier [Activity 6.2]. When growing plants detect light, a hormone called auxin, synthesised at the shoot tip, helps the cells to grow longer. When light is coming from one side of the plant, auxin diffuses towards the shady side of the shoot. This concentration of auxin stimulates the cells to grow longer on the side of the shoot which is away from light. Thus, the plant appears to bend towards light.

Another example of plant hormones are gibberellins which, like auxins, help in the growth of the stem. Cytokinins promote cell division, and it is natural then that they are present in greater concentration in areas of rapid cell division, such as in fruits and seeds. These are examples of plant hormones that help in promoting growth. But plants also need signals to stop growing. Abscisic acid is one example of a hormone which inhibits growth. Its effects include wilting of leaves.

Q U E S T I O N S

1. What are plant hormones?
2. How is the movement of leaves of the sensitive plant different from the movement of a shoot towards light?
3. Give an example of a plant hormone that promotes growth.
4. How do auxins promote the growth of a tendril around a support?
5. Design an experiment to demonstrate hydrotropism.

6.3 HORMONES IN ANIMALS

How are such chemical, or hormonal, means of information transmission used in animals? What do some animals, for instance squirrels, experience when they are in a scary situation? Their bodies have to prepare for either fighting or running away. Both are very complicated activities that will use a great deal of energy in controlled ways. Many different tissue types will be used and their activities integrated together in these actions. However, the two alternate activities, fighting or running, are also quite different! So here is a situation in which some common preparations can be usefully made in the body. These preparations should ideally make it easier to do either activity in the near future. How would this be achieved?

If the body design in the squirrel relied only on electrical impulses via nerve cells, the range of tissues instructed to prepare for the coming activity would be limited. On the other hand, if a chemical signal were to be sent as well, it would reach all cells of the body and provide the wide-ranging changes needed. This is done in many animals, including human beings, using a hormone called adrenaline that is secreted from the adrenal glands. Look at Fig. 6.7 to locate these glands.

Adrenaline is secreted directly into the blood and carried to different parts of the body. The target organs or the specific tissues on which it acts include the heart. As a result, the heart beats faster, resulting in supply of more oxygen to our muscles. The blood to the digestive system and skin is reduced due to contraction of muscles around small arteries in these organs. This diverts the blood to our skeletal muscles. The breathing rate also increases because of the contractions of the diaphragm and the rib muscles. All these responses together enable the animal body to be ready to deal with the situation. Such animal hormones are part of the endocrine system which constitutes a second way of control and coordination in our body.

Activity 6.3

- Look at Fig. 6.7.
- Identify the endocrine glands mentioned in the figure.
- Some of these glands have been listed in Table 6.1 and discussed in the text. Consult books in the library and discuss with your teachers to find out about other glands.

Remember that plants have hormones that control their directional growth. What functions do animal hormones perform? On the face of it, we cannot imagine their role in directional growth. We have never seen an animal growing more in one direction or the other, depending on light or gravity! But if we think about it a bit more, it will become evident that, even in animal bodies, growth happens in carefully controlled places. Plants will grow leaves in many places on the plant body, for example. But we do not grow fingers on our faces. The design of the body is carefully maintained even during the growth of children.

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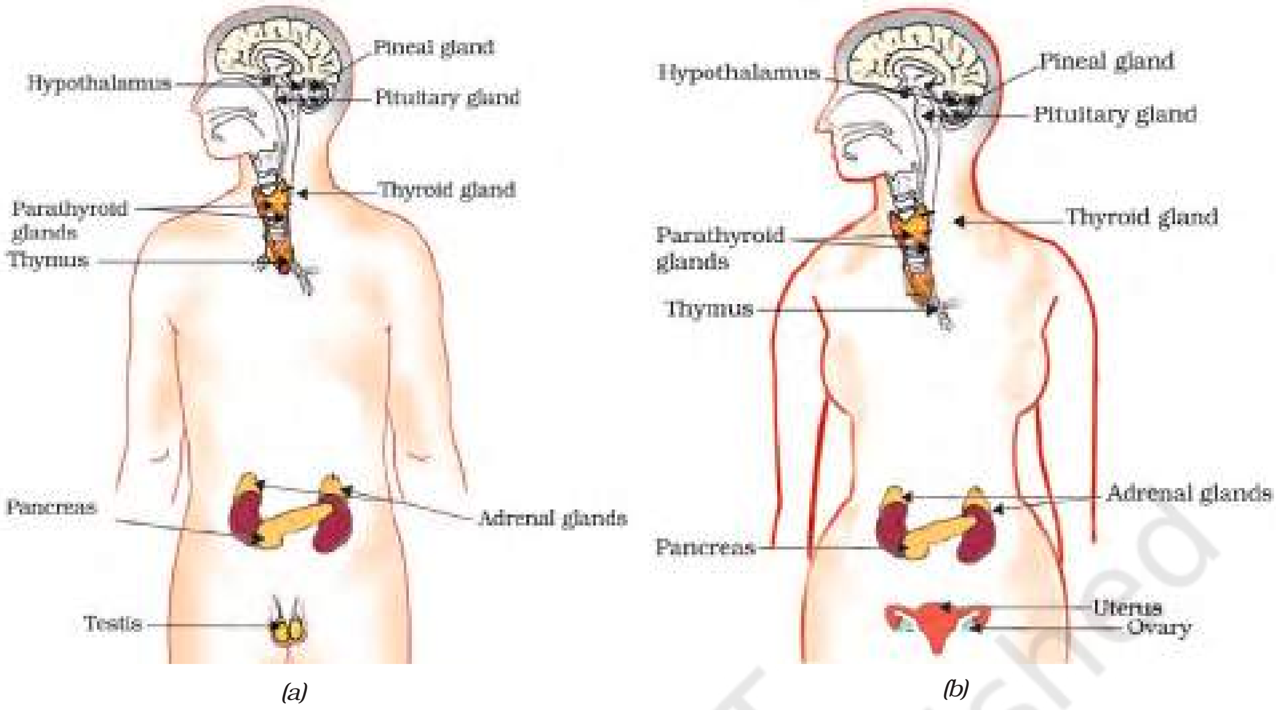


Figure 6.7 *Endocrine glands in human beings (a) male, (b) female*

Let us examine some examples to understand how hormones help in coordinated growth. We have all seen salt packets which say 'iodised salt' or 'enriched with iodine'. Why is it important for us to have iodised salt in our diet? Iodine is necessary for the thyroid gland to make thyroxin hormone. Thyroxin regulates carbohydrate, protein and fat metabolism in the body so as to provide the best balance for growth. Iodine is essential for the synthesis of thyroxin. In case iodine is deficient in our diet, there is a possibility that we might suffer from goitre. One of the symptoms in this disease is a swollen neck. Can you correlate this with the position of the thyroid gland in Fig. 6.7?

Sometimes we come across people who are either very short (dwarfs) or extremely tall (giants). Have you ever wondered how this happens? Growth hormone is one of the hormones secreted by the pituitary. As its name indicates, growth hormone regulates growth and development of the body. If there is a deficiency of this hormone in childhood, it leads to dwarfism.

You must have noticed many dramatic changes in your appearance as well as that of your friends as you approached 10–12 years of age. These changes associated with puberty are because of the secretion of testosterone in males and oestrogen in females.

Do you know anyone in your family or friends who has been advised by the doctor to take less sugar in their diet because they are suffering from diabetes? As a treatment, they might be taking injections of insulin. This is a hormone which is produced by the pancreas and helps in regulating blood sugar levels. If it is not secreted in proper amounts, the sugar level in the blood rises causing many harmful effects.

Do You Know?

Hypothalamus plays an important role in the release of many hormones. For example, when the level of growth hormone is low, the hypothalamus releases growth hormone releasing factor which stimulates the pituitary gland to release growth hormone.

If it is so important that hormones should be secreted in precise quantities, we need a mechanism through which this is done. The timing and amount of hormone released are regulated by feedback mechanisms. For example, if the sugar levels in blood rise, they are detected by the cells of the pancreas which respond by producing more insulin. As the blood sugar level falls, insulin secretion is reduced.

Activity 6.4

- Hormones are secreted by endocrine glands and have specific functions. Complete Table 6.1 based on the hormone, the endocrine gland or the functions provided.

Table 6.1 : Some important hormones and their functions

S.No.	Hormone	Endocrine Gland	Functions
1.	Growth hormone	Pituitary gland	Stimulates growth in all organs
2.		Thyroid gland	Regulates metabolism for body growth
3.	Insulin		Regulates blood sugar level
4.	Testosterone	Testes	
5.		Ovaries	Development of female sex organs, regulates menstrual cycle, etc.
6.	Adrenaline	Adrenal gland	
7.	Releasing hormones		Stimulates pituitary gland to release hormones

QUESTIONS

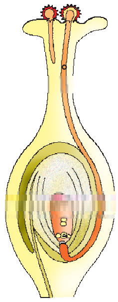
1. How does chemical coordination take place in animals?
2. Why is the use of iodised salt advisable?
3. How does our body respond when adrenaline is secreted into the blood?
4. Why are some patients of diabetes treated by giving injections of insulin?

What you have learnt

- Control and coordination are the functions of the nervous system and hormones in our bodies.
- The responses of the nervous system can be classified as reflex action, voluntary action or involuntary action.
- The nervous system uses electrical impulses to transmit messages.
- The nervous system gets information from our sense organs and acts through our muscles.
- Chemical coordination is seen in both plants and animals.
- Hormones produced in one part of an organism move to another part to achieve the desired effect.
- A feedback mechanism regulates the action of the hormones.

EXERCISES

1. Which of the following is a plant hormone?
   (a) Insulin
   (b) Thyroxin
   (c) Oestrogen
   (d) Cytokinin.
2. The gap between two neurons is called a
   (a) dendrite.
   (b) synapse.
   (c) axon.
   (d) impulse.
3. The brain is responsible for
   (a) thinking.
   (b) regulating the heart beat.
   (c) balancing the body.
   (d) all of the above.
4. What is the function of receptors in our body? Think of situations where receptors do not work properly. What problems are likely to arise?
5. Draw the structure of a neuron and explain its function.
6. How does phototropism occur in plants?
7. Which signals will get disrupted in case of a spinal cord injury?
8. How does chemical coordination occur in plants?
9. What is the need for a system of control and coordination in an organism?
10. How are involuntary actions and reflex actions different from each other?
11. Compare and contrast nervous and hormonal mechanisms for control and coordination in animals.
12. What is the difference between the manner in which movement takes place in a sensitive plant and the movement in our legs?



CHAPTER 7
How do Organisms Reproduce?

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Before we discuss the mechanisms by which organisms reproduce, let us ask a more basic question – why do organisms reproduce? After all, reproduction is not necessary to maintain the life of an individual organism, unlike the essential life processes such as nutrition, respiration, or excretion. On the other hand, if an individual organism is going to create more individuals, a lot of its energy will be spent in the process. So why should an individual organism waste energy on a process it does not need to stay alive? It would be interesting to discuss the possible answers in the classroom!

Whatever the answer to this question, it is obvious that we notice organisms because they reproduce. If there were to be only one, non-reproducing member of a particular kind, it is doubtful that we would have noticed its existence. It is the large numbers of organisms belonging to a single species that bring them to our notice. How do we know that two different individual organisms belong to the same species? Usually, we say this because they look similar to each other. Thus, reproducing organisms create new individuals that look very much like themselves.

7.1 DO ORGANISMS CREATE EXACT COPIES OF THEMSELVES?

Organisms look similar because their body designs are similar. If body designs are to be similar, the blueprints for these designs should be similar. Thus, reproduction at its most basic level will involve making copies of the blueprints of body design. In Class IX, we learnt that the chromosomes in the nucleus of a cell contain information for inheritance of features from parents to next generation in the form of DNA (Deoxyribo Nucleic Acid) molecules. The DNA in the cell nucleus is the information source for making proteins. If the information is changed, different proteins will be made. Different proteins will eventually lead to altered body designs.

Therefore, a basic event in reproduction is the creation of a DNA copy. Cells use chemical reactions to build copies of their DNA. This creates two copies of the DNA in a reproducing cell, and they will need to be separated from each other. However, keeping one copy of DNA in the original cell and simply pushing the other one out would not work, because the copy pushed out would not have any organised cellular structure for maintaining life processes. Therefore, DNA copying is accompanied by the creation of an additional cellular apparatus, and then the DNA copies separate, each with its own cellular apparatus. Effectively, a cell divides to give rise to two cells.

These two cells are of course similar, but are they likely to be absolutely identical? The answer to this question will depend on how accurately the copying reactions involved occur. No bio-chemical reaction is absolutely reliable. Therefore, it is only to be expected that the process of copying the DNA will have some variations each time. As a result, the DNA copies generated will be similar, but may not be identical to the original. Some of these variations might be so drastic that the new DNA copy cannot work with the cellular apparatus it inherits. Such a newborn cell will simply die. On the other hand, there could still be many other variations in the DNA copies that would not lead to such a drastic outcome. Thus, the surviving cells are similar to, but subtly different from each other. This inbuilt tendency for variation during reproduction is the basis for evolution, as we will discuss in the next chapter.

7.1.1 The Importance of Variation

Populations of organisms fill well-defined places, or niches, in the ecosystem, using their ability to reproduce. The consistency of DNA copying during reproduction is important for the maintenance of body design features that allow the organism to use that particular niche. Reproduction is therefore linked to the stability of populations of species.

However, niches can change because of reasons beyond the control of the organisms. Temperatures on earth can go up or down, water levels can vary, or there could be meteorite hits, to think of a few examples. If a population of reproducing organisms were suited to a particular niche and if the niche were drastically altered, the population could be wiped out. However, if some variations were to be present in a few individuals in these populations, there would be some chance for them to survive. Thus, if there were a population of bacteria living in temperate waters, and if the water temperature were to be increased by global warming, most of these bacteria would die, but the few variants resistant to heat would survive and grow further. Variation is thus useful for the survival of species over time.

QUESTIONS

1. What is the importance of DNA copying in reproduction?
2. Why is variation beneficial to the species but not necessarily for the individual?

7.2 MODES OF REPRODUCTION USED BY SINGLE ORGANISMS

Activity 7.1

- Dissolve about 10 gm of sugar in 100 mL of water.
- Take 20 mL of this solution in a test tube and add a pinch of yeast granules to it.
- Put a cotton plug on the mouth of the test tube and keep it in a warm place.
- After 1 or 2 hours, put a small drop of yeast culture from the test tube on a slide and cover it with a coverslip.
- Observe the slide under a microscope.

Activity 7.2

- Wet a slice of bread, and keep it in a cool, moist and dark place.
- Observe the surface of the slice with a magnifying glass.
- Record your observations for a week.

Compare and contrast the ways in which yeast grows in the first case, and how mould grows in the second.

Having discussed the context in which reproductive processes work, let us now examine how different organisms actually reproduce. The modes by which various organisms reproduce depend on the body design of the organisms.

7.2.1 Fission

For unicellular organisms, cell division, or fission, leads to the creation of new individuals. Many different patterns of fission have been observed. Many bacteria and protozoa simply split into two equal halves during cell division. In organisms such as *Amoeba*, the splitting of the two cells during division can take place in any plane.

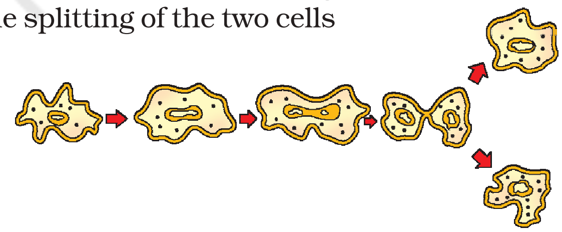

Figure 7.1(a) *Binary fission in Amoeba*

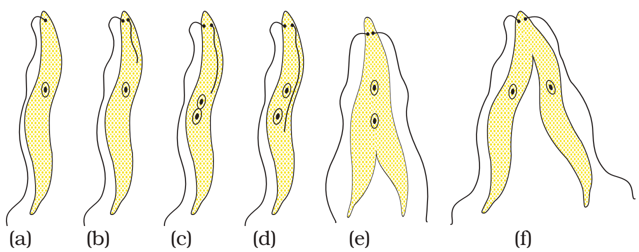

Figure 7.1(b) *Binary fission in Leishmania*

Activity 7.3

- Observe a permanent slide of *Amoeba* under a microscope.
- Similarly observe another permanent slide of *Amoeba* showing binary fission.
- Now, compare the observations of both the slides.

However, some unicellular organisms show somewhat more organisation of their bodies, such as is seen in *Leishmania* (which cause *kala-azar*), which have a whip-like structure at one end of the cell. In such organisms, binary fission occurs in a definite orientation in relation to

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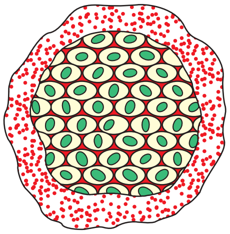

Figure 7.2
Multiple fission in Plasmodium

these structures. Other single-celled organisms, such as the malarial parasite, *Plasmodium*, divide into many daughter cells simultaneously by multiple fission.

Yeast, on the other hand, can put out small buds that separate and grow further, as we saw in Activity 7.1.

7.2.2 Fragmentation

Activity 7.4

- Collect water from a lake or pond that appears dark green and contains filamentous structures.
- Put one or two filaments on a slide.
- Put a drop of glycerine on these filaments and cover it with a coverslip.
- Observe the slide under a microscope.
- Can you identify different tissues in the *Spirogyra* filaments?

In multi-cellular organisms with relatively simple body organisation, simple reproductive methods can still work. *Spirogyra*, for example, simply breaks up into smaller pieces upon maturation. These pieces or fragments grow into new individuals. Can we work out the reason for this, based on what we saw in Activity 7.4?

This is not true for all multi-cellular organisms. They cannot simply divide cell-by-cell. The reason is that many multi-cellular organisms, as we have seen, are not simply a random collection of cells. Specialised cells are organised as tissues, and tissues are organised into organs, which then have to be placed at definite positions in the body. In such a carefully organised situation, cell-by-cell division would be impractical. Multi-cellular organisms, therefore, need to use more complex ways of reproduction.

A basic strategy used in multi-cellular organisms is that different cell types perform different specialised functions. Following this general pattern, reproduction in such organisms is also the function of a specific cell type. How is reproduction to be achieved from a single cell type, if the organism itself consists of many cell types? The answer is that there must be a single cell type in the organism that is capable of growing, proliferating and making other cell types under the right circumstances.

7.2.3 Regeneration

Many fully differentiated organisms have the ability to give rise to new individual organisms from their body parts. That is, if the individual is somehow cut or broken up into many pieces, many of these pieces grow into separate individuals. For example, simple animals like *Hydra* and *Planaria* can be cut into any number of pieces and each piece grows into a complete organism. This is known as regeneration (see Fig. 7.3). Regeneration is carried out by specialised cells. These cells proliferate and make large numbers of cells. From this mass of cells, different cells undergo changes to become various cell types and tissues. These changes

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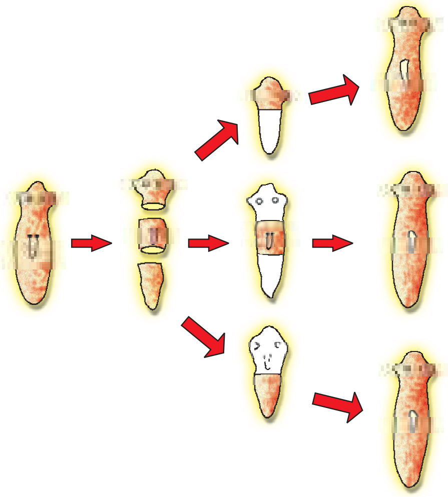

Figure 7.3 Regeneration in Planaria

take place in an organised sequence referred to as development. However, regeneration is not the same as reproduction, since most organisms would not normally depend on being cut up to be able to reproduce.

7.2.4 Budding

Organisms such as *Hydra* use regenerative cells for reproduction in the process of budding. In *Hydra*, a bud develops as an outgrowth due to repeated cell division at one specific site (Fig. 7.4). These buds develop into tiny individuals and when fully mature, detach from the parent body and become new independent individuals.

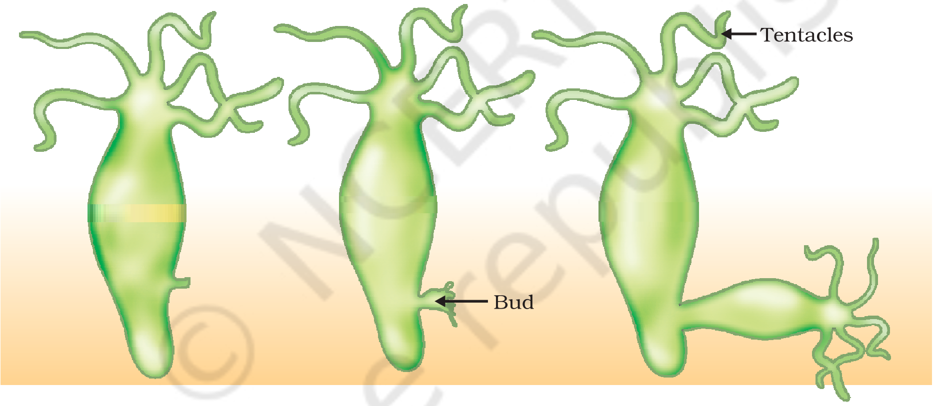

Figure 7.4 Budding in Hydra

7.2.5 Vegetative Propagation

There are many plants in which parts like the root, stem and leaves develop into new plants under appropriate conditions. Unlike in most animals, plants can indeed use such a mode for reproduction. This property of vegetative propagation is used in methods such as layering or grafting to grow many plants like sugarcane, roses, or grapes for agricultural purposes. Plants raised by vegetative propagation can bear flowers and fruits earlier than those produced from seeds. Such methods also make possible the propagation of plants such as banana, orange, rose and jasmine that have lost the capacity to produce seeds. Another advantage of vegetative propagation is that all plants produced are genetically similar enough to the parent plant to have all its characteristics.

Activity 7.5

- Take a potato and observe its surface. Can notches be seen?
- Cut the potato into small pieces such that some pieces contain a notch or bud and some do not.
- Spread some cotton on a tray and wet it. Place the potato pieces on this cotton. Note where the pieces with the buds are placed.
- Observe changes taking place in these potato pieces over the next few days. Make sure that the cotton is kept moistened.
- Which are the potato pieces that give rise to fresh green shoots and roots?

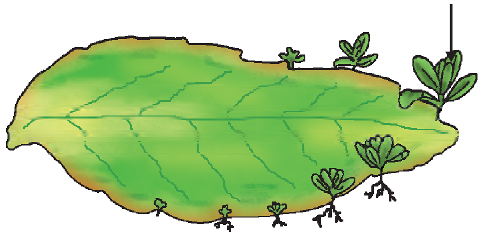

Figure 7.5
Leaf of Bryophyllum with buds

Similarly buds produced in the notches along the leaf margin of *Bryophyllum* fall on the soil and develop into new plants (Fig. 7.5).

Activity 7.6

- Select a money-plant.
- Cut some pieces such that they contain at least one leaf.
- Cut out some other portions between two leaves.
- Dip one end of all the pieces in water and observe over the next few days.
- Which ones grow and give rise to fresh leaves?
- What can you conclude from your observations?

More to Know?

Tissue culture

In tissue culture, new plants are grown by removing tissue or separating cells from the growing tip of a plant. The cells are then placed in an artificial medium where they divide rapidly to form a small group of cells or callus. The callus is transferred to another medium containing hormones for growth and differentiation. The plantlets are then placed in the soil so that they can grow into mature plants. Using tissue culture, many plants can be grown from one parent in disease-free conditions. This technique is commonly used for ornamental plants.

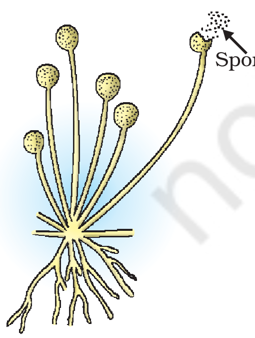

Figure 7.6
Spore formation in Rhizopus

7.2.6 Spore Formation

Even in many simple multi-cellular organisms, specific reproductive parts can be identified. The thread-like structures that developed on the bread in Activity 7.2 above are the hyphae of the bread mould (*Rhizopus*). They are not reproductive parts. On the other hand, the tiny blob-on-a-stick structures are involved in reproduction. The blobs are sporangia, which contain cells, or spores, that can eventually develop into new *Rhizopus* individuals (Fig. 7.6). The spores are covered by thick walls that protect them until they come into contact with another moist surface and can begin to grow.

All the modes of reproduction that we have discussed so far allow new generations to be created from a single individual. This is known as asexual reproduction.

QUESTIONS

1. How does binary fission differ from multiple fission?
2. How will an organism be benefited if it reproduces through spores?
3. Can you think of reasons why more complex organisms cannot give rise to new individuals through regeneration?
4. Why is vegetative propagation practised for growing some types of plants?
5. Why is DNA copying an essential part of the process of reproduction?

7.3 SEXUAL REPRODUCTION

We are also familiar with modes of reproduction that depend on the involvement of two individuals before a new generation can be created. Bulls alone cannot produce new calves, nor can hens alone produce new chicks. In such cases, both sexes, males and females, are needed to produce new generations. What is the significance of this sexual mode of reproduction? Are there any limitations of the asexual mode of reproduction, which we have been discussing above?

7.3.1 Why the Sexual Mode of Reproduction?

The creation of two new cells from one involves copying of the DNA as well as of the cellular apparatus. The DNA copying mechanism, as we have noted, cannot be absolutely accurate, and the resultant errors are a source of variations in populations of organisms. Every individual organism cannot be protected by variations, but in a population, variations are useful for ensuring the survival of the species. It would therefore make sense if organisms came up with reproductive modes that allowed more and more variation to be generated.

While DNA-copying mechanisms are not absolutely accurate, they are precise enough to make the generation of variation a fairly slow process. If the DNA copying mechanisms were to be less accurate, many of the resultant DNA copies would not be able to work with the cellular apparatus, and would die. So how can the process of making variants be speeded up? Each new variation is made in a DNA copy that already has variations accumulated from previous generations. Thus, two different individuals in a population would have quite different patterns of accumulated variations. Since all of these variations are in living individuals, it is assured that they do not have any really bad effects. Combining variations from two or more individuals would thus create new combinations of variants. Each combination would be novel, since it would involve two different individuals. The sexual mode of reproduction incorporates such a process of combining DNA from two different individuals during reproduction.

But this creates a major difficulty. If each new generation is to be the combination of the DNA copies from two pre-existing individuals, then each new generation will end up having twice the amount of DNA that the previous generation had. This is likely to mess up the control of the cellular apparatus by the DNA. How many ways can we think of for solving this difficulty?

We have seen earlier that as organisms become more complex, the specialisation of tissue increases. One solution that many multi-cellular organisms have found for the problem mentioned above is to have special lineages of cells in specialised organs in which only half the number of chromosomes and half the amount of DNA as compared to the non-reproductive body cells. This is achieved by a process of cell division called meiosis. Thus, when these germ-cells from two individuals combine during sexual reproduction to form a new individual, it results in re-establishment of the number of chromosomes and the DNA content in the new generation.

If the zygote is to grow and develop into an organism which has highly specialised tissues and organs, then it has to have sufficient stores of energy for doing this. In very simple organisms, it is seen that the two germ-cells are not very different from one another, or may even be similar. But as the body designs become more complex, the germ-cells also specialise. One germ-cell is large and contains the food-stores while the other is smaller and likely to be motile. Conventionally, the motile germ-cell is called the male gamete and the germ-cell containing the stored food is called the female gamete. We shall see in the next few sections how the need to create these two different types of gametes give rise to differences in the male and female reproductive organs and, in some cases, differences in the bodies of the male and female organisms.

7.3.2 Sexual Reproduction in Flowering Plants

The reproductive parts of angiosperms are located in the flower. You have already studied the different parts of a flower – sepals, petals, stamens and pistil. Stamens and pistil are the reproductive parts of a flower which contain the germ-cells. What possible functions could the petals and sepals serve?

The flower may be unisexual (papaya, watermelon) when it contains either stamens or pistil or bisexual (*Hibiscus*, mustard) when it contains both stamens and pistil. Stamen is the male reproductive part and it produces pollen grains that are yellowish in colour. You must have seen this yellowish powder that often sticks to our hands if we touch the stamen of a flower. Pistil is present in the centre of a flower and is the female reproductive part. It is made of three parts.

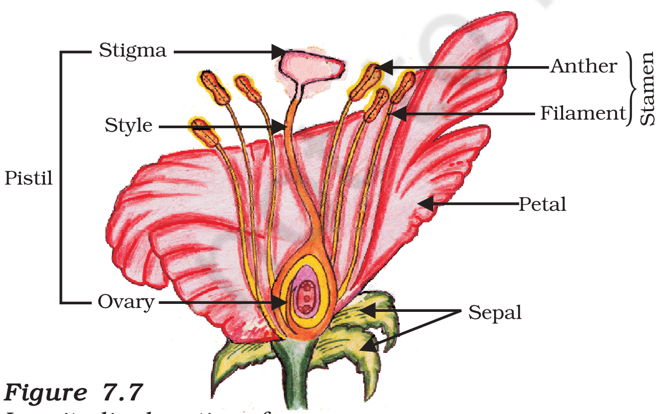

Figure 7.7
Longitudinal section of flower

The swollen bottom part is the ovary, middle elongated part is the style and the terminal part which may be sticky is the stigma. The ovary contains ovules and each ovule has an egg cell. The male germ-cell produced by pollen grain fuses with the female gamete present in the ovule. This fusion of the germ-cells or fertilisation gives us the zygote which is capable of growing into a new plant.

Thus the pollen needs to be transferred from the stamen to the stigma. If this transfer of pollen occurs in the same flower, it is referred to as self-pollination. On the other hand, if the pollen is transferred from one flower to another, it is known as cross-pollination. This transfer of pollen from one flower to another is achieved by agents like wind, water or animals.

After the pollen lands on a suitable stigma, it has to reach the female germ-cells which are in the ovary. For this, a tube grows out of the pollen grain and travels through the style to reach the ovary.

After fertilisation, the zygote divides several times to form an embryo within the ovule. The ovule develops a tough coat and is gradually converted into a seed. The ovary grows rapidly and ripens to form a fruit. Meanwhile, the petals, sepals, stamens, style and stigma may shrivel and fall off. Have you ever observed any flower part still persisting in the fruit? Try and work out the advantages of seed-formation for the plant. The seed contains the future plant or embryo which develops into a seedling under appropriate conditions. This process is known as germination.

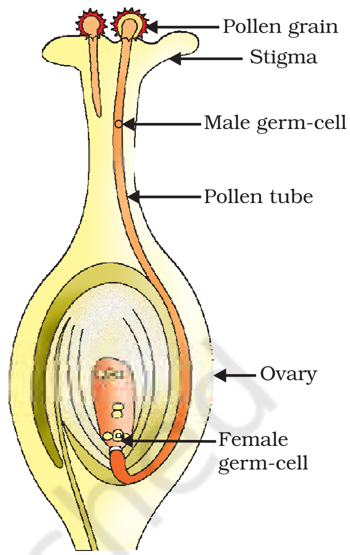

Figure 7.8
Germination of pollen on stigma

Activity 7.7

- Soak a few seeds of Bengal gram (*chana*) and keep them overnight.
- Drain the excess water and cover the seeds with a wet cloth and leave them for a day. Make sure that the seeds do not become dry.
- Cut open the seeds carefully and observe the different parts.
- Compare your observations with the Fig. 7.9 and see if you can identify all the parts.

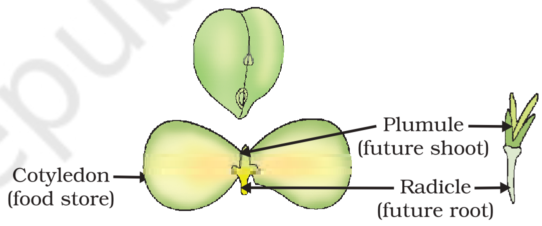

Figure 7.9
Germination

7.3.3 Reproduction in Human Beings

So far, we have been discussing the variety of modes that different species use for reproduction. Let us now look at the species that we are most interested in, namely, humans. Humans use a sexual mode of reproduction. How does this process work?

Let us begin at an apparently unrelated point. All of us know that our bodies change as we become older. You have learnt changes that take place in your body earlier in Class VIII also. We notice that our height has increased continuously from early age till now. We acquire teeth, we even lose the old, so-called milk teeth and acquire new ones.

All of these are changes that can be grouped under the general process of growth, in which the body becomes larger. But in early teenage years, a whole new set of changes occurs that cannot be explained simply as body enlargement. Instead, the appearance of the body changes. Proportions change, new features appear, and so do new sensations.

Some of these changes are common to both boys and girls. We begin to notice thick hair growing in new parts of the body such as armpits and the genital area between the thighs, which can also become darker in colour. Thinner hair can also appear on legs and arms, as well as on the face. The skin frequently becomes oily and we might begin to develop pimples. We begin to be conscious and aware of both our own bodies and those of others in new ways.

On the other hand, there are also changes taking place that are different between boys and girls. In girls, breast size begins to increase, with darkening of the skin of the nipples at the tips of the breasts. Also, girls begin to menstruate at around this time. Boys begin to have new thick hair growth on the face and their voices begin to crack. Further, the penis occasionally begins to become enlarged and erect, either in daydreams or at night.

All of these changes take place slowly, over a period of months and years. They do not happen all at the same time in one person, nor do they happen at an exact age. In some people, they happen early and quickly, while in others, they can happen slowly. Also, each change does not become complete quickly either. So, for example, thick hair on the face in boys appears as a few scattered hairs first, and only slowly does the growth begin to become uniform. Even so, all these changes show differences between people. Just as we have differently shaped noses or fingers, so also we have different patterns of hair growth, or size and shape of breast or penis. All of these changes are aspects of the sexual maturation of the body.

Why does the body show sexual maturation at this age? We have talked about the need for specialised cell types in multi-cellular bodies to carry out specialised functions. The creation of germ-cells to participate in sexual reproduction is another specialised function, and we have seen that plants develop special cell and tissue types to create them. Human beings also develop special tissues for this purpose. However, while the body of the individual organism is growing to its adult size, the resources of the body are mainly directed at achieving this growth. While that is happening, the maturation of the reproductive tissue is not likely to be a major priority. Thus, as the rate of general body growth begins to slow down, reproductive tissues begin to mature. This period during adolescence is called puberty.

So how do all the changes that we have talked about link to the reproductive process? We must remember that the sexual mode of reproduction means that germ-cells from two individuals have to join together. This can happen by the external release of germ-cells from the bodies of individuals, as happens in flowering plants. Or it can happen by two individuals joining their bodies together for internal transfer of germ-cells for fusion, as happens in many animals. If animals are to participate in this process of mating, their state of sexual maturity must be identifiable by other individuals. Many changes during puberty, such as new hair-growth patterns, are signals that sexual maturation is taking place.

On the other hand, the actual transfer of germ-cells between two people needs special organs for the sexual act, such as the penis when it is capable of becoming erect. In mammals such as humans, the baby is carried in the mother's body for a long period, and will be breast-fed later. The female reproductive organs and breasts will need to mature to accommodate these possibilities. Let us look at the systems involved in the process of sexual reproduction.

7.3.3 (a) Male Reproductive System

The male reproductive system (Fig. 7.10) consists of portions which produce the germ-cells and other portions that deliver the germ-cells to the site of fertilisation.

The formation of germ-cells or sperms takes place in the testes. These are located outside the abdominal cavity in scrotum because sperm formation requires a lower temperature than the normal body temperature. We have discussed the role of the testes in the secretion of the hormone, testosterone, in the previous chapter. In addition to regulating the formation of sperms, testosterone brings about changes in appearance seen in boys at the time of puberty.

The sperms formed are delivered through the vas deferens which unites with a tube coming from the urinary bladder. The urethra thus forms a common passage for both the sperms and urine. Along the path of the vas deferens, glands like the prostate and the seminal vesicles add their secretions so that the sperms are now in a fluid which makes their transport easier and this fluid also provides nutrition. The sperms are tiny bodies that consist of mainly genetic material and a long tail that helps them to move towards the female germ-cell.

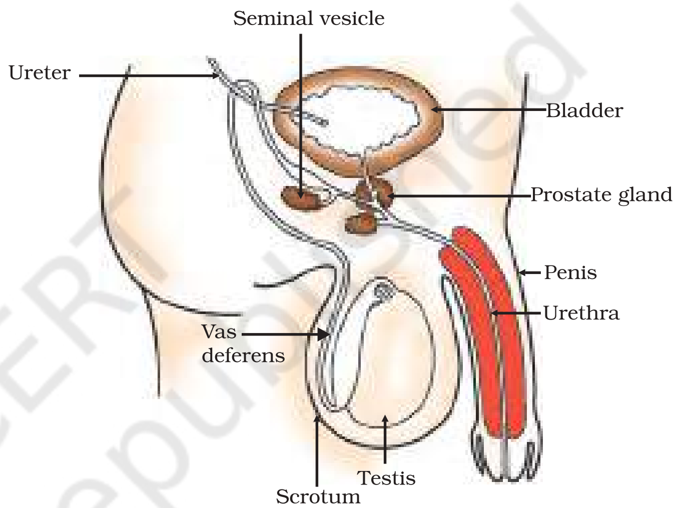

Figure 7.10 *Human–male reproductive system*

7.3.3 (b) Female Reproductive System

The female germ-cells or eggs are made in the ovaries. They are also responsible for the production of some hormones. Look at Fig. 7.11 and identify the various organs in the female reproductive system.

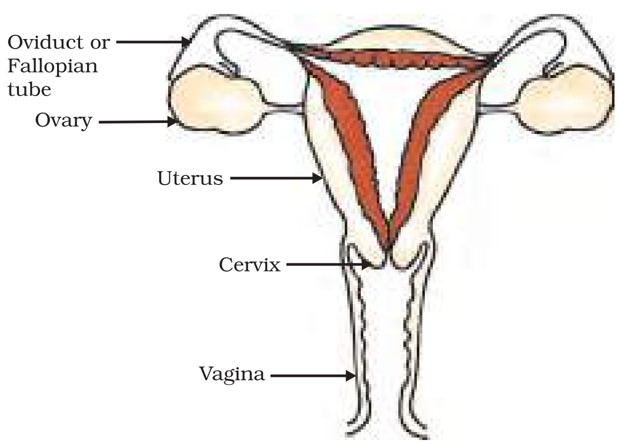

Figure 7.11 *Human–female reproductive system*

When a girl is born, the ovaries already contain thousands of immature eggs. On reaching puberty, some of these start maturing. One egg is produced every month by one of the ovaries. The egg is carried from the ovary to the womb through a thin oviduct or fallopian tube. The two oviducts unite into an elastic bag-like structure known as the uterus. The uterus opens into the vagina through the cervix.

The sperms enter through the vaginal passage during sexual intercourse. They travel upwards and reach the oviduct where they may encounter the egg. The fertilised egg (zygote) starts dividing and form a ball of cells or embryo. The embryo is implanted in the lining of the uterus where they continue to grow and develop organs to become foetus. We have seen in earlier sections that the mother's body is designed to undertake the development of the child. Hence the uterus prepares itself every month to receive and nurture the growing embryo. The lining thickens and is richly supplied with blood to nourish the growing embryo.

The embryo gets nutrition from the mother's blood with the help of a special tissue called placenta. This is a disc which is embedded in the uterine wall. It contains villi on the embryo's side of the tissue. On the mother's side are blood spaces, which surround the villi. This provides a large surface area for glucose and oxygen to pass from the mother to the embryo. The developing embryo will also generate waste substances which can be removed by transferring them into the mother's blood through the placenta. The development of the child inside the mother's body takes approximately nine months. The child is born as a result of rhythmic contractions of the muscles in the uterus.

7.3.3 (c) What happens when the Egg is not Fertilised?

If the egg is not fertilised, it lives for about one day. Since the ovary releases one egg every month, the uterus also prepares itself every month to receive a fertilised egg. Thus its lining becomes thick and spongy. This would be required for nourishing the embryo if fertilisation had taken place. Now, however, this lining is not needed any longer. So, the lining slowly breaks and comes out through the vagina as blood and mucous. This cycle takes place roughly every month and is known as menstruation. It usually lasts for about two to eight days.

7.3.3 (d) Reproductive Health

As we have seen, the process of sexual maturation is gradual, and takes place while general body growth is still going on. Therefore, some degree of sexual maturation does not necessarily mean that the body or the mind is ready for sexual acts or for having and bringing up children. How do we decide if the body or the mind is ready for this major responsibility? All of us are under many different kinds of pressures about these issues. There can be pressure from our friends for participating in many activities, whether we really want to or not. There can be pressure from families to get married and start having children. There can be pressure from government agencies to avoid having children. In this situation, making choices can become very difficult.

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We must also consider the possible health consequences of having sex. We have discussed in Class IX that diseases can be transmitted from person to person in a variety of ways. Since the sexual act is a very intimate connection of bodies, it is not surprising that many diseases can be sexually transmitted. These include bacterial infections such as gonorrhoea and syphilis, and viral infections such as warts and HIV-AIDS. Is it possible to prevent the transmission of such diseases during the sexual act? Using a covering, called a condom, for the penis during sex helps to prevent transmission of many of these infections to some extent.

The sexual act always has the potential to lead to pregnancy. Pregnancy will make major demands on the body and the mind of the woman, and if she is not ready for it, her health will be adversely affected. Therefore, many ways have been devised to avoid pregnancy. These contraceptive methods fall in a number of categories. One category is the creation of a mechanical barrier so that sperm does not reach the egg. Condoms on the penis or similar coverings worn in the vagina can serve this purpose. Another category of contraceptives acts by changing the hormonal balance of the body so that eggs are not released and fertilisation cannot occur. These drugs commonly need to be taken orally as pills. However, since they change hormonal balances, they can cause side-effects too. Other contraceptive devices such as the loop or the copper-T are placed in the uterus to prevent pregnancy. Again, they can cause side effects due to irritation of the uterus. If the vas deferens in the male is blocked, sperm transfer will be prevented. If the fallopian tube in the female is blocked, the egg will not be able to reach the uterus. In both cases fertilisation will not take place. Surgical methods can be used to create such blocks. While surgical methods are safe in the long run, surgery itself can cause infections and other problems if not performed properly. Surgery can also be used for removal of unwanted pregnancies. These may be misused by people who do not want a particular child, as happens in illegal sex-selective abortion of female foetuses. For a healthy society, the female-male sex ratio must be maintained. Because of reckless female foeticides, child sex ratio is declining at an alarming rate in some sections of our society, although prenatal sex determination has been prohibited by law.

We have noted earlier that reproduction is the process by which organisms increase their populations. The rates of birth and death in a given population will determine its size. The size of the human population is a cause for concern for many people. This is because an expanding population makes it harder to improve everybody's standard of living. However, if inequality in society is the main reason for poor standards of living for many people, the size of the population is relatively unimportant. If we look around us, what can we identify as the most important reason(s) for poor living standards?

Q U E S T I O N S

1. How is the process of pollination different from fertilisation?
2. What is the role of the seminal vesicles and the prostate gland?
3. What are the changes seen in girls at the time of puberty?
4. How does the embryo get nourishment inside the mother's body?
5. If a woman is using a copper-T, will it help in protecting her from sexually transmitted diseases?

What you have learnt

- Reproduction, unlike other life processes, is not essential to maintain the life of an individual organism.
- Reproduction involves creation of a DNA copy and additional cellular apparatus by the cell involved in the process.
- Various organisms use different modes of reproduction depending on their body design.
- In fission, many bacteria and protozoa simply divide into two or more daughter cells.
- Organisms such as hydra can regenerate if they are broken into pieces. They can also give out buds which mature into new individuals.
- Roots, stems and leaves of some plants develop into new plants through vegetative propagation.
- These are examples of asexual reproduction where new generations are created from a single individual.
- Sexual reproduction involves two individuals for the creation of a new individual.
- DNA copying mechanisms creates variations which are useful for ensuring the survival of the species. Modes of sexual reproduction allow for greater variation to be generated.
- Reproduction in flowering plants involves transfer of pollen grains from the anther to the stigma which is referred to as pollination. This is followed by fertilisation.
- Changes in the body at puberty, such as increase in breast size in girls and new facial hair growth in boys, are signs of sexual maturation.
- The male reproductive system in human beings consists of testes which produce sperms, vas deferens, seminal vesicles, prostate gland, urethra and penis.
- The female reproductive system in human beings consists of ovaries, fallopian tubes, uterus and vagina.
- Sexual reproduction in human beings involves the introduction of sperm in the vagina of the female. Fertilisation occurs in the fallopian tube.
- Contraception to avoid pregnancy can be achieved by the use of condoms, oral pills, copper-T and other methods.

EXERCISES

1. Asexual reproduction takes place through budding in
   (a) *Amoeba*.
   (b) Yeast.
   (c) *Plasmodium*.
   (d) *Leishmania*.
2. Which of the following is not a part of the female reproductive system in human beings?
   (a) Ovary
   (b) Uterus
   (c) Vas deferens
   (d) Fallopian tube
3. The anther contains
   (a) sepals.
   (b) ovules.
   (c) pistil.
   (d) pollen grains.
4. What are the advantages of sexual reproduction over asexual reproduction?
5. What are the functions performed by the testis in human beings?
6. Why does menstruation occur?
7. Draw a labelled diagram of the longitudinal section of a flower.
8. What are the different methods of contraception?
9. How are the modes for reproduction different in unicellular and multicellular organisms?
10. How does reproduction help in providing stability to populations of species?
11. What could be the reasons for adopting contraceptive methods?

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CHAPTER 8
Heredity

We have seen that reproductive processes give rise to new individuals that are similar, but subtly different. We have discussed how some amount of variation is produced even during asexual reproduction. And the number of successful variations are maximised by the process of sexual reproduction. If we observe a field of sugarcane we find very little variations among the individual plants. But in a number of animals including human beings, which reproduce sexually, quite distinct variations are visible among different individuals. In this chapter, we shall be studying the mechanism by which variations are created and inherited.

8.1 ACCUMULATION OF VARIATION DURING REPRODUCTION

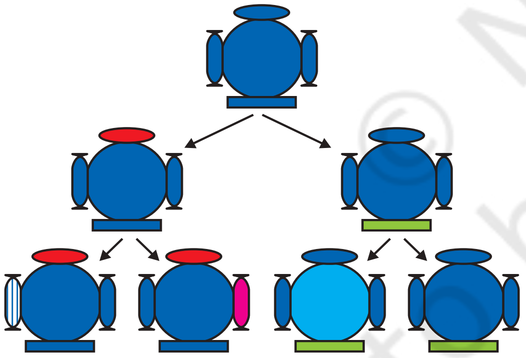


Figure 8.1
Creation of diversity over succeeding generations. The original organism at the top will give rise to, say, two individuals, similar in body design, but with subtle differences. Each of them, in turn, will give rise to two individuals in the next generation. Each of the four individuals in the bottom row will be different from each other. While some of these differences will be unique, others will be inherited from their respective parents, who were different from each other.

Inheritance from the previous generation provides both a common basic body design, and subtle changes in it, for the next generation. Now think about what would happen when this new generation, in its turn, reproduces. The second generation will have differences that they inherit from the first generation, as well as newly created differences (Fig. 8.1).

Figure 8.1 would represent the situation if a single individual reproduces, as happens in asexual reproduction. If one bacterium divides, and then the resultant two bacteria divide again, the four individual bacteria generated would be very similar. There would be only very minor differences between them, generated due to small inaccuracies in DNA copying. However, if sexual reproduction is involved, even greater diversity will be generated, as we will see when we discuss the rules of inheritance.

Do all these variations in a species have equal chances of surviving in the environment in which they find themselves? Obviously not. Depending on the nature of variations, different individuals would have different kinds of advantages. Bacteria that can withstand heat will survive better in a heat wave, as we have discussed earlier. Selection of variants by environmental factors forms the basis for evolutionary processes, as we will discuss in later sections.

QUESTIONS

1. If a trait A exists in 10% of a population of an asexually reproducing species and a trait B exists in 60% of the same population, which trait is likely to have arisen earlier?
2. How does the creation of variations in a species promote survival?

8.2 HEREDITY

The most obvious outcome of the reproductive process still remains the generation of individuals of similar design. The rules of heredity determine the process by which traits and characteristics are reliably inherited. Let us take a closer look at these rules.

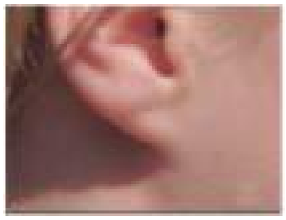
8.2.1 Inherited Traits

What exactly do we mean by similarities and differences? We know that a child bears all the basic features of a human being. However, it does not look exactly like its parents, and human populations show a great deal of variation.

Activity 8.1

- Observe the ears of all the students in the class. Prepare a list of students having free or attached earlobes and calculate the percentage of students having each (Fig. 8.2). Find out about the earlobes of the parents of each student in the class. Correlate the earlobe type of each student with that of their parents. Based on this evidence, suggest a possible rule for the inheritance of earlobe types.

(a)



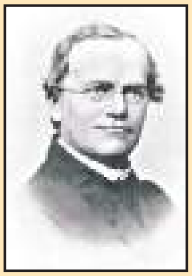
(b)

Figure 8.2
(a) Free and (b) attached earlobes. The lowest part of the ear, called the earlobe, is closely attached to the side of the head in some of us, and not in others. Free and attached earlobes are two variants found in human populations.

8.2.2 Rules for the Inheritance of Traits – Mendel's Contributions

The rules for inheritance of such traits in human beings are related to the fact that both the father and the mother contribute practically equal amounts of genetic material to the child. This means that each trait can be influenced by both paternal and maternal DNA. Thus, for each trait there will be two versions in each child. What will, then, the trait seen in the child be? Mendel (see box) worked out the main rules of such inheritance, and it is interesting to look at some of his experiments from more than a century ago.

Gregor Johann Mendel (1822–1884)



Mendel was educated in a monastery and went on to study science and mathematics at the University of Vienna. Failure in the examinations for a teaching certificate did not suppress his zeal for scientific quest. He went back to his monastery and started growing peas. Many others had studied the inheritance of traits in peas and other organisms earlier, but Mendel blended his knowledge of science and mathematics and was the first one to keep count of individuals exhibiting a particular trait in each generation. This helped him to arrive at the laws of inheritance.

Mendel used a number of contrasting visible characters of garden peas – round/wrinkled seeds, tall/short plants, white/violet flowers and so on. He took pea plants with different characteristics – a tall plant and a short plant, produced progeny by crossing them, and calculated the percentages of tall or short progeny.

In the first place, there were no halfway characteristics in this first-generation, or F1 progeny – no 'medium-height' plants. All plants were tall. This meant that only one of the parental traits was seen, not some mixture of the two. So the next question was, were the tall plants in the F1 generation exactly the same as the tall plants of the parent generation? Mendelian experiments test this by getting both the parental plants and these F1 tall plants to reproduce by self-pollination. The progeny of the parental plants are, of course, all tall. However, the second-generation, or F2, progeny of the F1 tall plants are not all tall. Instead, one quarter of them are short. This indicates that both the tallness and shortness traits were inherited in the F1 plants, but only the tallness trait was expressed. This led Mendel to propose that two copies of factor (now called genes) controlling traits are present in sexually reproducing organism. These two may be identical, or may be different, depending on the parentage. A pattern of inheritance can be worked out with this assumption, as shown in Fig. 8.3.

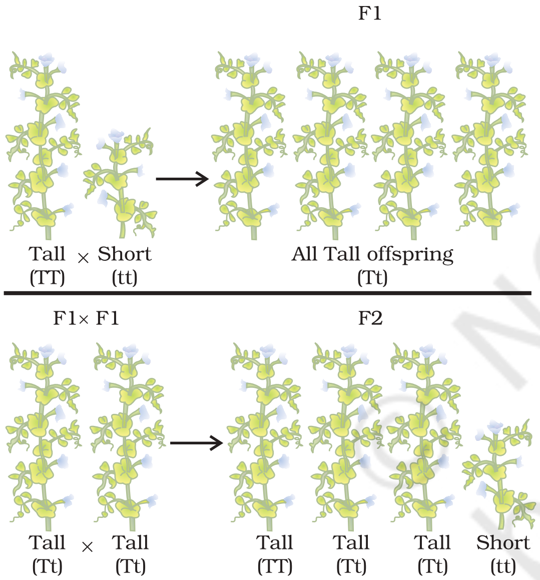


Figure 8.3
Inheritance of traits over two generations

Activity 8.2

- In Fig. 8.3, what experiment would we do to confirm that the F2 generation did in fact have a 1:2:1 ratio of TT, Tt and tt trait combinations?

In this explanation, both TT and Tt are tall plants, while only tt is a short plant. In other words, a single copy of 'T' is enough to make the plant tall, while both copies have to be 't' for the plant to be short. Traits like 'T' are called dominant traits, while those that behave like 't' are called recessive traits. Work out which trait would be considered dominant and which one recessive in Fig. 8.4.

What happens when pea plants showing two different characteristics, rather than just one, are bred with each other? What do the progeny of a tall plant with round seeds and a short plant with wrinkled-seeds look like? They are all tall and have round seeds. Tallness and round seeds are thus dominant traits. But what happens when these F1 progeny are used to generate F2 progeny by self-pollination? A Mendelian experiment will find that some F2 progeny are tall plants with round seeds, and some were short plants with wrinkled seeds. However, there would also be some F2 progeny that showed new combinations. Some of them would be tall, but have wrinkled seeds, while others would be short, but have round seeds. You can see as to how new combinations of traits are formed in F2 offspring when factors controlling for seed shape and seed colour recombine to form zygote leading to form F2 offspring (Fig. 8.5). Thus, the tall/short trait and the round seed/wrinkled seed trait are independently inherited.

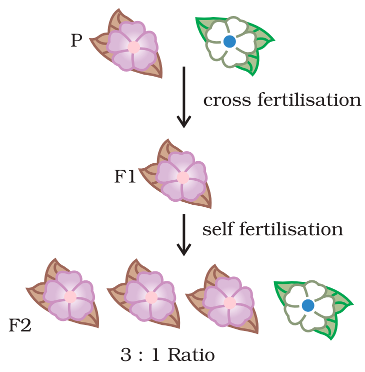


Figure 8.4

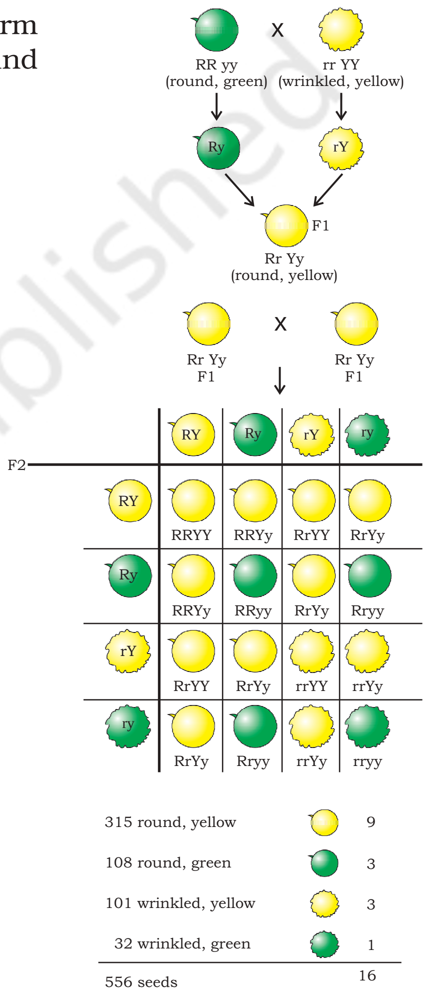


Figure 8.5
Independent inheritance of two separate traits, shape and colour of seeds

8.2.3 How do these Traits get Expressed?

How does the mechanism of heredity work? Cellular DNA is the information source for making proteins in the cell. A section of DNA that provides information for one protein is called the gene for that protein. How do proteins control the characteristics that we are discussing here? Let us take the example of tallness as a characteristic. We know that plants have hormones that can trigger growth. Plant height can thus depend on the amount of a particular plant hormone. The amount of the plant hormone made will depend on the efficiency of the process for making it. Consider now an enzyme that is important for this process. If this enzyme works efficiently, a lot of hormone will be made, and the plant will be tall. If the gene for that enzyme has an alteration that makes the enzyme less efficient, the amount of hormone will be less, and the plant will be short. Thus, genes control characteristics, or traits.

If the interpretations of Mendelian experiments we have been discussing are correct, then both parents must be contributing equally to the DNA of the progeny during sexual reproduction. We have disscussed this issue in the previous Chapter. If both parents can help determine the trait in the progeny, both parents must be contributing a copy of the same gene. This means that each pea plant must have two sets of all genes, one inherited from each parent. For this mechanism to work, each germ cell must have only one gene set.

How do germ-cells make a single set of genes from the normal two copies that all other cells in the body have? If progeny plants inherited a single whole gene set from each parent, then the experiment explained in Fig. 8.5 cannot work. This is because the two characteristics 'R' and 'y' would then be linked to each other and cannot be independently inherited. This is explained by the fact that each gene set is present, not as a single long thread of DNA, but as separate independent pieces, each called a chromosome. Thus, each cell will have two copies of each chromosome, one each from the male and female parents. Every germ-cell will take one chromosome from each pair and these may be of either maternal or paternal origin. When two germ cells combine, they will restore the normal number of chromosomes in the progeny, ensuring the stability of the DNA of the species. Such a mechanism of inheritance explains the results of the Mendel experiments, and is used by all sexually reproducing organisms. But asexually reproducing organisms also follow similar rules of inheritance. Can we work out how their inheritance might work?

8.2.4 Sex Determination

We have discussed the idea that the two sexes participating in sexual reproduction must be somewhat different from each other for a number of reasons. How is the sex of a newborn individual determined? Different species use very different strategies for this. Some rely entirely on environmental cues. Thus, in some animals like a few reptiles, the temperature at which fertilised eggs are kept determines whether the animals developing in the eggs will be male or female. In other animals, such as snails, individuals can change sex, indicating that sex is not genetically determined. However, in human beings, the sex of the individual is largely genetically determined. In other words, the genes inherited from our parents decide whether we will be boys or girls. But so far, we have assumed that similar gene sets are inherited from both parents. If that is the case, how can genetic inheritance determine sex?

The explanation lies in the fact that all human chromosomes are not paired. Most human chromosomes have a maternal and a paternal copy, and we have 22 such pairs. But one pair, called the sex chromosomes, is odd in not always being a perfect pair. Women have a perfect pair of sex chromosomes, both called X. But men have a mismatched pair in which one is a normal-sized X while the other is a short one called Y. So women are XX, while men are XY. Now, can we work out what the inheritance pattern of X and Y will be?

As Fig. 8.6 shows, half the children will be boys and half will be girls. All children will inherit an X chromosome from their mother regardless of whether they are boys or girls. Thus, the sex of the children will be determined by what they inherit from their father. A child who inherits an X chromosome from her father will be a girl, and one who inherits a Y chromosome from him will be a boy.

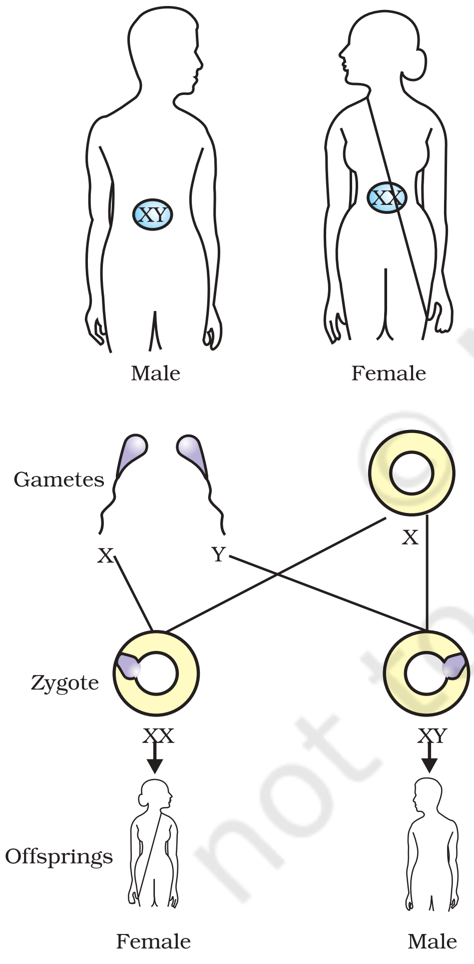


Figure 8.6
Sex determination in human beings

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QUESTIONS

1. How do Mendel's experiments show that traits may be dominant or recessive?
2. How do Mendel's experiments show that traits are inherited independently?
3. A man with blood group A marries a woman with blood group O and their daughter has blood group O. Is this information enough to tell you which of the traits – blood group A or O – is dominant? Why or why not?
4. How is the sex of the child determined in human beings?

What you have learnt

- Variations arising during the process of reproduction can be inherited.
- These variations may lead to increased survival of the individuals.
- Sexually reproducing individuals have two copies of genes for the same trait. If the copies are not identical, the trait that gets expressed is called the dominant trait and the other is called the recessive trait.
- Traits in one individual may be inherited separately, giving rise to new combinations of traits in the offspring of sexual reproduction.
- Sex is determined by different factors in various species. In human beings, the sex of the child depends on whether the paternal chromosome is X (for girls) or Y (for boys).

EXERCISES

1. A Mendelian experiment consisted of breeding tall pea plants bearing violet flowers with short pea plants bearing white flowers. The progeny all bore violet flowers, but almost half of them were short. This suggests that the genetic make-up of the tall parent can be depicted as
   (a) TTWW
   (b) TTww
   (c) TtWW
   (d) TtWw
2. A study found that children with light-coloured eyes are likely to have parents with light-coloured eyes. On this basis, can we say anything about whether the light eye colour trait is dominant or recessive? Why or why not?
3. Outline a project which aims to find the dominant coat colour in dogs.
4. How is the equal genetic contribution of male and female parents ensured in the progeny?

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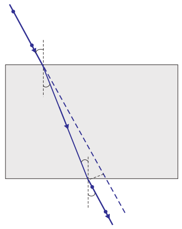


CHAPTER 9

Light – Reflection and Refraction

We see a variety of objects in the world around us. However, we are unable to see anything in a dark room. On lighting up the room, things become visible. What makes things visible? During the day, the sunlight helps us to see objects. An object reflects light that falls on it. This reflected light, when received by our eyes, enables us to see things. We are able to see through a transparent medium as light is transmitted through it. There are a number of common wonderful phenomena associated with light such as image formation by mirrors, the twinkling of stars, the beautiful colours of a rainbow, bending of light by a medium and so on. A study of the properties of light helps us to explore them.

By observing the common optical phenomena around us, we may conclude that light seems to travel in straight lines. The fact that a small source of light casts a *sharp* shadow of an opaque object points to this straight-line path of light, usually indicated as a ray of light.

More to Know!

If an opaque object on the path of light becomes *very small*, light has a tendency to bend around it and not walk in a straight line – an effect known as the diffraction of light. Then the straight-line treatment of optics using rays fails. To explain phenomena such as diffraction, light is thought of as a wave, the details of which you will study in higher classes. Again, at the beginning of the 20th century, it became known that the wave theory of light often becomes inadequate for treatment of the interaction of light with matter, and light often behaves somewhat like a *stream of particles*. This confusion about the true nature of light continued for some years till a modern quantum theory of light emerged in which light is neither a 'wave' nor a 'particle' – the new theory reconciles the particle properties of light with the wave nature.

In this Chapter, we shall study the phenomena of reflection and refraction of light using the straight-line propagation of light. These basic concepts will help us in the study of some of the optical phenomena in nature. We shall try to understand in this Chapter the reflection of light by spherical mirrors and refraction of light and their application in real life situations.

9.1 REFLECTION OF LIGHT

A highly polished surface, such as a mirror, reflects most of the light falling on it. You are already familiar with the laws of reflection of light.

Let us recall these laws –

(i) The angle of incidence is equal to the angle of reflection, and

(ii) The incident ray, the normal to the mirror at the point of incidence and the reflected ray, all lie in the same plane.

These laws of reflection are applicable to all types of reflecting surfaces including spherical surfaces. You are familiar with the formation of image by a plane mirror. What are the properties of the image? Image formed by a plane mirror is always virtual and erect. The size of the image is equal to that of the object. The image formed is as far behind the mirror as the object is in front of it. Further, the image is laterally inverted. How would the images be when the reflecting surfaces are curved? Let us explore.

Activity 9.1

- Take a large shining spoon. Try to view your face in its curved surface.
- Do you get the image? Is it smaller or larger?
- Move the spoon slowly away from your face. Observe the image. How does it change?
- Reverse the spoon and repeat the Activity. How does the image look like now?
- Compare the characteristics of the image on the two surfaces.

The curved surface of a shining spoon could be considered as a curved mirror. The most commonly used type of curved mirror is the spherical mirror. The reflecting surface of such mirrors can be considered to form a part of the surface of a sphere. Such mirrors, whose reflecting surfaces are spherical, are called spherical mirrors. We shall now study about spherical mirrors in some detail.

9.2 SPHERICAL MIRRORS

The reflecting surface of a spherical mirror may be curved inwards or outwards. A spherical mirror, whose reflecting surface is curved inwards, that is, faces towards the centre of the sphere, is called a concave mirror. A spherical mirror whose reflecting surface is curved outwards, is called a convex mirror. The schematic representation of these mirrors is shown in Fig. 9.1. You may note in these diagrams that the back of the mirror is shaded.

You may now understand that the surface of the spoon curved inwards can be approximated to a concave mirror and the surface of the spoon bulged outwards can be approximated to a convex mirror.

Before we move further on spherical mirrors, we need to recognise and understand the meaning of a few terms. These terms are commonly used in discussions about spherical mirrors. The centre of the reflecting surface of a spherical mirror is a point called the pole. It lies on the surface of the mirror. The pole is usually represented by the letter P.

(a) Concave mirror (b) Convex mirror

Figure 9.1
Schematic representation of spherical mirrors; the shaded side is non-reflecting.

The reflecting surface of a spherical mirror forms a part of a sphere. This sphere has a centre. This point is called the centre of curvature of the spherical mirror. It is represented by the letter C. Please note that the centre of curvature is not a part of the mirror. It lies outside its reflecting surface. The centre of curvature of a concave mirror lies in front of it. However, it lies behind the mirror in case of a convex mirror. You may note this in Fig.9.2 (a) and (b). The radius of the sphere of which the reflecting surface of a spherical mirror forms a part, is called the radius of curvature of the mirror. It is represented by the letter *R*. You may note that the distance PC is equal to the radius of curvature. Imagine a straight line passing through the pole and the centre of curvature of a spherical mirror. This line is called the principal axis. Remember that principal axis is normal to the mirror at its pole. Let us understand an important term related to mirrors, through an Activity.

Activity 9.2

CAUTION: Do not look at the Sun directly or even into a mirror reflecting sunlight. It may damage your eyes.

- Hold a concave mirror in your hand and direct its reflecting surface towards the Sun.
- Direct the light reflected by the mirror on to a sheet of paper held close to the mirror.
- Move the sheet of paper back and forth gradually until you find on the paper sheet a bright, sharp spot of light.
- Hold the mirror and the paper in the same position for a few minutes. What do you observe? Why?

The paper at first begins to burn producing smoke. Eventually it may even catch fire. Why does it burn? The light from the Sun is converged at a point, as a sharp, bright spot by the mirror. In fact, this spot of light is the image of the Sun on the sheet of paper. This point is the focus of the concave mirror. The heat produced due to the concentration of sunlight ignites the paper. The distance of this image from the position of the mirror gives the approximate value of focal length of the mirror.

Let us try to understand this observation with the help of a ray diagram.

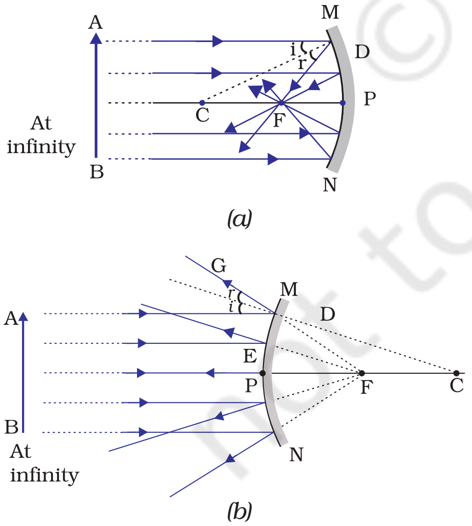


Figure 9.2
(a) Concave mirror
(b) Convex mirror

Observe Fig.9.2 (a) closely. A number of rays parallel to the principal axis are falling on a concave mirror. Observe the reflected rays. They are all meeting/intersecting at a point on the principal axis of the mirror. This point is called the principal focus of the concave mirror. Similarly, observe Fig. 9.2 (b). How are the rays parallel to the principal axis, reflected by a convex mirror? The reflected rays appear to come from a point on the principal axis. This point is called the principal focus of the convex mirror. The principal focus is represented by the letter F. The distance between the pole and the principal focus of a spherical mirror is called the focal length. It is represented by the letter *f*.

The reflecting surface of a spherical mirror is by-and-large spherical. The surface, then, has a circular outline. The diameter of the reflecting surface of spherical mirror is called its aperture. In Fig.9.2, distance MN represents the aperture. We shall consider in our discussion only such spherical mirrors whose aperture is much smaller than its radius of curvature.

Is there a relationship between the radius of curvature *R*, and focal length *f*, of a spherical mirror? For spherical mirrors of small apertures, the radius of curvature is found to be equal to twice the focal length. We put this as $R = 2f$. This implies that the principal focus of a spherical mirror lies midway between the pole and centre of curvature.

9.2.1 Image Formation by Spherical Mirrors

You have studied about the image formation by plane mirrors. You also know the nature, position and relative size of the images formed by them. How about the images formed by spherical mirrors? How can we locate the image formed by a concave mirror for different positions of the object? Are the images real or virtual? Are they enlarged, diminished or have the same size? We shall explore this with an Activity.

Activity 9.3

You have already learnt a way of determining the focal length of a concave mirror. In Activity 9.2, you have seen that the sharp bright spot of light you got on the paper is, in fact, the image of the Sun. It was a tiny, real, inverted image. You got the approximate focal length of the concave mirror by measuring the distance of the image from the mirror.

- Take a concave mirror. Find out its approximate focal length in the way described above. Note down the value of focal length. (You can also find it out by obtaining image of a distant object on a sheet of paper.)
- Mark a line on a Table with a chalk. Place the concave mirror on a stand. Place the stand over the line such that its pole lies over the line.
- Draw with a chalk two more lines parallel to the previous line such that the distance between any two successive lines is equal to the focal length of the mirror. These lines will now correspond to the positions of the points P, F and C, respectively. *Remember – For a spherical mirror of small aperture, the principal focus* F *lies mid-way between the pole* P *and the centre of curvature* C.
- Keep a bright object, say a burning candle, at a position far beyond C. Place a paper screen and move it in front of the mirror till you obtain a sharp bright image of the candle flame on it.
- Observe the image carefully. Note down its nature, position and relative size with respect to the object size.
- Repeat the activity by placing the candle – (a) just beyond C, (b) at C, (c) between F and C, (d) at F, and (e) between P and F.
- In one of the cases, you may not get the image on the screen. Identify the position of the object in such a case. Then, look for its virtual image in the mirror itself.
- Note down and tabulate your observations.

You will see in the above Activity that the nature, position and size of the image formed by a concave mirror depends on the position of the object in relation to points P, F and C. The image formed is real for some positions of the object. It is found to be a virtual image for a certain other position. The image is either magnified, reduced or has the same size, depending on the position of the object. A summary of these observations is given for your reference in Table 9.1.

Table 9.1 Image formation by a concave mirror for different positions of the object

Position of the object	Position of the image	Size of the image	Nature of the image
At infinity	At the focus F	Highly diminished, point-sized	Real and inverted
Beyond C	Between F and C	Diminished	Real and inverted
At C	At C	Same size	Real and inverted
Between C and F	Beyond C	Enlarged	Real and inverted
At F	At infinity	Highly enlarged	Real and inverted
Between P and F	Behind the mirror	Enlarged	Virtual and erect

9.2.2 Representation of Images Formed by Spherical Mirrors Using Ray Diagrams

We can also study the formation of images by spherical mirrors by drawing ray diagrams. Consider an extended object, of finite size, placed in front of a spherical mirror. Each small portion of the extended object acts like a point source. An infinite number of rays originate from each of these points. To construct the ray diagrams, in order to locate the image of an object, an arbitrarily large number of rays emanating from a point could be considered. However, it is more convenient to consider only two rays, for the sake of clarity of the ray diagram. These rays are so chosen that it is easy to know their directions after reflection from the mirror.

The intersection of at least two reflected rays give the position of image of the point object. Any two of the following rays can be considered for locating the image.

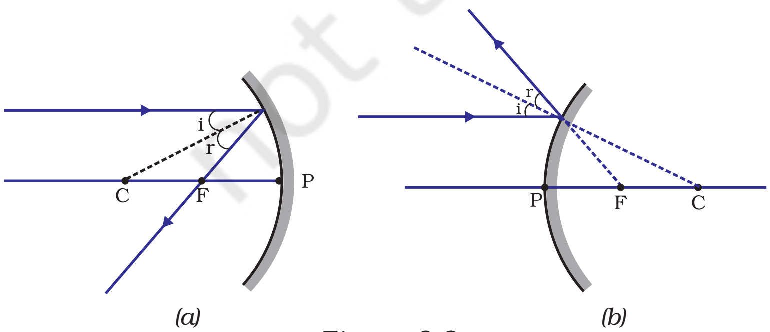
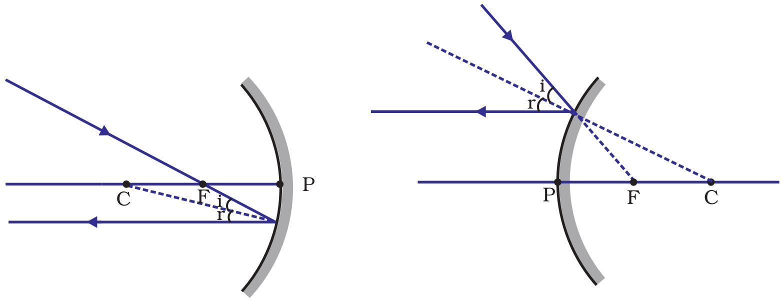


Figure 9.3

(i) *A ray parallel to the principal axis*, after reflection, will pass through the principal focus in case of a concave mirror or appear to diverge from the principal focus in case of a convex mirror. This is illustrated in Fig.9.3 (a) and (b).

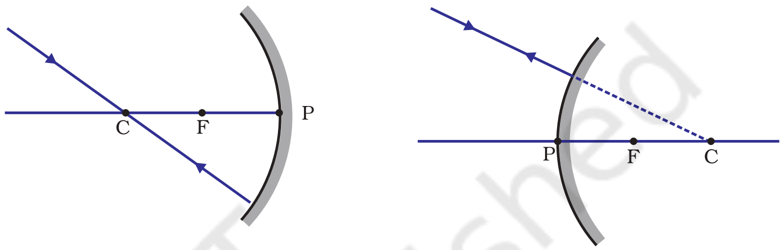
(ii) *A ray passing through the principal focus* of a concave mirror or *a ray which is directed towards the principal focus of* a convex mirror, after reflection, will emerge parallel to the principal axis. This is illustrated in Fig.9.4 (a) and (b).



(a) (b)

Figure 9.4

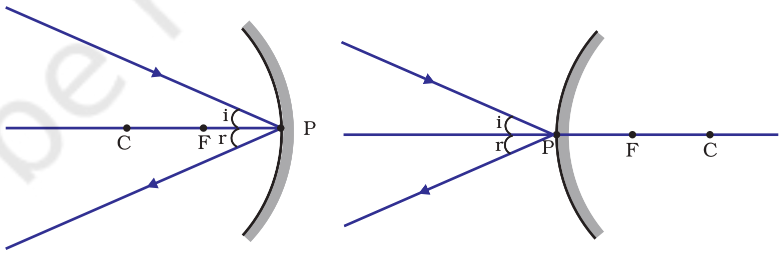
(iii) *A ray passing through the centre of curvature* of a concave mirror or directed in the direction of the centre of curvature of a convex mirror, after reflection, is reflected back along the same path. This is illustrated in Fig.9.5 (a) and (b). The light rays come back along the same path because the incident rays fall on the mirror along the normal to the reflecting surface.



(a) (b)

Figure 9.5

(iv) *A ray incident obliquely to the principal axis*, towards a point P (pole of the mirror), on the concave mirror [Fig. 9.6 (a)] or a convex mirror [Fig. 9.6 (b)], is reflected obliquely. The incident and reflected rays follow the laws of reflection at the point of incidence (point P), making equal angles with the principal axis.



(a) (b)

Figure 9.6

Remember that in all the above cases the laws of reflection are followed. At the point of incidence, the incident ray is reflected in such a way that the angle of reflection equals the angle of incidence.

(a) **Image formation by Concave Mirror**
Figure 9.7 illustrates the ray diagrams for the formation of image by a concave mirror for various positions of the object.

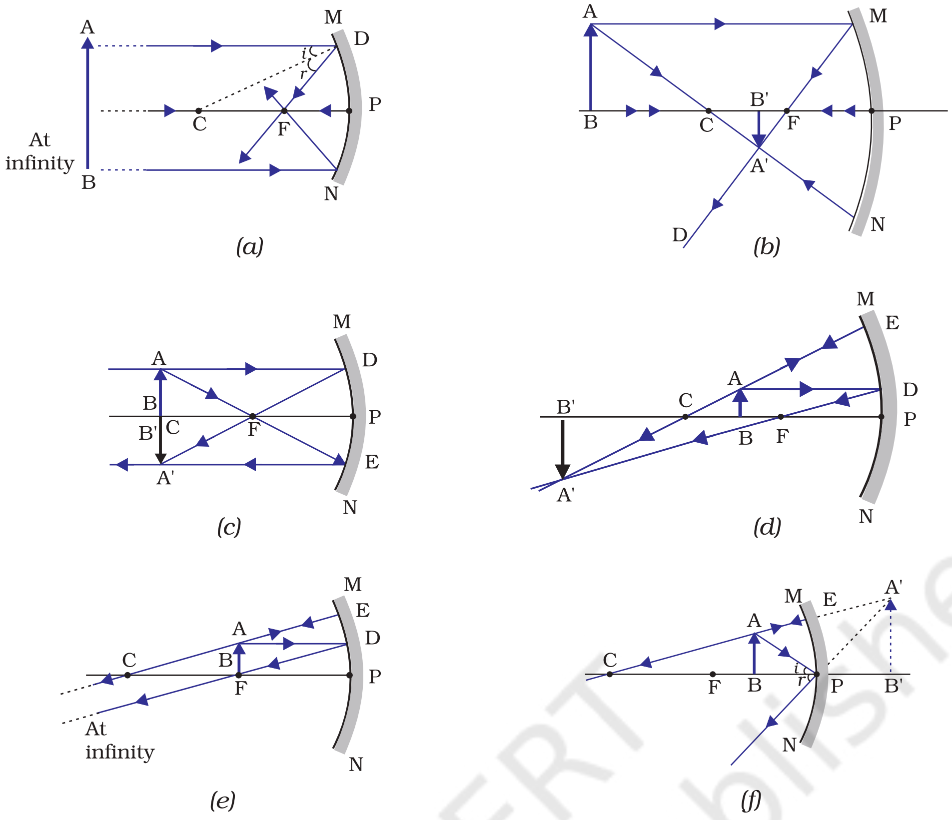


Figure 9.7 *Ray diagrams for the image formation by a concave mirror*

Activity 9.4

- Draw neat ray diagrams for each position of the object shown in Table 9.1.
- You may take any two of the rays mentioned in the previous section for locating the image.
- Compare your diagram with those given in Fig. 9.7.
- Describe the nature, position and relative size of the image formed in each case.
- Tabulate the results in a convenient format.

Uses of concave mirrors

Concave mirrors are commonly used in torches, search-lights and vehicles headlights to get powerful parallel beams of light. They are often used as shaving mirrors to see a larger image of the face. The dentists use concave mirrors to see large images of the teeth of patients. Large concave mirrors are used to concentrate sunlight to produce heat in solar furnaces.

(b) Image formation by a Convex Mirror

We studied the image formation by a concave mirror. Now we shall study the formation of image by a convex mirror.

Activity 9.5

- Take a convex mirror. Hold it in one hand.
- Hold a pencil in the upright position in the other hand.
- Observe the image of the pencil in the mirror. Is the image erect or inverted? Is it diminished or enlarged?
- Move the pencil away from the mirror slowly. Does the image become smaller or larger?
- Repeat this Activity carefully. State whether the image will move closer to or farther away from the focus as the object is moved away from the mirror?

We consider two positions of the object for studying the image formed by a convex mirror. First is when the object is at infinity and the second position is when the object is at a finite distance from the mirror. The ray diagrams for the formation of image by a convex mirror for these two positions of the object are shown in Fig.9.8 (a) and (b), respectively. The results are summarised in Table 9.2.

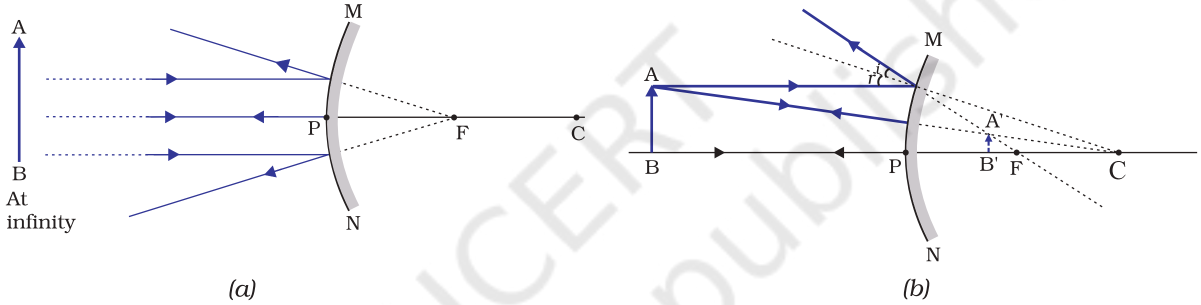


Figure 9.8 *Formation of image by a convex mirror*

Table 9.2 Nature, position and relative size of the image formed by a convex mirror

Position of the object	Position of the image	Size of the image	Nature of the image
At infinity	At the focus F, behind the mirror	Highly diminished, point-sized	Virtual and erect
Between infinity and the pole P of the mirror	Between P and F, behind the mirror	Diminished	Virtual and erect

You have so far studied the image formation by a plane mirror, a concave mirror and a convex mirror. Which of these mirrors will give the full image of a large object? Let us explore through an Activity.

Activity 9.6

- Observe the image of a distant object, say a distant tree, in a plane mirror.
- Could you see a full-length image?

- Try with plane mirrors of different sizes. Did you see the entire object in the image?
- Repeat this Activity with a concave mirror. Did the mirror show full length image of the object?
- Now try using a convex mirror. Did you succeed? Explain your observations with reason.

You can see a full-length image of a tall building/tree in a small convex mirror. One such mirror is fitted in a wall of Agra Fort facing Taj Mahal. If you visit the Agra Fort, try to observe the full image of Taj Mahal. To view distinctly, you should stand suitably at the terrace adjoining the wall.

Uses of convex mirrors

Convex mirrors are commonly used as rear-view (wing) mirrors in vehicles. These mirrors are fitted on the sides of the vehicle, enabling the driver to see traffic behind him/her to facilitate safe driving. Convex mirrors are preferred because they always give an erect, though diminished, image. Also, they have a wider field of view as they are curved outwards. Thus, convex mirrors enable the driver to view much larger area than would be possible with a plane mirror.

QUESTIONS

1. Define the principal focus of a concave mirror.
2. The radius of curvature of a spherical mirror is 20 cm. What is its focal length?
3. Name a mirror that can give an erect and enlarged image of an object.
4. Why do we prefer a convex mirror as a rear-view mirror in vehicles?

9.2.3 Sign Convention for Reflection by Spherical Mirrors

While dealing with the reflection of light by spherical mirrors, we shall follow a set of sign conventions called the *New Cartesian Sign Convention*. In this convention, the pole (P) of the mirror is taken as the origin (Fig. 9.9). The principal axis of the mirror is taken as the x-axis (X'X) of the coordinate system. The conventions are as follows –

(i) The object is always placed to the left of the mirror. This implies that the light from the object falls on the mirror from the left-hand side.

(ii) All distances parallel to the principal axis are measured from the pole of the mirror.

(iii) All the distances measured to the right of the origin (along + x-axis) are taken as positive while those measured to the left of the origin (along – x-axis) are taken as negative.

(iv) Distances measured perpendicular to and above the principal axis (along + y-axis) are taken as positive.

(v) Distances measured perpendicular to and below the principal axis (along –y-axis) are taken as negative.

The New Cartesian Sign Convention described above is illustrated in Fig.9.9 for your reference. These sign conventions are applied to obtain the mirror formula and solve related numerical problems.

9.2.4 Mirror Formula and Magnification

In a spherical mirror, the distance of the object from its pole is called the object distance (u). The distance of the image from the pole of the mirror is called the image distance (v). You already know that the distance of the principal focus from the pole is called the focal length (f). There is a relationship between these three quantities given by the *mirror formula* which is expressed as

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f} \qquad (9.1)$$

This formula is valid in all situations for all spherical mirrors for all positions of the object. You must use the New Cartesian Sign Convention while substituting numerical values for u, v, f, and R in the mirror formula for solving problems.

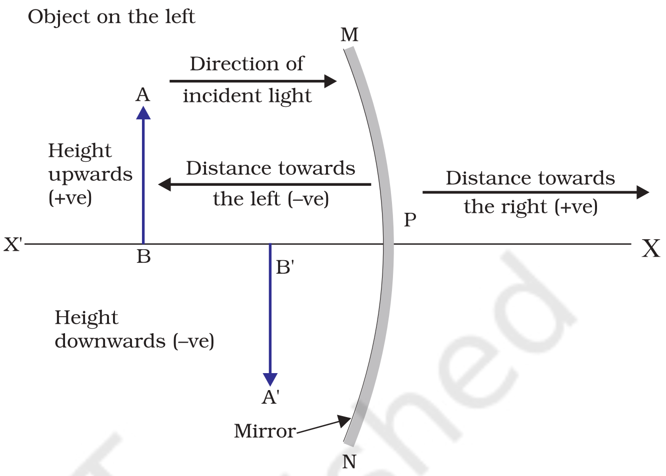


Figure 9.9
The New Cartesian Sign Convention for spherical mirrors

Magnification

Magnification produced by a spherical mirror gives the relative extent to which the image of an object is magnified with respect to the object size. It is expressed as the ratio of the height of the image to the height of the object. It is usually represented by the letter m.

If h is the height of the object and h' is the height of the image, then the magnification m produced by a spherical mirror is given by

$$m = \frac{\text{Height of the image } (h')}{\text{Height of the object } (h)}$$

$$m = \frac{h'}{h} \qquad (9.2)$$

The magnification m is also related to the object distance (u) and image distance (v). It can be expressed as:

$$\text{Magnification } (m) = \frac{h'}{h} = -\frac{v}{u} \qquad (9.3)$$

You may note that the height of the object is taken to be positive as the object is usually placed above the principal axis. The height of the image should be taken as positive for virtual images. However, it is to be taken as negative for real images. A negative sign in the value of the magnification indicates that the image is real. A positive sign in the value of the magnification indicates that the image is virtual.

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Example 9.1

A convex mirror used for rear-view on an automobile has a radius of curvature of 3.00 m. If a bus is located at 5.00 m from this mirror, find the position, nature and size of the image.

Solution

Radius of curvature, $R = + 3.00$ m;
Object-distance, $u = - 5.00$ m;
Image-distance, $v = ?$
Height of the image, $h' = ?$

Focal length, $f = R/2 = + \frac{3.00 \text{ m}}{2} = + 1.50$ m (as the principal focus of a convex mirror is behind the mirror)

Since $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$

or, $\frac{1}{v} = \frac{1}{f} - \frac{1}{u} = + \frac{1}{1.50} - \frac{1}{(-5.00)} = \frac{1}{1.50} + \frac{1}{5.00}$

$= \frac{5.00 + 1.50}{7.50}$

$v = \frac{+7.50}{6.50} = + 1.15$ m

The image is 1.15 m at the back of the mirror.

Magnification, $m = \frac{h'}{h} = - \frac{v}{u} = - \frac{1.15 \text{ m}}{-5.00 \text{ m}}$

$= + 0.23$

The image is virtual, erect and smaller in size by a factor of 0.23.

Example 9.2

An object, 4.0 cm in size, is placed at 25.0 cm in front of a concave mirror of focal length 15.0 cm. At what distance from the mirror should a screen be placed in order to obtain a sharp image? Find the nature and the size of the image.

Solution

Object-size, $h = + 4.0$ cm;
Object-distance, $u = - 25.0$ cm;
Focal length, $f = -15.0$ cm;
Image-distance, $v = ?$
Image-size, $h' = ?$
From Eq. (10.1):

$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$

or, $\frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{1}{-15.0} - \frac{1}{-25.0} = - \frac{1}{15.0} + \frac{1}{25.0}$

or, $\frac{1}{v} = \frac{-5.0 + 3.0}{75.0} = \frac{-2.0}{75.0}$ or, $v = -37.5$ cm

The screen should be placed at 37.5 cm in front of the mirror. The image is real.

Also, magnification, $m = \frac{h'}{h} = -\frac{v}{u}$

or, $h' = -\frac{vh}{u} = -\frac{(-37.5 \text{ cm})\ (+4.0 \text{ cm})}{(-25.0 \text{ cm})}$

Height of the image, $h' = -6.0$ cm

The image is inverted and enlarged.

QUESTIONS

1. Find the focal length of a convex mirror whose radius of curvature is 32 cm.
2. A concave mirror produces three times magnified (enlarged) real image of an object placed at 10 cm in front of it. Where is the image located?

9.3 REFRACTION OF LIGHT

Light seems to travel along straight-line paths in a transparent medium. What happens when light enters from one transparent medium to another? Does it still move along a straight-line path or change its direction? We shall recall some of our day-to-day experiences.

You might have observed that the bottom of a tank or a pond containing water appears to be raised. Similarly, when a thick glass slab is placed over some printed matter, the letters appear raised when viewed through the glass slab. Why does it happen? Have you seen a pencil partly immersed in water in a glass tumbler? It appears to be displaced at the interface of air and water. You might have observed that a lemon kept in water in a glass tumbler appears to be bigger than its actual size, when viewed from the sides. How can you account for such experiences?

Let us consider the case of the apparent displacement of a pencil, partly immersed in water. The light reaching you from the portion of the pencil inside water seems to come from a different direction, compared to the part above water. This makes the pencil appear to be displaced at the interface. For similar reasons, the letters appear to be raised, when seen through a glass slab placed over it.

Does a pencil appear to be displaced to the same extent, if instead of water, we use liquids like kerosene or turpentine? Will the letters appear to rise to the same height if we replace a glass slab with a transparent plastic slab? You will find that the extent of the effect is different for different pair of media. These observations indicate that light does not travel in the same direction in all media. It appears that when travelling obliquely from one medium to another, the direction of propagation of light in the second medium changes. This phenomenon is known as refraction of light. Let us understand this phenomenon further by doing a few activities.

Activity 9.7

- Place a coin at the bottom of a bucket filled with water.
- With your eye to a side above water, try to pick up the coin in one go. Did you succeed in picking up the coin?
- Repeat the Activity. Why did you not succeed in doing it in one go?
- Ask your friends to do this. Compare your experience with theirs.

Activity 9.8

- Place a large shallow bowl on a Table and put a coin in it.
- Move away slowly from the bowl. Stop when the coin just disappears from your sight.
- Ask a friend to pour water gently into the bowl without disturbing the coin.
- Keep looking for the coin from your position. Does the coin becomes visible again from your position? How could this happen?

The coin becomes visible again on pouring water into the bowl. The coin appears slightly raised above its actual position due to refraction of light.

Activity 9.9

- Draw a thick straight line in ink, over a sheet of white paper placed on a Table.
- Place a glass slab over the line in such a way that one of its edges makes an angle with the line.
- Look at the portion of the line under the slab from the sides. What do you observe? Does the line under the glass slab appear to be bent at the edges?
- Next, place the glass slab such that it is normal to the line. What do you observe now? Does the part of the line under the glass slab appear bent?
- Look at the line from the top of the glass slab. Does the part of the line, beneath the slab, appear to be raised? Why does this happen?

9.3.1 Refraction through a Rectangular Glass Slab

To understand the phenomenon of refraction of light through a glass slab, let us do an Activity.

Activity 9.10

- Fix a sheet of white paper on a drawing board using drawing pins.
- Place a rectangular glass slab over the sheet in the middle.
- Draw the outline of the slab with a pencil. Let us name the outline as ABCD.
- Take four identical pins.
- Fix two pins, say E and F, vertically such that the line joining the pins is inclined to the edge AB.
- Look for the images of the pins E and F through the opposite edge. Fix two other pins, say G and H, such that these pins and the images of E and F lie on a straight line.
- Remove the pins and the slab.
- Join the positions of tip of the pins E and F and produce the line up to AB. Let EF meet AB at O. Similarly, join the positions of tip of the pins G and H and produce it up to the edge CD. Let HG meet CD at O′.
- Join O and O′. Also produce EF up to P, as shown by a dotted line in Fig. 9.10.

In this Activity, you will note, the light ray has changed its direction at points O and O′. Note that both the points O and O′ lie on surfaces separating two transparent media. Draw a perpendicular NN' to AB at O and another perpendicular MM′ to CD at O′. The light ray at point O has entered from a rarer medium to a denser medium, that is, from air to glass. Note that the light ray has bent towards the normal. At O′, the light ray has entered from glass to air, that is, from a denser medium to a rarer medium. The light here has bent away from the normal. Compare the angle of incidence with the angle of refraction at both refracting surfaces AB and CD.

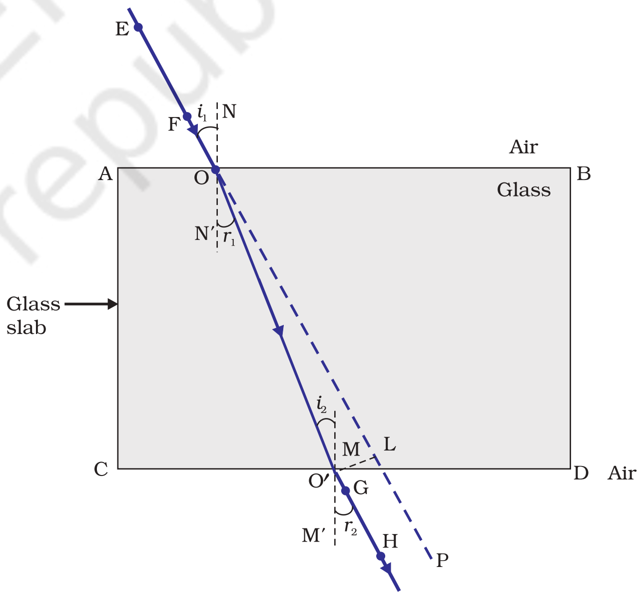


Figure 9.10
Refraction of light through a rectangular glass slab

In Fig. 9.10, a ray EO is obliquely incident on surface AB, called incident ray. OO′ is the refracted ray and O′H is the emergent ray. You may observe that the emergent ray is parallel to the direction of the incident ray. Why does it happen so? The extent of bending of the ray of light at the opposite parallel faces AB (air-glass interface) and CD (glass-air interface) of the rectangular glass slab is equal and opposite. This is why the ray emerges parallel to the incident ray. However, the light ray is shifted sideward slightly. What happens when a light ray is incident normally to the interface of two media? Try and find out.

Now you are familiar with the refraction of light. Refraction is due to change in the speed of light as it enters from one transparent medium to another. Experiments show that refraction of light occurs according to certain laws.

The following are the *laws of refraction of light.*

(i) *The incident ray, the refracted ray and the normal to the interface of two transparent media at the point of incidence, all lie in the same plane.*

(ii) *The ratio of sine of angle of incidence to the sine of angle of refraction is a constant, for the light of a given colour and for the given pair of media.* This law is also known as Snell's law of refraction. (This is true for angle $0 < i < 90^o$)

If i is the angle of incidence and r is the angle of refraction, then,

$$\frac{\sin i}{\sin r} = constant \tag{9.4}$$

This constant value is called the refractive index of the second medium with respect to the first. Let us study about refractive index in some detail.

9.3.2 The Refractive Index

You have already studied that a ray of light that travels obliquely from one transparent medium into another will change its direction in the second medium. The extent of the change in direction that takes place in a given pair of media may be expressed in terms of the refractive index, the "constant" appearing on the right-hand side of Eq.(9.4).

The refractive index can be linked to an important physical quantity, the relative speed of propagation of light in different media. It turns out that light propagates with different speeds in different media. Light travels fastest in vacuum with speed of 3×10^8 m s^{-1}. In air, the speed of light is only marginally less, compared to that in vacuum. It reduces considerably in glass or water. The value of the refractive index for a given pair of media depends upon the speed of light in the two media, as given below.

Consider a ray of light travelling from medium 1 into medium 2, as shown in Fig.9.11. Let v_1 be the speed of light in medium 1 and v_2 be the speed of light in medium 2. The refractive index of medium 2 with respect to medium 1 is given by the ratio of the speed of light in medium 1 and the speed of light in medium 2. This is usually represented by the symbol n_{21}. This can be expressed in an equation form as

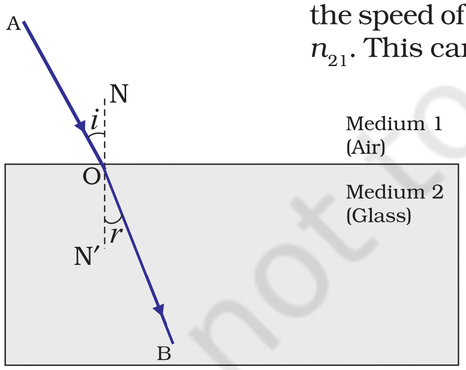


Figure 9.11

$$n_{21} = \frac{\text{Speed of light in medium 1}}{\text{Speed of light in medium 2}} = \frac{v_1}{v_2} \tag{9.5}$$

By the same argument, the refractive index of medium 1 with respect to medium 2 is represented as n_{12}. It is given by

$$n_{12} = \frac{\text{Speed of light in medium 2}}{\text{Speed of light in medium 1}} = \frac{v_2}{v_1} \tag{9.6}$$

If medium 1 is vacuum or air, then the refractive index of medium 2 is considered with respect to vacuum. This is called the absolute refractive index of the medium. It is simply represented as n_2. If c is the speed of light in air and v is the speed of light in the medium, then, the refractive index of the medium n_m is given by

$$n_m = \frac{\text{Speed of light in air}}{\text{Speed of light in the medium}} = \frac{c}{v} \qquad (9.7)$$

The absolute refractive index of a medium is simply called its refractive index. The refractive index of several media is given in Table 9.3. From the Table you can know that the refractive index of water, n_w = 1.33. This means that the ratio of the speed of light in air and the speed of light in water is equal to 1.33. Similarly, the refractive index of crown glass, n_g =1.52. Such data are helpful in many places. However, you need not memorise the data.

Table 9.3 Absolute refractive index of some material media

Material medium	Refractive index	Material medium	Refractive index
Air	1.0003	Canada Balsam	1.53
Ice	1.31		
Water	1.33	Rock salt	1.54
Alcohol	1.36		
Kerosene	1.44	Carbon disulphide	1.63
Fused quartz	1.46	Dense flint glass	1.65
Turpentine oil	1.47	Ruby	1.71
Benzene	1.50	Sapphire	1.77
Crown glass	1.52	Diamond	2.42

Note from Table 9.3 that an optically denser medium may not possess greater mass density. For example, kerosene having higher refractive index, is optically denser than water, although its mass density is less than water.

More to Know!

The ability of a medium to refract light is also expressed in terms of its optical density. Optical density has a definite connotation. It is not the same as mass density. We have been using the terms 'rarer medium' and 'denser medium' in this Chapter. It actually means 'optically rarer medium' and 'optically denser medium', respectively. When can we say that a medium is optically denser than the other? In comparing two media, the one with the larger refractive index is optically denser medium than the other. The other medium of lower refractive index is optically rarer. The speed of light is higher in a rarer medium than a denser medium. Thus, a ray of light travelling from a rarer medium to a denser medium slows down and bends towards the normal. When it travels from a denser medium to a rarer medium, it speeds up and bends away from the normal.

QUESTIONS

1. A ray of light travelling in air enters obliquely into water. Does the light ray bend towards the normal or away from the normal? Why?
2. Light enters from air to glass having refractive index 1.50. What is the speed of light in the glass? The speed of light in vacuum is 3×10^8 m s^{-1}.
3. Find out, from Table 9.3, the medium having highest optical density. Also find the medium with lowest optical density.
4. You are given kerosene, turpentine and water. In which of these does the light travel fastest? Use the information given in Table 9.3.
5. The refractive index of diamond is 2.42. What is the meaning of this statement?

9.3.3 Refraction by Spherical Lenses

You might have seen watchmakers using a small magnifying glass to see tiny parts. Have you ever touched the surface of a magnifying glass with your hand? Is it plane surface or curved? Is it thicker in the middle or at the edges? The glasses used in spectacles and that by a watchmaker are examples of lenses. What is a lens? How does it bend light rays? We shall discuss these in this section.

A transparent material bound by two surfaces, of which one or both surfaces are spherical, forms a lens. This means that a lens is bound by at least one spherical surface. In such lenses, the other surface would be plane. A lens may have two spherical surfaces, bulging outwards. Such a lens is called a double convex lens. It is simply called a convex lens. It is thicker at the middle as compared to the edges. Convex lens converges light rays as shown in Fig. 9.12 (a). Hence convex lenses are also called converging lenses. Similarly, a double concave lens is bounded by two spherical surfaces, curved inwards. It is thicker at the edges than at the middle. Such lenses diverge light rays as shown in Fig. 9.12 (b). Such lenses are also called diverging lenses. A double concave lens is simply called a concave lens.

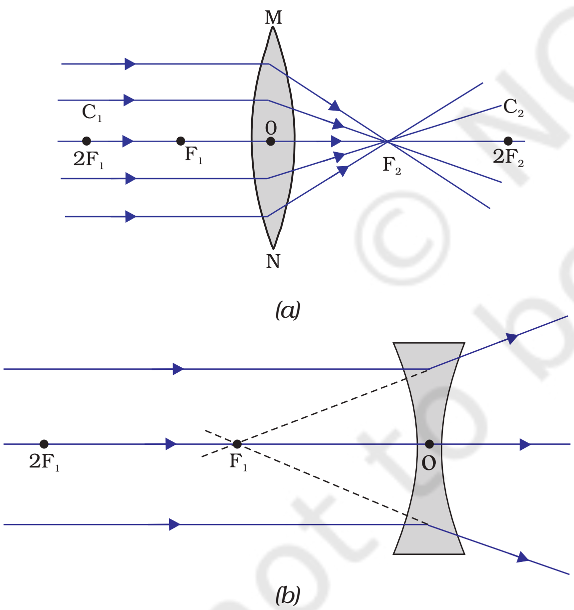


Figure 9.12
(a) Converging action of a convex lens, (b) diverging action of a concave lens

A lens, either a convex lens or a concave lens, has two spherical surfaces. Each of these surfaces forms a part of a sphere. The centres of these spheres are called centres of curvature of the lens. The centre of curvature of a lens is usually represented by the letter C. Since there are two centres of curvature, we may represent them as C_1 and C_2. An imaginary straight line passing through the two centres of curvature of a lens is called its principal axis. The central point of a lens is its optical centre. It is usually represented by the letter O. A ray of light through the optical centre of a lens passes without suffering any deviation. The effective diameter of the circular outline of a spherical lens is called its aperture. We shall confine our discussion in this Chapter to such lenses whose aperture is much less than its radius of curvature and the two centres of curvatures are equidistant from the optical centre O. Such lenses are called thin lenses with small apertures. What happens when parallel rays of light are incident on a lens? Let us do an Activity to understand this.

Activity 9.11

CAUTION: Do not look at the Sun directly or through a lens while doing this Activity or otherwise. You may damage your eyes if you do so.

- Hold a convex lens in your hand. Direct it towards the Sun.
- Focus the light from the Sun on a sheet of paper. Obtain a sharp bright image of the Sun.
- Hold the paper and the lens in the same position for a while. Keep observing the paper. What happened? Why? Recall your experience in Activity 9.2.

The paper begins to burn producing smoke. It may even catch fire after a while. Why does this happen? The light from the Sun constitutes parallel rays of light. These rays were converged by the lens at the sharp bright spot formed on the paper. In fact, the bright spot you got on the paper is a real image of the Sun. The concentration of the sunlight at a point generated heat. This caused the paper to burn.

Now, we shall consider rays of light parallel to the principal axis of a lens. What happens when you pass such rays of light through a lens? This is illustrated for a convex lens in Fig.9.12 (a) and for a concave lens in Fig.9.12 (b).

Observe Fig.9.12 (a) carefully. Several rays of light parallel to the principal axis are falling on a convex lens. These rays, after refraction from the lens, are converging to a point on the principal axis. This point on the principal axis is called the principal focus of the lens. Let us see now the action of a concave lens.

Observe Fig.9.12 (b) carefully. Several rays of light parallel to the principal axis are falling on a concave lens. These rays, after refraction from the lens, are appearing to diverge from a point on the principal axis. This point on the principal axis is called the principal focus of the concave lens.

If you pass parallel rays from the opposite surface of the lens, you get another principal focus on the opposite side. Letter F is usually used to represent principal focus. However, a lens has two principal foci. They are represented by F_1 and F_2. The distance of the principal focus from the optical centre of a lens is called its focal length. The letter f is used to represent the focal length. How can you find the focal length of a convex lens? Recall the Activity 9.11. In this Activity, the distance between the position of the lens and the position of the image of the Sun gives the approximate focal length of the lens.

9.3.4 Image Formation by Lenses

Lenses form images by refracting light. How do lenses form images? What is their nature? Let us study this for a convex lens first.

Activity 9.12

- Take a convex lens. Find its approximate focal length in a way described in Activity 9.11.
- Draw five parallel straight lines, using chalk, on a long Table such that the distance between the successive lines is equal to the focal length of the lens.
- Place the lens on a lens stand. Place it on the central line such that the optical centre of the lens lies just over the line.
- The two lines on either side of the lens correspond to F and 2F of the lens respectively. Mark them with appropriate letters such as $2F_1$, F_1, F_2 and $2F_2$, respectively.
- Place a burning candle, far beyond $2F_1$ to the left. Obtain a clear sharp image on a screen on the opposite side of the lens.
- Note down the nature, position and relative size of the image.
- Repeat this Activity by placing object just behind $2F_1$, between F_1 and $2F_1$ at F_1, between F_1 and O. Note down and tabulate your observations.

The nature, position and relative size of the image formed by convex lens for various positions of the object is summarised in Table 9.4.

Table 9.4 Nature, position and relative size of the image formed by a convex lens for various positions of the object

Position of the object	Position of the image	Relative size of the image	Nature of the image
At infinity	At focus F_2	Highly diminished, point-sized	Real and inverted
Beyond $2F_1$	Between F_2 and $2F_2$	Diminished	Real and inverted
At $2F_1$	At $2F_2$	Same size	Real and inverted
Between F_1 and $2F_1$	Beyond $2F_2$	Enlarged	Real and inverted
At focus F_1	At infinity	Infinitely large or highly enlarged	Real and inverted
Between focus F_1 and optical centre O	On the same side of the lens as the object	Enlarged	Virtual and erect

Let us now do an Activity to study the nature, position and relative size of the image formed by a concave lens.

Activity 9.13

- Take a concave lens. Place it on a lens stand.
- Place a burning candle on one side of the lens.
- Look through the lens from the other side and observe the image. Try to get the image on a screen, if possible. If not, observe the image directly through the lens.
- Note down the nature, relative size and approximate position of the image.
- Move the candle away from the lens. Note the change in the size of the image. What happens to the size of the image when the candle is placed too far away from the lens.

The summary of the above Activity is given in Table 9.5 below.

Table 9.5 Nature, position and relative size of the image formed by a concave lens for various positions of the object

Position of the object	Position of the image	Relative size of the image	Nature of the image
At infinity	At focus F_1	Highly diminished, point-sized	Virtual and erect
Between infinity and optical centre O of the lens	Between focus F_1 and optical centre O	Diminished	Virtual and erect

What conclusion can you draw from this Activity? A concave lens will always give a virtual, erect and diminished image, irrespective of the position of the object.

9.3.5 Image Formation in Lenses Using Ray Diagrams

We can represent image formation by lenses using ray diagrams. Ray diagrams will also help us to study the nature, position and relative size of the image formed by lenses. For drawing ray diagrams in lenses, alike of spherical mirrors, we consider any two of the following rays –

(i) A ray of light from the object, parallel to the principal axis, after refraction from a convex lens, passes through the principal focus on the other side of the lens, as shown in Fig. 9.13 (a). In case of a concave lens, the ray appears to diverge from the principal focus located on the same side of the lens, as shown in Fig. 9.13 (b).

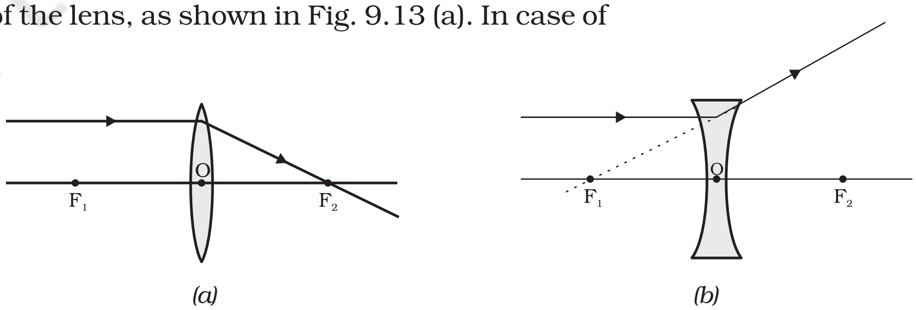


Figure 9.13

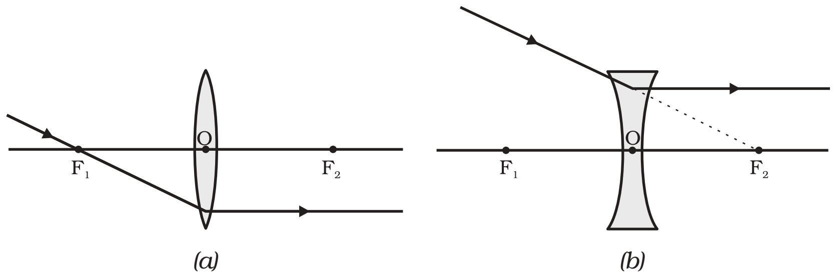


Figure 9.14

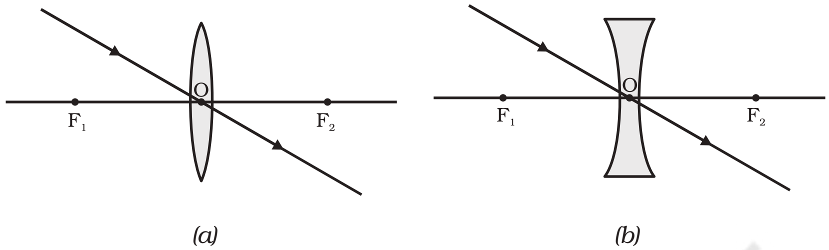
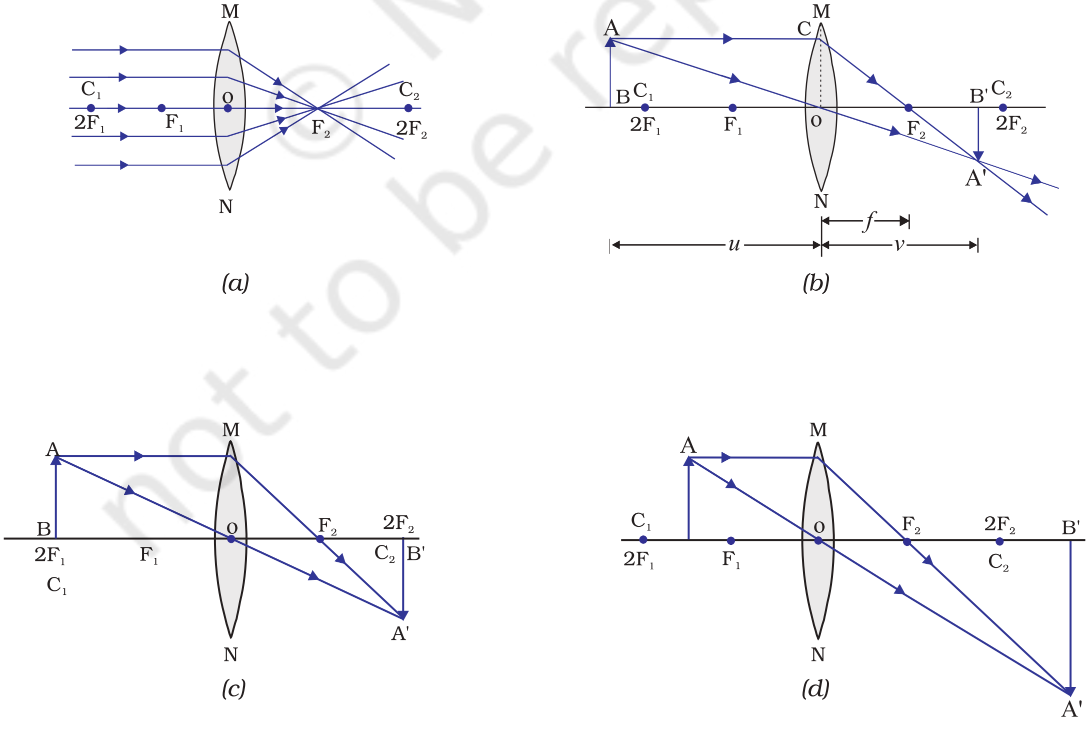


Figure 9.15

(ii) A ray of light passing through a principal focus, after refraction from a convex lens, will emerge parallel to the principal axis. This is shown in Fig. 9.14 (a). A ray of light appearing to meet at the principal focus of a concave lens, after refraction, will emerge parallel to the principal axis. This is shown in Fig.9.14 (b).

(iii) A ray of light passing through the optical centre of a lens will emerge without any deviation. This is illustrated in Fig.9.15(a) and Fig.9.15 (b).

The ray diagrams for the image formation in a convex lens for a few positions of the object are shown in Fig. 9.16. The ray diagrams representing the image formation in a concave lens for various positions of the object are shown in Fig. 9.17.



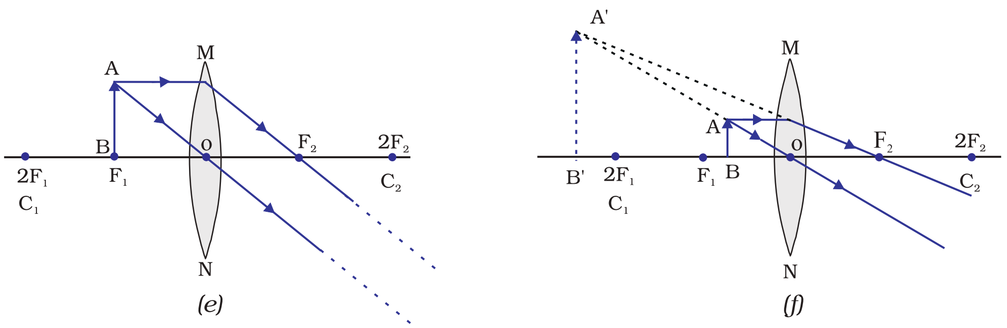


Figure 9.16 *The position, size and the nature of the image formed by a convex lens for various positions of the object*

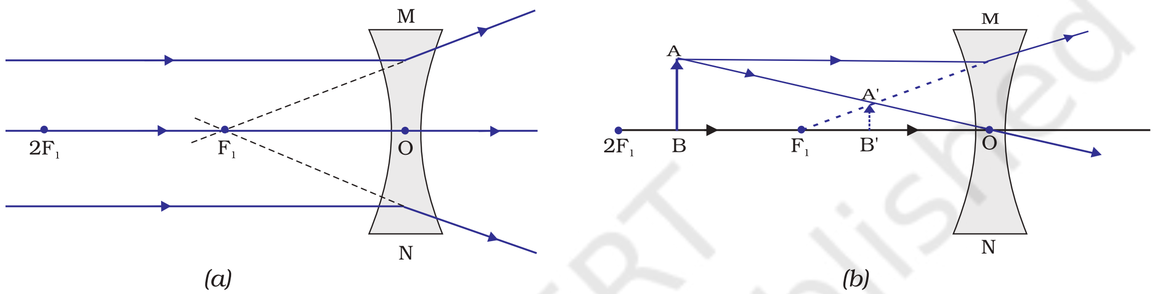


Figure 9.17 *Nature, position and relative size of the image formed by a concave lens*

9.3.6 Sign Convention for Spherical Lenses

For lenses, we follow sign convention, similar to the one used for spherical mirrors. We apply the rules for signs of distances, except that all measurements are taken from the optical centre of the lens. According to the convention, the focal length of a convex lens is positive and that of a concave lens is negative. You must take care to apply appropriate signs for the values of u, v, f, object height h and image height h'.

9.3.7 Lens Formula and Magnification

As we have a formula for spherical mirrors, we also have formula for spherical lenses. This formula gives the relationship between object-distance (u), image-distance (v) and the focal length (f). The lens formula is expressed as

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \qquad (9.8)$$

The lens formula given above is general and is valid in all situations for any spherical lens. Take proper care of the signs of different quantities, while putting numerical values for solving problems relating to lenses.

Magnification

The magnification produced by a lens, similar to that for spherical mirrors, is defined as the ratio of the height of the image and the height of the object. Magnification is represented by the letter m. If h is the height of the object and h' is the height of the image given by a lens, then the magnification produced by the lens is given by,

$$m = \frac{\text{Height of the Image}}{\text{Height of the object}} = \frac{h'}{h} \tag{9.9}$$

Magnification produced by a lens is also related to the object-distance u, and the image-distance v. This relationship is given by

$$\text{Magnification } (m) = h'/h = v/u \tag{9.10}$$

Example 9.3

A concave lens has focal length of 15 cm. At what distance should the object from the lens be placed so that it forms an image at 10 cm from the lens? Also, find the magnification produced by the lens.

Solution

A concave lens always forms a virtual, erect image on the same side of the object.

Image-distance v = –10 cm;
Focal length f = –15 cm;
Object-distance u = ?

Since $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

or, $\frac{1}{u} = \frac{1}{v} - \frac{1}{f}$

$$\frac{1}{u} = \frac{1}{-10} - \frac{1}{(-15)} = -\frac{1}{10} + \frac{1}{15}$$

$$\frac{1}{u} = \frac{-3+2}{30} = \frac{1}{-30}$$

or, $u = -30$ cm

Thus, the object-distance is 30 cm.

Magnification $m = v/u$

$$m = \frac{-10\text{ cm}}{-30\text{ cm}} = \frac{1}{3} ; +0.33$$

The positive sign shows that the image is erect and virtual. The image is one-third of the size of the object.

Example 9.4

A 2.0 cm tall object is placed perpendicular to the principal axis of a convex lens of focal length 10 cm. The distance of the object from the lens is 15 cm. Find the nature, position and size of the image. Also find its magnification.

Solution

Height of the object h = + 2.0 cm;
Focal length f = + 10 cm;
object-distance u = –15 cm;
Image-distance v = ?
Height of the image h' = ?

Since $\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$

or, $\frac{1}{v}=\frac{1}{u}+\frac{1}{f}$

$$\frac{1}{v}=\frac{1}{(-15)}+\frac{1}{10}=-\frac{1}{15}+\frac{1}{10}$$

$$\frac{1}{v}=\frac{-2+3}{30}=\frac{1}{30}$$

or, v = + 30 cm

The positive sign of v shows that the image is formed at a distance of 30 cm on the other side of the optical centre. The image is real and inverted.

Magnification $m=\frac{h'}{h}=\frac{v}{u}$

or, $h' = h\,(v/u)$

Height of the image, h' = (2.0) (+30/–15) = – 4.0 cm

Magnification $m = v/u$

or, $m=\frac{+30\,\text{cm}}{-15\,\text{cm}}=-2$

The negative signs of m and h' show that the image is inverted and real. It is formed below the principal axis. Thus, a real, inverted image, 4 cm tall, is formed at a distance of 30 cm on the other side of the lens. The image is two times enlarged.

9.3.8 Power of a Lens

You have already learnt that the ability of a lens to converge or diverge light rays depends on its focal length. For example, a convex lens of short focal length bends the light rays through large angles, by focussing them closer to the optical centre. Similarly, concave lens of very short focal length causes higher divergence than the one with longer focal length. The degree of convergence or divergence of light rays achieved by a lens is expressed in terms of its power. The power of a lens is defined as the reciprocal of its focal length. It is represented by the letter P. The power P of a lens of focal length f is given by

$$P=\frac{1}{f} \qquad (9.11)$$

The SI unit of power of a lens is 'dioptre'. It is denoted by the letter D. If f is expressed in metres, then, power is expressed in dioptres. Thus, 1 dioptre is the power of a lens whose focal length is 1 metre. $1D = 1m^{-1}$. You may note that the *power of a convex lens is positive and that of a concave lens is negative.*

Opticians prescribe corrective lenses indicating their powers. Let us say the lens prescribed has power equal to + 2.0 D. This means the lens prescribed is convex. The focal length of the lens is + 0.50 m. Similarly, a lens of power – 2.5 D has a focal length of – 0.40 m. The lens is concave.

More to Know!

Many optical instruments consist of a number of lenses. They are combined to increase the magnification and sharpness of the image. The net power (P) of the lenses placed in contact is given by the algebraic sum of the individual powers $P_1, P_2, P_3, \ldots$ as $P = P_1 + P_2 + P_3 + \ldots$

The use of powers, instead of focal lengths, for lenses is quite convenient for opticians. During eye-testing, an optician puts several different combinations of corrective lenses of known power, in contact, inside the testing spectacles' frame. The optician calculates the power of the lens required by simple algebraic addition. For example, a combination of two lenses of power + 2.0 D and + 0.25 D is equivalent to a single lens of power + 2.25 D. The simple additive property of the powers of lenses can be used to design lens systems to minimise certain defects in images produced by a single lens. Such a lens system, consisting of several lenses, in contact, is commonly used in the design of lenses of camera, microscopes and telescopes.

QUESTIONS

1. Define 1 dioptre of power of a lens.
2. A convex lens forms a real and inverted image of a needle at a distance of 50 cm from it. Where is the needle placed in front of the convex lens if the image is equal to the size of the object? Also, find the power of the lens.
3. Find the power of a concave lens of focal length 2 m.

What you have learnt

- Light seems to travel in straight lines.
- Mirrors and lenses form images of objects. Images can be either real or virtual, depending on the position of the object.
- The reflecting surfaces, of all types, obey the laws of reflection. The refracting surfaces obey the laws of refraction.
- New Cartesian Sign Conventions are followed for spherical mirrors and lenses.

- Mirror formula, $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$, gives the relationship between the object-distance (u), image-distance (v), and focal length (f) of a spherical mirror.
- The focal length of a spherical mirror is equal to half its radius of curvature.
- The magnification produced by a spherical mirror is the ratio of the height of the image to the height of the object.
- A light ray travelling obliquely from a denser medium to a rarer medium bends away from the normal. A light ray bends towards the normal when it travels obliquely from a rarer to a denser medium.
- Light travels in vacuum with an enormous speed of 3×10^{8} m s^{-1}. The speed of light is different in different media.
- The refractive index of a transparent medium is the ratio of the speed of light in vacuum to that in the medium.
- In case of a rectangular glass slab, the refraction takes place at both air-glass interface and glass-air interface. The emergent ray is parallel to the direction of incident ray.
- Lens formula, $\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$, gives the relationship between the object-distance (u), image-distance (v), and the focal length (f) of a spherical lens.
- Power of a lens is the reciprocal of its focal length. The SI unit of power of a lens is *dioptre*.

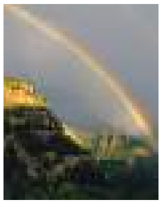
EXERCISES

1. Which one of the following materials cannot be used to make a lens?
   (a) Water (b) Glass (c) Plastic (d) Clay
2. The image formed by a concave mirror is observed to be virtual, erect and larger than the object. Where should be the position of the object?
   (a) Between the principal focus and the centre of curvature
   (b) At the centre of curvature
   (c) Beyond the centre of curvature
   (d) Between the pole of the mirror and its principal focus.
3. Where should an object be placed in front of a convex lens to get a real image of the size of the object?
   (a) At the principal focus of the lens
   (b) At twice the focal length
   (c) At infinity
   (d) Between the optical centre of the lens and its principal focus.
4. A spherical mirror and a thin spherical lens have each a focal length of –15 cm. The mirror and the lens are likely to be
   (a) both concave.
   (b) both convex.

(c) the mirror is concave and the lens is convex.
(d) the mirror is convex, but the lens is concave.

5. No matter how far you stand from a mirror, your image appears erect. The mirror is likely to be
   (a) only plane.
   (b) only concave.
   (c) only convex.
   (d) either plane or convex.
6. Which of the following lenses would you prefer to use while reading small letters found in a dictionary?
   (a) A convex lens of focal length 50 cm.
   (b) A concave lens of focal length 50 cm.
   (c) A convex lens of focal length 5 cm.
   (d) A concave lens of focal length 5 cm.
7. We wish to obtain an erect image of an object, using a concave mirror of focal length 15 cm. What should be the range of distance of the object from the mirror? What is the nature of the image? Is the image larger or smaller than the object? Draw a ray diagram to show the image formation in this case.
8. Name the type of mirror used in the following situations.
   (a) Headlights of a car.
   (b) Side/rear-view mirror of a vehicle.
   (c) Solar furnace.

   Support your answer with reason.
9. One-half of a convex lens is covered with a black paper. Will this lens produce a complete image of the object? Verify your answer experimentally. Explain your observations.
10. An object 5 cm in length is held 25 cm away from a converging lens of focal length 10 cm. Draw the ray diagram and find the position, size and the nature of the image formed.
11. A concave lens of focal length 15 cm forms an image 10 cm from the lens. How far is the object placed from the lens? Draw the ray diagram.
12. An object is placed at a distance of 10 cm from a convex mirror of focal length 15 cm. Find the position and nature of the image.
13. The magnification produced by a plane mirror is +1. What does this mean?
14. An object 5.0 cm in length is placed at a distance of 20 cm in front of a convex mirror of radius of curvature 30 cm. Find the position of the image, its nature and size.
15. An object of size 7.0 cm is placed at 27 cm in front of a concave mirror of focal length 18 cm. At what distance from the mirror should a screen be placed, so that a sharp focussed image can be obtained? Find the size and the nature of the image.
16. Find the focal length of a lens of power – 2.0 D. What type of lens is this?
17. A doctor has prescribed a corrective lens of power +1.5 D. Find the focal length of the lens. Is the prescribed lens diverging or converging?



CHAPTER 10
The Human Eye and the Colourful World

1064CH11

You have studied in the previous chapter about refraction of light by lenses. You also studied the nature, position and relative size of images formed by lenses. How can these ideas help us in the study of the human eye? The human eye uses light and enables us to see objects around us. It has a lens in its structure. What is the function of the lens in a human eye? How do the lenses used in spectacles correct defects of vision? Let us consider these questions in this chapter.

We have learnt in the previous chapter about light and some of its properties. In this chapter, we shall use these ideas to study some of the optical phenomena in nature. We shall also discuss about rainbow formation, splitting of white light and blue colour of the sky.

10.1 THE HUMAN EYE

The human eye is one of the most valuable and sensitive sense organs. It enables us to see the wonderful world and the colours around us. On closing the eyes, we can identify objects to some extent by their smell, taste, sound they make or by touch. It is, however, impossible to identify colours while closing the eyes. Thus, of all the sense organs, the human eye is the most significant one as it enables us to see the beautiful, colourful world around us.

The human eye is like a camera. Its lens system forms an image on a light-sensitive screen called the retina. Light enters the eye through a thin membrane called the cornea. It forms the transparent bulge on the front surface of the eyeball as shown in Fig. 10.1. The eyeball is approximately spherical in shape with a diameter of about 2.3 cm. Most of the refraction for the light rays entering the eye occurs at the outer surface of the cornea. The crystalline lens merely provides the finer adjustment of focal length required to focus objects at different distances on the retina. We find a structure called *iris* behind the cornea. Iris is a dark muscular diaphragm that controls the size of the pupil. The pupil regulates and controls the amount of light

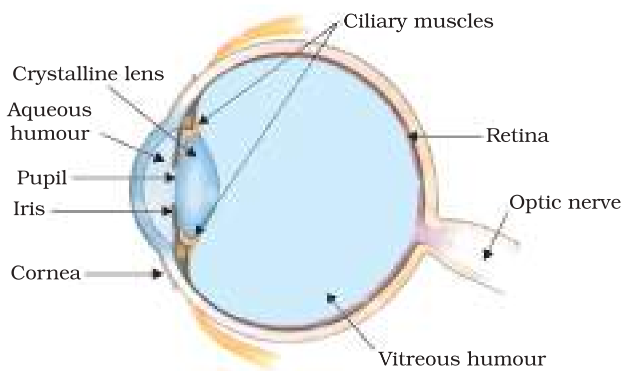


Figure 10.1
The human eye

entering the eye. The eye lens forms an inverted real image of the object on the retina. The retina is a delicate membrane having enormous number of light-sensitive cells. The light-sensitive cells get activated upon illumination and generate electrical signals. These signals are sent to the brain via the optic nerves. The brain interprets these signals, and finally, processes the information so that we perceive objects as they are.

10.1.1 Power of Accommodation

The eye lens is composed of a fibrous, jelly-like material. Its curvature can be modified to some extent by the ciliary muscles. The change in the curvature of the eye lens can thus change its focal length. When the muscles are relaxed, the lens becomes thin. Thus, its focal length increases. This enables us to see distant objects clearly. When you are looking at objects closer to the eye, the ciliary muscles contract. This increases the curvature of the eye lens. The eye lens then becomes thicker. Consequently, the focal length of the eye lens decreases. This enables us to see nearby objects clearly.

The ability of the eye lens to adjust its focal length is called accommodation. However, the focal length of the eye lens cannot be decreased below a certain minimum limit. Try to read a printed page by holding it very close to your eyes. You may see the image being blurred or feel strain in the eye. To see an object comfortably and distinctly, you must hold it at about 25 cm from the eyes. The minimum distance, at which objects can be seen most distinctly without strain, is called the least distance of distinct vision. It is also called the near point of the eye. For a young adult with normal vision, the near point is about 25 cm. The farthest point upto which the eye can see objects clearly is called the far point of the eye. It is infinity for a normal eye. You may note here a normal eye can see objects clearly that are between 25 cm and infinity.

Sometimes, the crystalline lens of people at old age becomes milky and cloudy. This condition is called cataract. This causes partial or complete loss of vision. It is possible to restore vision through a cataract surgery.

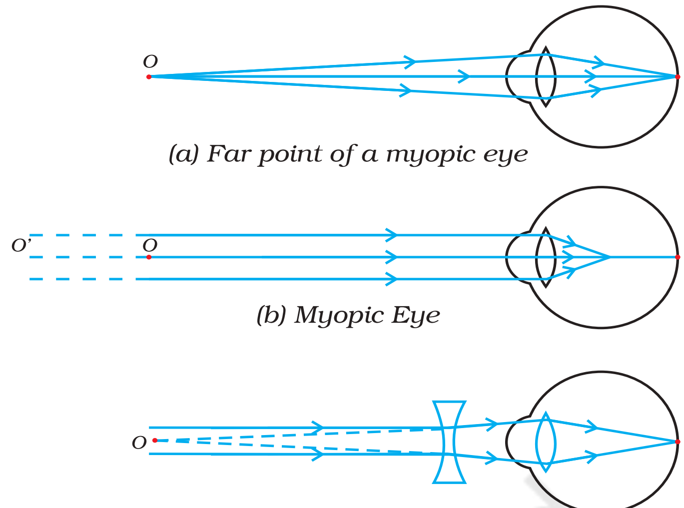
10.2 DEFECTS OF VISION AND THEIR CORRECTION

Sometimes, the eye may gradually lose its power of accommodation. In such conditions, the person cannot see the objects distinctly and comfortably. The vision becomes blurred due to the refractive defects of the eye.

There are mainly three common refractive defects of vision. These are (i) myopia or near-sightedness, (ii) Hypermetropia or far-sightedness, and (iii) Presbyopia. These defects can be corrected by the use of suitable spherical lenses. We discuss below these defects and their correction.

(a) **Myopia**

Myopia is also known as near-sightedness. A person with myopia can see nearby objects clearly but cannot see distant objects distinctly. A person with this defect has the far point nearer than infinity. Such a person may see clearly upto a distance of a few metres. In a myopic eye, the image of a distant object is formed in front of the retina [Fig. 10.2 (b)] and not at the retina itself. This defect may arise due to (i) excessive curvature of the eye lens, or (ii) elongation of the eyeball. This defect can be corrected by using a concave lens of suitable power. This is illustrated in Fig. 10.2 (c). A concave lens of suitable power will bring the image back on to the retina and thus the defect is corrected.



(a) Far point of a myopic eye

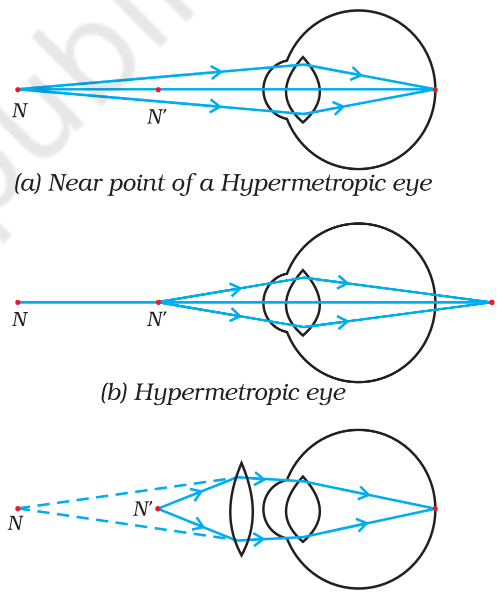
(b) Myopic Eye

(c) Correction for myopia

Figure 10.2
(a), (b) The myopic eye, and (c) correction for myopia with a concave lens

(b) **Hypermetropia**

Hypermetropia is also known as far-sightedness. A person with hypermetropia can see distant objects clearly but cannot see nearby objects distinctly. The near point, for the person, is farther away from the normal near point (25 cm). Such a person has to keep a reading material much beyond 25 cm from the eye for comfortable reading. This is because the light rays from a closeby object are focussed at a point behind the retina as shown in Fig. 10.3 (b). This defect arises either because (i) the focal length of the eye lens is too long, or (ii) the eyeball has become too small. This defect can be corrected by using a convex lens of appropriate power. This is illustrated in Fig. 10.3 (c). Eye-glasses with converging lenses provide the additional focussing power required for forming the image on the retina.



(a) Near point of a Hypermetropic eye

(b) Hypermetropic eye

(c) Correction for Hypermetropic eye

Figure 10.3
(a), (b) The hypermetropic eye, and (c) correction for hypermetropia

N = Near point of a hypermetropic eye.

N′ = Near point of a normal eye.

(c) **Presbyopia**

The power of accommodation of the eye usually decreases with ageing. For most people, the near point gradually recedes away. They find it difficult to see nearby objects comfortably and distinctly without corrective eye-glasses. This defect is called Presbyopia. It arises due to the gradual weakening of the ciliary muscles and diminishing flexibility of the eye lens. Sometimes, a person may suffer from both myopia and hypermetropia. Such people often require bi-focal lenses. A common type of bi-focal lenses consists of both concave and convex lenses. The upper portion consists of a concave lens. It facilitates distant vision. The lower part is a convex lens. It facilitates near vision.

These days, it is possible to correct the refractive defects with contact lenses or through surgical interventions.

QUESTIONS

1. What is meant by power of accommodation of the eye?
2. A person with a myopic eye cannot see objects beyond 1.2 m distinctly. What should be the type of the corrective lens used to restore proper vision?
3. What is the far point and near point of the human eye with normal vision?
4. A student has difficulty reading the blackboard while sitting in the last row. What could be the defect the child is suffering from? How can it be corrected?

Think it over

You talk of wondrous things you see,
You say the sun shines bright;
I feel him warm, but how can he
Or make it day or night?

– C. CIBBER

Do you know that our eyes can live even after our death? By donating our eyes after we die, we can light the life of a blind person.

About 35 million people in the developing world are blind and most of them can be cured. About 4.5 million people with corneal blindness can be cured through corneal transplantation of donated eyes. Out of these 4.5 million, 60% are children below the age of 12. So, if we have got the gift of vision, why not pass it on to somebody who does not have it? What do we have to keep in mind when eyes have to be donated?

- Eye donors can belong to any age group or sex. People who use spectacles, or those operated for cataract, can still donate the eyes. People who are diabetic, have hypertension, asthma patients and those without communicable diseases can also donate eyes.

- Eyes must be removed within 4-6 hours after death. Inform the nearest eye bank immediately.
- The eye bank team will remove the eyes at the home of the deceased or at a hospital.
- Eye removal takes only 10-15 minutes. It is a simple process and does not lead to any disfigurement.
- Persons who were infected with or died because of AIDS, Hepatitis B or C, rabies, acute leukaemia, tetanus, cholera, meningitis or encephalitis cannot donate eyes.

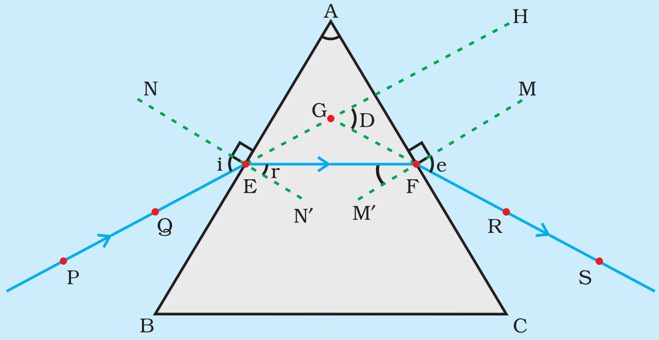
An eye bank collects, evaluates and distributes the donated eyes. All eyes donated are evaluated using strict medical standards. Those donated eyes found unsuitable for transplantation are used for valuable research and medical education. The identities of both the donor and the recipient remain confidential.
One pair of eyes gives vision to up to FOUR CORNEAL BLIND PEOPLE.

10.3 REFRACTION OF LIGHT THROUGH A PRISM

You have learnt how light gets refracted through a rectangular glass slab. For parallel refracting surfaces, as in a glass slab, the emergent ray is parallel to the incident ray. However, it is slightly displaced laterally. How would light get refracted through a transparent prism? Consider a triangular glass prism. It has two triangular bases and three rectangular lateral surfaces. These surfaces are inclined to each other. The angle between its two lateral faces is called the angle of the prism. Let us now do an activity to study the refraction of light through a triangular glass prism.

Activity 10.1

- Fix a sheet of white paper on a drawing board using drawing pins.
- Place a glass prism on it in such a way that it rests on its triangular base. Trace the outline of the prism using a pencil.
- Draw a straight line PE inclined to one of the refracting surfaces, say AB, of the prism.
- Fix two pins, say at points P and Q, on the line PE as shown in Fig. 10.4.
- Look for the images of the pins, fixed at P and Q, through the other face AC.
- Fix two more pins, at points R and S, such that the pins at R and S and the images of the pins at P and Q lie on the same straight line.
- Remove the pins and the glass prism.
- The line PE meets the boundary of the prism at point E (see Fig. 10.4). Similarly, join and produce the points R and S. Let these lines meet the boundary of the prism at E and F, respectively. Join E and F.
- Draw perpendiculars to the refracting surfaces AB and AC of the prism at points E and F, respectively.
- Mark the angle of incidence (∠i), the angle of refraction (∠r) and the angle of emergence (∠e) as shown in Fig. 10.4.



PE – Incident ray
EF – Refracted ray
FS – Emergent ray
∠A – Angle of the prism

∠i – Angle of incidence
∠r – Angle of refraction
∠e – Angle of emergence
∠D – Angle of deviation

Figure 10.4 *Refraction of light through a triangular glass prism*

Here PE is the incident ray, EF is the refracted ray and FS is the emergent ray. You may note that a ray of light is entering from air to glass at the first surface AB. The light ray on refraction has bent towards the normal. At the second surface AC, the light ray has entered from glass to air. Hence it has bent away from normal. Compare the angle of incidence and the angle of refraction at each refracting surface of the prism. Is this similar to the kind of bending that occurs in a glass slab? The peculiar shape of the prism makes the emergent ray bend at an angle to the direction of the incident ray. This angle is called the angle of deviation. In this case ∠D is the angle of deviation. Mark the angle of deviation in the above activity and measure it.

10.4 DISPERSION OF WHITE LIGHT BY A GLASS PRISM

You must have seen and appreciated the spectacular colours in a rainbow. How could the white light of the Sun give us various colours of the rainbow? Before we take up this question, we shall first go back to the refraction of light through a prism. The inclined refracting surfaces of a glass prism show exciting phenomenon. Let us find it out through an activity.

Activity 10.2

- Take a thick sheet of cardboard and make a small hole or narrow slit in its middle.
- Allow sunlight to fall on the narrow slit. This gives a narrow beam of white light.
- Now, take a glass prism and allow the light from the slit to fall on one of its faces as shown in Fig. 10.5.
- Turn the prism slowly until the light that comes out of it appears on a nearby screen.
- What do you observe? You will find a beautiful band of colours. Why does this happen?

The prism has probably split the incident white light into a band of colours. Note the colours that appear at the two ends of the colour band. What is the sequence of colours that you see on the screen? The various colours seen are Violet, Indigo, Blue, Green, Yellow, Orange and Red, as shown in Fig. 10.5. The acronym VIBGYOR will help you to remember the sequence of colours. The band of the coloured components of a light beam is called its spectrum. You might not be able to see all the colours separately. Yet something makes each colour distinct from the other. The splitting of light into its component colours is called dispersion.

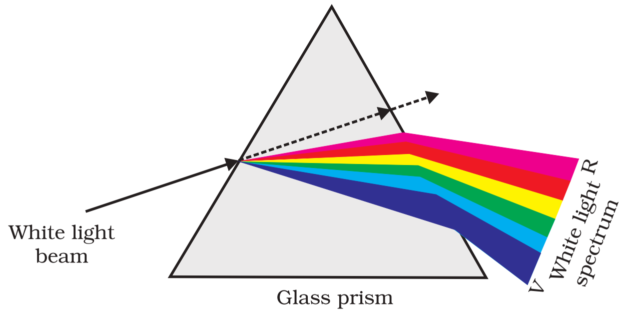


Figure 10.5 *Dispersion of white light by the glass prism*

You have seen that white light is dispersed into its seven-colour components by a prism. Why do we get these colours? Different colours of light bend through different angles with respect to the incident ray, as they pass through a prism. The red light bends the least while the violet the most. Thus the rays of each colour emerge along different paths and thus become distinct. It is the band of distinct colours that we see in a spectrum.

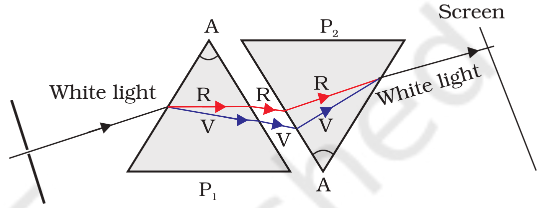


Figure 10.6 *Recombination of the spectrum of white light*

Isaac Newton was the first to use a glass prism to obtain the spectrum of sunlight. He tried to split the colours of the spectrum of white light further by using another similar prism. However, he could not get any more colours. He then placed a second identical prism in an inverted position with respect to the first prism, as shown in Fig. 10.6. This allowed all the colours of the spectrum to pass through the second prism. He found a beam of white light emerging from the other side of the second prism. This observation gave Newton the idea that the sunlight is made up of seven colours.


Figure 10.7 *Rainbow in the sky*

Any light that gives a spectrum similar to that of sunlight is often referred to as white light.

A rainbow is a natural spectrum appearing in the sky after a rain shower (Fig. 10.7). It is caused by dispersion of sunlight by tiny water droplets, present in the atmosphere. A rainbow is always formed in a direction opposite to that of the Sun. The water droplets act like small prisms. They refract and disperse the incident sunlight, then reflect it internally, and finally refract it again when it comes out of the raindrop (Fig. 10.8). Due to the dispersion of light and internal reflection, different colours reach the observer's eye.

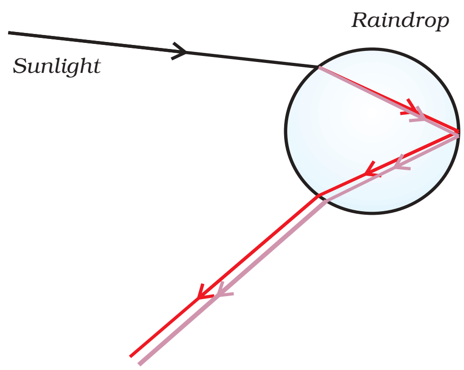


Figure 10.8 *Rainbow formation*

You can also see a rainbow on a sunny day when you look at the sky through a waterfall or through a water fountain, with the Sun behind you.

10.5 ATMOSPHERIC REFRACTION

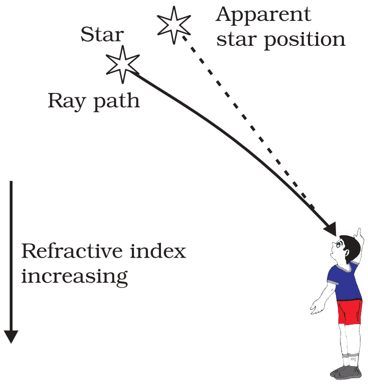


Figure 10.9
Apparent star position due to atmospheric refraction

You might have observed the apparent random wavering or flickering of objects seen through a turbulent stream of hot air rising above a fire or a radiator. The air just above the fire becomes hotter than the air further up. The hotter air is lighter (less dense) than the cooler air above it, and has a refractive index slightly less than that of the cooler air. Since the physical conditions of the refracting medium (air) are not stationary, the apparent position of the object, as seen through the hot air, fluctuates. This wavering is thus an effect of atmospheric refraction (refraction of light by the earth's atmosphere) on a small scale in our local environment. The twinkling of stars is a similar phenomenon on a much larger scale. Let us see how we can explain it.

Twinkling of stars

The twinkling of a star is due to atmospheric refraction of starlight. The starlight, on entering the earth's atmosphere, undergoes refraction continuously before it reaches the earth. The atmospheric refraction occurs in a medium of gradually changing refractive index. Since the atmosphere bends starlight towards the normal, the apparent position of the star is slightly different from its actual position. The star appears slightly higher (above) than its actual position when viewed near the horizon (Fig. 10.9). Further, this apparent position of the star is not stationary, but keeps on changing slightly, since the physical conditions of the earth's atmosphere are not stationary, as was the case in the previous paragraph. Since the stars are very distant, they approximate point-sized sources of light. As the path of rays of light coming from the star goes on varying slightly, the apparent position of the star fluctuates and the amount of starlight entering the eye flickers – the star sometimes appears brighter, and at some other time, fainter, which is the twinkling effect.

Why don't the planets twinkle? The planets are much closer to the earth, and are thus seen as extended sources. If we consider a planet as a collection of a large number of point-sized sources of light, the total variation in the amount of light entering our eye from all the individual point-sized sources will average out to zero, thereby nullifying the twinkling effect.

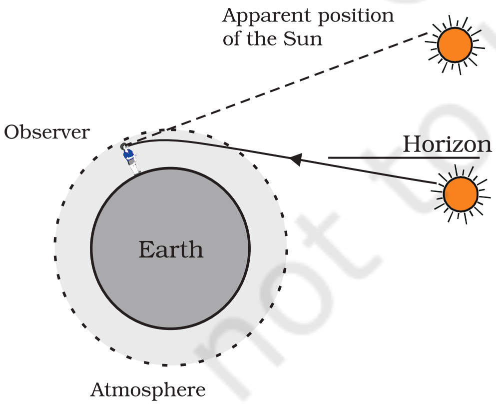


Figure 10.10
Atmospheric refraction effects at sunrise and sunset

Advance sunrise and delayed sunset

The Sun is visible to us about 2 minutes before the actual sunrise, and about 2 minutes after the actual sunset because of atmospheric refraction. By actual sunrise, we mean the actual crossing of the horizon by the Sun. Fig. 10.10 shows the actual and apparent positions of the Sun with respect to the horizon. The time difference between actual sunset and the apparent sunset is about 2 minutes. The apparent flattening of the Sun's disc at sunrise and sunset is also due to the same phenomenon.

10.6 SCATTERING OF LIGHT

The interplay of light with objects around us gives rise to several spectacular phenomena in nature. The blue colour of the sky, colour of water in deep sea, the reddening of the sun at sunrise and the sunset are some of the wonderful phenomena we are familiar with. In the previous class, you have learnt about the scattering of light by colloidal particles. The path of a beam of light passing through a true solution is not visible. However, its path becomes visible through a colloidal solution where the size of the particles is relatively larger.

10.6.1 Tyndall Effect

The earth's atmosphere is a heterogeneous mixture of minute particles. These particles include smoke, tiny water droplets, suspended particles of dust and molecules of air. When a beam of light strikes such fine particles, the path of the beam becomes visible. The light reaches us, after being reflected diffusely by these particles. The phenomenon of scattering of light by the colloidal particles gives rise to Tyndall effect which you have studied in Class IX. This phenomenon is seen when a fine beam of sunlight enters a smoke-filled room through a small hole. Thus, scattering of light makes the particles visible. Tyndall effect can also be observed when sunlight passes through a canopy of a dense forest. Here, tiny water droplets in the mist scatter light.

The colour of the scattered light depends on the size of the scattering particles. Very fine particles scatter mainly blue light while particles of larger size scatter light of longer wavelengths. If the size of the scattering particles is large enough, then, the scattered light may even appear white.

10.6.2 Why is the colour of the clear Sky Blue?

The molecules of air and other fine particles in the atmosphere have size smaller than the wavelength of visible light. These are more effective in scattering light of shorter wavelengths at the blue end than light of longer wavelengths at the red end. The red light has a wavelength about 1.8 times greater than blue light. Thus, when sunlight passes through the atmosphere, the fine particles in air scatter the blue colour (shorter wavelengths) more strongly than red. The scattered blue light enters our eyes. If the earth had no atmosphere, there would not have been any scattering. Then, the sky would have looked dark. The sky appears dark to passengers flying at very high altitudes, as scattering is not prominent at such heights.

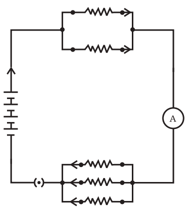
You might have observed that 'danger' signal lights are red in colour. Do you know why? The red is least scattered by fog or smoke. Therefore, it can be seen in the same colour at a distance.

What you have learnt

- The ability of the eye to focus on both near and distant objects, by adjusting its focal length, is called the accommodation of the eye.
- The smallest distance, at which the eye can see objects clearly without strain, is called the near point of the eye or the least distance of distinct vision. For a young adult with normal vision, it is about 25 cm.
- The common refractive defects of vision include myopia, hypermetropia and presbyopia. Myopia (short-sightedness – the image of distant objects is focussed before the retina) is corrected by using a concave lens of suitable power. Hypermetropia (far-sightedness – the image of nearby objects is focussed beyond the retina) is corrected by using a convex lens of suitable power. The eye loses its power of accommodation at old age.
- The splitting of white light into its component colours is called dispersion.
- Scattering of light causes the blue colour of sky.

EXERCISES

1. The human eye can focus on objects at different distances by adjusting the focal length of the eye lens. This is due to
   (a) presbyopia. (b) accommodation.
   (c) near-sightedness. (d) far-sightedness.
2. The human eye forms the image of an object at its
   (a) cornea. (b) iris. (c) pupil. (d) retina.
3. The least distance of distinct vision for a young adult with normal vision is about
   (a) 25 m. (b) 2.5 cm. (c) 25 cm. (d) 2.5 m.
4. The change in focal length of an eye lens is caused by the action of the
   (a) pupil. (b) retina. (c) ciliary muscles. (d) iris.
5. A person needs a lens of power –5.5 dioptres for correcting his distant vision. For correcting his near vision he needs a lens of power +1.5 dioptre. What is the focal length of the lens required for correcting (i) distant vision, and (ii) near vision?
6. The far point of a myopic person is 80 cm in front of the eye. What is the nature and power of the lens required to correct the problem?
7. Make a diagram to show how hypermetropia is corrected. The near point of a hypermetropic eye is 1 m. What is the power of the lens required to correct this defect? Assume that the near point of the normal eye is 25 cm.
8. Why is a normal eye not able to see clearly the objects placed closer than 25 cm?
9. What happens to the image distance in the eye when we increase the distance of an object from the eye?
10. Why do stars twinkle?
11. Explain why the planets do not twinkle.
12. Why does the sky appear dark instead of blue to an astronaut?



CHAPTER 11
Electricity

1064CH12

Electricity has an important place in modern society. It is a controllable and convenient form of energy for a variety of uses in homes, schools, hospitals, industries and so on. What constitutes electricity? How does it flow in an electric circuit? What are the factors that control or regulate the current through an electric circuit? In this Chapter, we shall attempt to answer such questions. We shall also discuss the heating effect of electric current and its applications.

11.1 ELECTRIC CURRENT AND CIRCUIT

We are familiar with air current and water current. We know that flowing water constitute water current in rivers. Similarly, if the electric charge flows through a conductor (for example, through a metallic wire), we say that there is an electric current in the conductor. In a torch, we know that the cells (or a battery, when placed in proper order) provide flow of charges or an electric current through the torch bulb to glow. We have also seen that the torch gives light only when its switch is *on*. What does a switch do? A switch makes a conducting link between the cell and the bulb. A continuous and closed path of an electric current is called an electric circuit. Now, if the circuit is broken anywhere (or the switch of the torch is turned *off*), the current stops flowing and the bulb does not glow.

How do we express electric current? Electric current is expressed by the amount of charge flowing through a particular area in unit time. In other words, it is the rate of flow of electric charges. In circuits using metallic wires, electrons constitute the flow of charges. However, electrons were not known at the time when the phenomenon of electricity was first observed. So, electric current was considered to be the flow of positive charges and the direction of flow of positive charges was taken to be the direction of electric current. Conventionally, in an electric circuit the direction of electric current is taken as opposite to the direction of the flow of electrons, which are negative charges.

If a net charge Q, flows across any cross-section of a conductor in time t, then the current I, through the cross-section is

$$I = \frac{Q}{t} \tag{11.1}$$

The SI unit of electric charge is coulomb (C), which is equivalent to the charge contained in nearly 6×10^{18} electrons. (We know that an electron possesses a negative charge of 1.6×10^{-19} C.) The electric current is expressed by a unit called ampere (A), named after the French scientist, Andre-Marie Ampere (1775–1836). One ampere is constituted by the flow of one coulomb of charge per second, that is, 1 A = 1 C/1 s. Small quantities of current are expressed in milliampere (1 mA = 10^{-3} A) or in microampere (1 μA = 10^{-6} A). An instrument called ammeter measures electric current in a circuit. It is always connected in series in a circuit through which the current is to be measured. Figure 11.1 shows the schematic diagram of a typical electric circuit comprising a cell, an electric bulb, an ammeter and a plug key. Note that the electric current flows in the circuit from the positive terminal of the cell to the negative terminal of the cell through the bulb and ammeter.

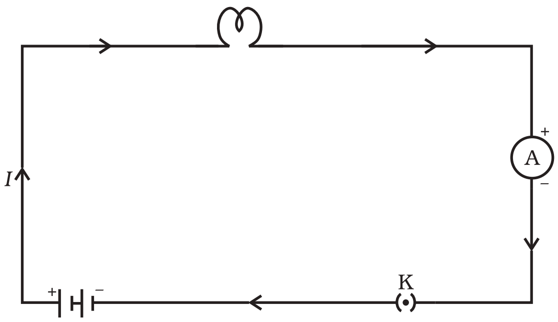


Figure 11.1
A schematic diagram of an electric circuit comprising – cell, electric bulb, ammeter and plug key

Example 11.1
A current of 0.5 A is drawn by a filament of an electric bulb for 10 minutes. Find the amount of electric charge that flows through the circuit.

Solution
We are given, $I = 0.5$ A; $t = 10$ min = 600 s.
From Eq. (11.1), we have

$$\begin{aligned} Q &= It \\ &= 0.5\text{ A} \times 600\text{ s} \\ &= 300\text{ C} \end{aligned}$$

Q U E S T I O N S

1. What does an electric circuit mean?
2. Define the unit of current.
3. Calculate the number of electrons constituting one coulomb of charge.

11.2 ELECTRIC POTENTIAL AND POTENTIAL DIFFERENCE

What makes the electric charge to flow? Let us consider the analogy of flow of water. Charges do not flow in a copper wire by themselves, just as water in a perfectly horizontal tube does not flow. If one end of the tube is connected to a tank of water kept at a higher level, such that there is a pressure difference between the two ends of the tube, water flows out of the other end of the tube. For flow of charges in a conducting metallic wire, the gravity, of course, has no role to play; the electrons move only if there is a difference of electric pressure – called the *potential difference* – along the conductor. This difference of potential may be produced by a battery, consisting of one or more electric cells. The chemical action within a cell generates the potential difference across the terminals of the cell, even when no current is drawn from it. When the cell is connected to a conducting circuit element, the potential difference sets the charges in motion in the conductor and produces an electric current. In order to maintain the current in a given electric circuit, the cell has to expend its chemical energy stored in it.

We define the electric potential difference between two points in an electric circuit carrying some current as the work done to move a unit charge from one point to the other –

Potential difference (V) between two points = Work done (W)/Charge (Q)

$$V = W/Q \qquad (11.2)$$

The SI unit of electric potential difference is volt (V), named after Alessandro Volta (1745–1827), an Italian physicist. One volt is the potential difference between two points in a current carrying conductor when 1 joule of work is done to move a charge of 1 coulomb from one point to the other.

Therefore, $1 \text{ volt} = \dfrac{1 \text{ joule}}{1 \text{ coulomb}}$

$$(11.3)$$

$$1 \text{ V} = 1 \text{ J C}^{-1}$$

The potential difference is measured by means of an instrument called the voltmeter. The voltmeter is always connected in parallel across the points between which the potential difference is to be measured.

Example 11.2

How much work is done in moving a charge of 2 C across two points having a potential difference 12 V?

Solution

The amount of charge Q, that flows between two points at potential difference V (= 12 V) is 2 C. Thus, the amount of work W, done in moving the charge [from Eq. (11.2)] is

$$
\begin{aligned}
W &= VQ \\
&= 12\ \mathrm{V} \times 2\ \mathrm{C} \\
&= 24\ \mathrm{J}.
\end{aligned}
$$

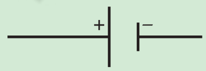
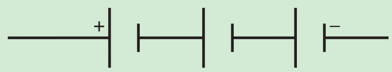
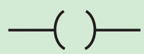
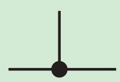
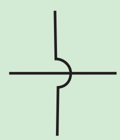
QUESTIONS

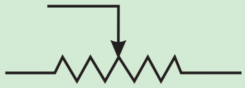
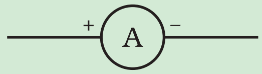
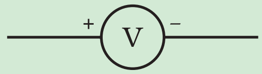
1. Name a device that helps to maintain a potential difference across a conductor.
2. What is meant by saying that the potential difference between two points is 1 V?
3. How much energy is given to each coulomb of charge passing through a 6 V battery?

11.3 CIRCUIT DIAGRAM

We know that an electric circuit, as shown in Fig. 11.1, comprises a cell (or a battery), a plug key, electrical component(s), and connecting wires. It is often convenient to draw a schematic diagram, in which different components of the circuit are represented by the symbols conveniently used. Conventional symbols used to represent some of the most commonly used electrical components are given in Table 11.1.

Table 11.1 Symbols of some commonly used components in circuit diagrams

Sl. No.	Components	Symbols
1	An electric cell	
2	A battery or a combination of cells	
3	Plug key or switch (open)	
4	Plug key or switch (closed)	
5	A wire joint	
6	Wires crossing without joining	

7	Electric bulb	 or 
8	A resistor of resistance *R*	
9	Variable resistance or rheostat	 or 
10	Ammeter	
11	Voltmeter	

11.4 OHM'S LAW

Is there a relationship between the potential difference across a conductor and the current through it? Let us explore with an Activity.

Activity 11.1

- Set up a circuit as shown in Fig. 11.2, consisting of a nichrome wire XY of length, say 0.5 m, an ammeter, a voltmeter and four cells of 1.5 V each. (Nichrome is an alloy of nickel, chromium, manganese, and iron metals.)
- First use only one cell as the source in the circuit. Note the reading in the ammeter *I*, for the current and reading of the voltmeter *V* for the potential difference across the nichrome wire XY in the circuit. Tabulate them in the Table given.

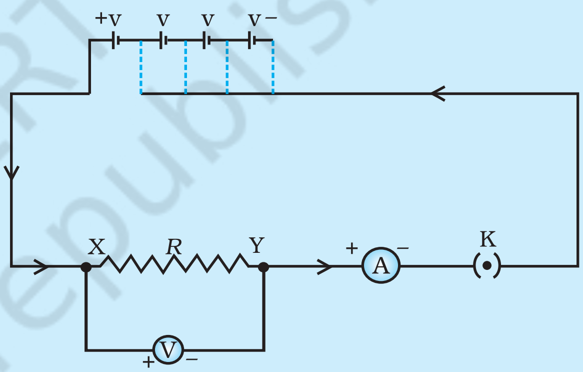


Figure 11.2 *Electric circuit for studying Ohm's law*

- Next connect two cells in the circuit and note the respective readings of the ammeter and voltmeter for the values of current through the nichrome wire and potential difference across the nichrome wire.
- Repeat the above steps using three cells and then four cells in the circuit separately.
- Calculate the ratio of *V* to *I* for each pair of potential difference *V* and current *I*.

S. No.	Number of cells used in the circuit (ampere)	Current through the nichrome wire, *I* wire, *V* (volt)	Potential difference across the nichrome	*V*/*I* (volt/ampere)
1	1			
2	2			
3	3			
4	4			

- Plot a graph between *V* and *I*, and observe the nature of the graph.

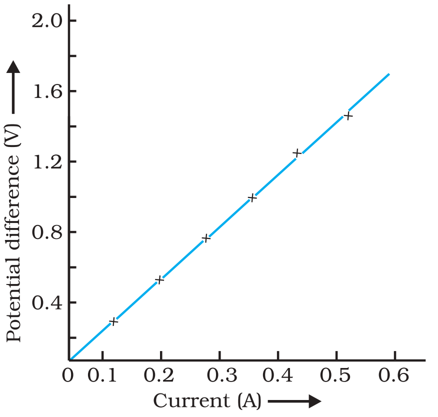


Figure 11.3
V–I graph for a nichrome wire. A straight line plot shows that as the current through a wire increases, the potential difference across the wire increases linearly – this is Ohm's law.

In this Activity, you will find that approximately the same value for V/I is obtained in each case. Thus the V–I graph is a straight line that passes through the origin of the graph, as shown in Fig. 11.3. Thus, V/I is a constant ratio.

In 1827, a German physicist Georg Simon Ohm (1787–1854) found out the relationship between the current I, flowing in a metallic wire and the potential difference across its terminals. The potential difference, V, across the ends of a given metallic wire in an electric circuit is directly proportional to the current flowing through it, provided its temperature remains the same. This is called Ohm's law. In other words –

$$V \propto I \tag{11.4}$$

$$\text{or} \quad V/I = \text{constant} = R$$

$$\text{or} \quad V = IR \tag{11.5}$$

In Eq. (11.4), R is a constant for the given metallic wire at a given temperature and is called its resistance. It is the property of a conductor to resist the flow of charges through it. Its SI unit is ohm, represented by the Greek letter Ω. According to Ohm's law,

$$R = V/I \tag{11.6}$$

If the potential difference across the two ends of a conductor is 1 V and the current through it is 1 A, then the resistance R, of the conductor is 1 Ω. That is, $1 \text{ ohm} = \dfrac{1 \text{ volt}}{1 \text{ ampere}}$

Also from Eq. (11.5) we get

$$I = V/R \tag{11.7}$$

It is obvious from Eq. (11.7) that the current through a resistor is inversely proportional to its resistance. If the resistance is doubled the current gets halved. In many practical cases it is necessary to increase or decrease the current in an electric circuit. A component used to regulate current without changing the voltage source is called variable resistance. In an electric circuit, a device called rheostat is often used to change the resistance in the circuit. We will now study about electrical resistance of a conductor with the help of following Activity.

Activity 11.2

- Take a nichrome wire, a torch bulb, a 10 W bulb and an ammeter (0 – 5 A range), a plug key and some connecting wires.
- Set up the circuit by connecting four dry cells of 1.5 V each in series with the ammeter leaving a gap XY in the circuit, as shown in Fig. 11.4.

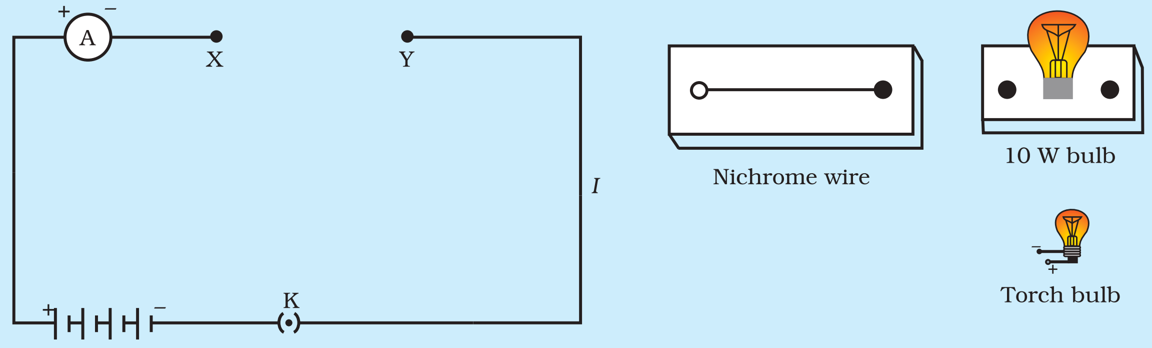


Figure 11.4

- Complete the circuit by connecting the nichrome wire in the gap XY. Plug the key. Note down the ammeter reading. Take out the key from the plug. [Note: *Always take out the key from the plug after measuring the current through the circuit.*]
- Replace the nichrome wire with the torch bulb in the circuit and find the current through it by measuring the reading of the ammeter.
- Now repeat the above step with the 10 W bulb in the gap XY.
- Are the ammeter readings different for different components connected in the gap XY? What do the above observations indicate?
- You may repeat this Activity by keeping any material component in the gap. Observe the ammeter readings in each case. Analyse the observations.

In this Activity we observe that the current is different for different components. Why do they differ? Certain components offer an easy path for the flow of electric current while the others resist the flow. We know that motion of electrons in an electric circuit constitutes an electric current. The electrons, however, are not completely free to move within a conductor. They are restrained by the attraction of the atoms among which they move. Thus, motion of electrons through a conductor is retarded by its resistance. A component of a given size that offers a low resistance is a good conductor. A conductor having some appreciable resistance is called a resistor. A component of identical size that offers a higher resistance is a poor conductor. An insulator of the same size offers even higher resistance.

11.5 FACTORS ON WHICH THE RESISTANCE OF A CONDUCTOR DEPENDS

Activity 11.3

- Complete an electric circuit consisting of a cell, an ammeter, a nichrome wire of length l [say, marked (1)] and a plug key, as shown in Fig. 11.5.

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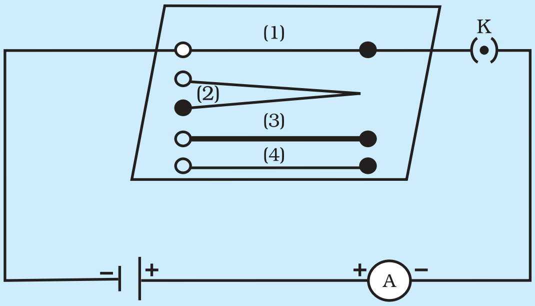

Figure 11.5 *Electric circuit to study the factors on which the resistance of conducting wires depends*

- Now, plug the key. Note the current in the ammeter.
- Replace the nichrome wire by another nichrome wire of same thickness but twice the length, that is $2l$ [marked (2) in the Fig. 11.5].
- Note the ammeter reading.
- Now replace the wire by a thicker nichrome wire, of the same length l [marked (3)]. A thicker wire has a larger cross-sectional area. Again note down the current through the circuit.
- Instead of taking a nichrome wire, connect a copper wire [marked (4) in Fig. 11.5] in the circuit. Let the wire be of the same length and same area of cross-section as that of the first nichrome wire [marked (1)]. Note the value of the current.
- Notice the difference in the current in all cases.
- Does the current depend on the length of the conductor?
- Does the current depend on the area of cross-section of the wire used?

It is observed that the ammeter reading decreases to one-half when the length of the wire is doubled. The ammeter reading is increased when a thicker wire of the same material and of the same length is used in the circuit. A change in ammeter reading is observed when a wire of different material of the same length and the same area of cross-section is used. On applying Ohm's law [Eqs. (11.5) – (11.7)], we observe that the resistance of the conductor depends (i) on its length, (ii) on its area of cross-section, and (iii) on the nature of its material. Precise measurements have shown that resistance of a uniform metallic conductor is directly proportional to its length (l) and inversely proportional to the area of cross-section (A). That is,

$$R \propto l \qquad (11.8)$$

and $$R \propto 1/A \qquad (11.9)$$

Combining Eqs. (11.8) and (11.9) we get

$$R \propto \frac{l}{A}$$

or, $$R = \rho \frac{l}{A} \qquad (11.10)$$

where ρ (rho) is a constant of proportionality and is called the electrical resistivity of the material of the conductor. The SI unit of resistivity is Ω m. It is a characteristic property of the material. The metals and alloys have very low resistivity in the range of 10^{-8} Ω m to 10^{-6} Ω m. They are good conductors of electricity. Insulators like rubber and glass have resistivity of the order of 10^{12} to 10^{17} Ω m. Both the resistance and resistivity of a material vary with temperature.

Table 11.2 reveals that the resistivity of an alloy is generally higher than that of its constituent metals. Alloys do not oxidise (burn) readily at high temperatures. For this reason, they are commonly used in electrical heating devices, like electric iron, toasters etc. Tungsten is used almost exclusively for filaments of electric bulbs, whereas copper and aluminium are generally used for electrical transmission lines.

Table 11.2 Electrical resistivity* of some substances at 20°C

	Material	Resistivity (Ω m)
Conductors	Silver	1.60×10^{-8}
	Copper	1.62×10^{-8}
	Aluminium	2.63×10^{-8}
	Tungsten	5.20×10^{-8}
	Nickel	6.84×10^{-8}
	Iron	10.0×10^{-8}
	Chromium	12.9×10^{-8}
	Mercury	94.0×10^{-8}
	Manganese	1.84×10^{-6}
Alloys	Constantan (alloy of Cu and Ni)	49×10^{-6}
	Manganin (alloy of Cu, Mn and Ni)	44×10^{-6}
	Nichrome (alloy of Ni, Cr, Mn and Fe)	100×10^{-6}
Insulators	Glass	$10^{10} - 10^{14}$
	Hard rubber	$10^{13} - 10^{16}$
	Ebonite	$10^{15} - 10^{17}$
	Diamond	$10^{12} - 10^{13}$
	Paper (dry)	10^{12}

* *You need not memorise these values. You can use these values for solving numerical problems.*

Example 11.3

(a) How much current will an electric bulb draw from a 220 V source, if the resistance of the bulb filament is 1200 Ω? (b) How much current will an electric heater coil draw from a 220 V source, if the resistance of the heater coil is 100 Ω?

Solution

(a) We are given $V = 220$ V; $R = 1200$ Ω.
From Eq. (12.6), we have the current $I = 220$ V/1200 Ω = 0.18 A.

(b) We are given, $V = 220$ V, $R = 100$ Ω.
From Eq. (11.6), we have the current $I = 220$ V/100 Ω = 2.2 A.

Note the difference of current drawn by an electric bulb and electric heater from the same 220 V source!

Example 11.4

The potential difference between the terminals of an electric heater is 60 V when it draws a current of 4 A from the source. What current will the heater draw if the potential difference is increased to 120 V?

Solution

We are given, potential difference V = 60 V, current I = 4 A.

According to Ohm's law, $R = \dfrac{V}{I} = \dfrac{60\ \text{V}}{4\ \text{A}} = 15\ \Omega$.

When the potential difference is increased to 120 V the current is given by

$$\text{current} = \frac{V}{R} = \frac{120\ \text{V}}{15\ \Omega} = 8\ \text{A}.$$

The current through the heater becomes 8 A.

Example 11.5

Resistance of a metal wire of length 1 m is 26 Ω at 20°C. If the diameter of the wire is 0.3 mm, what will be the resistivity of the metal at that temperature? Using Table 11.2, predict the material of the wire.

Solution

We are given the resistance R of the wire = 26 Ω, the diameter d = 0.3 mm = 3×10^{-4} m, and the length l of the wire = 1 m.

Therefore, from Eq. (11.10), the resistivity of the given metallic wire is

$$\rho = (RA/l) = (R\pi d^2/4l)$$

Substitution of values in this gives

$$\rho = 1.84 \times 10^{-6}\ \Omega\ \text{m}$$

The resistivity of the metal at 20°C is 1.84×10^{-6} Ω m. From Table 11.2, we see that this is the resistivity of manganese.

Example 11.6

A wire of given material having length l and area of cross-section A has a resistance of 4 Ω. What would be the resistance of another wire of the same material having length $l/2$ and area of cross-section $2A$?

Solution

For first wire

$$R_1 = \rho \frac{l}{A} = 4\Omega$$

Now for second wire

$$R_2 = \rho \frac{l/2}{2A} = \frac{1}{4} \rho \frac{l}{A}$$

$$R_2 = \frac{1}{4} R_1$$

$$R_2 = 1\Omega$$

The resistance of the new wire is 1Ω.

Q U E S T I O N S

1. On what factors does the resistance of a conductor depend?
2. Will current flow more easily through a thick wire or a thin wire of the same material, when connected to the same source? Why?
3. Let the resistance of an electrical component remains constant while the potential difference across the two ends of the component decreases to half of its former value. What change will occur in the current through it?
4. Why are coils of electric toasters and electric irons made of an alloy rather than a pure metal?
5. Use the data in Table 11.2 to answer the following –
   (a) Which among iron and mercury is a better conductor?
   (b) Which material is the best conductor?

11.6 RESISTANCE OF A SYSTEM OF RESISTORS

In preceding sections, we learnt about some simple electric circuits. We have noticed how the current through a conductor depends upon its resistance and the potential difference across its ends. In various electrical gadgets, we often use resistors in various combinations. We now therefore intend to see how Ohm's law can be applied to combinations of resistors.

There are two methods of joining the resistors together. Figure 11.6 shows an electric circuit in which three resistors having resistances R_1, R_2 and R_3, respectively, are joined end to end. Here the resistors are said to be connected in series.

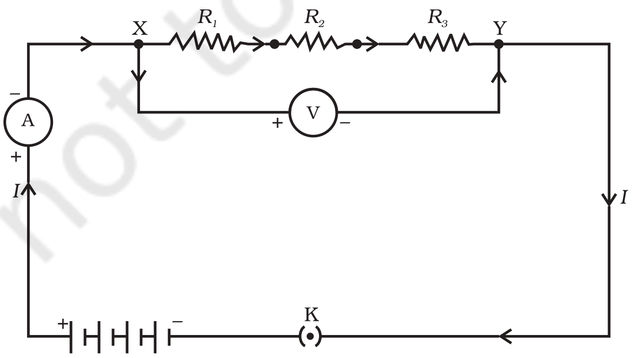

Figure 11.6 *Resistors in series*

Figure 11.7 shows a combination of resistors in which three resistors are connected together between points X and Y. Here, the resistors are said to be connected in parallel.

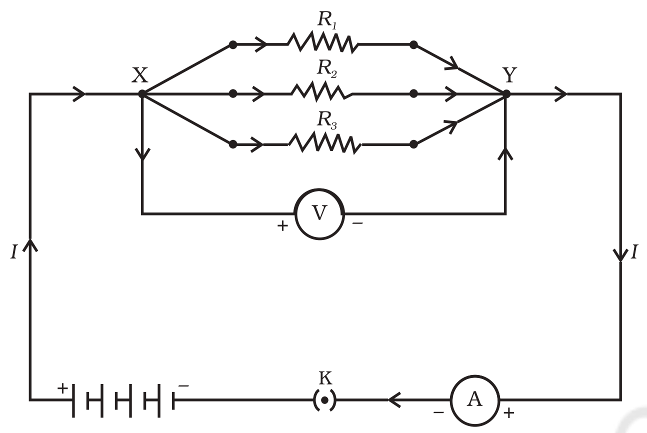

Figure 11.7 *Resistors in parallel*

11.6.1 Resistors in Series

What happens to the value of current when a number of resistors are connected in series in a circuit? What would be their equivalent resistance? Let us try to understand these with the help of the following activities.

Activity 11.4

- Join three resistors of different values in series. Connect them with a battery, an ammeter and a plug key, as shown in Fig. 11.6. You may use the resistors of values like 1 Ω, 2 Ω, 3 Ω etc., and a battery of 6 V for performing this Activity.
- Plug the key. Note the ammeter reading.
- Change the position of ammeter to anywhere in between the resistors. Note the ammeter reading each time.
- Do you find any change in the value of current through the ammeter?

You will observe that the value of the current in the ammeter is the same, independent of its position in the electric circuit. It means that in a series combination of resistors the current is the same in every part of the circuit or the same current through each resistor.

Activity 11.5

- In Activity 11.4, insert a voltmeter across the ends X and Y of the series combination of three resistors, as shown in Fig. 11.6.
- Plug the key in the circuit and note the voltmeter reading. It gives the potential difference across the series combination of resistors. Let it be *V*. Now measure the potential difference across the two terminals of the battery. Compare the two values.
- Take out the plug key and disconnect the voltmeter. Now insert the voltmeter across the ends X and P of the first resistor, as shown in Fig. 11.8.

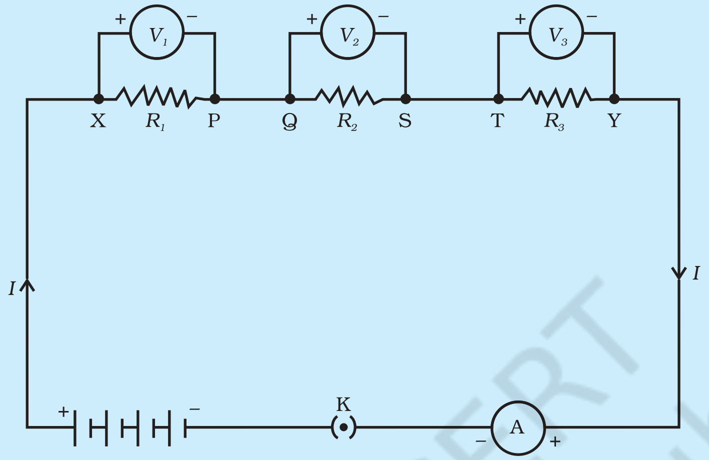

Figure 11.8

- Plug the key and measure the potential difference across the first resistor. Let it be V_1.
- Similarly, measure the potential difference across the other two resistors, separately. Let these values be V_2 and V_3, respectively.
- Deduce a relationship between V, V_1, V_2 and V_3.

You will observe that the potential difference *V* is equal to the sum of potential differences V_1, V_2, and V_3. That is the total potential difference across a combination of resistors in series is equal to the sum of potential difference across the individual resistors. That is,

$$V = V_1 + V_2 + V_3 \tag{11.11}$$

In the electric circuit shown in Fig. 11.8, let *I* be the current through the circuit. The current through each resistor is also *I*. It is possible to replace the three resistors joined in series by an equivalent single resistor of resistance *R*, such that the potential difference *V* across it, and the current *I* through the circuit remains the same. Applying the Ohm's law to the entire circuit, we have

$$V = I R \tag{11.12}$$

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On applying Ohm's law to the three resistors separately, we further have

$$V_1 = I R_1 \quad [11.13(a)]$$

$$V_2 = I R_2 \quad [11.13(b)]$$

and $$V_3 = I R_3 \quad [11.13(c)]$$

From Eq. (11.11),

$$I R = I R_1 + I R_2 + I R_3$$

or

$$R_s = R_1 + R_2 + R_3 \quad (11.14)$$

We can conclude that when several resistors are joined in series, the resistance of the combination R_s equals the sum of their individual resistances, R_1, R_2, R_3, and is thus greater than any individual resistance.

Example 11.7

An electric lamp, whose resistance is 20 Ω, and a conductor of 4 Ω resistance are connected to a 6 V battery (Fig. 11.9). Calculate (a) the total resistance of the circuit, (b) the current through the circuit, and (c) the potential difference across the electric lamp and conductor.

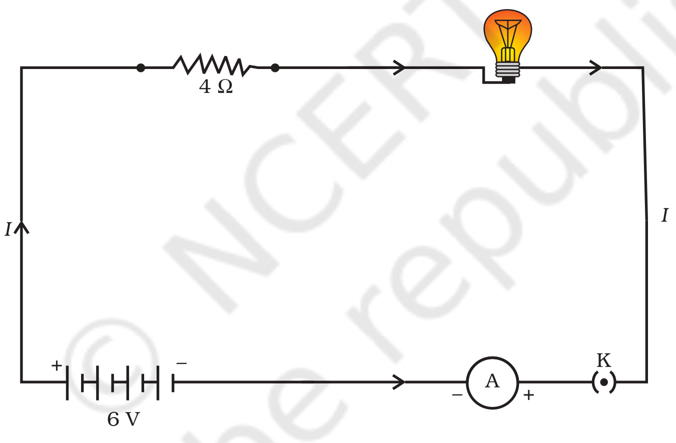


Figure 11.9 *An electric lamp connected in series with a resistor of 4 Ω to a 6 V battery*

Solution

The resistance of electric lamp, R_1 = 20 Ω,
The resistance of the conductor connected in series, R_2 = 4 Ω.
Then the total resistance in the circuit

$$R = R_1 + R_2$$

$$R_s = 20\ \Omega + 4\ \Omega = 24\ \Omega.$$

The total potential difference across the two terminals of the battery V = 6 V.

Now by Ohm's law, the current through the circuit is given by

$$I = V/R_s = 6\ \text{V}/24\ \Omega = 0.25\ \text{A}.$$

Applying Ohm's law to the electric lamp and conductor separately, we get potential difference across the electric lamp,

$V_1 = 20\ \Omega \times 0.25\ \text{A}$
$= 5\ \text{V};$

and,

that across the conductor, $V_2 = 4\ \Omega \times 0.25\ \text{A}$
$= 1\ \text{V}.$

Suppose that we like to replace the series combination of electric lamp and conductor by a single and equivalent resistor. Its resistance must be such that a potential difference of 6 V across the battery terminals will cause a current of 0.25 A in the circuit. The resistance R of this equivalent resistor would be

$R = V/I$
$= 6\ \text{V}/\ 0.25\ \text{A}$
$= 24\ \Omega.$

This is the total resistance of the series circuit; it is equal to the sum of the two resistances.

QUESTIONS

1. Draw a schematic diagram of a circuit consisting of a battery of three cells of 2 V each, a 5 Ω resistor, an 8 Ω resistor, and a 12 Ω resistor, and a plug key, all connected in series.
2. Redraw the circuit of Question 1, putting in an ammeter to measure the current through the resistors and a voltmeter to measure the potential difference across the 12 Ω resistor. What would be the readings in the ammeter and the voltmeter?

11.6.2 Resistors in Parallel

Now, let us consider the arrangement of three resistors joined in parallel with a combination of cells (or a battery), as shown in Fig.11.7.

Activity 11.6

- Make a parallel combination, XY, of three resistors having resistances R_1, R_2, and R_3, respectively. Connect it with a battery, a plug key and an ammeter, as shown in Fig. 11.10. Also connect a voltmeter in parallel with the combination of resistors.
- Plug the key and note the ammeter reading. Let the current be I. Also take the voltmeter reading. It gives the potential difference V, across the combination. The potential difference across each resistor is also V. This can be checked by connecting the voltmeter across each individual resistor (see Fig. 11.11).

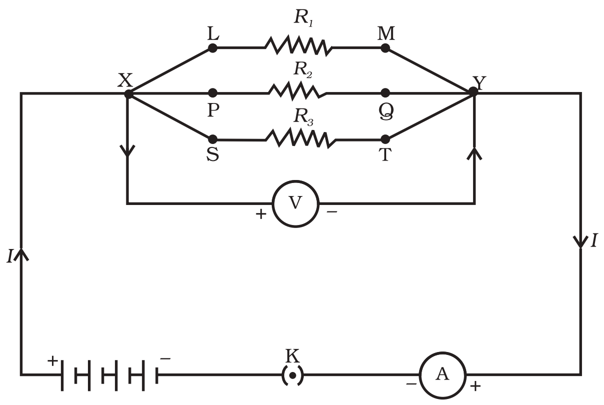


Figure 11.10

2024-25

- Take out the plug from the key. Remove the ammeter and voltmeter from the circuit. Insert the ammeter in series with the resistor R_1, as shown in Fig. 11.11. Note the ammeter reading, I_1.

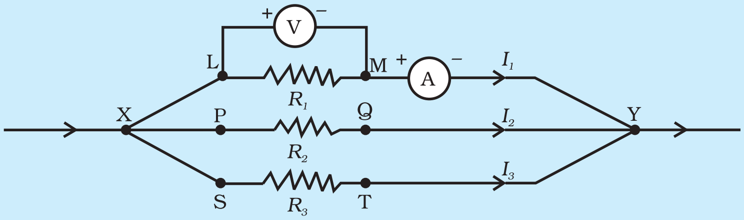


Figure 11.11

- Similarly, measure the currents through R_2 and R_3. Let these be I_2 and I_3, respectively. What is the relationship between I, I_1, I_2 and I_3?

It is observed that the total current I, is equal to the sum of the separate currents through each branch of the combination.

$$I = I_1 + I_2 + I_3 \tag{11.15}$$

Let R_p be the equivalent resistance of the parallel combination of resistors. By applying Ohm's law to the parallel combination of resistors, we have

$$I = V/R_p \tag{11.16}$$

On applying Ohm's law to each resistor, we have

$$I_1 = V/R_1; \quad I_2 = V/R_2; \text{ and } I_3 = V/R_3 \tag{11.17}$$

From Eqs. (11.15) to (11.17), we have

$$V/R_p = V/R_1 + V/R_2 + V/R_3$$

or

$$1/R_p = 1/R_1 + 1/R_2 + 1/R_3 \tag{11.18}$$

Thus, we may conclude that the reciprocal of the equivalent resistance of a group of resistances joined in parallel is equal to the sum of the reciprocals of the individual resistances.

Example 11.8

In the circuit diagram given in Fig. 11.10, suppose the resistors R_1, R_2 and R_3 have the values 5 Ω, 10 Ω, 30 Ω, respectively, which have been connected to a battery of 12 V. Calculate (a) the current through each resistor, (b) the total current in the circuit, and (c) the total circuit resistance.

Solution

R_1 = 5 Ω, R_2 = 10 Ω, and R_3 = 30 Ω.

Potential difference across the battery, V = 12 V.

This is also the potential difference across each of the individual resistor; therefore, to calculate the current in the resistors, we use Ohm's law.

The current I_1, through R_1 = V/R_1

I_1 = 12 V/5 Ω = 2.4 A.

The current I_2, through R_2 = V/R_2

I_2 = 12 V/10 Ω = 1.2 A.

The current I_3, through R_3 = V/R_3

I_3 = 12 V/30 Ω = 0.4 A.

The total current in the circuit,

$$I = I_1 + I_2 + I_3$$
$$= (2.4 + 1.2 + 0.4) \text{ A}$$
$$= 4 \text{ A}$$

The total resistance R_p, is given by [Eq. (11.18)]

$$\frac{1}{R_p} = \frac{1}{5} + \frac{1}{10} + \frac{1}{30} = \frac{1}{3}$$

Thus, $R_p = 3\ \Omega$.

Example 11.9

If in Fig. 11.12, $R_1 = 10\ \Omega$, $R_2 = 40\ \Omega$, $R_3 = 30\ \Omega$, $R_4 = 20\ \Omega$, $R_5 = 60\ \Omega$, and a 12 V battery is connected to the arrangement. Calculate (a) the total resistance in the circuit, and (b) the total current flowing in the circuit.

Solution

Suppose we replace the parallel resistors R_1 and R_2 by an equivalent resistor of resistance, R'. Similarly we replace the parallel resistors R_3, R_4 and R_5 by an equivalent single resistor of resistance R''. Then using Eq. (11.18), we have

$1/R' = 1/10 + 1/40 = 5/40$; that is $R' = 8\ \Omega$.

Similarly, $1/R'' = 1/30 + 1/20 + 1/60 = 6/60$;

that is, $R'' = 10\ \Omega$.

Thus, the total resistance, $R = R' + R'' = 18\ \Omega$.

To calculate the current, we use Ohm's law, and get

$I = V/R = 12\text{ V}/18\ \Omega = 0.67$ A.

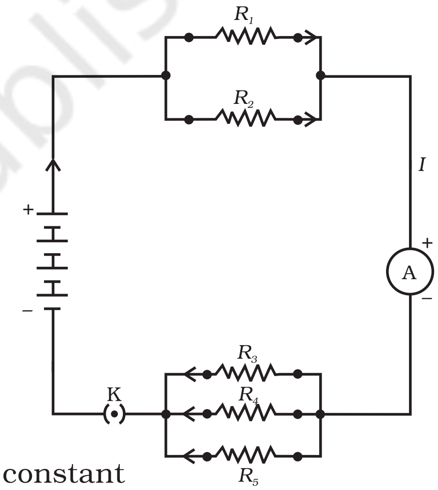


Figure 11.12
An electric circuit showing the combination of series and parallel resistors

We have seen that in a series circuit the current is constant throughout the electric circuit. Thus it is obviously impracticable to connect an electric bulb and an electric heater in series, because they need currents of widely different values to operate properly (see Example 11.3). Another major disadvantage of a series circuit is that when one component fails the circuit is broken and none of the components works. If you have used 'fairy lights' to decorate buildings on festivals, on marriage celebrations etc., you might have seen the electrician spending lot of time in trouble-locating and replacing the 'dead' bulb – each has to be tested to find which has fused or gone. On the other hand, a parallel circuit divides the current through the electrical gadgets. The total resistance in a parallel circuit is decreased as per Eq. (11.18). This is helpful particularly when each gadget has different resistance and requires different current to operate properly.

QUESTIONS

1. Judge the equivalent resistance when the following are connected in parallel – (a) 1 Ω and 10^6 Ω, (b) 1 Ω and 10^3 Ω, and 10^6 Ω.
2. An electric lamp of 100 Ω, a toaster of resistance 50 Ω, and a water filter of resistance 500 Ω are connected in parallel to a 220 V source. What is the resistance of an electric iron connected to the same source that takes as much current as all three appliances, and what is the current through it?
3. What are the advantages of connecting electrical devices in parallel with the battery instead of connecting them in series?
4. How can three resistors of resistances 2 Ω, 3 Ω, and 6 Ω be connected to give a total resistance of (a) 4 Ω, (b) 1 Ω?
5. What is (a) the highest, (b) the lowest total resistance that can be secured by combinations of four coils of resistance 4 Ω, 8 Ω, 12 Ω, 24 Ω?

11.7 HEATING EFFECT OF ELECTRIC CURRENT

We know that a battery or a cell is a source of electrical energy. The chemical reaction within the cell generates the potential difference between its two terminals that sets the electrons in motion to flow the current through a resistor or a system of resistors connected to the battery. We have also seen, in Section 11.2, that to maintain the current, the source has to keep expending its energy. Where does this energy go? A part of the source energy in maintaining the current may be consumed into useful work (like in rotating the blades of an electric fan). Rest of the source energy may be expended in heat to raise the temperature of gadget. We often observe this in our everyday life. For example, an electric fan becomes warm if used continuously for longer time etc. On the other hand, if the electric circuit is purely resistive, that is, a configuration of resistors only connected to a battery; the source energy continually gets dissipated entirely in the form of heat. This is known as the heating effect of electric current. This effect is utilised in devices such as electric heater, electric iron etc.

Consider a current I flowing through a resistor of resistance R. Let the potential difference across it be V (Fig. 11.13). Let t be the time during which a charge Q flows across. The work done in moving the charge Q through a potential difference V is VQ. Therefore, the source must supply energy equal to VQ in time t. Hence the power input to the circuit by the source is

$$P = V\frac{Q}{t} = VI \tag{11.19}$$

Or the energy supplied to the circuit by the source in time t is $P \times t$, that is, VIt. What happens to this energy expended by the source? This energy gets dissipated in the resistor as heat. Thus for a steady current I, the amount of heat H produced in time t is

$$H = VIt \tag{11.20}$$

Applying Ohm's law [Eq. (11.5)], we get

$$H = I^2 Rt \qquad (11.21)$$

This is known as Joule's law of heating. The law implies that heat produced in a resistor is (i) directly proportional to the square of current for a given resistance, (ii) directly proportional to resistance for a given current, and (iii) directly proportional to the time for which the current flows through the resistor. In practical situations, when an electric appliance is connected to a known voltage source, Eq. (11.21) is used after calculating the current through it, using the relation $I = V/R$.

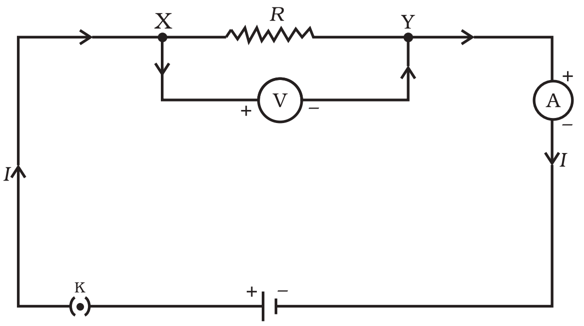


Figure 11.13
A steady current in a purely resistive electric circuit

Example 11.10

An electric iron consumes energy at a rate of 840 W when heating is at the maximum rate and 360 W when the heating is at the minimum. The voltage is 220 V. What are the current and the resistance in each case?

Solution

From Eq. (11.19), we know that the power input is

$P = V\,I$

Thus the current $I = P/V$

(a) When heating is at the maximum rate,
$I = 840\text{ W}/220\text{ V} = 3.82\text{ A}$;
and the resistance of the electric iron is
$R = V/I = 220\text{ V}/3.82\text{ A} = 57.60\ \Omega$.

(b) When heating is at the minimum rate,
$I = 360\text{ W}/220\text{ V} = 1.64\text{ A}$;
and the resistance of the electric iron is
$R = V/I = 220\text{ V}/1.64\text{ A} = 134.15\ \Omega$.

Example 11.11

100 J of heat is produced each second in a 4 Ω resistance. Find the potential difference across the resistor.

Solution

$H = 100\text{ J}$, $R = 4\ \Omega$, $t = 1\text{ s}$, $V = ?$

From Eq. (11.21) we have the current through the resistor as

$$I = \sqrt{(H/Rt)} = \sqrt{[100\text{ J}/(4\ \Omega \times 1\text{ s})]} = 5\text{ A}$$

Thus the potential difference across the resistor, V [from Eq. (11.5)] is

$$V = IR = 5\text{ A} \times 4\ \Omega = 20\text{ V}.$$

QUESTIONS

1. Why does the cord of an electric heater not glow while the heating element does?
2. Compute the heat generated while transferring 96000 coulomb of charge in one hour through a potential difference of 50 V.
3. An electric iron of resistance 20 Ω takes a current of 5 A. Calculate the heat developed in 30 s.

11.7.1 Practical Applications of Heating Effect of Electric Current

The generation of heat in a conductor is an inevitable consequence of electric current. In many cases, it is undesirable as it converts useful electrical energy into heat. In electric circuits, the unavoidable heating can increase the temperature of the components and alter their properties. However, heating effect of electric current has many useful applications. The electric laundry iron, electric toaster, electric oven, electric kettle and electric heater are some of the familiar devices based on Joule's heating.

The electric heating is also used to produce light, as in an electric bulb. Here, the filament must retain as much of the heat generated as is possible, so that it gets very hot and emits light. It must not melt at such high temperature. A strong metal with high melting point such as tungsten (melting point 3380°C) is used for making bulb filaments. The filament should be thermally isolated as much as possible, using insulating support, etc. The bulbs are usually filled with chemically inactive nitrogen and argon gases to prolong the life of filament. Most of the power consumed by the filament appears as heat, but a small part of it is in the form of light radiated.

Another common application of Joule's heating is the fuse used in electric circuits. It protects circuits and appliances by stopping the flow of any unduly high electric current. The fuse is placed in series with the device. It consists of a piece of wire made of a metal or an alloy of appropriate melting point, for example aluminium, copper, iron, lead etc. If a current larger than the specified value flows through the circuit, the temperature of the fuse wire increases. This melts the fuse wire and breaks the circuit. The fuse wire is usually encased in a cartridge of porcelain or similar material with metal ends. The fuses used for domestic purposes are rated as 1 A, 2 A, 3 A, 5 A, 10 A, etc. For an electric iron which consumes 1 kW electric power when operated at 220 V, a current of (1000/220) A, that is, 4.54 A will flow in the circuit. In this case, a 5 A fuse must be used.

11.8 ELECTRIC POWER

You have studied in your earlier Class that the rate of doing work is power. This is also the rate of consumption of energy.

Equation (11.21) gives the rate at which electric energy is dissipated or consumed in an electric circuit. This is also termed as electric power. The power P is given by

$$P = VI$$

Or $$P = I^2R = V^2/R \qquad (11.22)$$

The SI unit of electric power is watt (W). It is the power consumed by a device that carries 1 A of current when operated at a potential difference of 1 V. Thus,

$$1\text{ W} = 1\text{ volt} \times 1\text{ ampere} = 1\text{ V A} \qquad (11.23)$$

The unit 'watt' is very small. Therefore, in actual practice we use a much larger unit called 'kilowatt'. It is equal to 1000 watts. Since electrical energy is the product of power and time, the unit of electric energy is, therefore, watt hour (W h). One watt hour is the energy consumed when 1 watt of power is used for 1 hour. The commercial unit of electric energy is kilowatt hour (kW h), commonly known as 'unit'.

$$\begin{aligned} 1\text{ kW h} &= 1000\text{ watt} \times 3600\text{ second} \\ &= 3.6 \times 10^6\text{ watt second} \\ &= 3.6 \times 10^6\text{ joule (J)} \end{aligned}$$

More to Know!

Many people think that electrons are consumed in an electric circuit. This is wrong! We pay the electricity board or electric company to provide energy to move electrons through the electric gadgets like electric bulb, fan and engines. We pay for the energy that we use.

Example 11.12

An electric bulb is connected to a 220 V generator. The current is 0.50 A. What is the power of the bulb?

Solution

$$\begin{aligned} P &= VI \\ &= 220\text{ V} \times 0.50\text{ A} \\ &= 110\text{ J/s} \\ &= 110\text{ W}. \end{aligned}$$

Example 11.13

An electric refrigerator rated 400 W operates 8 hour/day. What is the cost of the energy to operate it for 30 days at Rs 3.00 per kW h?

Solution

The total energy consumed by the refrigerator in 30 days would be

400 W × 8.0 hour/day × 30 days = 96000 W h

= 96 kW h

Thus the cost of energy to operate the refrigerator for 30 days is

96 kW h × Rs 3.00 per kW h = Rs 288.00

Q U E S T I O N S

1. What determines the rate at which energy is delivered by a current?
2. An electric motor takes 5 A from a 220 V line. Determine the power of the motor and the energy consumed in 2 h.

What you have learnt

- A stream of electrons moving through a conductor constitutes an electric current. Conventionally, the direction of current is taken opposite to the direction of flow of electrons.
- The SI unit of electric current is ampere.
- To set the electrons in motion in an electric circuit, we use a cell or a battery. A cell generates a potential difference across its terminals. It is measured in volts (V).
- Resistance is a property that resists the flow of electrons in a conductor. It controls the magnitude of the current. The SI unit of resistance is ohm (Ω).
- Ohm's law: The potential difference across the ends of a resistor is directly proportional to the current through it, provided its temperature remains the same.
- The resistance of a conductor depends directly on its length, inversely on its area of cross-section, and also on the material of the conductor.
- The equivalent resistance of several resistors in series is equal to the sum of their individual resistances.
- A set of resistors connected in parallel has an equivalent resistance R_p given by

  $$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$$

- The electrical energy dissipated in a resistor is given by

  $W = V \times I \times t$
- The unit of power is watt (W). One watt of power is consumed when 1 A of current flows at a potential difference of 1 V.
- The commercial unit of electrical energy is kilowatt hour (kWh).

  1 kW h = 3,600,000 J = 3.6×10^6 J.

EXERCISES

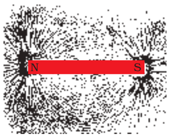
1. A piece of wire of resistance R is cut into five equal parts. These parts are then connected in parallel. If the equivalent resistance of this combination is R', then the ratio R/R' is –
   (a) 1/25 (b) 1/5 (c) 5 (d) 25
2. Which of the following terms does not represent electrical power in a circuit?
   (a) I^2R (b) IR^2 (c) VI (d) V^2/R
3. An electric bulb is rated 220 V and 100 W. When it is operated on 110 V, the power consumed will be –
   (a) 100 W (b) 75 W (c) 50 W (d) 25 W
4. Two conducting wires of the same material and of equal lengths and equal diameters are first connected in series and then parallel in a circuit across the same potential difference. The ratio of heat produced in series and parallel combinations would be –
   (a) 1:2 (b) 2:1 (c) 1:4 (d) 4:1
5. How is a voltmeter connected in the circuit to measure the potential difference between two points?
6. A copper wire has diameter 0.5 mm and resistivity of 1.6×10^{-8} Ω m. What will be the length of this wire to make its resistance 10 Ω? How much does the resistance change if the diameter is doubled?
7. The values of current I flowing in a given resistor for the corresponding values of potential difference V across the resistor are given below –

I (amperes)	0.5	1.0	2.0	3.0	4.0
V (volts)	1.6	3.4	6.7	10.2	13.2

   Plot a graph between V and I and calculate the resistance of that resistor.
8. When a 12 V battery is connected across an unknown resistor, there is a current of 2.5 mA in the circuit. Find the value of the resistance of the resistor.
9. A battery of 9 V is connected in series with resistors of 0.2 Ω, 0.3 Ω, 0.4 Ω , 0.5 Ω and 12 Ω, respectively. How much current would flow through the 12 Ω resistor?
10. How many 176 Ω resistors (in parallel) are required to carry 5 A on a 220 V line?
11. Show how you would connect three resistors, each of resistance 6 Ω, so that the combination has a resistance of (i) 9 Ω, (ii) 4 Ω.
12. Several electric bulbs designed to be used on a 220 V electric supply line, are rated 10 W. How many lamps can be connected in parallel with each other across the two wires of 220 V line if the maximum allowable current is 5 A?
13. A hot plate of an electric oven connected to a 220 V line has two resistance coils A and B, each of 24 Ω resistance, which may be used separately, in series, or in parallel. What are the currents in the three cases?
14. Compare the power used in the 2 Ω resistor in each of the following circuits: (i) a 6 V battery in series with 1 Ω and 2 Ω resistors, and (ii) a 4 V battery in parallel with 12 Ω and 2 Ω resistors.

15. Two lamps, one rated 100 W at 220 V, and the other 60 W at 220 V, are connected in parallel to electric mains supply. What current is drawn from the line if the supply voltage is 220 V?
16. Which uses more energy, a 250 W TV set in 1 hr, or a 1200 W toaster in 10 minutes?
17. An electric heater of resistance 44 Ω draws 5 A from the service mains for 2 hours. Calculate the rate at which heat is developed in the heater.
18. Explain the following.
    - (a) Why is the tungsten used almost exclusively for filament of electric lamps?
    - (b) Why are the conductors of electric heating devices, such as bread-toasters and electric irons, made of an alloy rather than a pure metal?
    - (c) Why is the series arrangement not used for domestic circuits?
    - (d) How does the resistance of a wire vary with its area of cross-section?
    - (e) Why are copper and aluminium wires usually employed for electricity transmission?

CHAPTER 12



Magnetic Effects of Electric Current

1064CH13

In the previous Chapter on 'Electricity' we learnt about the heating effects of electric current. What could be the other effects of electric current? We know that an electric current-carrying wire behaves like a magnet. Let us perform the following Activity to reinforce it.

Activity 12.1

- Take a straight thick copper wire and place it between the points X and Y in an electric circuit, as shown in Fig. 12.1. The wire XY is kept perpendicular to the plane of paper.
- Horizontally place a small compass near to this copper wire. See the position of its needle.
- Pass the current through the circuit by inserting the key into the plug.
- Observe the change in the position of the compass needle.

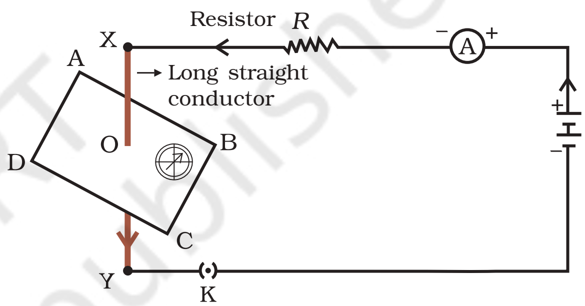


Figure 12.1
Compass needle is deflected on passing an electric current through a metallic conductor

We see that the needle is deflected. What does it mean? It means that the electric current through the copper wire has produced a magnetic effect. Thus we can say that electricity and magnetism are linked to each other. Then, what about the reverse possibility of an electric effect of moving magnets? In this Chapter we will study magnetic fields and such electromagnetic effects. We shall also study about electromagnets which involve the magnetic effect of electric current.

Hans Christian Oersted (1777–1851)

Hans Christian Oersted, one of the leading scientists of the 19th century, played a crucial role in understanding *electromagnetism*. In 1820 he accidentally discovered that a compass needle got deflected when an electric current passed through a metallic wire placed nearby. Through this observation Oersted showed that electricity and magnetism were related phenomena. His research later created technologies such as the radio, television and fiber optics. The unit of magnetic field strength is named the oersted in his honor.

12.1 MAGNETIC FIELD AND FIELD LINES

We are familiar with the fact that a compass needle gets deflected when brought near a bar magnet. A compass needle is, in fact, a small bar magnet. The ends of the compass needle point approximately towards north and south directions. The end pointing towards north is called *north seeking* or north pole. The other end that points towards south is called *south seeking* or south pole. Through various activities we have observed that like poles repel, while unlike poles of magnets attract each other.

QUESTION

1. Why does a compass needle get deflected when brought near a bar magnet?

Activity 12.2

- Fix a sheet of white paper on a drawing board using some adhesive material.
- Place a bar magnet in the centre of it.
- Sprinkle some iron filings uniformly around the bar magnet (Fig. 12.2). A salt-sprinkler may be used for this purpose.
- Now tap the board gently.
- What do you observe?

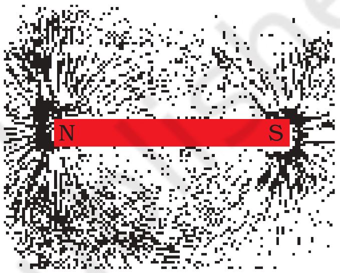


Figure 12.2
Iron filings near the bar magnet align themselves along the field lines.

The iron filings arrange themselves in a pattern as shown Fig. 12.2. Why do the iron filings arrange in such a pattern? What does this pattern demonstrate? The magnet exerts its influence in the region surrounding it. Therefore the iron filings experience a force. The force thus exerted makes iron filings to arrange in a pattern. The region surrounding a magnet, in which the force of the magnet can be detected, is said to have a magnetic field. The lines along which the iron filings align themselves represent magnetic field lines.

Are there other ways of obtaining magnetic field lines around a bar magnet? Yes, you can yourself draw the field lines of a bar magnet.

Activity 12.3

- Take a small compass and a bar magnet.
- Place the magnet on a sheet of white paper fixed on a drawing board, using some adhesive material.
- Mark the boundary of the magnet.
- Place the compass near the north pole of the magnet. How does it behave? The south pole of the needle points towards the north pole of the magnet. The north pole of the compass is directed away from the north pole of the magnet.

- Mark the position of two ends of the needle.
- Now move the needle to a new position such that its south pole occupies the position previously occupied by its north pole.
- In this way, proceed step by step till you reach the south pole of the magnet as shown in Fig. 12.3.
- Join the points marked on the paper by a smooth curve. This curve represents a field line.
- Repeat the above procedure and draw as many lines as you can. You will get a pattern shown in Fig. 12.4. These lines represent the magnetic field around the magnet. These are known as magnetic field lines.
- Observe the deflection in the compass needle as you move it along a field line. The deflection increases as the needle is moved towards the poles.

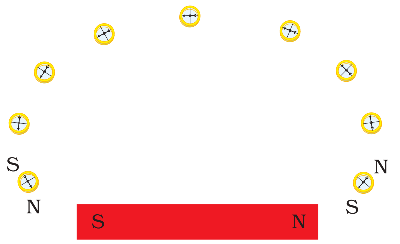


Figure 12.3
Drawing a magnetic field line with the help of a compass needle

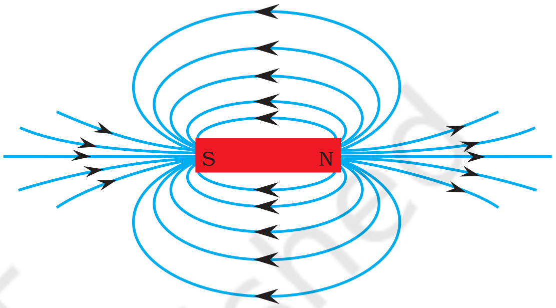


Figure 12.4
Field lines around a bar magnet

Magnetic field is a quantity that has both direction and magnitude. The direction of the magnetic field is taken to be the direction in which a north pole of the compass needle moves inside it. Therefore it is taken by convention that the field lines emerge from north pole and merge at the south pole (note the arrows marked on the field lines in Fig. 12.4). Inside the magnet, the direction of field lines is from its south pole to its north pole. Thus the magnetic field lines are closed curves.

The relative strength of the magnetic field is shown by the degree of closeness of the field lines. The field is stronger, that is, the force acting on the pole of another magnet placed is greater where the field lines are crowded (see Fig. 12.4).

No two field-lines are found to cross each other. If they did, it would mean that at the point of intersection, the compass needle would point towards two directions, which is not possible.

12.2 MAGNETIC FIELD DUE TO A CURRENT-CARRYING CONDUCTOR

In Activity 12.1, we have seen that an electric current through a metallic conductor produces a magnetic field around it. In order to find the direction of the field produced let us repeat the activity in the following way –

Activity 12.4

- Take a long straight copper wire, two or three cells of 1.5 V each, and a plug key. Connect all of them in series as shown in Fig. 12.5 (a).
- Place the straight wire parallel to and over a compass needle.
- Plug the key in the circuit.
- Observe the direction of deflection of the north pole of the needle. If the current flows from north to south, as shown in Fig. 12.5 (a), the north pole of the compass needle would move towards the east.
- Replace the cell connections in the circuit as shown in Fig. 12.5 (b). This would result in the change of the direction of current through the copper wire, that is, from south to north.
- Observe the change in the direction of deflection of the needle. You will see that now the needle moves in opposite direction, that is, towards the west [Fig. 12.5 (b)]. It means that the direction of magnetic field produced by the electric current is also reversed.

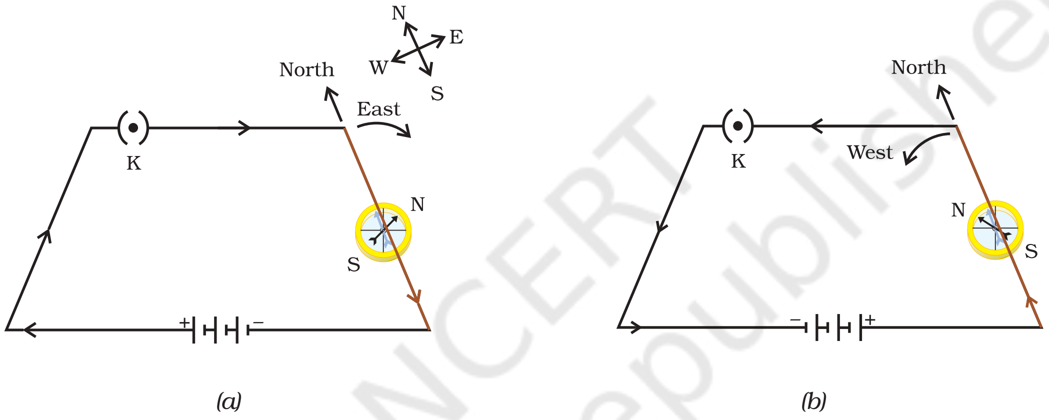


Figure 12.5 *A simple electric circuit in which a straight copper wire is placed parallel to and over a compass needle. The deflection in the needle becomes opposite when the direction of the current is reversed.*

12.2.1 Magnetic Field due to a Current through a Straight Conductor

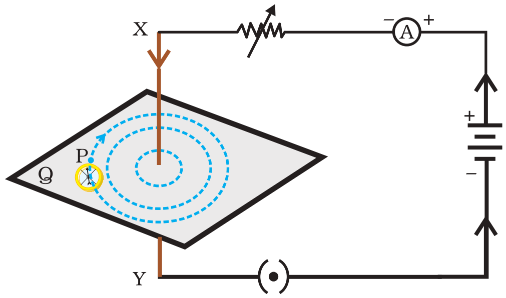
What determines the pattern of the magnetic field generated by a current through a conductor? Does the pattern depend on the shape of the conductor? We shall investigate this with an activity.

We shall first consider the pattern of the magnetic field around a straight conductor carrying current.

Activity 12.5

- Take a battery (12 V), a variable resistance (or a rheostat), an ammeter (0–5 A), a plug key, connecting wires and a long straight thick copper wire.
- Insert the thick wire through the centre, normal to the plane of a rectangular cardboard. Take care that the cardboard is fixed and does not slide up or down.

- Connect the copper wire vertically between the points X and Y, as shown in Fig. 12.6 (a), in series with the battery, a plug and key.
- Sprinkle some iron filings uniformly on the cardboard. (You may use a salt sprinkler for this purpose.)
- Keep the variable of the rheostat at a fixed position and note the current through the ammeter.
- Close the key so that a current flows through the wire. Ensure that the copper wire placed between the points X and Y remains vertically straight.
- Gently tap the cardboard a few times. Observe the pattern of the iron filings. You would find that the iron filings align themselves showing a pattern of concentric circles around the copper wire (Fig. 12.6).
- What do these concentric circles represent? They represent the magnetic field lines.
- How can the direction of the magnetic field be found? Place a compass at a point (say P) over a circle. Observe the direction of the needle. The direction of the north pole of the compass needle would give the direction of the field lines produced by the electric current through the straight wire at point P. Show the direction by an arrow.
- Does the direction of magnetic field lines get reversed if the direction of current through the straight copper wire is reversed? Check it.



(a)


(b)

Figure 12.6
(a) A pattern of concentric circles indicating the field lines of a magnetic field around a straight conducting wire. The arrows in the circles show the direction of the field lines.
(b) A close up of the pattern obtained.

What happens to the deflection of the compass needle placed at a given point if the current in the copper wire is changed? To see this, vary the current in the wire. We find that the deflection in the needle also changes. In fact, if the current is increased, the deflection also increases. It indicates that the magnitude of the magnetic field produced at a given point increases as the current through the wire increases.

What happens to the deflection of the needle if the compass is moved away from the copper wire but the current through the wire remains the same? To see this, now place the compass at a farther point from the conducting wire (say at point Q). What change do you observe? We see that the deflection in the needle decreases. Thus the magnetic field produced by a given current in the conductor decreases as the distance from it increases. From Fig. 12.6, it can be noticed that the concentric circles representing the magnetic field around a current-carrying straight wire become larger and larger as we move away from it.

12.2.2 Right-Hand Thumb Rule

A convenient way of finding the direction of magnetic field associated with a current-carrying conductor is given in Fig. 12.7.

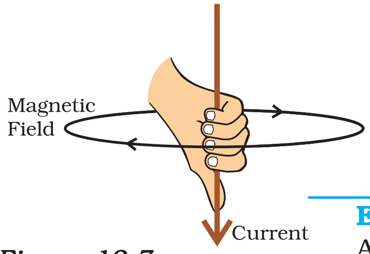


Figure 12.7
Right-hand thumb rule

Imagine that you are holding a current-carrying straight conductor in your right hand such that the thumb points towards the direction of current. Then your fingers will wrap around the conductor in the direction of the field lines of the magnetic field, as shown in Fig. 12.7. This is known as the right-hand thumb rule*.

Example 12.1

A current through a horizontal power line flows in east to west direction. What is the direction of magnetic field at a point directly below it and at a point directly above it?

Solution

The current is in the east-west direction. Applying the right-hand thumb rule, we get that the magnetic field (at any point below or above the wire) turns clockwise in a plane perpendicular to the wire, when viewed from the east end, and anti-clockwise, when viewed from the west end.

QUESTIONS

1. Draw magnetic field lines around a bar magnet.
2. List the properties of magnetic field lines.
3. Why don't two magnetic field lines intersect each other?

12.2.3 Magnetic Field due to a Current through a Circular Loop

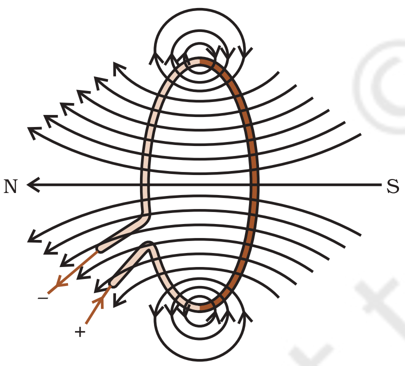


Figure 12.8
Magnetic field lines of the field produced by a current-carrying circular loop

We have so far observed the pattern of the magnetic field lines produced around a current-carrying straight wire. Suppose this straight wire is bent in the form of a circular loop and a current is passed through it. How would the magnetic field lines look like? We know that the magnetic field produced by a current-carrying straight wire depends inversely on the distance from it. Similarly at every point of a current-carrying circular loop, the concentric circles representing the magnetic field around it would become larger and larger as we move away from the wire (Fig. 12.8). By the time we reach at the centre of the circular loop, the arcs of these *big* circles would appear as straight lines. Every point on the wire carrying current would give rise to the magnetic field appearing as straight lines at the center of the loop. By applying the right hand rule, it is easy to check that every section of the wire contributes to the magnetic field lines in the same direction within the loop.

* *This rule is also called Maxwell's corkscrew rule. If we consider ourselves driving a corkscrew in the direction of the current, then the direction of the rotation of corkscrew is the direction of the magnetic field.*

We know that the magnetic field produced by a current-carrying wire at a given point depends directly on the current passing through it. Therefore, if there is a circular coil having n turns, the field produced is n times as large as that produced by a single turn. This is because the current in each circular turn has the same direction, and the field due to each turn then just adds up.

Activity 12.6

- Take a rectangular cardboard having two holes. Insert a circular coil having large number of turns through them, normal to the plane of the cardboard.
- Connect the ends of the coil in series with a battery, a key and a rheostat, as shown in Fig. 12.9.
- Sprinkle iron filings uniformly on the cardboard.
- Plug the key.
- Tap the cardboard gently a few times. Note the pattern of the iron filings that emerges on the cardboard.

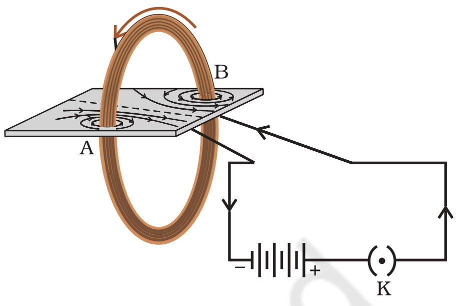


Figure 12.9
Magnetic field produced by a current-carrying circular coil.

12.2.4 Magnetic Field due to a Current in a Solenoid

A coil of many circular turns of insulated copper wire wrapped closely in the shape of a cylinder is called a solenoid. The pattern of the magnetic field lines around a current-carrying solenoid is shown in Fig. 12.10. Compare the pattern of the field with the magnetic field around a bar magnet (Fig. 12.4). Do they look similar? Yes, they are similar. In fact, one end of the solenoid behaves as a magnetic north pole, while the other behaves as the south pole. The field lines inside the solenoid are in the form of parallel straight lines. This indicates that the magnetic field is the same at all points inside the solenoid. That is, the field is uniform inside the solenoid.

A strong magnetic field produced inside a solenoid can be used to magnetise a piece of magnetic material, like soft iron, when placed inside the coil (Fig. 12.11). The magnet so formed is called an electromagnet.

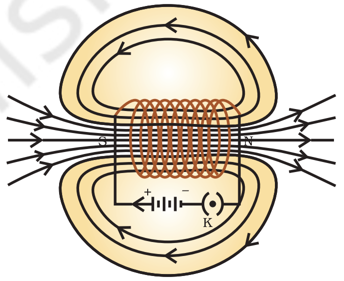


Figure 12.10
Field lines of the magnetic field through and around a current carrying solenoid.

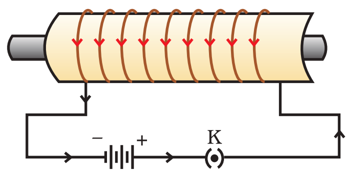


Figure 12.11
A current-carrying solenoid coil is used to magnetise steel rod inside it – an electromagnet.

QUESTIONS

1. Consider a circular loop of wire lying in the plane of the table. Let the current pass through the loop clockwise. Apply the right-hand rule to find out the direction of the magnetic field inside and outside the loop.
2. The magnetic field in a given region is uniform. Draw a diagram to represent it.

3. Choose the correct option.

The magnetic field inside a long straight solenoid-carrying current

(a) is zero.

(b) decreases as we move towards its end.

(c) increases as we move towards its end.

(d) is the same at all points.

12.3 FORCE ON A CURRENT-CARRYING CONDUCTOR IN A MAGNETIC FIELD

We have learnt that an electric current flowing through a conductor produces a magnetic field. The field so produced exerts a force on a magnet placed in the vicinity of the conductor. French scientist Andre Marie Ampere (1775–1836) suggested that the magnet must also exert an equal and opposite force on the current-carrying conductor. The force due to a magnetic field acting on a current-carrying conductor can be demonstrated through the following activity.

Activity 12.7

- Take a small aluminium rod AB (of about 5 cm). Using two connecting wires suspend it horizontally from a stand, as shown in Fig. 12.12.
- Place a strong horse-shoe magnet in such a way that the rod lies between the two poles with the magnetic field directed upwards. For this put the north pole of the magnet vertically below and south pole vertically above the aluminium rod (Fig. 12.12).
- Connect the aluminium rod in series with a battery, a key and a rheostat.
- Now pass a current through the aluminium rod from end B to end A.
- What do you observe? It is observed that the rod is displaced towards the left. You will notice that the rod gets displaced.
- Reverse the direction of current flowing through the rod and observe the direction of its displacement. It is now towards the right.

  Why does the rod get displaced?

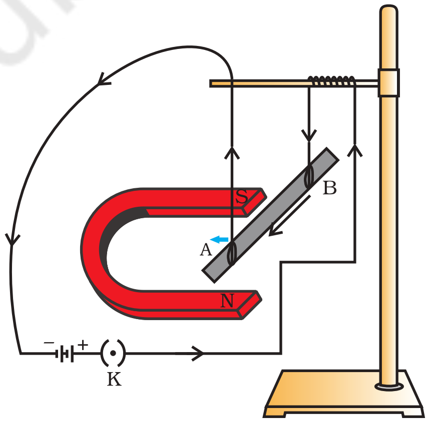


Figure 12.12
A current-carrying rod, AB, experiences a force perpendicular to its length and the magnetic field. Support for the magnet is not shown here, for simplicity.

The displacement of the rod in the above activity suggests that a force is exerted on the current-carrying aluminium rod when it is placed in a magnetic field. It also suggests that the direction of force is also reversed when the direction of current through the conductor is reversed. Now change the direction of field to vertically downwards by interchanging the two poles of the magnet. It is once again observed that the direction of force acting on the current-carrying rod gets reversed. It shows that the direction of the force on the conductor depends upon the direction of current and the direction of the magnetic field. Experiments have shown that the displacement of the rod is largest (or the magnitude of the force is the highest) when the direction of current is at right angles to the direction of the magnetic field. In such a condition we can use a simple rule to find the direction of the force on the conductor.

In Activity 12.7, we considered the direction of the current and that of the magnetic field perpendicular to each other and found that the force is perpendicular to both of them. The three directions can be illustrated through a simple rule, called Fleming's left-hand rule. According to this rule, stretch the thumb, forefinger and middle finger of your left hand such that they are mutually perpendicular (Fig. 12.13). If the first finger points in the direction of magnetic field and the second finger in the direction of current, then the thumb will point in the direction of motion or the force acting on the conductor.

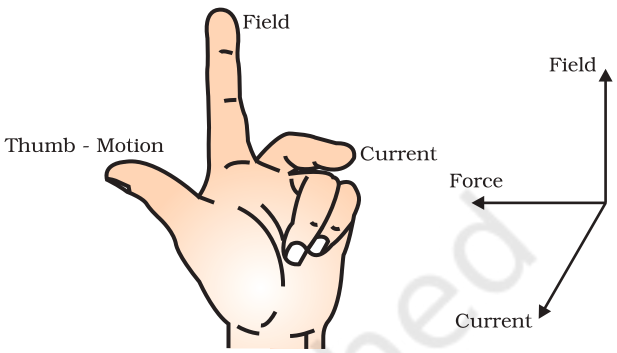


Figure 12.13
Fleming's left-hand rule

Devices that use current-carrying conductors and magnetic fields include electric motor, electric generator, loudspeakers, microphones and measuring instruments.

Example 12.2

An electron enters a magnetic field at right angles to it, as shown in Fig. 12.14. The direction of force acting on the electron will be

(a) to the right.
(b) to the left.
(c) out of the page.
(d) into the page.

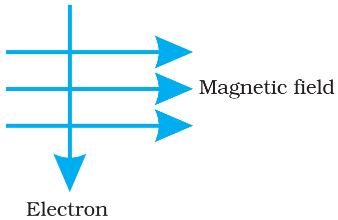


Figure 12.14

Solution

Answer is option (d). The direction of force is perpendicular to the direction of magnetic field and current as given by Fleming's left hand rule. Recall that the direction of current is taken opposite to the direction of motion of electrons. The force is therefore directed into the page.

Q U E S T I O N S

1. Which of the following property of a proton can change while it moves freely in a magnetic field? (There may be more than one correct answer.)

(a) mass (b) speed
(c) velocity (d) momentum

2. In Activity 12.7, how do we think the displacement of rod AB will be affected if (i) current in rod AB is increased; (ii) a stronger horse-shoe magnet is used; and (iii) length of the rod AB is increased?
3. A positively-charged particle (alpha-particle) projected towards west is deflected towards north by a magnetic field. The direction of magnetic field is
   (a) towards south (b) towards east
   (c) downward (d) upward

More to Know!

Magnetism in medicine

An electric current always produces a magnetic field. Even weak ion currents that travel along the nerve cells in our body produce magnetic fields. When we touch something, our nerves carry an electric impulse to the muscles we need to use. This impulse produces a temporary magnetic field. These fields are very weak and are about one-billionth of the earth's magnetic field. Two main organs in the human body where the magnetic field produced is significant, are the heart and the brain. The magnetic field inside the body forms the basis of obtaining the images of different body parts. This is done using a technique called Magnetic Resonance Imaging (MRI). Analysis of these images helps in medical diagnosis. Magnetism has, thus, got important uses in medicine.

12.4 DOMESTIC ELECTRIC CIRCUITS

In our homes, we receive supply of electric power through a main supply (also called mains), either supported through overhead electric poles or by underground cables. One of the wires in this supply, usually with red insulation cover, is called live wire (or positive). Another wire, with black insulation, is called neutral wire (or negative). In our country, the potential difference between the two is 220 V.

At the meter-board in the house, these wires pass into an electricity meter through a main fuse. Through the main switch they are connected to the line wires in the house. These wires supply electricity to separate circuits within the house. Often, two separate circuits are used, one of 15 A current rating for appliances with higher power ratings such as geysers, air coolers, etc. The other circuit is of 5 A current rating for bulbs, fans, etc. The earth wire, which has insulation of green colour, is usually connected to a metal plate deep in the earth near the house. This is used as a safety measure, especially for those appliances that have a metallic body, for example, electric press, toaster, table fan, refrigerator, etc. The metallic body is connected to the earth wire, which provides a low-resistance conducting path for the current. Thus, it ensures that any leakage of current to the metallic body of the appliance keeps its potential to that of the earth, and the user may not get a severe electric shock.

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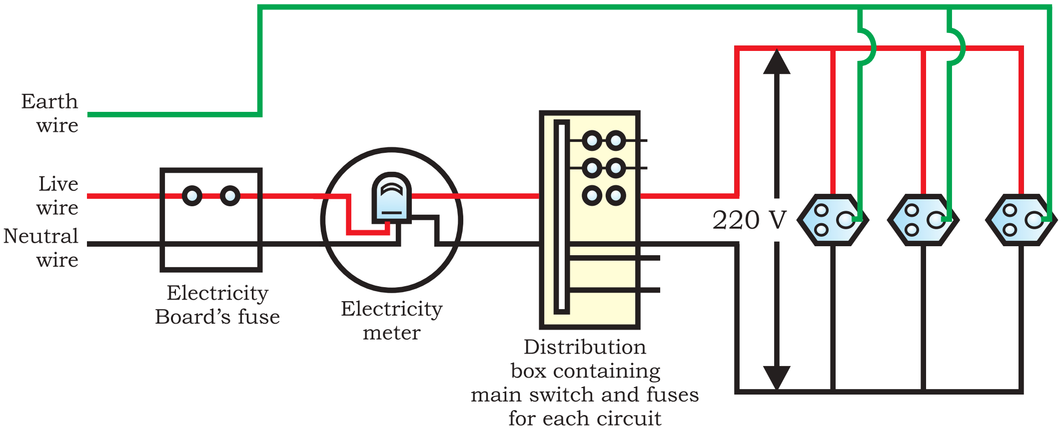

Figure 12.15 *A schematic diagram of one of the common domestic circuits*

Figure 12.15 gives a schematic diagram of one of the common domestic circuits. In each separate circuit, different appliances can be connected across the live and neutral wires. Each appliance has a separate switch to 'ON'/'OFF' the flow of current through it. In order that each appliance has equal potential difference, they are connected parallel to each other.

Electric fuse is an important component of all domestic circuits. We have already studied the principle and working of a fuse in the previous chapter (see Section 11.7). A fuse in a circuit prevents damage to the appliances and the circuit due to overloading. Overloading can occur when the live wire and the neutral wire come into direct contact. (This occurs when the insulation of wires is damaged or there is a fault in the appliance.) In such a situation, the current in the circuit abruptly increases. This is called short-circuiting. The use of an electric fuse prevents the electric circuit and the appliance from a possible damage by stopping the flow of unduly high electric current. The Joule heating that takes place in the fuse melts it to break the electric circuit. Overloading can also occur due to an accidental hike in the supply voltage. Sometimes overloading is caused by connecting too many appliances to a single socket.

QUESTIONS

1. Name two safety measures commonly used in electric circuits and appliances.
2. An electric oven of 2 kW power rating is operated in a domestic electric circuit (220 V) that has a current rating of 5 A. What result do you expect? Explain.
3. What precaution should be taken to avoid the overloading of domestic electric circuits?

What you have learnt

- A compass needle is a small magnet. Its one end, which points towards north, is called a north pole, and the other end, which points towards south, is called a south pole.
- A magnetic field exists in the region surrounding a magnet, in which the force of the magnet can be detected.
- Field lines are used to represent a magnetic field. A field line is the path along which a hypothetical free north pole would tend to move. The direction of the magnetic field at a point is given by the direction that a north pole placed at that point would take. Field lines are shown closer together where the magnetic field is greater.
- A metallic wire carrying an electric current has associated with it a magnetic field. The field lines about the wire consist of a series of concentric circles whose direction is given by the right-hand rule.
- The pattern of the magnetic field around a conductor due to an electric current flowing through it depends on the shape of the conductor. The magnetic field of a solenoid carrying a current is similar to that of a bar magnet.
- An electromagnet consists of a core of soft iron wrapped around with a coil of insulated copper wire.
- A current-carrying conductor when placed in a magnetic field experiences a force. If the direction of the field and that of the current are mutually perpendicular to each other, then the force acting on the conductor will be perpendicular to both and will be given by Fleming's left-hand rule.
- In our houses we receive AC electric power of 220 V with a frequency of 50 Hz. One of the wires in this supply is with red insulation, called live wire. The other one is of black insulation, which is a neutral wire. The potential difference between the two is 220 V. The third is the earth wire that has green insulation and this is connected to a metallic body deep inside earth. It is used as a safety measure to ensure that any leakage of current to a metallic body does not give any severe shock to a user.
- Fuse is the most important safety device, used for protecting the circuits due to short-circuiting or overloading of the circuits.

EXERCISES

1. Which of the following correctly describes the magnetic field near a long straight wire?
   (a) The field consists of straight lines perpendicular to the wire.
   (b) The field consists of straight lines parallel to the wire.
   (c) The field consists of radial lines originating from the wire.
   (d) The field consists of concentric circles centred on the wire.
2. At the time of short circuit, the current in the circuit
   (a) reduces substantially.
   (b) does not change.
   (c) increases heavily.
   (d) vary continuously.
3. State whether the following statements are true or false.
   (a) The field at the centre of a long circular coil carrying current will be parallel straight lines.
   (b) A wire with a green insulation is usually the live wire of an electric supply.
4. List two methods of producing magnetic fields.
5. When is the force experienced by a current–carrying conductor placed in a magnetic field largest?
6. Imagine that you are sitting in a chamber with your back to one wall. An electron beam, moving horizontally from back wall towards the front wall, is deflected by a strong magnetic field to your right side. What is the direction of magnetic field?
7. State the rule to determine the direction of a (i) magnetic field produced around a straight conductor-carrying current, (ii) force experienced by a current-carrying straight conductor placed in a magnetic field which is perpendicular to it, and (iii) current induced in a coil due to its rotation in a magnetic field.
8. When does an electric short circuit occur?
9. What is the function of an earth wire? Why is it necessary to earth metallic appliances?

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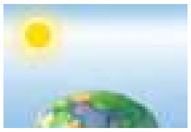

CHAPTER 13
Our Environment

We have heard the word 'environment' often being used on the television, in newspapers and by people around us. Our elders tell us that the 'environment' is not what it used to be earlier; others say that we should work in a healthy 'environment'; and global summits involving the developed and developing countries are regularly held to discuss 'environmental' issues. In this chapter, we shall be studying how various components in the environment interact with each other and how we impact the environment.

13.1 ECO-SYSTEM — WHAT ARE ITS COMPONENTS?

All organisms such as plants, animals, microorganisms and human beings as well as the physical surroundings interact with each other and maintain a balance in nature. All the interacting organisms in an area together with the non-living constituents of the environment form an ecosystem. Thus, an ecosystem consists of biotic components comprising living organisms and abiotic components comprising physical factors like temperature, rainfall, wind, soil and minerals.

For example, if you visit a garden you will find different plants, such as grasses, trees; flower bearing plants like rose, jasmine, sunflower; and animals like frogs, insects and birds. All these living organisms interact with each other and their growth, reproduction and other activities are affected by the abiotic components of ecosystem. So a garden is an ecosystem. Other types of ecosystems are forests, ponds and lakes. These are natural ecosystems while gardens and crop-fields are human-made (artificial) ecosystems.

Activity 13.1

- You might have seen an aquarium. Let us try to design one.
- What are the things that we need to keep in mind when we create an aquarium? The fish would need a free space for swimming (it could be a large jar), water, oxygen and food.
- We can provide oxygen through an oxygen pump (aerator) and fish food which is available in the market.

- If we add a few aquatic plants and animals it can become a self-sustaining system. Can you think how this happens? An aquarium is an example of a human-made ecosystem.
- Can we leave the aquarium as such after we set it up? Why does it have to be cleaned once in a while? Do we have to clean ponds or lakes in the same manner? Why or why not?

We have seen in earlier classes that organisms can be grouped as producers, consumers and decomposers according to the manner in which they obtain their sustenance from the environment. Let us recall what we have learnt through the self sustaining ecosystem created by us above. Which organisms can make organic compounds like sugar and starch from inorganic substances using the radiant energy of the Sun in the presence of chlorophyll? All green plants and certain bacteria which can produce food by photosynthesis come under this category and are called the producers.

Organisms depend on the producers either directly or indirectly for their sustenance? These organisms which consume the food produced, either directly from producers or indirectly by feeding on other consumers are the consumers. Consumers can be classed variously as herbivores, carnivores, omnivores and parasites. Can you give examples for each of these categories of consumers?

- Imagine the situation where you do not clean the aquarium and some fish and plants have died. Have you ever thought what happens when an organism dies? The microorganisms, comprising bacteria and fungi, break-down the dead remains and waste products of organisms. These microorganisms are the decomposers as they break-down the complex organic substances into simple inorganic substances that go into the soil and are used up once more by the plants. What will happen to the garbage, and dead animals and plants in their absence? Will the natural replenishment of the soil take place, even if decomposers are not there?

Activity 13.2

- While creating an aquarium did you take care not to put an aquatic animal which would eat others? What would have happened otherwise?
- Make groups and discuss how each of the above groups of organisms are dependent on each other.
- Write the aquatic organisms in order of who eats whom and form a chain of at least three steps. $\boxed{} \rightarrow \boxed{} \rightarrow \boxed{}$
- Would you consider any one group of organisms to be of primary importance? Why or why not?

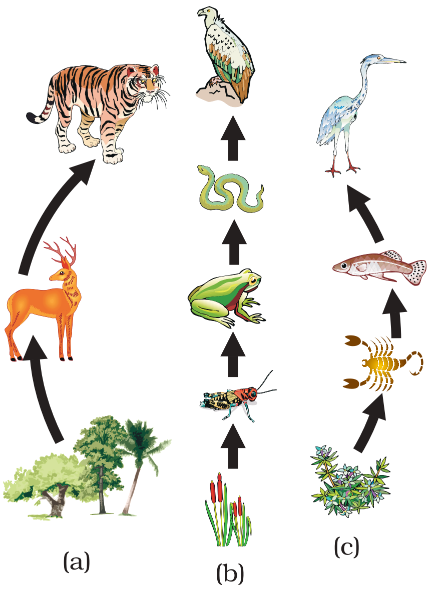

Figure 13.1
Food chain in nature (a) in forest, (b) in grassland and (c) in a pond

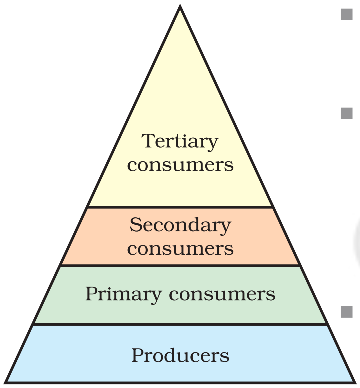

Figure 13.2
Trophic levels

13.1.1 Food Chains and Webs

In Activity 13.4 we have formed a series of organisms feeding on one another. This series or organisms taking part at various biotic levels form a food chain (Fig. 13.1).

Each step or level of the food chain forms a trophic level. The autotrophs or the producers are at the first trophic level. They fix up the solar energy and make it available for heterotrophs or the consumers. The herbivores or the primary consumers come at the second, small carnivores or the secondary consumers at the third and larger carnivores or the tertiary consumers form the fourth trophic level (Fig. 13.2).

We know that the food we eat acts as a fuel to provide us energy to do work. Thus the interactions among various components of the environment involves flow of energy from one component of the system to another. As we have studied, the autotrophs capture the energy present in sunlight and convert it into chemical energy. This energy supports all the activities of the living world. From autotrophs, the energy goes to the heterotrophs and decomposers. However, as we saw in the previous Chapter on 'Sources of Energy', when one form of energy is changed to another, some energy is lost to the environment in forms which cannot be used again. The flow of energy between various components of the environment has been extensively studied and it has been found that –

- The green plants in a terrestrial ecosystem capture about 1% of the energy of sunlight that falls on their leaves and convert it into food energy.
- When green plants are eaten by primary consumers, a great deal of energy is lost as heat to the environment, some amount goes into digestion and in doing work and the rest goes towards growth and reproduction. An average of 10% of the food eaten is turned into its own body and made available for the next level of consumers.
- Therefore, 10% can be taken as the average value for the amount of organic matter that is present at each step and reaches the next level of consumers.
- Since so little energy is available for the next level of consumers, food chains generally consist of only three or four steps. The loss of energy at each step is so great that very little usable energy remains after four trophic levels.
- There are generally a greater number of individuals at the lower trophic levels of an ecosystem, the greatest number is of the producers.
- The length and complexity of food chains vary greatly. Each organism is generally eaten by two or more other kinds of organisms which in turn are eaten by several other organisms. So instead of a straight line food chain, the relationship can be shown as a series of branching lines called a food web (Fig. 13.3).

From the energy flow diagram (Fig. 13.4), two things become clear. Firstly, the flow of energy is unidirectional. The energy that is captured by the autotrophs does not revert back to the solar input and the energy which passes to the herbivores does not come back to autotrophs. As it moves progressively through the various trophic levels it is no longer available to the previous level. Secondly, the energy available at each trophic level gets diminished progressively due to loss of energy at each level.

Another interesting aspect of food chain is how unknowingly some harmful chemicals enter our bodies through the food chain. You have read in Class IX how water gets polluted. One of the reasons is the use of several pesticides and other chemicals to protect our crops from diseases and pests. These chemicals are either washed down into the soil or into the water bodies. From the soil, these are absorbed by the plants along with water and minerals, and from the water bodies these are taken up by aquatic plants

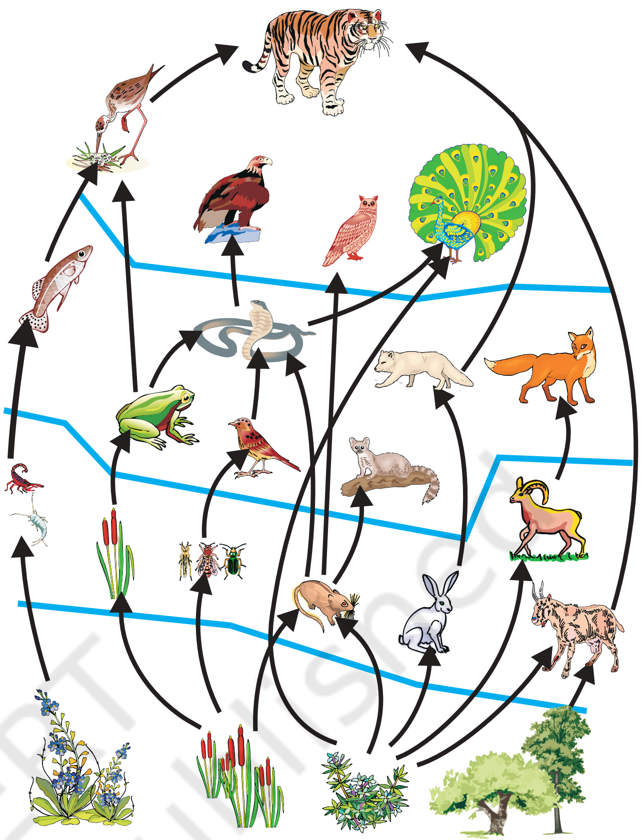

Figure 13.3
Food web, consisting of many food chains

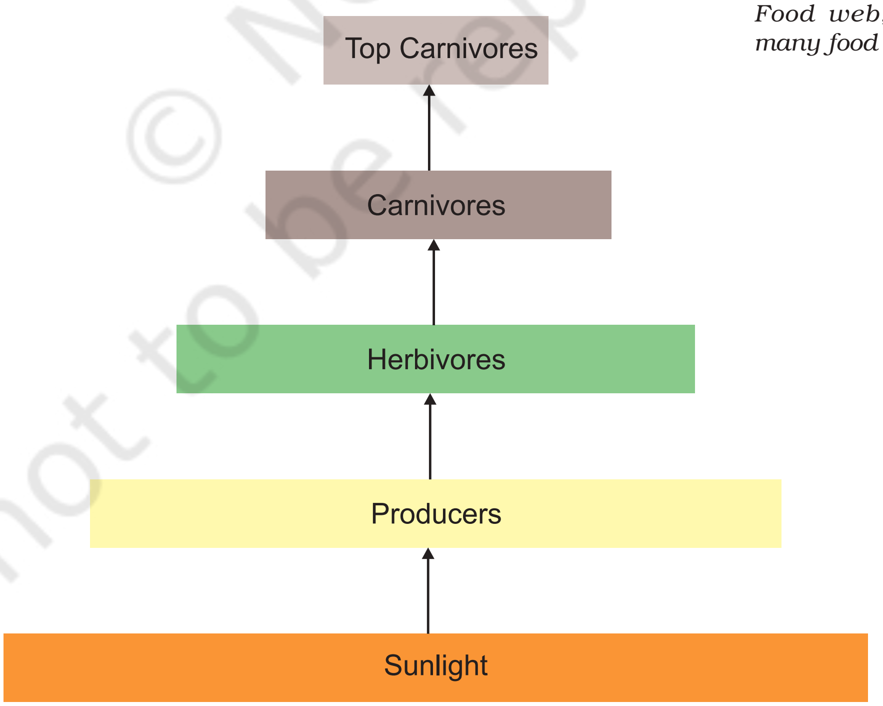

Figure 13.4 *Diagram showing flow of energy in an ecosystem*

and animals. This is one of the ways in which they enter the food chain. As these chemicals are not degradable, these get accumulated progressively at each trophic level. As human beings occupy the top level in any food chain, the maximum concentration of these chemicals get accumulated in our bodies. This phenomenon is known as biological magnification. This is the reason why our food grains such as wheat and rice, vegetables and fruits, and even meat, contain varying amounts of pesticide residues. They cannot always be removed by washing or other means.

Activity 13.3

- Newspaper reports about pesticide levels in ready-made food items are often seen these days and some states have banned these products. Debate in groups the need for such bans.
- What do you think would be the source of pesticides in these food items? Could pesticides get into our bodies from this source through other food products too?
- Discuss what methods could be applied to reduce our intake of pesticides.

QUESTIONS

1. What are trophic levels? Give an example of a food chain and state the different trophic levels in it.
2. What is the role of decomposers in the ecosystem?

?

13.2 HOW DO OUR ACTIVITIES AFFECT THE ENVIRONMENT?

We are an integral part of the environment. Changes in the environment affect us and our activities change the environment around us. We have already seen in Class IX how our activities pollute the environment. In this chapter, we shall be looking at two of the environmental problems in detail, that is, depletion of the ozone layer and waste disposal.

13.2.1 Ozone Layer and How it is Getting Depleted

Ozone (O_3) is a molecule formed by three atoms of oxygen. While O_2, which we normally refer to as oxygen, is essential for all aerobic forms of life. Ozone, is a deadly poison. However, at the higher levels of the atmosphere, ozone performs an essential function. It shields the surface of the earth from ultraviolet (UV) radiation from the Sun. This radiation is highly damaging to organisms, for example, it is known to cause skin cancer in human beings.

Ozone at the higher levels of the atmosphere is a product of UV radiation acting on oxygen (O_2) molecule. The higher energy UV radiations split apart some moleculer oxygen (O_2) into free oxygen (O) atoms. These atoms then combine with the molecular oxygen to form ozone as shown—

$$O_2 \xrightarrow{UV} O + O$$

$$O + O_2 \rightarrow \underset{\text{(Ozone)}}{O_3}$$

The amount of ozone in the atmosphere began to drop sharply in the 1980s. This decrease has been linked to synthetic chemicals like chlorofluorocarbons (CFCs) which are used as refrigerants and in fire extinguishers. In 1987, the United Nations Environment Programme (UNEP) succeeded in forging an agreement to freeze CFC production at 1986 levels. It is now mandatory for all the manufacturing companies to make CFC-free refrigerators throughout the world.

Activity 13.4

- Find out from the library, internet or newspaper reports, which chemicals are responsible for the depletion of the ozone layer.
- Find out if the regulations put in place to control the emission of these chemicals have succeeded in reducing the damage to the ozone layer. Has the size of the hole in the ozone layer changed in recent years?

13.2.2 Managing the Garbage we Produce

In our daily activities, we generate a lot of material that are thrown away. What are some of these waste materials? What happens after we throw them away? Let us perform an activity to find answers to these questions.

Activity 13.5

- Collect waste material from your homes. This could include all the waste generated during a day, like kitchen waste (spoilt food, vegetable peels, used tea leaves, milk packets and empty cartons), waste paper, empty medicine bottles/strips/bubble packs, old and torn clothes and broken footwear.
- Bury this material in a pit in the school garden or if there is no space available, you can collect the material in an old bucket/ flower pot and cover with at least 15 cm of soil.
- Keep this material moist and observe at 15-day intervals.
- What are the materials that remain unchanged over long periods of time?
- What are the materials which change their form and structure over time?
- Of these materials that are changed, which ones change the fastest?

We have seen in the chapter on 'Life Processes' that the food we eat is digested by various enzymes in our body. Have you ever wondered why the same enzyme does not break-down everything we eat? Enzymes are specific in their action, specific enzymes are needed for the break-down of a particular substance. That is why we will not get any energy if we try to eat coal! Because of this, many human-made materials like plastics will not be broken down by the action of bacteria or other saprophytes. These materials will be acted upon by physical processes like heat and pressure, but under the ambient conditions found in our environment, these persist for a long time.

Substances that are broken down by biological processes are said to be biodegradable. How many of the substances you buried were biodegradable? Substances that are not broken down in this manner are said to be non-biodegradable. These substances may be inert and simply persist in the environment for a long time or may harm the various members of the eco-system.

Activity 13.6

- Use the library or internet to find out more about biodegradable and non-biodegradable substances.
- How long are various non-biodegradable substances expected to last in our environment?
- These days, new types of plastics which are said to be biodegradable are available. Find out more about such materials and whether they do or do not harm the environment.

QUESTIONS

1. Why are some substances biodegradable and some non-biodegradable?
2. Give any two ways in which biodegradable substances would affect the environment.
3. Give any two ways in which non-biodegradable substances would affect the environment.

Visit any town or city, and we are sure to find heaps of garbage all over the place. Visit any place of tourist interest and we are sure to find the place littered with empty food wrappers. In the earlier classes we have talked about this problem of dealing with the garbage that we generate. Let us now look at the problem a bit more deeply.

Activity 13.7

- Find out what happens to the waste generated at home. Is there a system in place to collect this waste?
- Find out how the local body (*panchayat*, municipal corporation, resident welfare association) deals with the waste. Are there mechanisms in place to treat the biodegradable and non-biodegradable wastes separately?
- Calculate how much waste is generated at home in a day.
- How much of this waste is biodegradable?
- Calculate how much waste is generated in the classroom in a day.
- How much of this waste is biodegradable?
- Suggest ways of dealing with this waste.

Activity 13.8

- Find out how the sewage in your locality is treated. Are there mechanisms in place to ensure that local water bodies are not polluted by untreated sewage.
- Find out how the local industries in your locality treat their wastes. Are there mechanisms in place to ensure that the soil and water are not polluted by this waste?

Improvements in our life-style have resulted in greater amounts of waste material generation. Changes in attitude also have a role to play, with more and more things we use becoming disposable. Changes in packaging have resulted in much of our waste becoming non-biodegradable. What do you think will be the impact of these on our environment?

Think it over

Disposable cups in trains

If you ask your parents, they will probably remember a time when tea in trains was served in plastic glasses which had to be returned to the vendor. The introduction of disposable cups was hailed as a step forward for reasons of hygiene. No one at that time perhaps thought about the impact caused by the disposal of millions of these cups on a daily basis. Some time back, *kulhads*, that is, disposable cups made of clay, were suggested as an alternative. But a little thought showed that making these *kulhads* on a large scale would result in the loss of the fertile top-soil. Now disposable paper-cups are being used. What do you think are the advantages of disposable paper-cups over disposable plastic cups?

Activity 13.9

- Search the internet or library to find out what hazardous materials have to be dealt with while disposing of electronic items. How would these materials affect the environment?
- Find out how plastics are recycled. Does the recycling process have any impact on the environment?

QUESTIONS

1. What is ozone and how does it affect any ecosystem?
2. How can you help in reducing the problem of waste disposal? Give any two methods.

What you have learnt

- The various components of an ecosystem are interdependent.
- The producers make the energy from sunlight available to the rest of the ecosystem.
- There is a loss of energy as we go from one trophic level to the next, this limits the number of trophic levels in a food-chain.
- Human activities have an impact on the environment.
- The use of chemicals like CFCs has endangered the ozone layer. Since the ozone layer protects against the ultraviolet radiation from the Sun, this could damage the environment.
- The waste we generate may be biodegradable or non-biodegradable.
- The disposal of the waste we generate is causing serious environmental problems.

EXERCISES

1. Which of the following groups contain only biodegradable items?
   (a) Grass, flowers and leather
   (b) Grass, wood and plastic
   (c) Fruit-peels, cake and lime-juice
   (d) Cake, wood and grass
2. Which of the following constitute a food-chain?
   (a) Grass, wheat and mango
   (b) Grass, goat and human

(c) Goat, cow and elephant

(d) Grass, fish and goat

3. Which of the following are environment-friendly practices?

   (a) Carrying cloth-bags to put purchases in while shopping

   (b) Switching off unnecessary lights and fans

   (c) Walking to school instead of getting your mother to drop you on her scooter

   (d) All of the above

4. What will happen if we kill all the organisms in one trophic level?
5. Will the impact of removing all the organisms in a trophic level be different for different trophic levels? Can the organisms of any trophic level be removed without causing any damage to the ecosystem?
6. What is biological magnification? Will the levels of this magnification be different at different levels of the ecosystem?
7. What are the problems caused by the non-biodegradable wastes that we generate?
8. If all the waste we generate is biodegradable, will this have no impact on the environment?
9. Why is damage to the ozone layer a cause for concern? What steps are being taken to limit this damage?

Answers

Chapter 1

1. (i) 2. (d) 3. (a)

Chapter 2

1. (d) 2. (b) 3. (d) 4. (c)

Chapter 3

1. (d) 2. (c) 3. (a) 4. (c)

Chapter 4

1. (b) 2. (c) 3. (b)

Chapter 5

1. (c) 2. (a) 3. (d) 4. (b)

Chapter 6

1. (d) 2. (b) 3. (d)

Chapter 7

1. (b) 2. (c) 3. (d)

Chapter 8

1. (c)

Chapter 9

1. (d) 2. (d) 3. (b)
4. (a) 5. (d) 6. (c)

7. Distance less than 15 cm; virtual; Enlarged.
9. Yes
10. 16.7 cm from the lens on the other side; 3.3 cm, reduced; real, inverted.
11. 30 cm
12. 6.0 cm, behind the mirror; virtual, erect
13. m = 1 indicates that image formed by a plane mirror is of the same size as the object. Further, the positive sign of m indicates that the image is virtual and erect.
14. 8.6 cm, behind the mirror; virtual, erect; 2.2 cm, reduced.
15. 54 cm on the object side; 14 cm, magnified; real, inverted.
16. –0.50 m; concave lens
17. + 0.67 m; converging lens

Chapter 10

1. (b) 2. (d) 3. (c) 4. (c)
5. (i) –0.18 m; (ii) +0.67 m
6. Concave lens; –1.25 D
7. Convex lens; +3.0 D

Chapter 11

1. (d) 2. (b) 3. (d) 4. (c)
5. Parallel 6. 122.7 m; ¼ times
7. 3.33 Ω 8. 4.8 kΩ 9. 0.67 A
10. 4 resistors 12. 110 bulbs
13. 9.2 A, 4.6 A, 18.3 A
14. (i) 8 W; (ii) 8 W
15. 0.73 A
16. 250 W TV set in 1 hour
17. 1100 W
18. (b) High resistivity of alloys
(d) inversely.

Chapter 12

1. (d) 2. (c)
3. (a) True (b) False
6. vertically downwards
7. (i) Right-hand thumb rule, (ii) Fleming's left-hand rule

Chapter 13

1. (a), (c), (d) 2. (b) 3. (d)

Notes