8 Pressure

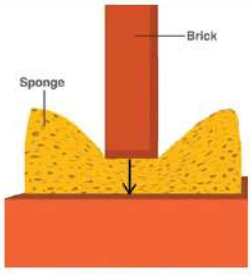


Figure 8.1 Pressure generated in the foam by the weight of the brick

Figure 8.2 Pressure exerted by water on the pipe wall

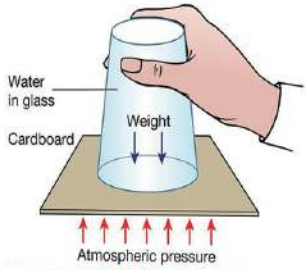


Figure 8.3 Pressure exerted by the air on the postcard

In the above figures, the pressure exerted by solid, liquid and gas is presented. Placing a brick on foam creates pressure on the surface of the foam [figure 8.1]. Solids exert pressure on the surfaces due to their weight. The pipe shown in Fig. 8.2, cracked because it could not withstand the pressure exerted by the water on its walls. When the pipe burst, water came out exerting high pressure on both the right and left sides of the walls. Similarly, in Figure 8.3, it is shown that the postcard is pushed up by the wind without letting it fall. Pressure is generated by the normal force (thrust) exerted by liquids and gases on the walls of various objects. A force acting perpendicular to the surface of an object is thrust. Its SI unit is Newton. The thrust acting per unit area of an object is called pressure. The SI unit of pressure is Pascal i.e., Newton per square meter (N/m^2).

Since liquid and gas are substances that can flow easily, they are called fluids. Like solids, the fluids too exert pressure. Fluid not only exerts pressure on the bottom of the vessel in which it is kept but on all the walls of the vessel.

Figure 8.4 Balloon placed in water

Figure 8.5 Hydrogen balloon released into the air

When an object is placed in a fluid, the fluid exerts pressure on the surfaces of the object. Figure 8.4 shows the upward force exerted on the surface of the balloon by the water pressure. If the balloon is filled with hydrogen or helium and released into the air, the balloon will fly due to the upward force caused by the air pressure. As the air density decreases with increasing height, the balloon will float at a certain height where the upward force exerted by the air and its weight are equal.

Transmission of pressure

The structure of molecules in solid, liquid and gas is shown in Figure 8.6. Molecules in solids are packed very close to each other. They have a definite shape and volume. The molecules in a solid do not move and change their position. When a force is applied to one side of a solid object, the pressure generated is not transmitted throughout the solid object. But, since molecules can move in liquid and gas, pressure is transmitted in the fluid kept in a closed container.

Activity 8.1 Transmission of pressure in fluid

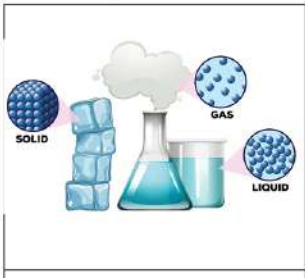


Fig.8.6 Structure of molecules in matter

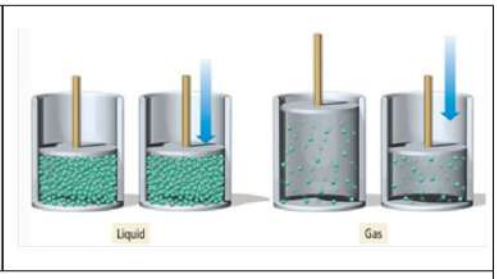


Fig.8.7 A process of compressing fluid in a closed vessel

Take two syringes. Fill one of them with water and leave the other empty. Close the nozzle of the empty syringe using a finger and push the piston inside as shown in Figure 8.7. Do the same with the syringe filled with water. Piston of which syringe can be pushed in? When the piston of an air-filled syringe is pushed in, did it show the same effect as in the water-filled syringe?

In this activity, when the piston of the water-filled syringe is pushed in, it does not move in. This means the water in the syringe cannot be compressed. But in a syringe filled with air, it is easy to push the piston in.But, when the air in it gets compressed, it becomes difficult to push the piston further just like in the syringe filled with water.

The intermolecular spaces between the molecules of liquids are very small. As shown in Figure 8.7, the external pressure cannot move the liquid molecules closer together. Therefore, since the liquid in the closed vessel cannot be pressed by pressure, its volume does not decrease. Hence, the pressure exerted at any point in the liquid gets transmitted uniformly in all directions. For example, in Figure 8.8a, it is shown that the toothpaste comes out of the mouth because the pressure generated by pressing the tube gets transmitted to the paste. But in gases, the space between molecules is larger than that in liquids. The volume of gas can be reduced by applying external pressure to them. Therefore, pressure is transmitted in compressed gas but not as effectively as in a liquid.

a b

Fig.8.8 Transmission of pressure in a fluid

Figure 8.8b shows the pressure generated by a force applied by a hand in a balloon containing compressed air being transmitted to all parts of the balloon. Therefore, to transmit the pressure in the gas, as in the liquid, it should initially be compressed sufficiently.

Pascal's law

Activity 8.2

Fill a polythene bag with water. As shown in Figure 8.9, squeeze the bag from the top with a fist and make fine holes around it and observe the water coming out of these holes. Does the water come out from all the holes uniformly? As the level of water decreases in the polythene bag, move the first downward and tighten the grip.

Fig. 8.9 Transmission of pressure in the water in a closed polythene bag

In the above activity, when the fist is tightened, the pressure generated in the water at the upper part of the polythene bag is transmitted through the water to the walls of the bag. As a result, water streams come out from all the holes' perpendicular to the surface of the bag. Here, the pressure generated at a point in the water enclosed inside the polythene bag is transmitted normally in all directions. French mathematician Blaise Pascal propounded a law about this in 1653 BC and it is known as Pascal's law.

This law states that, when a force is exerted at a point in an enclosed liquid, the pressure generated is transmitted normally throughout the liquid in all directions.

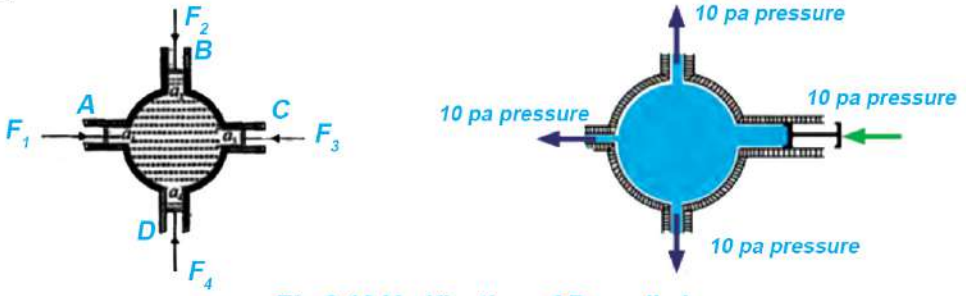


Fig.8.10 Verification of Pascal's Law

For verification of Pascal's law, a circular vessel with four pistons A, B, C and D can be taken as shown in Figure 8.10. Suppose the cross-sectional areas of the four pistons are a_1, a_2, a_3 and a_4 respectively. When the vessel filled with liquid is pushed inwards by applying a force F1 onto piston A, the pressure is generated on the cross-sectional area of this piston. Due to this pressure, the remaining three pistons move outwards. This means the pressure generated at piston A is transmitted normally throughout the liquid. If the inward forces applied to the outward moving pistons to prevent them from moving are, F_2, F_3 and F_4 respectively, the following result is obtained.

$$\frac{F_1}{a_1} = \frac{F_2}{a_2} = \frac{F_3}{a_3} = \frac{F_4}{a_4}$$

Therefore, the pressure generated at one point in a liquid kept in a closed vessel is transmitted equally everywhere.

Applications of Pascal's Law

Based on Pascal's law, various types of hydraulic machines such as hydraulic brakes, hydraulic lifts, hydraulic presses, etc. are manufactured.

Hydraulic machine

Activity 8.3 Making a model of a hydraulic machine

Take two syringes of different thicknesses, a saline pipe and water. Connect the mouths of both syringes with a saline pipe as shown in Figure 8.11.

Pull out the piston of a syringe and fill it with water. While filling with water, the barrel of the syringe should be filled a little more than halfway, leaving space for the piston to move outwards. If a weight is placed on top of the small piston and an object with a heavier weight is placed on the other side of the piston, will the heavier object be lifted?

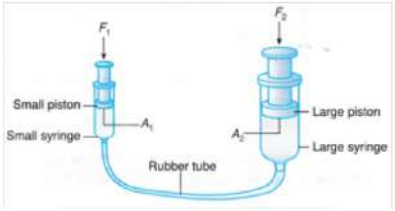


Fig.8.11 Construction of a model of a hydraulic machine

When the weight on the top of the larger piston increases and becomes equal to the maximum weight that can be lifted by the small piston, both pistons remain in a balanced condition. What is the weight necessary for that? Data can be tabulated in a table similar to the one shown below.

The weight placed on the smaller piston (F^1)	The weight placed on the larger piston (F^2)	Result
		Force on smaller piston increases ..... times

A hydraulic machine is a force-multiplying device based on Pascal's law. The excavator or backhoe shown in Figure 8.12 is an example of a hydraulic machine used for digging purposes. Hydraulic cylinders and pistons are used to move the digging part. While digging the ground, the upper part of the machine should bend towards the ground along with the backhoe so that the backhoe sinks into the ground. For that, as shown in the diagram above, the fluid in the black coloured flexible pipes is pushed with the help of the piston. As a result, the force exerted by the driver from the small piston magnifies and the ground is dug.

fig. 8.12

Construction and working mechanism of hydraulic machine

For the construction of a hydraulic machine, at least two cylinders with different cross-sectional areas are connected as shown in Figure 8.13. A piston is connected to each cylinder in such a way that the liquid inside does not leak.

The cross-sectional areas of the small piston and the large piston of the hydraulic machine shown in the figure are A_1 and A_2 respectively. Similarly, F_2 is the outward force produced on the large piston when a force F_1 is applied on the smaller piston.

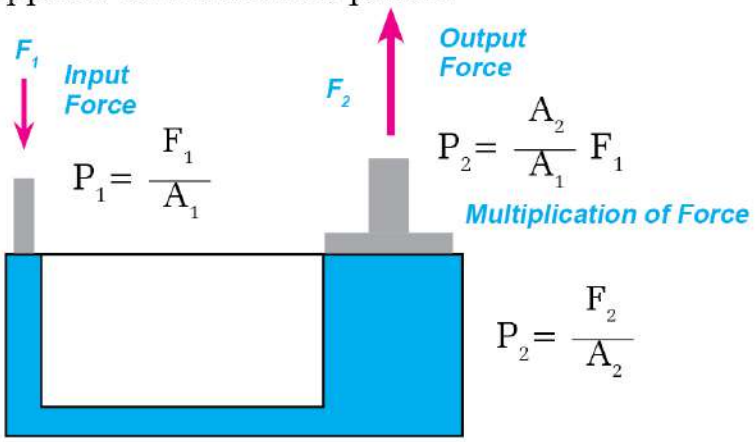


Figure 8.13 Structure and working principle of hydraulic machine

In a hydraulic machine, conditions are created for Pascal's law to apply. That is, when force is applied via the small piston of the machine, the pressure generated on the surface of the piston ($P_1 = \frac{F_1}{A_1}$) is transmitted perpendicularly and equally in all directions by the incompressible liquid in the cylinders. According to Pascal's law, the pressure generated on the surface of the small piston (P_1) = the pressure generated on the surface of the large piston (P_2)

Or $$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

$$F_2 = F_1 \left(\frac{A_2}{A_1} \right) \quad \text{.....(i)}$$

From equation (i), the force acting on the larger piston (F2) is $\frac{A_2}{A_1}$ (the ratio of the area of the larger piston to the smaller piston) times F1. In this equation, the factor is always more than 1 because in $\frac{A_2}{A_1}$ a bigger number is divided by a smaller number. For example, if the cross-sectional area of the large piston is twice $(\frac{A_2}{A_1} = 2)$

the cross-sectional area of the small piston, then the force exerted on the small piston of the machine becomes double when it is transferred to the large piston.

Some examples of hydraulic machine

Hydraulic machines are constructed in various designs, shapes, and sizes depending on their uses. Some of the examples are presented below.

hydraulic lift

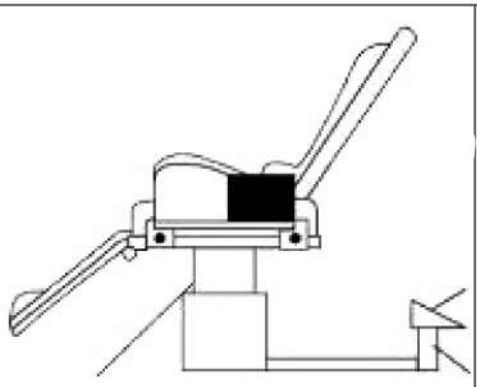


Figure 8.14 Hydraulic car lift

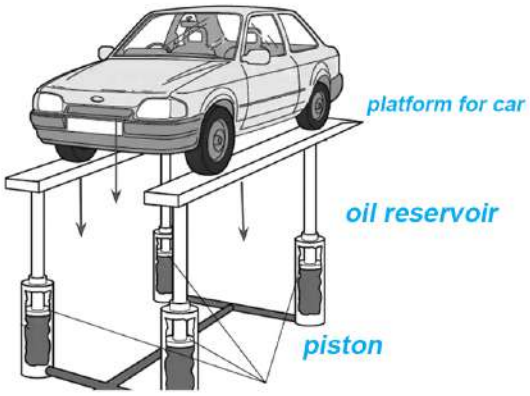


Figure 8.15 Hydraulic car lift

Figure 8.14 shows, the hydraulic lift used by the dentist to adjust the height of the chair according to the need during the treatment. The force applied to the small piston connected to the pedal of the chair gets amplified so that the surface of the big piston receives a large force and the patient is lifted upwards easily. Similarly, the hydraulic car lift, used to lift the car is shown in Figure 8.15. The oil in the small cylinder of the lift is pushed inward by the compressed air through the compressor and the car placed on the big piston on the other side is lifted. Hydraulic lift is used to lift heavy objects easily.

Example 8.1

In a hydraulic lift, the cross-sectional areas of the small piston and the large piston are 0.25 m^2 and 5 m^2 respectively. Calculate the force

required to lift the car of 1200 kg using the lift.

The cross-sectional area of small piston = 0.25 m^2

The cross-sectional area of large piston = 5 m^2

The mass of the car lifted by the upward force on the big piston (m) =1200 kg

That is, the upward force on the large piston (F_2) =Weight of the car (W) = mg=1200×9.8=11760 N

Force applied on the small piston (F_1)

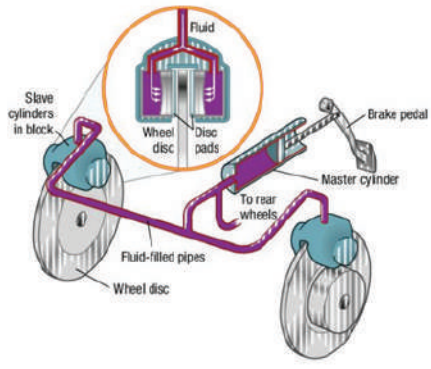
According to Pascal's law, $\frac{F_1}{A_1} = \frac{F_2}{A_2}$

Or $F_1 = F_2 \times \frac{A_1}{A_2} = 11760 \times \frac{0.25}{5}$

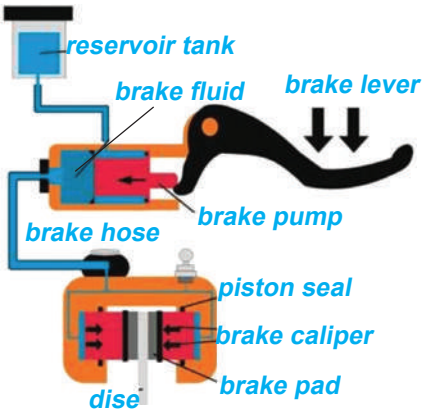
$F_1 = 588$ N

The force required to lift a car of mass 1200 kg using the given lift is 588 N.

hydraulic brake



a. Used in four-wheeled vehicles



b. Used in two-wheeler vehicles

Fig. 8.16 Hydraulic brake system

In the hydraulic brake system, the pipe connected to the master

cylinder and the brake cylinder is filled with a special type of brake oil. Pistons are fitted in both cylinders so that they become air-tight. As shown in Figure 8.16a, in four-wheeled vehicles, the piston of the master cylinder is connected to the brake pedal located at the driver's foot by a lever. Similarly, as shown in Figure 8.16b, in two-wheeled vehicles, the piston of the master cylinder is connected to the brake lever on the handle.

Brake cylinders are located on the wheels of vehicles. The piston of the brake cylinder is connected to the brake shoes or brake pads. By applying a small force on the small piston of the master cylinder, the pressure generated by pushing the fluid inside it is transmitted and a large force is applied to the large piston connected to the brake cylinder. Due to this a vehicle moving at high speed can be stopped in an instant.

(e) Hydraulic jack

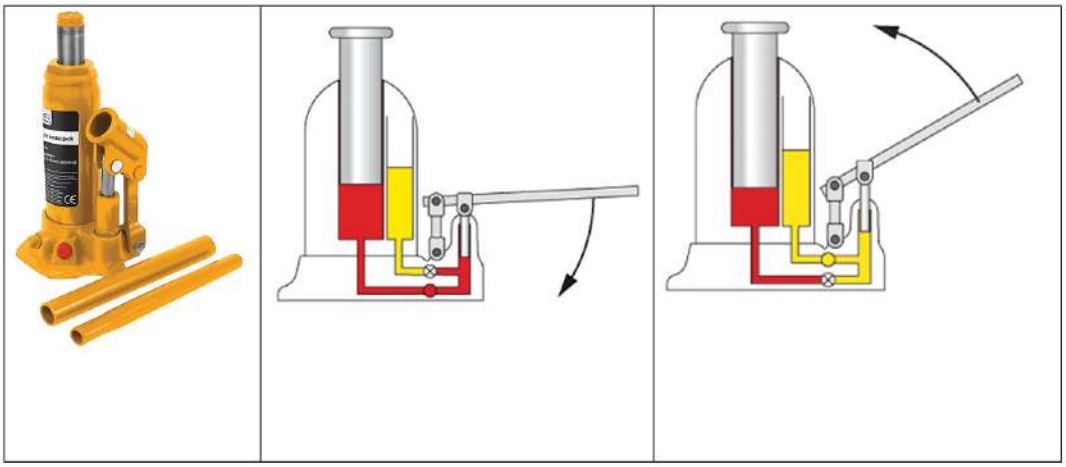


Figure 8.17 Hydraulic jack

Trucks, buses, cars, etc. are lifted at a certain above the ground by the use of hydraulic jacks. As shown in 8.17, a pumping piston with a small cross-sectional area and a lifting piston with a large cross-sectional area are connected. A bottom valve is kept between these two pistons for the one-way flow of the oil, from right to left only.

Similarly, a top valve is placed for the flow of oil from left to right, from the oil reservoir to the pumping piston.

In a hydraulic jack, when the releasing valve is tightened and the lever is pushed down, the upper valve closes and the lower valve opens. As a result, the force exerted on the pumping piston of the jack increases and the load on the lifting piston is pushed a little higher. After that, when the lever is pulled up, the bottom valve closes due to high pressure and the top valve opens. As a result, the oil from the reservoir fills the cylinder of the pumping piston. Then, in the next stage of pumping, the load is pushed up again. By repeatedly pushing the lever up and down, the load can be pushed up to the required height.

(e) Hydraulic press

Various objects can be pressed by applying a small force to the small piston of the hydraulic press. As in Figure 8.18, the object to be pressed is kept between a large piston and a rigid support above the piston. The hydraulic press is used to fit mechanical parts of vehicles, bend metal sheets or make holes in them, to pack paper, cotton and straw by compressing them.

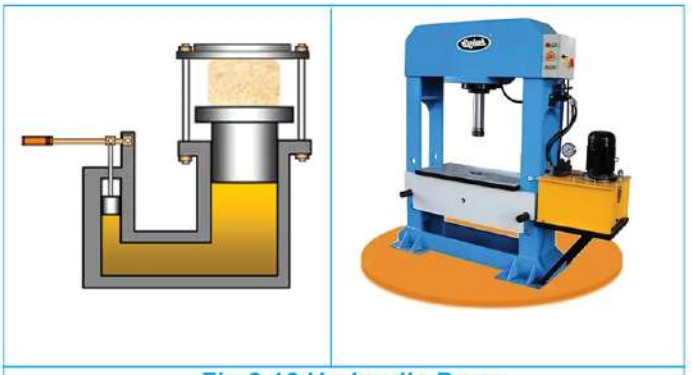


Fig.8.18 Hydraulic Press

Upthrust

Activity 8.4 Observation of Upthrust

Take an empty plastic bottle and some water in a bucket. Tighten the cap of the bottle to make it airtight. Drop the bottle into the bucket.

The bottle floats on the water. Push the bottle into the water. Observe, discuss and answer the following questions.

(a) When the bottle is pushed into the water, do you feel that the bottle is being pushed upwards?

(b) When the plastic bottle is let go in the air it falls because of gravity, but why doesn't it sink when it is placed on the surface of the water? Doesn't gravity act on the bottle when it is placed in water?

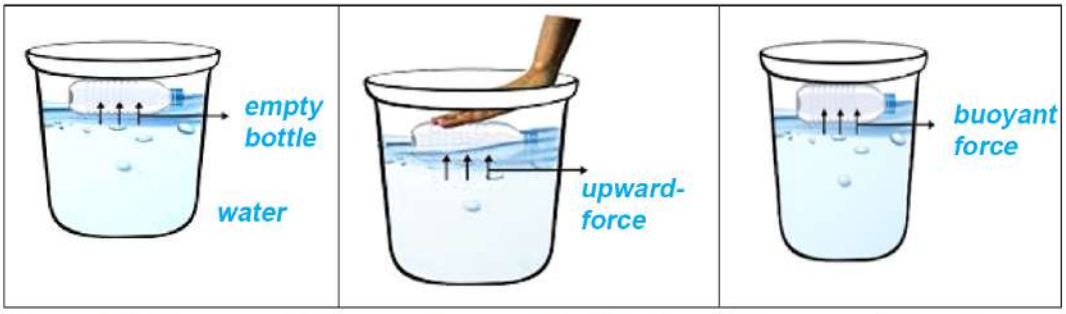


Figure 8.19 The upward force on the empty bottle when it is immersed in water

It is difficult to push the bottle into the water. It means the water is pushing the bottle upward. As the bottle is pushed into the water, the upward force exerted by the water goes on increasing until the bottle is completely submerged. When the bottle is released, it returns to the surface of the water. The net upward force by which water pushes the object in it is called upthrust. All fluids exert upthrust but the magnitude of the upthrust depends upon their density.

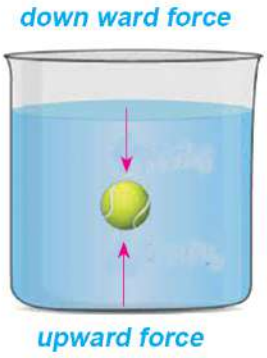


fig 8.20

fig 8.21

fig 8.22

As shown in Figure 8.20 and Figure 8.21, when an object is placed in air or water, it is acted upon by two forces; weight caused by gravity and the upthrust of the liquid. Since both these forces are in the opposite direction, the upthrust reduces or neutralizes the weight. For example, in the above activity 8.4, the weight of the

bottle (W) i.e., the force of gravity is greater than the upthrust exerted by air exerted (U) on the plastic bottle. Upthrust cannot neutralize the downward pull of gravity (weight of the bottle) and the bottle sinks in the air or falls. On the contrary, when the bottle is forcefully submerged in the water, the upthrust becomes more than the weight of the bottle. The upthrust neutralizes the gravity and the submerged bottle comes out of the water. When the upthrust equals the weight of the bottle, the bottle floats on the water. Therefore, when an object is partially or completely immersed in a gas or liquid (fluid), the upward force acting on the object is called upthrust. Its SI unit is Newton (N).

Question to think

(a) What happens when the bottle used in the above activity 8.4 is filled with water and then placed in the bucket again?

(b) When a bucket submerged in water is pulled out with a rope, what is the difference between the force required to pull a bucket while it is in the water and after it comes out in the air?

When a bucket is dropped into a well, it initially floats for a while, but once it is filled with water, its weight increases. In that case, the downward force of gravity on the bucket cannot be neutralized by the upthrust of the water and the bucket sinks into the water. The upthrust acting on the bucket submerged in water reduces the weight of the bucket inside the water. In that case, the weight of the bucket is less than the actual weight. So, when the bucket submerged in the water is pulled up by the rope, less force needs to be applied than its actual weight. When the bucket is pulled out into the air, the upthrust of the air is negligible compared to that caused by the water. In that situation, the force required to pull the bucket increases. Therefore, it is easy to pull a bucket full of water when the bucket is inside the well.

In all cases, the upthrust caused by the air is not negligible. Plastic bottles, buckets, etc. occupy little space in the air and the upthrust on them is very small. But the aeroplane experiences a large upthrust.

Cause of upthrust

In Figure 8.23, the force exerted by water due to its pressure on the surface of a cubic object immersed in water is shown by the arrows. The forces acting on all surfaces, except the upper and lower surfaces, are equal and opposite in directions. Due to this, the force acting on the right surface is canceled by the force on the left surface and the force acting on the front surface is canceled by the force on the back surface.

The liquid exerts normal pressure on the object immersed in it from all sides. The pressure increases as the depth of the object increases. Since the lower surface of the cubical object is at a greater depth, the pressure and force on the lower surface are greater than the pressure and force on the upper surface. Thus, when the force on the upper surface of the object is subtracted from the force on the lower surface, the resultant force has an upward direction. Hence, the direction of the upthrust is upwards.

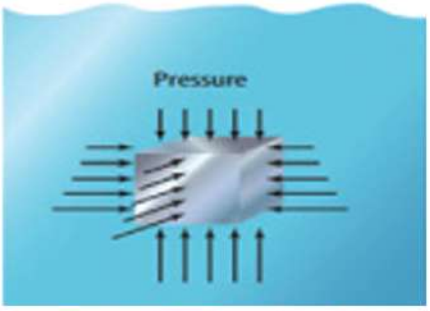


Figure 8.23Direction of upthrust

Activity 8.3 Calculation of the upthrust acting on a stone immersed in water

Take a small stone, a beaker that is filled more than half with water, a spring balance and a piece of thread. Tie the stone with the thread and hang it on the spring balance as shown in Figure 8.24. Measure the weight of the stone when it is suspended in air and the weight of the stone when it is submerged in water. Is the weight in air equal to the weight in water?

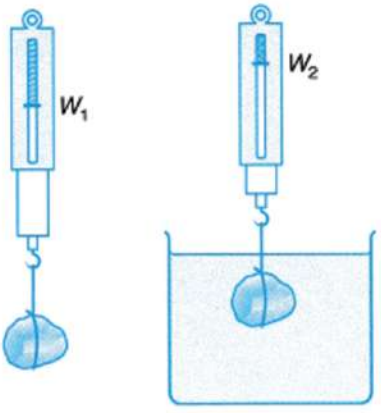


Figure 8.24 Upthrust acting on a stone submerged in water

When an object is immersed in a liquid, its weight is found to be decreased due to the upthrust exerted on it. The weight of an object measured in air (W_1) is called real weight and the weight of an object inside a liquid (W_2) is called apparent weight.

Therefore, the upthrust created when an object is immersed in a liquid can be represented by the following formula:

Upthrust (U) = Actual weight (W_1) - Unreal weight (W_2)

Factors affecting upthrust

(a) Density of a liquid

Activity 8.4 Observation of the weight of stones in different media

Prediction: In which liquid, is the weight of the stone least, when it is immersed in water, glycerin, and cooking oil respectively?

Take some amount of water and edible oil in two beakers. Hang the stone on a spring balance and measure the weight of the stone in these three liquids.

Weight in Water	Weight in edible oil	Results
.....	.....	.....

The density of edible oil and water are 0.90g/cm^3 and 1g/cm^3 respectively. In the above activity, the weight of the stone is less in water than that in edible oil. Since the density of water is more than that of edible oil, the upthrust exerted by water is also more than that of edible oil. Thus, the upthrust exerted on a body is directly proportional to the density of the liquid. Therefore, when an object is immersed first in a liquid with lower density and then in a liquid with higher density, the upthrust exerted by the liquid of higher density is more.

Upthrust ∝ Density of liquid

Since the upthrust is directly proportional to the density of the liquid, the iron ball sinks in water but floats on the surface of mercury which has a high density. Similarly, as shown in Figure 8.25, when an egg is placed in a glass filled more than half with tap water, it sinks. But when salt is dissolved in the water, the egg starts to float. The density of salty water is higher than that of tap water.

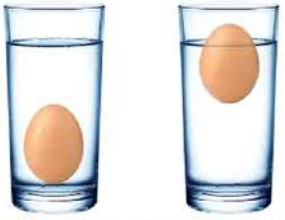


Figure 8.25 Eggs kept in tap water and salty water

That's why salty water exerts more upthrust than tap water. As a result, the egg sinks in tap water but floats on salt water. This is the reason why it is easy to swim in seawater. Similarly, a ship sinks less in seawater than in river water.

(b) Volume of liquid displaced

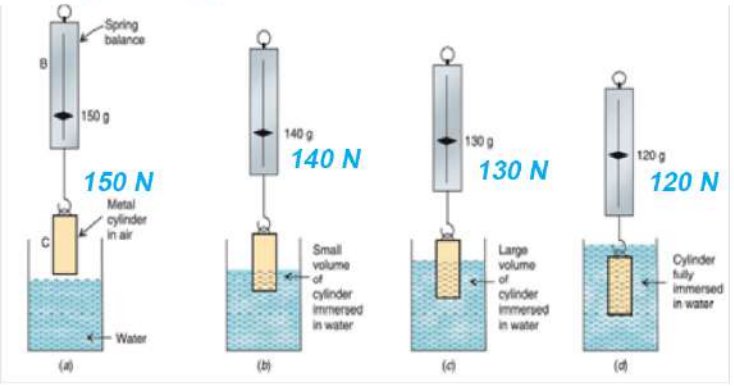


Figure 8.26 Upthrust and volume of the displaced liquid

Figure 8.26 shows the weight of a solid cylindrical object in different stages as it gets submerged in water. The figure shows the decrease in the reading on the spring balance as the volume of the immersed part of the object increases. The more the solid submerges in water the more volume it displaces. Once the object is completely submerged in water, the reading on the spring balance stays constant.

When a solid object is immersed in a liquid, as its volume inside the liquid increases, the 'upthrust' on it also increases and when the object is completely immersed in the liquid, the upthrust is maximum. After the object is immersed in the liquid, even though the depth of the object increases, the upthrust remains constant. For example, two cubic solids of different weights but equal volume are completely immersed in a liquid; the upthrust acting on them is the same as shown in Figure 8.27. Therefore, when an object is partially or completely immersed in a liquid, the upthrust acting on it is directly proportional to the volume of the displaced liquid.

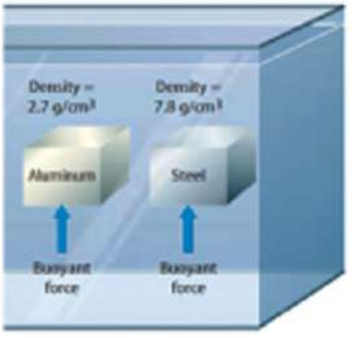


Figure 8.27 Upthrust acting on the object with the same volume

This means, when the volume of an object immersed in liquid increases, the upthrust acting on it also increases.

Upthrust ∝ volume of fluid displaced

When trying to submerge a big water-tight plastic bottle and a small water-tight plastic bottle, the big bottle displaces more water than the smaller one. As a result, a large plastic bottle experiences more upthrust. Therefore, to submerge a large plastic bottle in water, more force should be applied than that on a small bottle. A similar effect applies to large and small balloons filled with helium gas. Since the large balloon displaces more air than a small balloon, the upthrust acting on it is also greater.

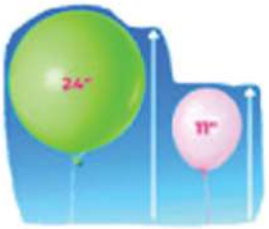


Figure 8.28 Upthrust on large and small balloons

When an object is placed in a fluid, the relationship between the upthrust on the object and the weight of the displaced fluid is given by Archimedes' principle.

Archimedes' principle

Activity 8.5: Verification of Archimedes' Principle

Take a spring balance, a eureka can (beaker that can collect displaced water), a beaker, a small stone, and a mug. Hang the stone on a spring balance as shown in Figure 8.29, and measure its weight first in the air and then in water in the eureka can. While measuring the weight of the stone in water, note the weight of the water displaced by the stone too. For this, first, weigh the empty beaker and subtract that weight from the weight of the beaker with displaced water.

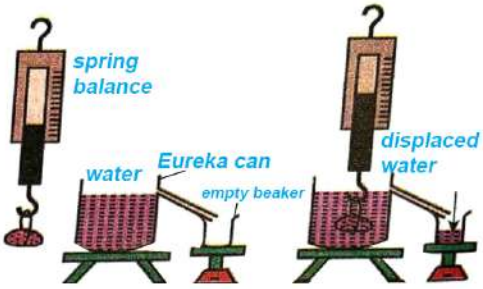
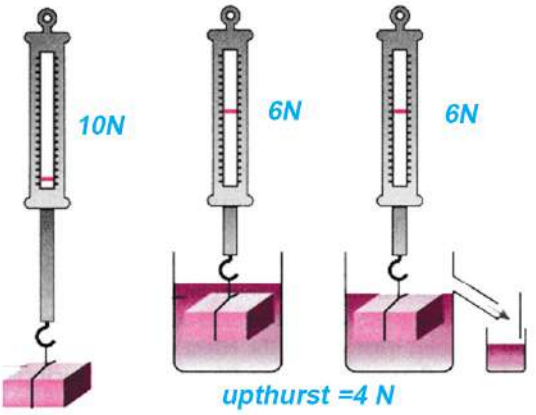


Figure 8.29: Verification of Archimedes' Principle

The data required for this activity can be collected in a table as the table below.

Weight of the stone in the air. (W1)	Weight of the stone in water (W2)	Upthrust (U)= (W1)- (W2)	Weight of the empty beaker (W3)	Weight of beaker and displaced water(W1)	Weight of displaced water (W1)	Result

In this process, when a stone is immersed in water, the upthrust exerted on it is equal to the weight of the displaced water. This proves Archimedes' Principle. For example, in Figure 8.30, it is shown that the upthrust exerted on the solid object immersed in water (4N) and the weight of water displaced, are equal.



Irq 8.30 upthurst and displaced liquid weight

Archimedes is a Greek mathematician born in 287 BC. According to Archimedes' Principle, when an object is partially or completely immersed in a liquid, the upthrust is equal to the weight of the liquid displaced by it. This principle is not only true for liquids but applies to all fluids.

Mathematically,

Upthrust (U) = Weight of liquid displaced (W)

$$U = mg = V \rho g \quad \text{Because, density of liquid } (\rho) = \frac{\text{Mass } (m)}{\text{Volume } (V)}$$

In the above equation, V, 'ρ'and g represent the volume of liquid displaced, density, and acceleration due to gravity respectively.

The upthrust exerted on an object placed in a liquid depends on the volume of liquid displaced by the object. Likewise, according to Archimedes' principle, the upthrust on an object is equal to the weight of the displaced liquid. Therefore, when an object is placed in a liquid, whether it floats or sinks depends on its weight of the object and the upthrust which depends on the volume of liquid displaced.

Floatation

Question to think

(a) Why do objects sink or float?

(b) Oil, which is less dense than water, floats on the surface of the water. Can an object made of iron, which is denser than water, also float on water?

If the density of the object is less than the density of the liquid, the object will float on the liquid. But, simply comparing the density of an object to the density of a liquid does not determine whether an object floats or sinks. The fact can be justified by the following activity.

Activity 8.6 Observation of the state of sinking and floating

Take two pieces of aluminum foil of equal area and a beaker that is filled more than half with water. Squeeze one of the aluminium foils in the shape of a ball. Then, as shown in Figure 8.31, drop both aluminium pieces into the water. Observe which floats and which sinks. If the aluminum foil is turned into a ball, its surface area gets reduced. Since it displaces less water, the upthrust acting on it will be less than its weight. So, it sinks in the water. If the aluminum foil is placed in the water as a sheet, the surface area increases and so does the upthrust acting on it. When weight and upthrust become equal, the foil floats.

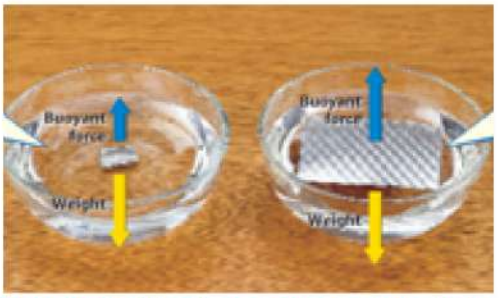


Figure 8.31 Aluminum foil placed in water

The density of aluminum is 2700kg/m^3 which is 2.7 times the density of water. Thus, it can be concluded that the foil sinks in water. But, according to the result of Activity 8.8, the aluminum foil kept as a sheet floats on the water. Therefore, whether an object floats or sinks in a liquid depends not only on the density of the substance but also on the shape of the object, i.e., the resultant force acting on an object when it is placed in the liquid.

The weight of an object and the upthrust are the forces acting on the object in exactly opposite directions. When the upthrust cancels the

weight of the object, the resultant force becomes zero and hence the object floats in the liquid.

An object floating in a liquid may be partially or completely inside the surface of the liquid. When partially floating, only the submerged part of the object displaces the liquid. For an object to float in a liquid, the weight of the object must be equal to the weight of the liquid that it displaces. This is known as the law of floatation. This means, for an object to float on a liquid,

Weight of object = weight of the liquid displaced

This fact applies to various phenomena that occur in the liquid and air around us. Some examples are given below:

(a) Floating in a liquid

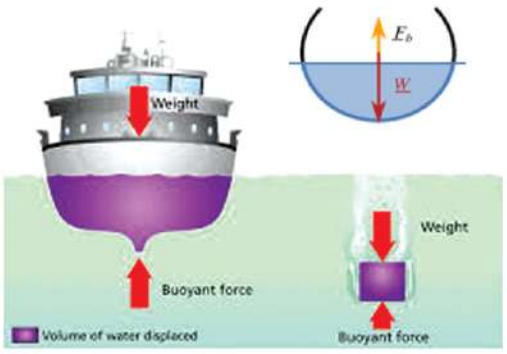


Figure 8.32 An iron block, bowls and a ship made up of iron in the water

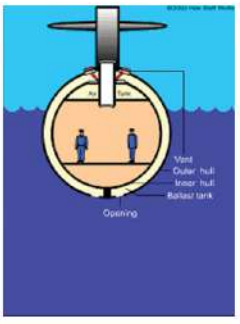
Figure 8.33 An empty boat and a boat carrying passengers

As shown in Figure 8.32, when an iron block is placed in water, it cannot displace the volume of water whose weight is equal to its weight, and thus, it sinks. If the iron block is shaped like a bowl, the bowl can displace water equal to its weight. Similarly, in a ship, its hull is to be made wide, long and deep. Because of this, the ship can displace enough water to generate upthrust equal to its weight. For

example, to prevent a ship weighing 50000 tons from sinking, the size of the hull should be able to displace 50000 tons of water. Therefore, iron sinks in water, but a ship made of iron floats on water.

Just like a ship, when a boat floats, the weight of the displaced water is equal to the boat's weight. As the lower part of the boat slowly sinks into the water, the volume and weight of the water it displaces also increases. According to Archimedes' principle, the upthrust exerted on the boat is equal to the weight of water displaced by the boat. As shown in Figure 8.33, the more people get on the boat, the more the boat sinks in the water and the boat displaces an additional amount of water. As the weight of the displaced water increases, the upthrust on the boat also increases. The increased upthrust supports the weight of the people added. If the water level reaches the top of the boat, no more water can be displaced and the upthrust does not increase. In that case, as the weight on the boat increases, the boat sinks. If a hole is formed at the bottom of a floating boat, it sinks, why? This concept applies to the submarine, too.

Submarines are built in such a way that they can float visibly on the surface of the water as well as inside the water. When its blast tank is filled with water, the weight increases and the submarine goes deeper into the water, and when the water is blown out of the tanks by the compressed air, the weight decreases and it floats back on the surface. Like submarines, fish also use Archimedes' principle to float and sink in water. When air is filled in the fish's swim bladder i.e. air sac, the volume of the body increases and the upthrust also increases. The fish floats toward the surface of the water. On the contrary, fish empty their bladders to reduce their body volume as well as the upthrust acting on their body. This helps them to go deeper into the water.



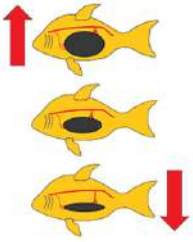


Figure 8.34

A hydrometer is a device used to measure the relative density of liquids. It contains a wide glass bulb filled with heavy metal which is attached to a calibrated fine tube. Due to the liquid displaced by

its heavy bulb, it gets the necessary upthrust and floats vertically on the surface of the liquid. The hydrometer floats more on liquid of high density because such liquid exerts more upthrust. On the contrary, if the density of the liquid is low, the hydrometer sinks more. Lactometer is a type of hydrometer used to test the mixture of water in milk.

Figure 8.35 Use of Lactometer

(b) Floating in the atmosphere

Like in the water, there is upthrust in the air too. But the density of air is much less than that of water; therefore, the upthrust of air is much less than that exerted by water on an object.

Figure 8.36 Helium Balloons

Question to think

Why does a balloon filled with helium float in the air?

Objects can float on gases as well as on liquids. Objects float or fly in the air due to the upthrust produced by the air pressure. In Figure 8.36, balloons filled with helium gas are shown flying in the air. Air is denser than helium. If the weight of the air displaced by the helium-filled balloon i.e., the upthrust on it is greater than the weight of the balloon, the balloon will fly upwards. As the altitude increases, the density of air decreases and this makes the upthrust acting on the balloon decrease. When it reaches a certain height, the weight of the balloon equals the upthrust. As a result, the balloon floats in the air. At a certain height, the pressure inside and outside the balloon becomes unbalanced and the volume of the balloon keeps increasing until it finally bursts.

Like hydrogen or helium balloons, hot air balloons also fly in the air. The density of air inside a hot-air balloon is less than the density of the surrounding air. Since such a balloon displaces a large amount of air, the upthrust on the balloon becomes greater than its weight. As

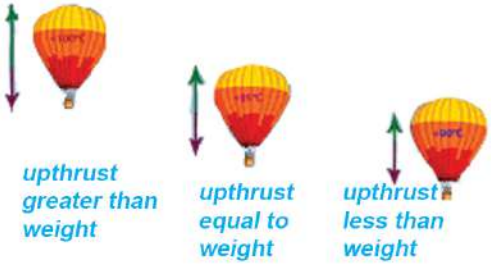


Figure 8.37 Hot air balloons in the air

a result, the balloon flies upwards in the air. When the balloon reaches a maximum altitude, the weight of the displaced air i.e., upthrust balances the weight of the balloon. Then the balloon floats in the air.

A balloon filled with hot air rises or falls in the air and such a condition is controlled by changing the temperature of the air inside the balloon with the help of a burner. When the flame from the burner heats the air in the balloon, the density of the air decreases. This causes the balloon to fly upwards. On the contrary, when the burner is turned off, the air in the balloon cools and its density increases. When the air in the balloon is cold enough, the weight of the balloon becomes greater than the upthrust on it and the balloon sinks in the air i.e., descends to the ground.

Project work

Use locally available plywood, cardboard, syringe, saline pipe, etc. as shown in the figure, and prepare the models of hydraulic bridges, hydraulic lifts, hydraulic doors, dozers, etc. based on Pascal's law.

Exercise

1. Choose the correct option for the following questions:

(a) On which law/principle is a lactometer based?

(i) Pascal's law (ii) Archimedes' principle

(iii) Law of Gravitation (iv) Newton's law

(b) What is the condition for flying a hydrogen balloon upwards in the air?

(i) weight of the balloon = weight of air displaced

(ii) weight of balloon > weight of air displaced

(iii) weight of the balloon = volume of air displaced

(iv) weight of balloon < weight of air displaced

(c) In a hydraulic machine, if the cross-sectional area of the larger piston is twice the area of the smaller piston, what is the correct group of the weights on the smaller piston (W_1) and the larger piston (W_2) to keep the machine balanced?

(i) $W_1 = 4$ N, $W_2 = 2$ N

(ii) $W_1 = 5$ N, $W_2 = 10$ N

(iii) $W_1 = 2$ N, $W_2 = 1$ N

(iv) $W_1 = 3$ N, $W_2 = 1.5$ N

(d) (d) When an object is suspended using spring balance in air, water and glycerin, the weight is founded to be W_1, W_2, and W_3 respectively. What will be the weight of the object in those mediums in increasing order?

(i) $W_1 < W_2 < W_3$

(ii) $W_2 < W_1 < W_3$ (iv) $W_3 < W_1 < W_2$

(iii) $W_3 < W_2 < W_1$

(e) When a ship enters a river from a sea, it was found to sink more than before. What is the reason for this?

(i) the temperature of seawater is more than that of river water

(ii) the density of seawater is more than that of river water

(iii) the temperature of seawater is less than that of river water

(iv) the density of seawater is less than that of river water

(f) Which one of the following statements is correct for a hand pushing a ball into the water as shown in the given figure?

(i) equal pressure acts on all parts of the ball under the water

(ii) the more the ball is pushed into the water, the lesser the upthrust it experiences

(iii) the pressure on the ball acts only in the upward direction

(iv) the upthrust on the ball increases until it completely sinks into the water

(g) If the same magnitude of upthrust acts on the three cubical balls made up of different materials on keeping them in water, which one of the following quantities is equal for them?

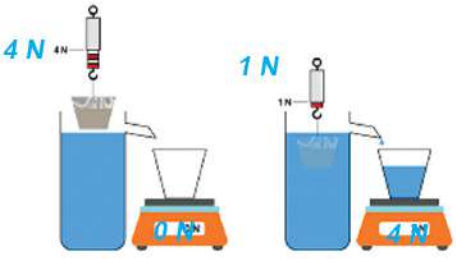
(i) density (ii) weight

(iii) volume (iv) mass

(h) What is the upthrust when the cork shown in the figure is placed in the liquid?

(i) 3N (ii) 4N

(iii) 5N (iv) 1N



2. Differentiate between:

(a) pressure and upthrust

(b) the reason for a steel pin sinking in water and a steel plate floating on water

(c) the process of a hot air balloon sinking and rising in the air

3. Give a reason for

(a) A special type of oil is used in hydraulic brakes.

(b) A wooden cork dipped below the surface of the water by applying force with a finger comes to the surface when the finger is removed.

(c) We feel lighter while floating on water.

(d) On lifting a stone submerged in water, it feels heavier when it comes out of the water.

(e) It is easier to float in the Dead Sea than in a swimming pool, (the density of water in the Dead Sea is 1240kg/m^3).

(f) If more passengers climb a boat than its maximum capacity, the boat is likely to sink.

4. Answers the following questions:

(a) State Pascal's law.

(b) Write any two applications of Pascal's law in daily life.

(c) What is a hydraulic machine?

(d) State Archimedes' principle.

(e) What is upthrust?

(f) Mention the forces acting on a floating object and their directions.

(g) State the law of floatation.

(h) Write any two applications of Archimedes' Principle.

(i) Explain, with a figure, the cause of the production of upthrust.

(j) When a stone is dropped into the water, it sinks. Does this happen because of the absence of upthrust?

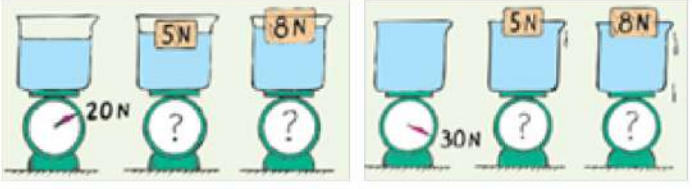
(k) A person is trying to lift a stone of 500N keeping it on the smaller piston of a hydraulic machine by applying a force on the larger piston. What suggestion would you give him/her so that he/she can lift the load easily? Explain, with an appropriate figure, the process of increasing the force in the hydraulic machine.

(l) Substances with a density greater than the density of the liquid sink in it. Is this statement always true? Justify with an example.

(m) Two balloons, one filled with air and the other with hydrogen, look identical. What difference can be noticed when they are released into the air? Explain with reasons.

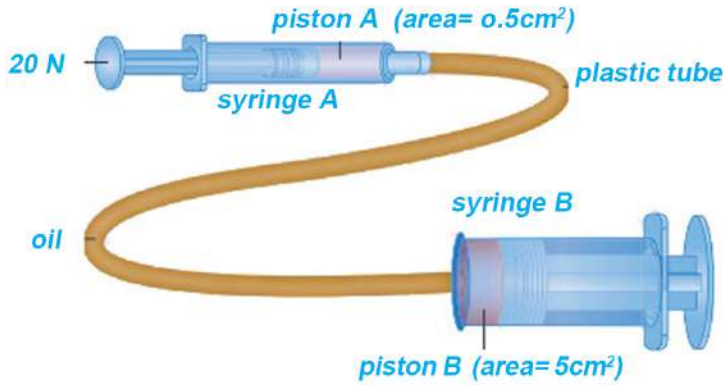
(n) An object is suspending /floating just below the surface of the water. If the amount of salt dissolving in the water goes on increasing, what change will occur in the position of the balloon? Explain with reasons.

(o) What are the readings shown by the weighing machine given in figures (a) and (b)? Explain with reason.



(p) When a person puts a lactometer into the milk, the whole part of the narrow stem sinks into the milk. What conclusions can be drawn from this event?

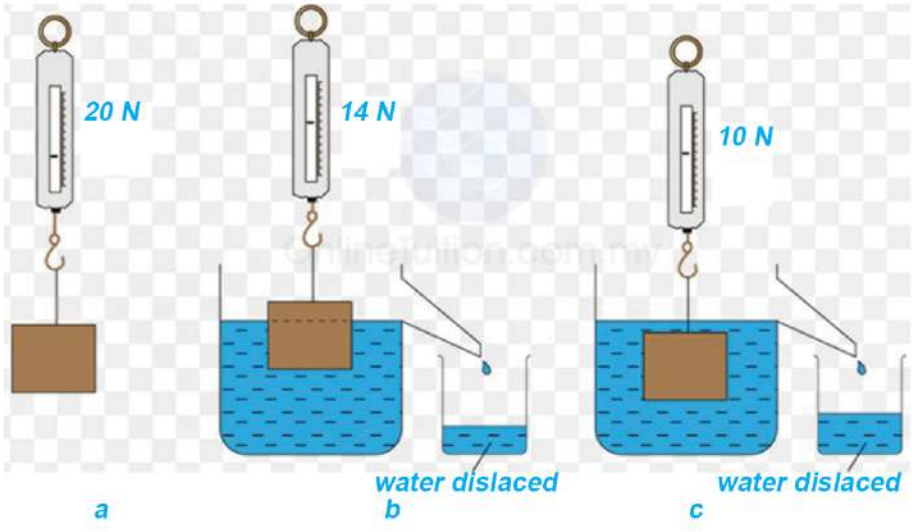
5. Solve the following mathematical problems:



(a) In the figure, a sample of a hydraulic machine constructed by using syringes is shown. How much force is to be applied through syringe B to balance the force on piston A?

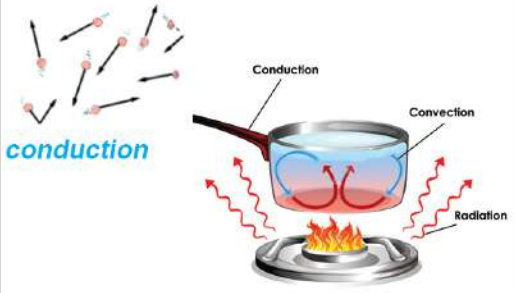
(b) Pressure of 30000 Pa is generated in the liquid of a hydraulic lift. If the cross-sectional area of the piston used to lift a weight is 0_1 m^2, how much load can it lift?

(c) Calculate the upthrust acting on the object in situations b and c shown in the figure. Mention the cause for the occurrence of different upthrusts under these two situations.



9 Heat

Discuss the scientific reasons related to the precautions given in the following table



conduction

We should not put our hands over boiling water.

Hot water should not be poured into a glass tumbler during the winter season.

A glass bottle full of water should not be kept in the deep fridge.

A steel plate covering the cooking food should not be taken out using bare hands.

Fig 9.1 Precautions used in daily life

In Figure 9.1, the rapid movement of molecules in water vapor is demonstrated by long arrows. Due to the rapid movement, the kinetic energy of the molecules is high. When the skin of our body comes in contact with steam, its molecules easily penetrate the skin and burn the inner parts. This causes a lot of pain.

When boiling water is suddenly poured into a thick glass tumbler, it cracks because theheat from its inner part cannot be transferred to the outer part and thus the increase in the volume of the inner part of the glass createspressure on the outer part. When a glass bottle filled with water is placed in the deep freeze, the volume of the water increases and the glass bottle cracks. Similarly, when different objects are heated, the temperature does not increase at the same rate. When boiling water is poured into a steel glass we are holding, the temperature of the steel glass increases instantly and burns our hands.

Thermal energy, heat and temperature

Activity 9.1

(a) Pour boiled water, tap water,and cold water from the refrigerator into three different beakers. Add an equal amount of food coloring agent or abirinto each and observe how the color mixes. If the movement of the color particles is considered to be the same as the movement of the water molecules, the molecules of which beaker has the fastest movement? Why?

(b) Pour lukewarm water, tap water, and cold water from the refrigerator into three separate beakers. Immerse the fingers of one hand in the lukewarm water and the fingers of the other hand in the cold water. After a minute, place all fingers in a beaker filled withtap water. Discussion about your observation.

Matter consists of many atoms or molecules. These atoms or moleculesare always in motion. The kinetic energy of molecules in lukewarm water is greater than the kinetic energy of molecules in cold water. The speed of molecules in hot water is even higher than that oflukewarm water. The sum of the kinetic energy of the molecules is the thermal energy. When the mass of warm water, tap water, and cold water are equal, the thermal energy of the hot water is the highest and that of the cold water is the lowest.

Absolute Zero Temperature: This is a theoretically considered state of zero thermal energy. 0 K = - 273.15°C.

When water is boiled, the external energy supplied makes the molecules move faster. The kinetic energy of all the atoms or molecules of a substance is not equal at any time. Therefore, their average kinetic energy is important. The average kinetic energy of the atoms or molecules of a substance determines its temperature. The temperature is an index of the average kinetic energy of the molecules in the substance. The SI unit of heat is the kelvin (K) but degree celsius (°C) is the most commonly used unit. It is measured using a thermometer.

The temperature of boiling water in a panis 100°C and the temperature of lukewarm water kept in the bucket is 30°C means that the average kinetic energy of the molecules of boiling water in the pan is much higherthan that of the molecules of the lukewarm water in the bucket. But the number of water molecules in the pan is much less thanthe water molecules in the bucket. Hence, although the average kinetic energy of the molecules in the boiling water in the pan is more, the sum of the kinetic energy of the molecules of the lukewarm water is higher because of the number of molecules. Therefore, the lukewarm water in the bucket has more thermal energy than the boiling water in the pan. The thermal energy of a substance depends on its mass and the average speed of its molecules.

When both the waters mentioned above are mixed, thermal energy is transferred from the boiling water to the lukewarm water. Thus, the amount of thermal energy transmitted from one place to another place due to the temperature difference is called heat. Like other types of energy, the SI unit of heat is the joule (J). It can be measured by using a calorimeter.

Heat is not stored in any object. It is only the quantity of thermal energy transferred from one object to another. When heat is transmitted, the thermal energy of one objectdecreases and that of the other increases. Therefore, when heat is transmitted, the temperature of one object decreases and that of another increases.

Heat is transmitted by the methods of conduction, convection and radiation. When we touch an object, if heat enters our body from the object feels hot and if heat leaves our body, itfeels cold.

Heat flows from a body at a higher temperature to a body at a lower temperature until both attain the same temperature.

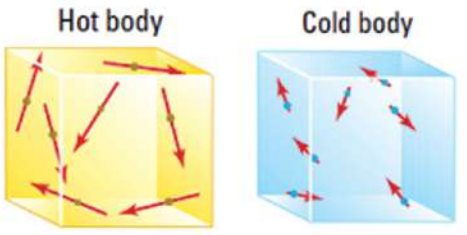


Figure: 9.2 the average kinetic energy of atoms/molecules of a hot object is greater than that of a cold object.

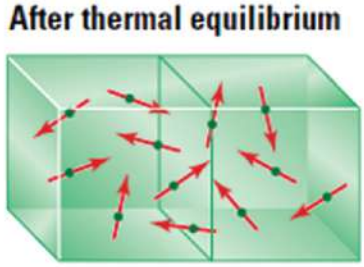


Figure: 9.3 Heat flows from a hotter object to a colder object until they attain thermal equilibrium.

Effect of heat on volume

In the figures below, the fact that the distances between the atoms/molecules are different in solid, liquid and gaseous substances is demonstrated comparatively.

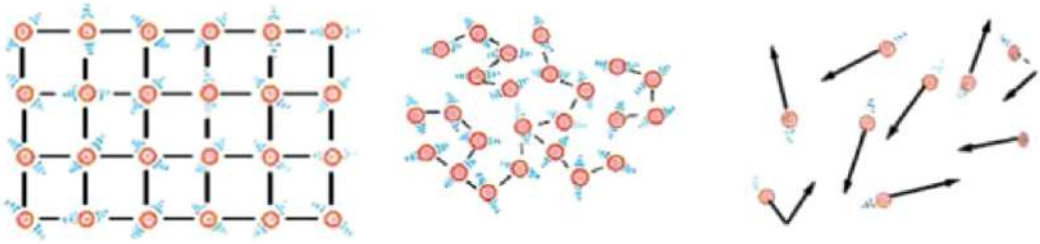


Figure 9.4 states of atoms/molecules in solids, liquids and gases

Molecules of solid matter are bound in a certain pattern due to the force of attraction between them. However, they are not stationary but constantly vibrating. When a solid is heated, its atoms/molecules gain more energy and their vibration increases. When heat is continuously supplied, the atom/molecules vibrate rapidly. That is why, the force of attraction between them weakens and they move away from each other, i.e.,the volume increases. Contrary to this, when an object releases thermal energy, average speed decreases. Therefore, temperature decreases and the object contracts.In this way, most of the matters expand when the temperature increases and contract when the temperature decreases.

Activity 9.2

Take an iron sphere having small hook and a similar-sized iron ring that fits the sphere. Heat the iron sphere for some time and try to pass it through the ring. Let the sphere cool down and then try to passit through the ring once again.Based on the concept of thermal energy or heat, discussyour observations. Fill up the following table and conclude.

Observation	**Observation**	**Explanation**	
	While trying to pass through the ring	Speed of the molecules in the sphere	Distance between the molecules in the sphere
On heating the iron sphere	.....	increases/ decreases	increases/de-creases .....
On cooling the iron sphere	.....	.....	.....

Anomalous expansion of water

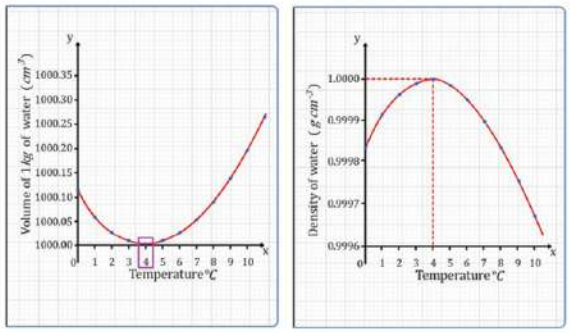


Figure 9.4 Relation between the volume and density of water, and between the density and temperature of the water

When most substances are heated, their volume increases. But water shows a different nature. Although its volume increases when heated, its volume decreases on heating from 0°C to 4°C. Also, on cooling down to 4°C, its volume decreases, but from 4°C to 0°C its volume increases (expands). Therefore, water at 4°C has the minimum volume and the maximum density.This unique property of water is known as the anomalous expansion of water.

The graph in Figure 9.4 shows the relation between the volume and the density of water. On heating or cooling the water at 4°C, its volume increases and the density decreases.

Effects of anomalous expansion of water

Invery coldplaces, the temperature of the environment drops below 0°C during the winter season. Along with the drop in the temperature of the environment, the temperature of the water also decreases. Once it reaches 4°C, the density of water becomes the heaviest. So, it sinks to the bottom. Above this, layersare formed of water at 3°C, 2°C, 1°C and 0°C respectively from the bottom to the top.As the surface water reaches 0°C, it freezes and floats on the surface of the water below. Therefore, fish and other aquatic creatures can survive in the water below the ice.

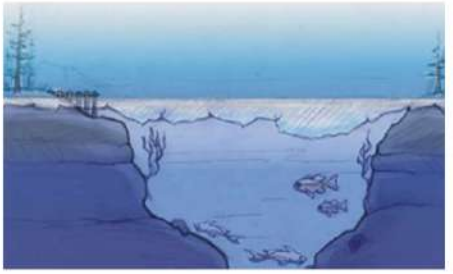


Figure 9.5 Aquatic organisms living under the surface of the ice

In winter in very cold places, as the temperature of the environment gradually decreases, the volume of water inside the pipe increases and it exerts pressure on the inner wall of the pipe. When the water freezes and becomes ice, the pressure can become very high and the pipe may burst. For the same reason, a bottle filled with water that is kept in the deep freeze cracks.

Specific heat capacity

Observe the groups of substances shown in the figure below.

Figure 9.6 Steel plate and ceramic plate

Figure 9.7 Wooden chair and a plastic chair

Figure 9.8 Sand and soil

Figure 9.9 Steel vessel and glass

Which one heats faster when all of the above materials are exposed simultaneouslyto the sun for about 15-20 minutes? What is the effect of the heat on each of these groups? Discuss.

Factors affecting the heat-absorbing capacity of matters

Even if the objects are made up of the same material but have different shapes, the rate and the amount of heat they absorb may differ according to the state they are in.

Activity 9.6 Relation among heat, temperature change (difference), and mass of the substance

(a) Take two beakers. Pour 200g of water into one of the beakers and 400g of water at the same temperature into the other beaker. Heat both beakers slowly with the help of sources of the same capacity.Water in which of the beakers absorbed more amount of heat energy when the temperature wasincreased by 10°C? Again, heat the water of 400g mass slowly. Note the quantity of heat absorbed by the water in each case when the temperature increases by 100C and 20°C respectively. In which case is the amount of heat absorbed more? Compare both the above activities and draw a suitable conclusion.

The quantity of heat absorbed by a substance (Q) is directly proportional to its mass (m)

$Q \propto m$.....i [Keeping the temperature constant]

The quantity of heat absorbed by a substance (Q) is directly proportional to the change/increase in temperature (T_2-T_1).

$Q \propto (T_2 - T_1)$.....ii [Keeping the mass constant]

Combining (i) and (ii)

$Q \propto m (T_2 - T_1)$

$Q = ms (T_2 - T_1)$ .....(iii)

where s is a constant and refers to the specific heat capacity of the substance.

Therefore, the heat absorbed or released by a substance is equal to the product of the mass (m), the specific heat capacity (s) and the temperature change (T_2-T_1) of that substance. This equation is called the heat equation.

From equation (iii) $s = Q/m (T_2 - T_1)$

If the mass of the substance m = 1kg and the temperature change due to the quantity of heat absorbed or released is 1°C, then s = Q

Therefore, the heat required to change the temperature of a substance of 1 kg mass by 1°C is the specific heat capacity of that substance. Its SI unit is joule per kilogram per degree Celsius (J/kg°C). The specific heat capacity varies according to the nature of the material. Some materials and their specific heat capacities are presented in the table below.

Substance	**Specific heat capacity**	**Substance**	**Specific heatcapacity**
Water	4200	Aluminum	884
Ethyl alcohol	2400	Iron	460
Kerosene oil	2010	Copper	385
Ice	2100	Silver	236
Mercury	126	Gold	130

According to the specific heat capacity given in the above table, the amount of heat required to change the temperature of every 1kg of water by 1°C is 4200J. Similarly, the amount of heat required to change the temperature of every 1kg of iceby 1°C is 2100J. Here, even though ice and water are two states of the same substance, their specific heat capacities are different.

Example 3.1

Calculate the amount of heat energy consumed by an electric kettle to heat 5 kg of water at 10^0C up to 100^0C.(

Specific heat capacity of water = 4200 J kg^{-1} $^oC^{-1}$)

Solution:

Given in the question,

Mass of water(m) = 5 kg

Specific heat capacity of water (m)= 4200 J kg^{-1} $^oC^{-1}$

The initial temperature of the water (T_1) = 10° C

The final temperature of water (T_2) = 100° C

Change in temperature of water(dt) = T_2- T_1= 100° C - 10° C =90° C

According to the heat equation, $Q = m\ s\ (T_2 - T_1)$

Or Or $Q=5\times 4200 \times 90$

$\therefore Q=1890000\ J=1.89\times 10^6\ J$

When 5 kg of water at 10°C is heated to 100°C, the heat consumed is 1.89×10^6J.

Example 3.2

Calculate the final temperature of the water when 5 kg of water at 100°C is mixed with 15 kg of water at 15°C for bathing. (When the water of different temperatures is mixed with it, the heat lost to the outside environment is considered to be negligible.)

Solution: As given in the question,

Let the final temperature be T

For hot water,	For cold water,
Mass of hot water(m_1)=15 kg	Mass of cold water (m_2) = 5 kg
tem of cold water (T_1)=15° C	tem of cold water (T_2)=100°C

Specific heat capacity of hot water $s_1 = s_2 = s = 4200\ J\ kg^{-1}\ {}^{o}C^{-1}$

The final temperature of hot water $= T$

Heat released by the hot water = Heat absorbed by thecold water

or, $m_1\ s\ (T-T_1) = m_2\ s\ (T_2-T)$

or, $15 \times (T-15) = 5 \times (100-T)$

or, $3 \times (T-15) = (100-T)$

or, $3T - 45 = 100 - T$

or, $4T = 145$

$\therefore \quad T = 36.25\ {}^{o}C$

In the case of no heat lost to the outside environment, the final temperature of the water is 36.25°C.

Uses of specific heat capacity

The specific heat capacity of water is very high. Every kilogram of water absorbs or releases 4200J of heat to change its temperature by 1°C. This property makes water an effective coolant for cooling hot objects. For example, water is used as a coolant in car radiators. The water absorbs a large amount of heat from the car's engine, but the temperature of the water does not increase significantly. For this reason, water is also used as a coolant in thermal power stationsthat produce electricity.

Contrary to the purpose of heating, the high specific heat capacity of the hot water kept in the hot water bag releases its heat for a long time. That is why it is used as a hot compressor for soothing muscular pain. Water found naturally in the body of living creatures

(about 70- 90 % of the body mass), controls the body temperature.

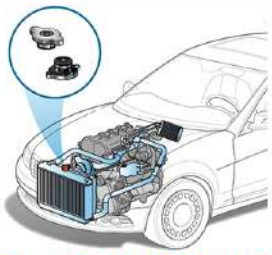
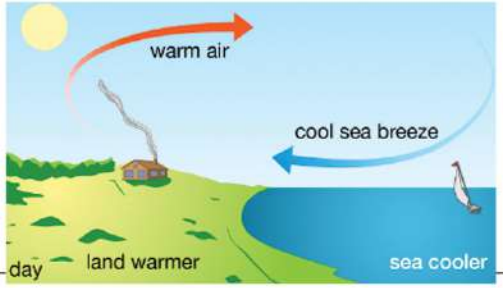


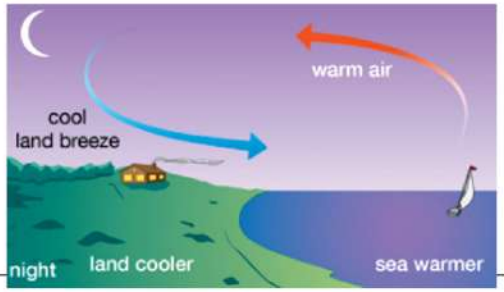
Figure 9.10 Water used as a coolant in a car radiator

Figure 9.11 Cloth wet in water used on the forehead of a person suffering from fever

Figure 9.12 Use of hot water bag

In the coastal area, because of the difference in the specific heat capacity of the land and the seawater, the air keeps circulating between the land and the sea.During the afternoon, the sun heats the land and the sea equally. But, since the specific heat capacity of land/sand is about five times less than that of the water, the temperature of land increases faster than that of water in the sea. Thus, the air above the ground becomes warm and light and rises to create a low-pressure above the ground. As a result, the cold air from the sea begins to flow toward the land. This is called Sea Breeze.





At night, the land and the sea release heat through radiation and their temperature decreases. In comparison to the temperature of seawater, the temperature of land decreases rapidly. Because of the higher specific heat capacity of water, the temperature of seawater remains higher than that of land at night. As a result, when the warm air above the seawater raises the air pressure above the sea level decreases and the cold air flows from the land to the sea. This is called the land breeze.

Thus, near the coastal areas, temperature varies much between the day and night because of the wind blowing from the sea to the land in the daytime and from the land to the sea at night.

Measurement of temperature

Different types of thermometers and their working principle

(a) Liquid in glass thermometer

A liquid in glass thermometer contains a thermometric liquid inside a heat-sensitive bulb. Mercury is a good conductor of heat and a high-density thermometric liquid. When the bulb of a thermometer is brought into contact with a hot object, heat is transferred from the object to the mercury and the mercury expands. The expanded mercury moves forward through the capillary tube attached to the bulb. The point where the mercury stops after the expansion indicates the temperature of the object. In a liquid in a glass thermometer, the temperature is determined by reading the scale marked on the outer wall.

(b) Digital Thermometer

It is a device for measuring the temperature of an object by using a heat-sensitive thermistor connected to an electric circuit. While using it, the thermometer is turned on and the end of the thermistor is brought in contact with the body. Due to the heat transmitted from the body, the electric current in the circuit changes because of the change in the thermistor's resistance. Based on this change, the measured temperature gets displayed as a number on the display panel.

(c) Radiation Thermometer

It is a device for measuring the temperature of a body without contact. Its working principle is based on theintensity of the infrared radiation produced by the body. To use it, the sensor is turned towards the body. The lens in the device focuses on the infrared radiation coming from the object on the sensor. Based on the heat carried by the radiation, electrical signals are generated and the temperature of the object is displayed on the display panel. This type of thermometer is very quick and easy to measure temperature.

Calibration of thermometer

Calibration is the process of determining the scale of a thermometer. At first, two fixed points (lower fixed point upper fixed point) are determined and then the distance between these two points is divided into a certain number of equal parts as per requirement. For the calibration of a thermometer, the temperature of melting ice (0°C) is taken as the lower fixed point and the temperature (100°C) of the steam just above the surface of the water boiling at one atmospheric pressure is taken as the upper fixed point. Then the distance between these two points is divided into 100 equal parts so that each part represents 1°C.

Activity 9.4

1. Take a thermometer.
2. Cover its scale by pasting a white paper over it.
3. Take some pieces of ice in a beaker.
4. Arrange a beaker, burner, stand, etc. required to boil water.
5. Insert the bulb of the thermometer into the melting ice and hold it on a stand for a while. Observe the falling mercury level inside the capillary tube of the thermometer. Mark the point on the paper at which the mercury stops andwrite 0°C.
6. Make an arrangement to hold the bulb of the thermometer in the steam coming from the boiling water. Observe the rising mercury level inside the capillary tube. Mark the point at which the mercury stops at 100°C.
7. Divide the portion between the two marks into 10 equal parts by drawing 9lines so that each line represents 10°C. The Celsius scale is ready.

The fixed points are different for different scales of a thermometer. For the Celsius scale, the lower and upper fixed points are taken as 0°C and 100°C respectively.For the Fahrenheit scale, the lower and upper points are taken as 32°F and 312°F respectively. Similarly, for the Kelvin scale, the lower and upper points are taken as 273K and 373K respectively.

Exercise

1. Choose the correct option for the following questions.

(a) Which statement defines heat?

(i) total kinetic energy of molecules

(ii) average kinetic energy of molecules

(iii) sum of kinetic energy and positional energy of molecules

(iv) energy transmitted due to difference in average kinetic energy of molecules

(b) On what basis can the increase in the volume of an object be explained when it is heated?

Order	The kinetic energy of atoms/ molecules	The attraction between the atoms/ molecules	Distance between the atoms/molecules
i	Increases	Decreases	Decreases
ii	Increases	Increase	Decreases
iii	Increases	Increases	Decreases
iv	Increases	Decreases	Increases

(c) Specific heat capacity of a substance depends on which of the following?

(i) mass of the substance

(ii) volume of the substance

(iii) temperature of the substance

(iv) nature of the substance

(d) What is the effect of the high specific heat capacity of water?

(i) water in the seaheats up faster than the land during the day in coastal areas

(ii) water in the sea cools faster than the land at night in coastal areas

(iii) the land heats up slower than the water in thesea in the daytime in coastal areas

(iv) the land cools faster than the water in the sea at night in coastal areas

(d) Which one of the following is the best way to insert a wide pipe into a narrower pipe?

(i) heat both the pipes

(ii) cool both the pipes

(iii) heat the wider pipe and cool the narrow one

(iv) cool the wider pipe and heat the narrow pipe

(f) What are the lower fixed points of the thermometer in Celsius, Fahrenheit, and Kelvin scales respectively?

(i) 0°C, 0°F, 0K

(ii) 0°C, 32°F, 273K

(iii) 0°C, 180°F, 373K

(iv) 0°C, 212°F, 373K

2. Differentiate between:

(i) Thermal energy and heat

(ii) heat and temperature

(iii) the lower fixed point and the upper fixed point of a thermometer

3. Give reason:

(a) An iron bar heats upwhen it is hammered continuously for some time.

(b) Tea in an open teacup stopscooling after some time.

(c) Water pipes crack in cold places in the winter.

(d) To cool the car's engine, water is kept in its radiator.

(e) The hot water bag is used to give hot pressure to the parts of a body.

(f) There is no significant difference in temperature between the daytime and the nighttime in the coastal areas.

(g) Temperature differs a lot betweenthe day and night in the desert.

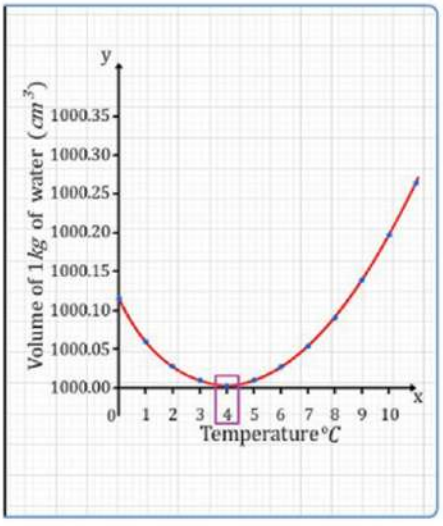
4. Answer the following questions:

(a) In the perception of a certain man, a bucket of lukewarm water contains more thermal energy than a large tank of cold water.Correct this understanding based onthe definitions of thermal energy and temperature.

(b) Touching a cup of hot tea feels hot but touching an ice cube feels cool. Explain it based on the motion of their molecules.

(c) If the lid of a glass bottle does not open, how may it be opened using your knowledge of the effects of heat? Explain based on the kinetic energy of molecules.

(d) Study the relationship between the volume and temperature of water shown in the given graph and answer the following questions.



(i) What is the special property of water shown in the graph called?

(ii) Mention the change in volume of water that appears when water is heated from 0^0C to 10^0C.

(iii) How does the property of water shown in the graph differ from the property of other liquids?

(iv) Explain the importance of this knowledge in daily life.

(v) Draw a model graph to show the relationship between the density of water and temperature based on the relationship shown in the graph.

(e) Once in winter, while drinking the water from a steel jug on the table Samir felt the water to be warmer towards the bottom. Justify his experience based on scientific facts.

(f) What are the differences between the process of freezing ghee and honey in terms of their volume and density?

(h) Of the two ice cubes of identical shape, one is kept in an aluminum box and the other in a wooden box. Which ice cube melts faster? Explain in terms of the melting process.

(i) What is specific heat capacity? Write its SI unit.

(j) What is the heat equation?

(k) Write any two applications of specific heat capacity.

(l) Describe the conditionin which water can be boiled at a temperature less than 100°C.

(m) Write the types of thermometers used in daily life. Also, mention their working principles.

(n) What is thermometer calibration? Describe the method.

5. Solve the following mathematical problems:

(a) Calculate the amount of heat required to raise the temperature of 500 g of water from 15°C to 85°C. [Answer:147 KJ]

(b) The specific heat capacity of iron is 460J/kg.Calculate the heat released by an iron sphere of mass 5kg while cooling it from 430°C to 30°C. [Answer: 920J]

(c) If 2kg of paraffin needs 4200J of heat to increase its temperature through 10°C, calculate the amount of heat required to increase the temperature of 4kg of paraffin from 20°C to 40°C. [Answer: 8.4×10^4J]

(d) If a substance of mass 500g needs 7938J of heat to increase its temperature from 100°C to 226°C, calculate its specific heat capacity. [Answer: 126J/kg°C]

(e) A bucket contains 16kg of water at25°C. Calculate the temperature of the mixture formed when 4 kg of water at 80°C is mixed with it. (Here, the heat lost to the surrounding is neglected) [Answer: 36°C]

10

Wave

fig. 10.1

fig. 10.2

fig. 10.3

fig. 10.4 rainbow

Figure 10.1 shows a pencil, which is partially dipped in water, bending at the air-glass interface (in between the borderline of water and air). This event is related to the difference in the speed of light waves in water and air media.

Figure 10.2 shows air bubbles shining in the water just the way a mirror shines when light is reflected from its surface. In this event, light passing from water to air gets reflected from its outer surface instead of passing into the air medium. In the same way, optical fiber is constructed on the principle that light going from one optical medium to another optical medium is reflected into the same medium.

Figure 10.3 shows the alphabet getting enlarged when the light coming from the letters passes through a hand lens. Because of the special structure of the glass used in the hand lens, the alphabets appear large when they are viewed through the hand lens.

A rainbow is shown in figure 10.4. During the formation of a rainbow, the light from the sun splits into its seven constituent colours. To observe the seven colours of the rainbow, the cone cells found in the inner rings ofour eye plays an important role. Rainbow is like a far object to us. It has become possible to see distant and nearby objects because our eyes have natural lensessimilar to the hand lens.

Sometimes, our vision becomes blurred due to the inability of our eye to change the thickness of its lens or because of the loss of transparency. Some people have the problems like not seeing distantor nearby objects distinctly or not being able to distinguish colours. The problem of not seeing distant or nearby objects is solved by getting the eyes checked and wearing spectacles with lenses of suitable power.

The light from the objects we observe is transmitted through different natural or artificial transparent medium. The speed of light in such media is different. These mediums can be categorized into rarer mediums and denser mediums by comparing the speed of light in a pair of mediums.

Denser and rarer medium

The substance through which light propagates is a transparent medium. Air, glass, and water are three different transparent media. The speed of light in a few media is given in the table below.

Medium	Speed of light(m/s)	Medium	Speed of light(m/s)
Air	3.00×10^8	Kerosene oil	2.08×10^8
Water	2.25×10^8	Glass	2.00×10^8
Alcohol	2.19×10^8	Diamond	1.24×10^8

From the above table, it is clear that among the given media the speed of light is the highest in the air whereas it is the least in the diamond. In a given pair of media, the medium in which the speed of light is less in comparison to another one is the denser medium. Likewise, the medium in which the speed of light is comparatively more is the rarer medium. For example, glass is a denser medium in comparison to air.In this example, air is rarer medium and glass is denser medium.

Question to think

Compare the speed of light in water and kerosene oil, given in the above table. Does an optically denser medium mean a medium witha higher physical density?

Kerosene oil floats on water; it means the physical density of kerosene oil is less than that of water. While comparing the speed of light in these two media, the speed of light is less in kerosene oil than that in the water. Thus, the medium with comparatively higher optical density does not mean that, it is physically denser. When light is passed from one medium to another medium, denser and rarer mediums can be identified onthe basis of change in the direction of the light ray with change in medium, i.e., the refraction of light.

Refraction of light

Activity 10.1

As shown in figure 10.5, take a laser beam pointer and a beaker filled more than half with water. If a laser beam pointer is not available, make a ray box (as shown in figure 10.6) by making a thin slit on a wall of a box made up of cardboard paper and a bulb inside it. To avoid the box from burning due to heat, put off the switch after some time.

Figure 10.5 Laser beam

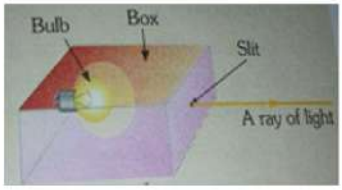


Figure10.6 Simple ray box

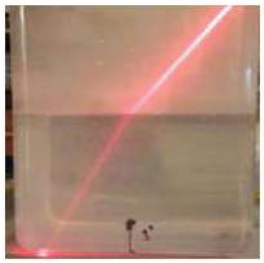


Figure 10.7 Transmission of light from air to water

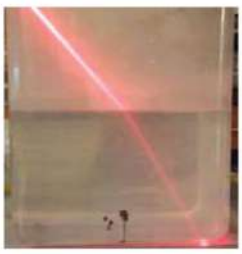


Figure 10.8 Transmission of light from water to air

At first, pass the laser beam from the upper side of the beaker as shown in figure 10.7 and then observe the direction of the transmitted beam inside the water.Again, repeat the same activity from the lower part of the beaker as shown in figure 10.8 and observe the direction of the beam emerging out from the water. Is the direction of the transmitted beam while passing from air to water and water to air different?

The speeds of light in air and water are 3×10^8 m/s and 2.25×10 m/s respectively. When light enters from air to water, its speed decreases due to which the transmitted laser beam bends towards the imaginary normal as shown in figure 10.7. Since the transmitted beam in the water bends towards the normal, water can be considered a denser medium. When light entersfrom water to air, the speed of light increases. This results in the beam moving away from the normal as shown in Figure 10.8. Since the laser beam moves away from thenormal while passing from water to air, air must be a rarer medium.

In this activity, the light which moves away from the normal or bends towards the normal due to a change in speed while passing from one medium to another is the refracted light. The process of bending of light or changingthe direction of light while passing from one optical medium to another is called refraction of light. The change in the speed of light while passing from one medium to another is the cause of the refraction of light. Greater the change in speed of light, more the bending of light i.e., the refraction. Of course, not only the light waves but also the other waves like sound follow the laws of refraction.

Activity 10.2: Refraction through a glass slab

Take a light box or laser beam pointer, a pencil, a scale, a sheet of plain paper, etc. Put the glass slab on the paper and draw its outline PQRS with the pencil as shown in figure 10.9. Take a point O on the outline of the face PQ and draw a normal NN'. Draw a line AO making a desirable angle 'i' with the normal. Now from the face PQof the slab, pass a laser beam such that it passes along the line AO and emerges out from the face RS. Use the pencil to indicate a point B from which the beam emerges and take another point C on the emergent ray. Then remove the slab from the paper and draw a perpendicular N_1N_1' at point B. Join BC and OB. Here the lines AO, OB and BC represent incident ray, refracted ray, and emergent ray respectively.

Observe the bending or the change in the direction of the rays while entering the glass slab and while emerging from it.

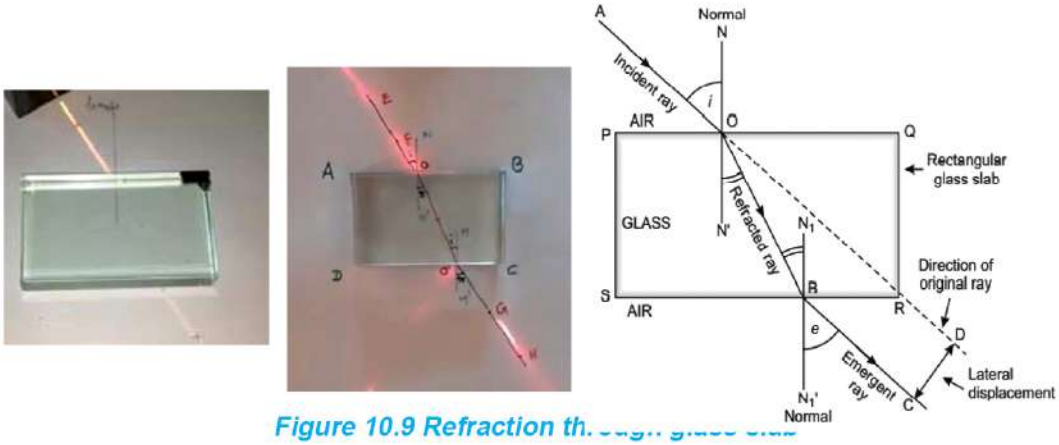


Figure 10.9 Refraction th... glass slab

Some terminologies related to refraction of light are as follows:

a. Normal

The imaginary line perpendicular to the interface of two media is called the normal. In the above Figure NN' and N_1N_1' are normal.

b. Incident ray

The ray AO from the source of light is the incident ray.

c. Angle of incidence

The angle (∠AON) made by the incident ray AO with the normal NN' is the angle of incidence.

d. Refracted ray

The ray (OR) which bends at the border and enters the second medium is the refracted ray.

e. Angle of refraction

The angle (∠BON') made by the refracted ray AO with the normal NN'is called the angle of refraction.

f. Emergent ray

The ray (BC) which comes out of the object into the first medium after refraction is called an emergent ray.

g. Emergent angle

The angle ($\angle CBN_1'$) made by the emergent ray BC with the normal N_1N_1' is called the angle of emergence.

f. Lateral shift

The perpendicular distance (CD) between the emergent ray and the line formed when the refracted ray is produced, is called the lateral shift.

In this activity, when light is passed from the air (rarer medium) to glass (denser medium) it bends towards the normal. Contrary to this, it bends away from the normal while emerging out from the glass slab.

In the figure that you drew, which is similar to figure 10.9, measure the angle of incidence ($\angle AON$), angle of refraction ($\angle BON'$) and angle of emergence ($\angle CBN_1'$).Fill in the table given below. What is the length CD called? Also, measure it.

$\angle AON=i$	$\angle BON'=r$	$\angle CBN_1'=e$	**Result**
30°	.....	.....	..... $\angle$ ..... , ... = ...

What will be the result when a ray of light is passed by changing the angle of incidence in activity 10.2?

In figure 10.9, for the light passing through air-glass interference 'PQ' the angle of refraction(r) is always smaller than the angle of incidence (i). Similarly, for the ray passing through glass-air interference 'RS', due to the increase in speed of light in air, light moves away from the normal. As a result, the value of the angle of incidence (i) and that of the angle of emergence (e) becomes equal. This means lateral shift CD occurs due to the bending of light ray AO towards the normal inside the glass slab and away from the normal when it emerges out to the air medium.When light ray entersfrom air into any transparent medium, the angle of refraction (r) depends on the nature of medium and the angle of incidence (i). On increasing or decreasing the value of angle of incidence,the angle of refraction also varies respectively. On the basis of law of refraction, the value of angle of refraction can be obtained for the particular value of angle of incidence.

Laws of refraction of light

Activity 10.3 Verification of laws of refraction of light

Take a semicircular glass slab, a ray box or laser beam pointer, a sheet of plain paper, a protector, a pencil, etc. Draw four quadrants on the plain paper as you used to draw on the graph paper as shown in figure 10.10. Draw the degree scales in the first and the fourth quadrants using a pencil and a protractor. Place the semicircular glass slab on the plain paper taking the x-axis as a base and the origin lies at the mid-point of its base as shown in the Figure. Pass the light beam making different angles of incidence through the base plane of the glass slab using the ray box or laser beam pointer. During this process, measure the angles of incidence and the angles of refraction and fill in their corresponding values in the given table. Do the necessary calculations and draw an appropriateconclusion.

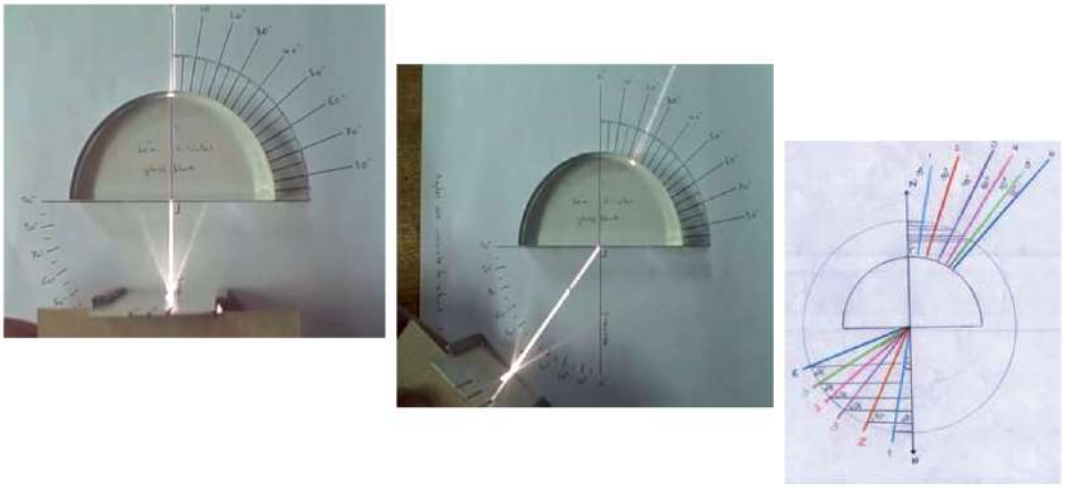


Figure 10.10 Refraction through semicircular glass slab

When the light beam falls normally on the glass slab, it passes through a straight line without bending as shown in figure 10.10. Then, on increasing the angle of incidence (i), the value of the corresponding angle of refraction (r) goes on increasing.

Ratio of speed of light in air to that in glass	Angle of incidence ($\angle i$)	Angle of refraction (r) ($\angle r$)	sin i	sin r	$\frac{\sin i}{\sin r}$	Result
$\frac{\text{speed of light in air}}{\text{speed of light in medium}} = \frac{(3\times10^8)}{(2\times10^8)} = 1.5$	15	10	.....	.....	1.49	$\mu = 1.49$
	.....	.....	....	...	.....	.....
Conclusion:						

The laws of refraction of light are listed below.

a. When light passes from one optical medium to another medium, the incident ray, the normal and the refracted ray all lie on the same plane at the point of incidence.

b. The ratio of sine of the angle of incidence to the sine of the angle of refraction remains constant for a pair of media. The constant value is refractive index of pair of media which is denoted by μ.

$$\text{or, } \frac{\sin i}{\sin r} = \text{constant } (\mu) \quad \text{.....(i)}$$

This law is named as Snell's law after the name of the mathematician Willebrord Snellius, who discovered it.

The value of the constant μ, i.e., the ratio of Sini to Sinr, while passing the light from air to glass is equal to the ratio of the speed of light in the air (c) to the speed of light in glass(v). Thus, the ratio of the speed of light in a vacuum or air to the speed of light in any medium gives the refractive index of light in that medium.

$$\text{This means, } \mu = \frac{\text{speed of light in air or vacuum (c)}}{\text{speed of light in the medium (v)}}$$

The speed of light in some media and their refractive indices are given in the table below. What can be concluded from the study of the increasing order of refractive index of the different media given in the table and the decreasing order of the speed of light in those media?

Medium	Refractive index	Speed of light (m/s)	Medium	Refractive index	Speed of light (m/s)
Water	1.33	2.25×10^8	Glycerin	1.47	2.04×10^8
Alcohol	1.36	2.19×10^8	Glass	1.50	2.00×10^8
Kerosene oil	1.44	2.08×10^8	Diamond	2.42	1.24×10^8

Consequences of refraction of light

Activity 10.4 Observation of the coin at the bottom of a beaker lying below the line of sight

Take a steel glass, a coin and some water. Put the beaker on a table and drop a coin into the beaker. Shift your head in the backward direction until the coin lies outside the line of sight, i.e., not visible. Keep your head still at that point and ask a friend to pour water into the beaker without disturbing the coin. Does the coin reappear as the level of water rises?

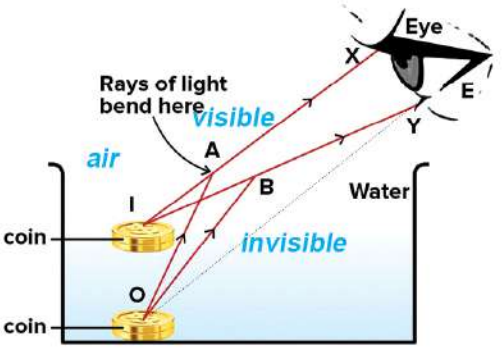
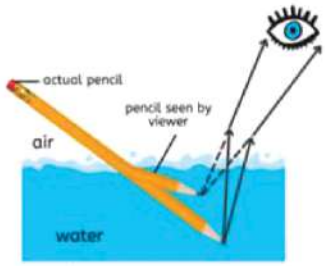


Figure10.11

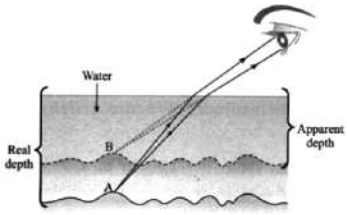
In this activity, the light rays reflected by the coin at the bottom of the glass pass from water to air when water is poured into the beaker. The rays of light move away from the normal at the water-air interface while passing from water (denser medium) to air (rarer medium) as shown in figure 10.11. When these refracted rays are produced backward, they form the image of the coin at the point 'I' and the observer sees the coin(O) at 'I'. In this way, the coin is seen due to the refraction of light rays at the surface of the water.

In our daily life, there are so many situations created in nature due to refraction of light. Some specific examples are listed below.

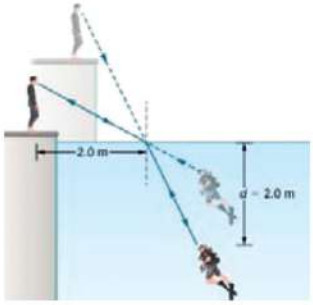
a. Consequences of the refraction of light in the water-air interface (from water to air)



Figures 10.12,



Figures 10.13,



Figures10.14

The above Figures show the bending of an object that is partially dipped in water and the depth of objects in water appearing less than their actual depths.

b. Consequences of refraction in the atmosphere

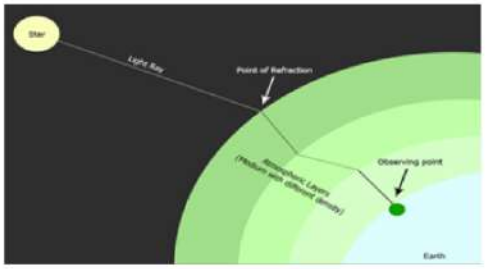


Figure 10.15 Refraction of light from the stars in the atmosphere

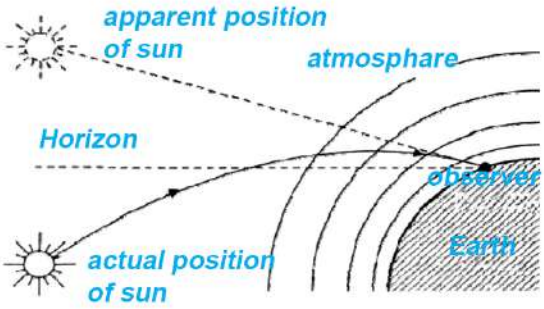


Figure 10.16 Refraction of sunlight in the atmosphere

While observing the stars, the rays coming from outer space reach the earth after successive refractions through different layers of the earth's atmosphere. Thedifferent layers in the atmosphere have different refractive indicesand the layers keep changing their position

continuously. This results in the bending of light sometimes away from the normal and sometimes towards the normal even in the same place.

This causes a change in the brightness and the position of the stars. In this way, the stars appear to be twinkling due to the refraction of light in the atmosphere. But, the change of position of the planets and satellites due to the refraction of light in the atmosphere cannot be noticed because they are closer to the earth and appear big. Hence, they cannot be seen twinkling.

Question: Compare the sun seen below the horizon in figure10.16 and the coin inside the steel glass in figure 10.4. Just the way the coin in the empty steel glass becomes visible after pouring the water into it, the sun appears above the horizon even when it is actually below the horizon because of atmospheric refraction.

As shown in figure 10.16, as the rays of sunlight from outer space entering into the atmosphere pass from rarer medium to denser medium, they bend towards the normal. The refractive index of the atmospheric layers changes with the increase in altitude of the earth's surface. As the rays of light from the sun below the horizon reach the observer's eyes, they appear tocome from above the horizon since they suffer successive refractions through these layers of the atmosphere. Therefore, the sun is visible two minutes before and two minutes after the actual sunrise and sunset respectively.

Total internal reflection of light

In figure 10.17, the rays of light passing from water (denser medium) to air (rarer medium) are bending away from the normal. In this situation,the angle of refraction 'r' is greater than the angle of incidence (i) i.e., r ∠ i. If the value of the angle of incidence (i) increases, the value of the corresponding angle of refraction (r) also increases.

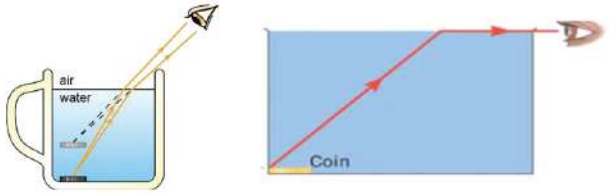


Figure 10.17 Observation of the coin in the water from different angles

Question: On increasing the value of angle of incidence (i) continuously, what could be the maximum value of angle of refraction (r)?

In the second figure of 10.17, the coin in the glass is seen even when we observe it along the air-water boundary. In this situation, the refracted ray makes an angle of 90o with the normal. This is the maximum value of the angle of refraction (r) when light passes from a denser medium to a rarer medium. In this situation, the angle of incidence (i) formed in water with the normal is known as the critical angle.

Critical angle

Activity 10.5 Refraction of light while passing from denser to the rarer medium by making different angles of incidence

Take a semicircular glass slab,a laser beam pointer or ray box, a protractor, etc. as shown in the figure. On a plain sheet of paper, draw lines as if they are the two axis of a graph. Prepare a scale for measuring the angles with the center of the protractor as the origin (O) and the reference line that is parallel to the x-axis as shown in the figure. Take a semi-circular glass slab and place it on the sheet such that its center lies at O and the flat edge becomes parallel to the x-axis. Pass the laser beam into the glass making itperpendicular to the semicircular surface. Measure the angle of incidence (i) and the angle of refraction (r) at O and then fill in the table below.

Keep on increasing the value of the angle of incidence. Observe the angle for which the refracted ray becomes parallel to the glass-air

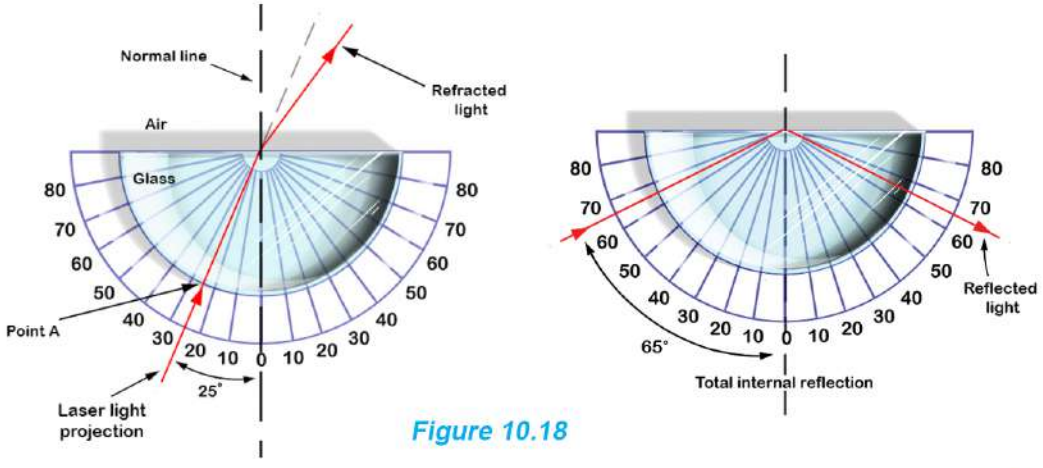


Figure 10.18

interface making an angle of 90° with the normal, and note it down. In which medium does the light goif the angle of incidence is increased after having the angle of refraction 90°?

Angle of incidence	Angle of refraction/ angle of reflection	Result: refraction of light/ reflection of light
30°	.....	Refraction of light
35°	.....	...
.....	90°	Refraction of light
50°	.....	.....

On continuing to increase the angle of incidence in the denser medium as shown in the figure, for a particular value of angle of incidence, the refracted ray becomes parallel to the water-air interface, i.e., the value of angle of refraction becomes 90°. The angle of incidence in the denser medium under the condition whichthe value of its corresponding angle of refraction in the rarer medium becomes 90° is known asthe critical angle.

The value of the critical angle depends upon the materials of the two media. The values of the critical angle of a few substances to air are given in the table below.

Medium	Critical angle	Medium	Critical angle
Water	49°	Glycerin	43°
Alcohol	48°	Glass	42°
Kerosene oil	44°	Diamond	24°

Total internal reflection of light

If the angle of incidence becomes greater than the critical angle (figure 10.5), the light gets reflected in the same medium instead of being refracted. This means the light passing through the semicircular surface of the glass returns to the glass. The phenomenon of reflecting of light to the same medium when it is passed from a denser medium to a rarer medium is called the total internal reflection of light. All laws of reflection of light are applicable in this process.

When a fish inside the aquarium (figure 10.19) is viewed from a certain angle outside the aquarium, the light rays from the body of the fish suffer total internal reflection from the water-air interface and reach the observer's eyes. The observer sees the fish below the surface of the water, and its image above the mirror like a shiny water-air interface, i.e., in the air.

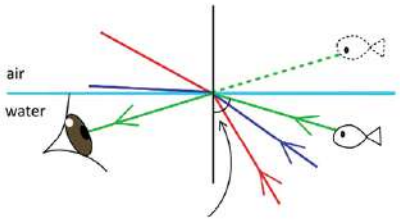


Figure 10.19 aquarium

Normally, when light falls on the interface between any two media, a part of it is reflected and the rest is refracted to the other medium. But, in the condition of total internal reflection, all the light is reflected. Therefore, the word 'total' is used here. The necessary conditions for the total reflection of light are given below.

a. Light must be travelling from the denser medium to the rarer medium.

b. The angle of incidence must be greater than the critical angle.

Activity 10.6 Total internal reflections that take place in different media

a. Total internal reflection in the water

As shown in figure 10.20, take a plastic bottle and a laser beam pointer.

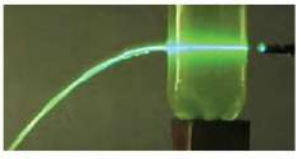


Figure 10.20

Fill the bottle with water and make it blurred by adding a few drops of Dettol or milk in it and then shaking it. Now make a small hole in the bottle a little above its base. Pass a beam of laser light from its opposite side so that the light falls on the current of water coming from the hole. Does the light propagate along with the current of water?

Pass a laser beam through the outer surface of a beaker filled with water as shown in figure 10.21.

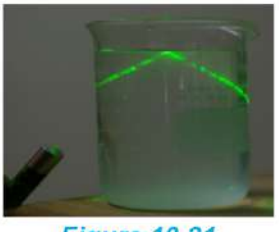


Figure 10.21

Change the value of the angle of incidence by tilting the laser beam pointer. Does the laser beam suffer total internal reflection from the surface of the water at a certainangle of incidence?

The drops of milk added to the water spreads out the laser beam and it becomes easier to observe the propagation of light in water.

In figure 10.22, water flowing out of the bottle from a hole in its surface is shown. A laser beam, directed from the opposite side of the bottle such that it is perpendicular to the hole, falls on the curved surface of the stream of water gushing out of the bottle. When the laser beam falls on this curved surface of the stream of water, the light istravelling from a denser medium (water) to a rarer medium (air) and the value of the angle of incidence is greater than the critical angle(49°) of water.

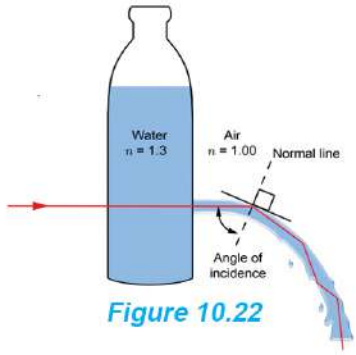


Figure 10.22

Hence, the laser light does not come out of the surface of the water but rather undergoes total internal reflection and returns to water. After that, the reflected ray falls on the opposite surface of the stream.Again, the total internal reflection takes place on that surface and the beam reflects to the water.In this way, the total internal reflection occurs repeatedly in a cyclic manner and the laser light travels downwards with the stream.

(a) Total internal reflection in a prism

As shown in figure 10.23 and figure 10.24, tilt a laser light pointer normally towards different faces of equilateral and isosceles triangular prisms. Observe the condition in which the total internal reflection occurs from the surface of the prisms.

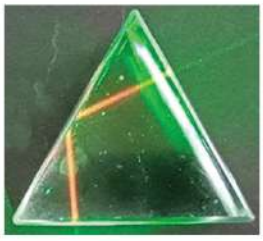


Figure 10.23 Total internal reflections in equilateral triangular prism

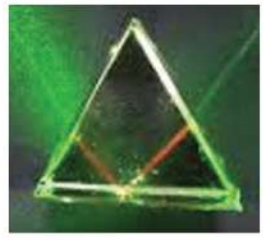



Figure 10.24 Total internal reflections in an isosceles right-angled triangular prism

A prism is a three-dimensional solid object. It is boundedby three

rectangular surfaces and two triangular surfaces. The base of an equilateral triangular prism is in the form of an equilateral triangle.

Similarly, the base of the right-angled triangular prism is in the form of a right-angled triangle. As seen in figure 10.25, a ray of light PQ, falling normally on a face of an equilateral triangular prism, passes straight through the glass without deviation. When that ray falls on the face of the prism it makes an angle of 60o with the normal.Here, the ray is travelling from the denser medium (glass) to the rarer medium (air) and the angle of incidence is greater than the critical angle for the glass(42°). Hence, a total internal reflection of light occurs. Then it falls normally on the face BC and emerges in the air.

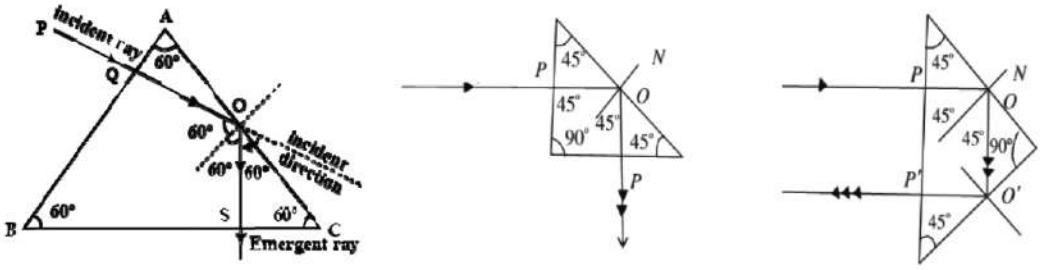


Figure 10.25 Total internal reflection of light in a prism

In Figure 10.25a, as well as in figure 10.25b and figure 10.25c, the light suffers total internal refraction once and twice respectively and finally emerges in the air. Since light can be reflected through 90o in the right-angled triangular prism due to total internal reflection, prismsare used in periscopes, Single Lens Reflector (SLR) cameras and binoculars as shown in figure 10.26.During the total internal reflection of light, the power of the waves is not weakened and the objects can be seen clearly.

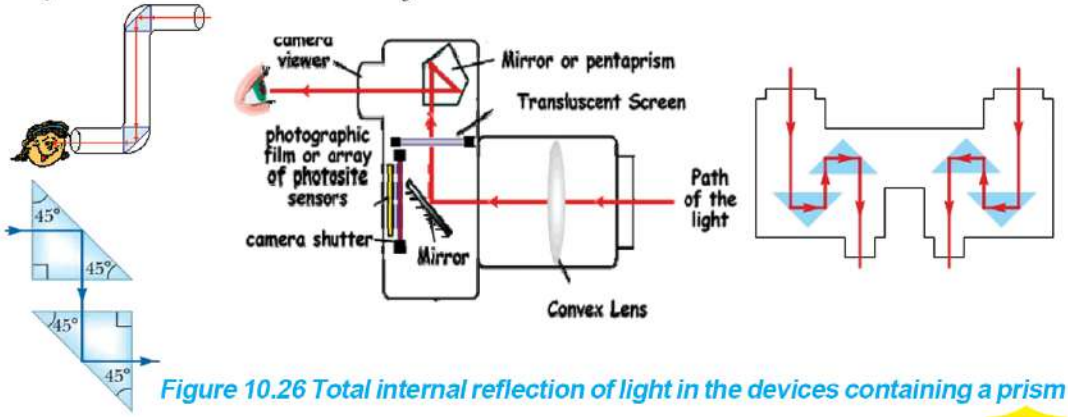


Figure 10.26 Total internal reflection of light in the devices containing a prism

Consequences of total internal reflection of light

a. Sparkling of diamond

Due to the high refractive index of the diamond, its critical angle is small (24°). The angle of incidence at the diamond-air interference easily becomes greater than its critical angle. This results in the total internal reflection of light in the diamond.

The shape of the diamond is determined by the number of its faces. It is cut intovarious faces in such a way that maximum numbers of raysof light that enter the diamond undergo multiple internal reflections. Because of this, the rays of light that aresupposed to pass throughthe diamond experience total internal reflectionand thus the diamond sparkles. If, however, a block of glass is cut with faces like a diamond, this glass will not shine like a diamond because thecritical angle for glass is 42° and most of the rays of light that enter ontheglassisarerefractedand come out fromthe opposite face.

b. Shining of a surface

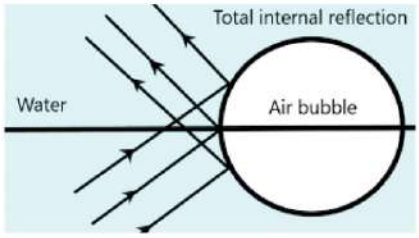


Figure 10.27 An air bubble inside the water

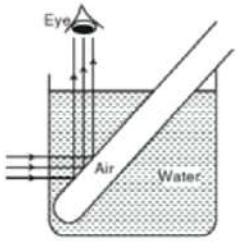


Figure 10.28 Outer wall of a test tube dipped into the water

An object shines due to the reflection of light from its smooth surface. Due to the total internal reflection of light from the water-air interface and glass-air interface, these surfaces appear to be shining.As shown in Figure 10.37, when the light goes from water (denser medium) to air (rarer medium), the angle of incidence at the interface of water-air becomes greater than the critical angleand thus, total internal reflection takes place at the surface of the air bubble formed inside the water. While observing the air bubble from outside, it shines. Also,as shown in figure 10.28, the rays of light going from water (denser

medium) to the air (rarer medium) inside an empty test tube,whichis partiallydipped in water and held at an angle,undergoes total internal reflection at the thin wall of the glass testtube. When it is observed from outside the beaker, the immersed part of the tube appears shiny.

c. Mirage

Question: Have you ever seen an illusionof a pool of still water on a pitched road as shown in figure 10.29, while traveling during the summer days?

Figure 10.29 Mirage on pitched road

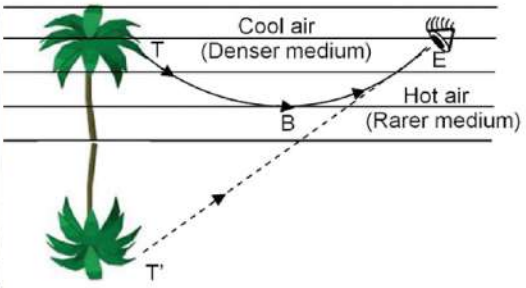


Figure 10.30 Total internal reflections during the formation of mirage

As shown in figure 10.29, while walking on the pitched road on a hot summer day, usually an illusion of a pool of still water is created in front of the observer. When the observer reaches that place, the road is found to be dry. This type of illusion is called a mirage.

Mirage occurs due to the total internal reflection of light. When the surface of the earth gets heated up due to intense sunlight, there is a formation of different layers of air having a different temperature that decreases as we go up. This happens because the layer which is closer to the hot surface becomes hotter than the above one. That is why the refractive index of the upper layer is higher than that of the layer just below it. Thehot layerbehaves like the rarer medium whereas the comparatively colder layer behaves like the denser medium. Hence, the reflected rays from tall objects in the areatravel down from the cold layer (denser medium) tothe hotter layer (rarer medium). When refraction of light occurs continuously at different air layers as it travels from denser to rarer medium, at a certain layer, the angle of incidence becomes greater than the critical angle for that layer.

As a result, the total internal reflection of light occurs. Hence the reflected rays start travelling upwards and finally fall on the observer's eyes. The observer, thus, sees an inverted image of an object on the surface of the road. Since the refractive indices of the layers of air change continuously, the image so formed seems to be flickering on the surface of a pool ofwater.

Considerable question

What effect would be observed, when sound waves undergo refraction as the refraction of light waves occurred during the formation of mirage?

Figure 10.31 Refraction of sound

As shown in figure 10.31a, during the daytime, as the sound waves travel through the upper layer of air, they continuously refract towards the normal at different air layers. Thus,sound waves bend upward and a listener some distance away from the source cannot hear the sound distinctly. Likewise,at night, refraction of the sound waves at various air layers makes the sound waves bend away from the normal (downwards) and at a certain layer;the total internal reflection of sound waves takes place, as shown in figure 10.31b. Due to this, a listener on the ground, even at a distance away from the source, can hear the sound distinctly.

Application of total internal reflection of sound

Optical fibre

Activity 10.7 Observation of the internet cables based on fibre optics

Take a piece of internet wire based on fibre optics. Observe its outer plastic coat andthe inner fibres by gradually removing the plastic coat.

Figure 10.32 Connection of optical fibre connector in a router

For a cabled network internet service, the internet provider brings a cable up to our home. The outer covering of one end of a cable is removed toexpose a thin fibre. Then the fibre is connected to the router using a connecter as shown in Figure 10.32. In the cabled internet system, the optic fibreinside the cable provides fast communication and internet service based on fibre optics. Fibre optics is a technology of transmitting light through a thin and transparent medium like glass. The thin optical medium used for the transmission of light in fibre optics is called optical fibre.

Figure 10.33 Router connector

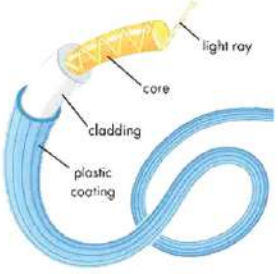


Figure 10.34 Transmission of light through an optical fibre.

As shown in figures 10.33 and 10.34, the inner part of an optical cable has a core that contains a bundle of thin fibers made of transparent material like glass.The core is surrounded by a cladding which is made of material ofa lower refractive than the core creating a suitable environment for total internal reflection in the core. Light is passed through the fibremaking the angle of incidence on the fibre-cladding layer greater than the critical angle. Then as the light travelsin the core without coming out from the cladding, irrespective of the condition of the fibre, be it straight or bent, finally emerges from another end of the fibre.

At first, the optical fibres were used in the medical field to observe the internal part of the body by passing the light into the body.

After that, they are used to transmit communication signals at the speed of light. Nowadays, although optics fibres are used to check up and to makedecorative items and many more, they have been widely used in the communication sector.

a. Use of optical fibres in telecommunication

In communication technology, optical fibres are used for the rapid transmission of signals or data in the form of light waves using the principle of total internal reflection. For this purpose, the communication signal is converted into light and transmitted through optic fibers, which allows for high-speed propagation through total internal reflection. Compared to other methods such as wire and copper cables, a large volume of data can be transmitted very fast and securely over a long distance using optic fibres. For example, data can be transmitted at the rate of 1 Gigabyte per second (1Gbps). An optical fiber can transmit data of thousands of telephone calls simultaneously. The same feature allows people to use optical fiber to receive internet signals and watch high-definition videos, upload and download large files to the internet, and perform other tasks.

As shown in figure 10.35, fibre cables are bundled and laid on the ground. Optical fibre cables have been laid alongvarious national roads such as the East-West Highway, the Mid-hill Highway, and other roads in our country. These cables are connected to the international network through India and China. Optical fibre cable bundles are also laid not only on the ground but also in the air and under the sea for long-distance communication purposes. An international network of optical fibre has been created using these cables.

b. Use of optical fibres in the medical field

Endoscopy and colonoscopy

Endoscopy is a nonsurgical method for examining the internal organs of the body.

In this technique, an endoscope with an optical fiber and a camera is used to examine the digestive system including the esophagus, stomach, and small intestine. For example, endoscopy can be used to diagnose ulcers in the stomach. To do this, the endoscope is inserted through the patient's mouth and guided to the stomach viathe esophagus.

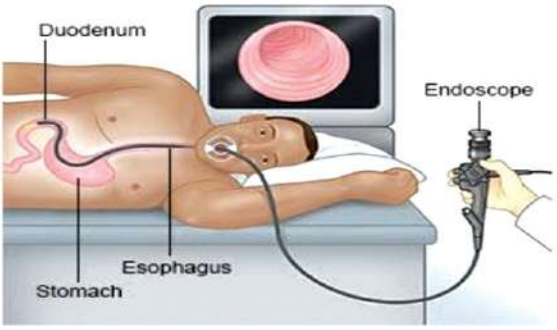


Figure 10.35 Use of endoscopy

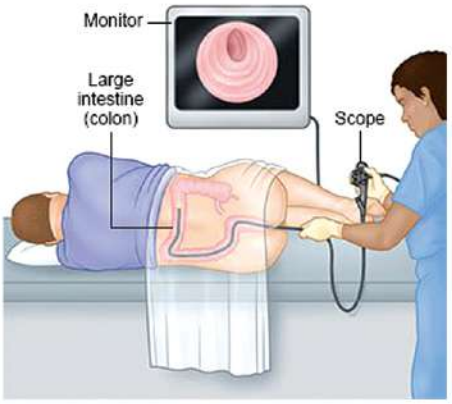


Figure 10.36 Use of colonoscopy

In an endoscope, two bundles of optical fibers are kept parallel to each other. One bundle carries light to the internal organs of the body while the other bundle collects the light reflected by the illuminated organs. The shape of the internal organ can be viewed directly or displayed on a video monitor connected to a camera. Colonoscopy is a type of endoscope that is used to examine the colon and large intestine by inserting it through the rectum.

Keyhole surgery

Keyhole surgery is a procedure performed by a surgeon to operate inside the body through a small incision in the skin. The keyhole surgery is also referred to as laparoscopic surgery because the laparoscope is used in this procedure to visualize the shape of the internal organs, is inserted through a small incision. The laparoscope incorporates bundles of optical fibers and a camera to send light inside the body and capture the shape of the internal organs, which is displayed on a monitor. Surgeons performing keyhole surgery also use other surgical instruments along with the laparoscope.

This procedure is used to remove damaged or diseased organs, take tissue samples for examination (biopsy), remove gallstones and kidney stones, etc.

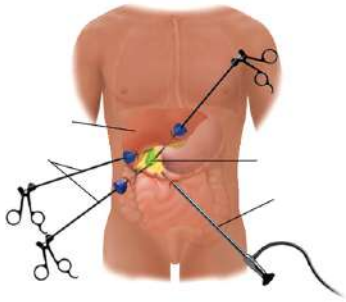


Figure 10.37 Keyhole surgery

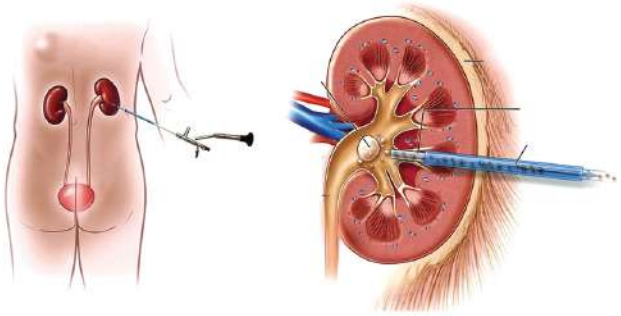


Figure 10.38 Keyhole surgeries to remove the kidney stone

Dispersion of light

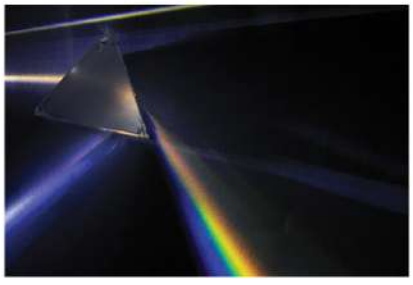
Figure 10.39 Color from the burning natural gas

Figure 10.40 Color from the sodium vapour light

In figure 10.39, a blue light source is shown and in figure 10.40, a yellow light source is shown. Even though the sunlight we see every day is a mixture of red, orange, yellow, green, blue, indigo and, violet colours we see it as white, not theindividual colours. These seven colors of sunlight can be separated by passing it through a specific medium.

Dispersion of light through a prism

Activity 10.8 Observation of dispersion of light through a prism



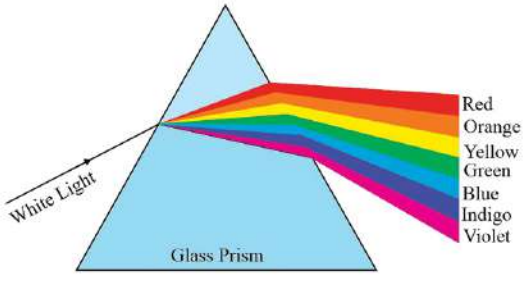


Figure 10.41 Color from the sodium vapour light

Take a ray box and a prism. Send the narrow beam of light from a ray box or the sun light onto the rectangular surface of a prism. Can you project the light passing through the prism onto a wall or a screen as shown in figure 10.41? Now, keep the prism rotating until a band of seven colours is created on the wall or the screen.

The process in which light falling on the surface of a prism or a similarly shaped object splits into seven colours [i.e.,red, orange, yellow, green, blue, indigo, and violet respectively] while passing through the object is known as the dispersion of light. The waves of these seven colors have different wavelengths. Their values are presented in the table below.

Color of light	**Limit of wavelength(in meters)**
Red	From 6.2×10^{-7} to 7.8×10^{-7}
Orange	From 5.9×10^{-7} to 6.2×10^{-7}
Yellow	From 5.8×10^{-7} to 5.9×10^{-7}
Green	From 5.0×10^{-7} to 5.8×10^{-7}
Blue	From 4.6×10^{-7} to 5.0×10^{-7}
Indigo	From 4.4×10^{-7} to 4.6×10^{-7}
Violet	From 3.8×10^{-7} to 4.4×10^{-7}

The band of the seven colors with the decreasing order of their wavelengths given above is called the visible spectrum. The seven colors of the visible spectrum can be remembered as "VIBGYOR".

Cause of dispersion of light

The speed of all electromagnetic waves is same in vacuum but it is different in different media. The speed of a wave in a given medium depends on its wavelength. The speed of different colors in the visible spectrum is different. The light wave with the longest wavelength in the visible spectrum is red light. Its speed is comparatively more than that of waves of other colors in the visible spectrum. The speed and the wavelength of violet are the least among these seven colors.

As shown in figure 10.41, when light rays enter a prism and exit from it, two refractions occur. As a result, the light rays of different velocities that have separated inside the prism exit it by bending toward the base and falling on the screen at different places. In this process, red light rays having the longest wavelength and the fastestspeed deviate the least and are thus seen at the upper portion of the screen. In contrast, violet rays with the shortest wavelength andthe least speed deviate more than others and fall on the lower part of the screen.

Light as a group of seven colours

Activity 10.9 Newton's disc

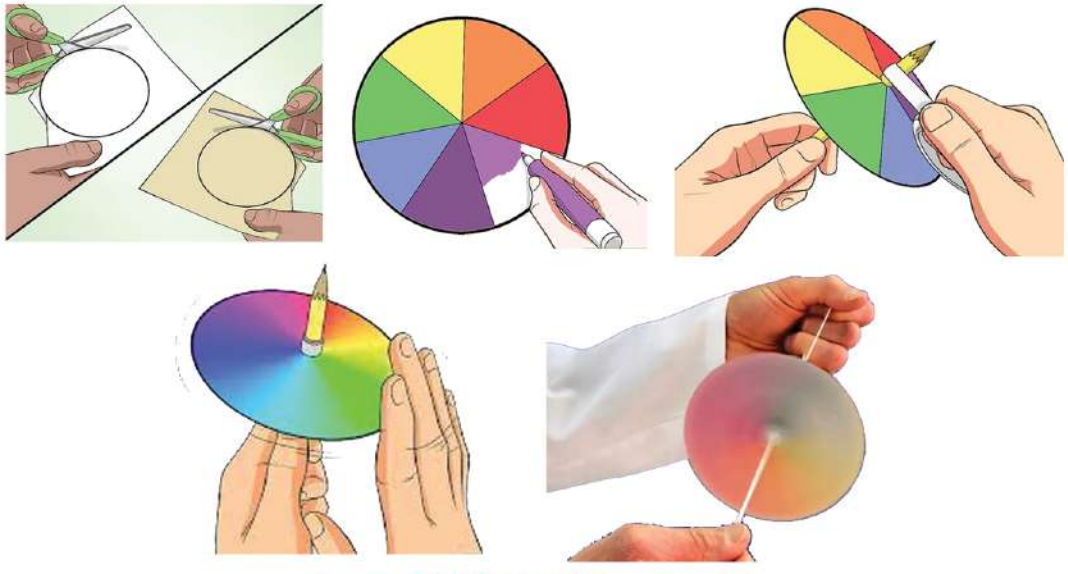


Figure 10.42 Making Newton's disc

Takea cardboard, printing paper, seven colours found in the visible spectrum, scissors, a pencil, a pair of compasses, and a piece of strong thread (about 60 cm long). Paste the printing paper on the cardboard and cut it in the shape of a circle with the help of a compass, pencil, and a pair of scissors. Divide the circle into seven equal parts on the printing paper of the circle.Now paint the parts with the colours in the order VIBGYOR. This is the model of Newton's disc. Now, make two thin holes near the centre such that the centre lies in between the holes. Insert the two ends of the thread through the holes separately and then tie the ends that come out from the holes. Hold the strings with one hand and use the other to spin the wheel quickly. When the wheel spins fast enough, pull both strings outwards, and then back towards each other. By doing this, the strings wind and unwind, causing the wheel to spin fast. As the wheel spins, observe the seven colors of the rainbow that are painted on its surface. Will the colors of the rainbow combine and disappear to form a white colour?

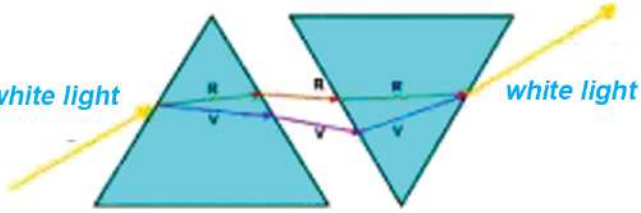


Figure 10.43 Newton's disc *Figure 10.44 Recombination of seven colours of light.*

A disc made by painting seven constituent colours of light in proportion on it is called Newton's disc. As shown in Figure 10.43, on spinning the disc at high speed, the seven colours mix and the disc appears white.

In figure 10.44, two identical prisms are shown with one prism placed upside down near the other. The seven colors of light rays separated by the first prism are recombined by the second prism as they pass through it. The ray emerging out from the second prism becomes parallel to the direction of the light entering from the first prism.

Rainbow

A rainbow is a circular colourful arc that appears in the sky when the sun lies behind water droplets present in the air. A rainbow is formed due to the dispersion of light by the water droplets that are suspended in the air. In this process, water droplets play a role similar to that of a prism.

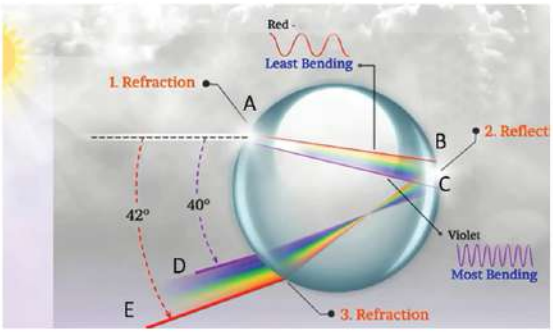


Figure 10.45 Dispersion of light through a water droplet

Figure 10.46 The circular rainbow observed from the sky

In figure 10.45, the ray of light from the sun strikes the point A on the surface of the spherical water droplet and then enters it. Because of refraction, the light rays get separated into seven colors inside the droplet. Then, the seven colours of light in the droplet are totally internally reflected by the opposite surface of the droplet. In the figure, the red light, which is deviated the least, is reflected from point B, while the violet light, which is deviated the most, is shown to be reflected from point C. Finally, the light rays come out of the droplet and form a rainbow. The rainbow appears to be semicircular while observed from the ground but can be seen as a circle from the sky.

Lens

A pair of spectacles is shown in figure 10.47. The glasses used in it have spherical surfaces.

Figure 10.47

The shape of glass or plastic used in a hand lens also has a spherical surface. The refraction of light that occurs through such types of surfaces causes light rays to converge at a single point or diverge from a single point.

Activity 10.10 Making a hand lens

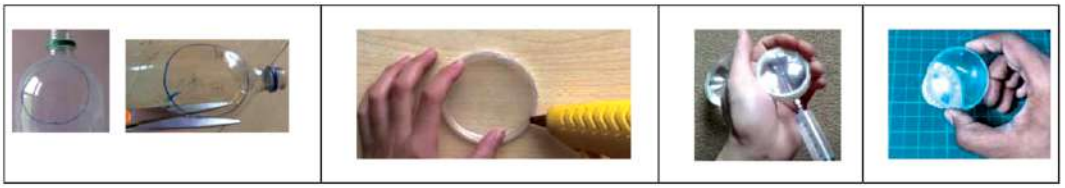


Figure 10.48 Making a hand lens

As shown in figure 10.48, take a plastic bottle, scissors, a hot glue gun, a syringe, and water. Cut the plastic bottle into circular pieces. Overlap the two pieces in such a way that the raised portions lie outside, and stick them together with a hot glue gun. Then fill it with water with the help of a syringe. Can you use the resulting lens to read small letters in a book or magnify small objects?

By filling water between the two circular surfaces made of plastic, a lens is created. That lens refracts light rays. When light passes through this lens, objects appear larger than they are. The lens and the spherical mirror have some similar properties. In figure 10.10, a convex lens and a concave mirror are shown being made from a spherical glass ball. Similarly, by filling water between the two circular surfaces, a sample lens is formed in the above activity. Even when water is poured into one of the circular pieces of the bottle, it will refract light like a lens. The resulting lens, shown in figure 10.50, appears to have been made from two solid spherical portions. Therefore, a lens is a transparent medium that has at least one spherical surface.

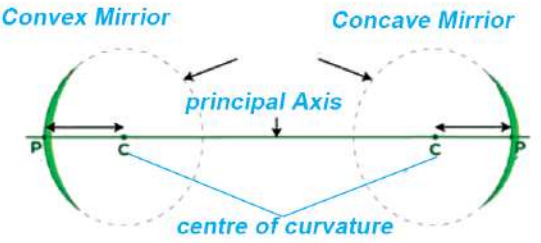


Figure 10.49 Circular mirrors

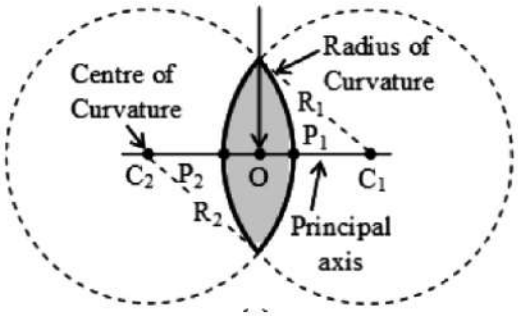


Figure 10.50 Convex lens

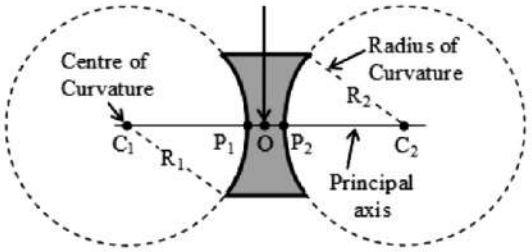


Figure 10.51 Concave lens

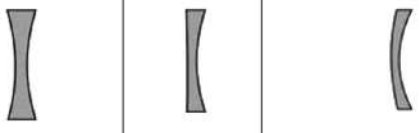
Types of lenses

Mainly there are two types of lenses. They are convex lens and concave lens. As shown in figure 10.50, the lens which is thicker at the middle part than that at the edges is a convex lens. Since convex lens can converge the light rays, it is also known as a converging lens. Convex lenses are used in devices such as spectacles, cameras, microscopes, projectors, etc. Natural convex lenses also exist in our eyes.

As shown in figure 10.51, the lens which is thinner in the middle part than that at the edges is concave lens. The concave lens is known as a diverging lens because of its ability to diverge light rays.

a.biconvex | b. planoconvex | c concavo convex

Figure 10.52 Converging lenses



a.biconcave | b. plano concave | c.convexo concave)

Figure 10.53 Diverging lenses

Terminologies related with lens

a. centre of curvature

The center of curvature is the center of the sphere that forms the curved part of the lens. Since most lenses are formed from two spherical curved surfaces, they will have two centers of curvature, usually labeled C_1 and C_2.

b. Radius of curvature

The radius of curvature is the distance from the center of curvature to the surface of the lens. In a ray diagram, it is denoted by R.

c. Optical center

The optical center is the geometrical center of the lens, where the principal axis intersects the lens surface. In a ray diagram, it is denoted by O.

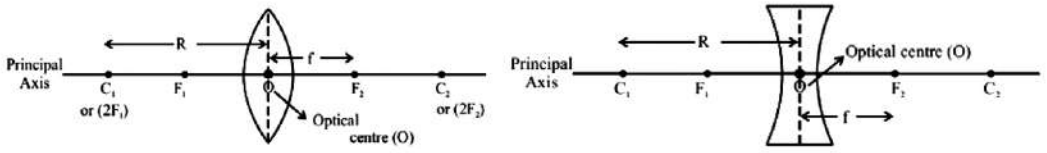


Figure 10.54 Terminologies related to lens

d. Principal axis

The principal axis is the line passing through the optical center and the two centers of curvature of the lens. It divides the lens into two symmetric halves.

e. Principal focus

Activity 10.11 Converging action in convex lens and diverging action in concave lens

Take a ray box with three slits, and thick convex and concave lenses. As shown in figure 10.55, place the convex lens and concave lens in front of the box in turn.

a.

b.

figure 10.55 observing and diversing process

Observe how the rays coming out of the ray box are bent and measure the distances mentioned below.

Convex lens	**Distance between the midpoint of the lens and the point where light rays conversed**	.....
Concave lens	Distance between the midpoint of the lens and the point where light rays diverged	.....

A convex lens can be considered as a combination of prisms. As shown in figure 10.56, on the upper half of the convex lens, the bases of the prisms face downwards and on the lower half, the bases of the prisms face upwards. The emergent rays from the prism are always bent towards the base. The prisms in the center of the lens refract the light more than those on the edges and the rays passing through the principal axis passes in a straight line without any deviation. As a result of this, rays that are travelling parallel to the principal axis converge at a point on the principal axis after passing through the lens as shown in figure 10.57. That point is known as the principal focus of the convex lens and is denoted by F in the diagram.

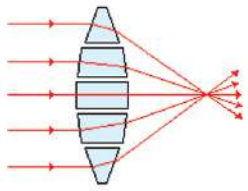


Figure 10.56 Converging process in a convex lens

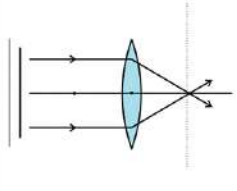


Figure 10.57 Focal length of a convex lens

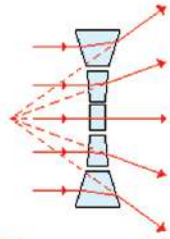


Figure 10.58 Diverging process in concave lens

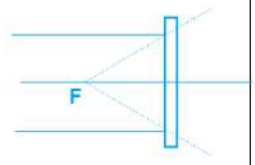


Figure 10.59 Focal length of a concave lens

A concave lens can also be considered as a combination of prisms. As shown in figure 10.58, on the upper half of this lens, the bases of the prisms face upwards and on the lower half of the lens the bases of the prism face downwards. Like in a convex lens, the rays of light are refracted towards the base of the prism and the center portion refracts more than the edges. This makes the rays travelling parallel to the principal axis diverge after passing through the lens. The rays travelling along the principal axis do not deviate. As a result of this, the diverged rays from a concave lens do not intersect each other but

appear to diverge from a point as shown in figure 10.56. Thus, the point from where the light appears to diverge is called the principal focus of the concave lens. The principal focus is the point on the principal axis from where the light rays travelling parallel to the principal axis converge or appear to converge after passing through the lens.

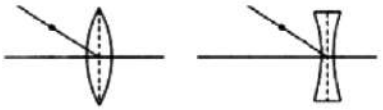
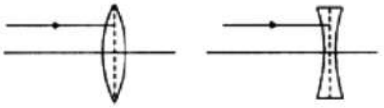
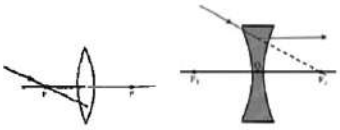
focal length

The focal length is the distance from the optical center O of the lens to its focus F. It is denoted by f. The radius of curvature is twice its focal length.

Rules to draw image formed by a convex lens

Activity 10.11

Take a convex and a concave lens whose focal lengths were determined in activities 10.11. Pass a laser beam through each of the lenses as shown in the ray diagrams below and observe the results.

The direction of a laser beam	Ray diagram	Result (direction of emergent beam)
Through the optical centre O		.....
Parallel to the principal axis		.....
Through focus F		.....

The ray diagrams of images formed by lenses depend on their shape. When light rays are converged by a convex lens and diverged by a concave lens, the following rules apply while drawing the ray diagrams:

(a) Light rays passing through the optical center of the lens do not bend. They continue to move forward in a straight line.

(b) light rays travelling parallel to the principal axis converge and pass through the focus. When the same rays pass through a concave lens, they appear to diverge from the focus.

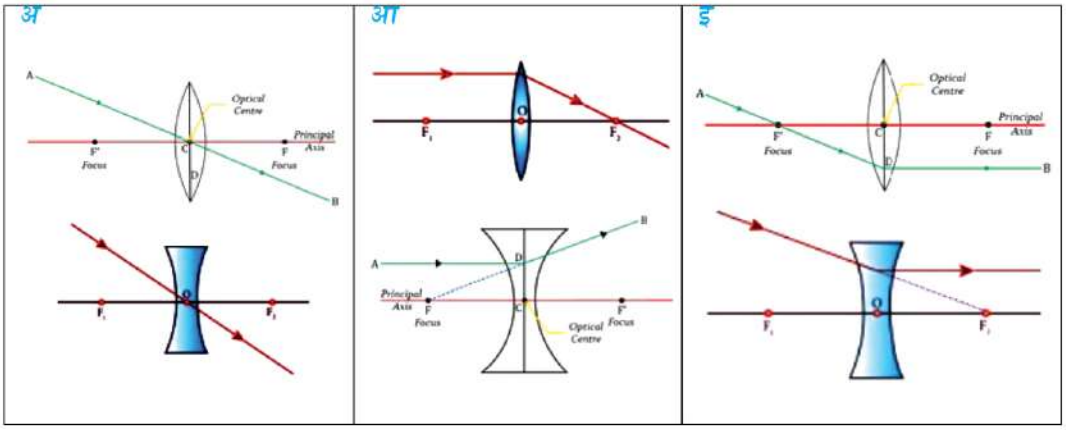


Figure 10.60 Rules to draw a ray diagram

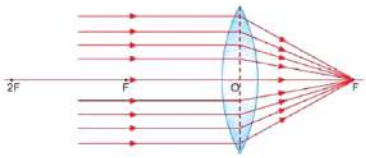
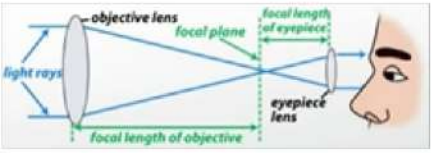
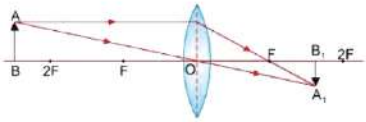
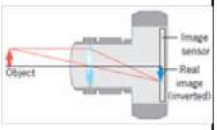
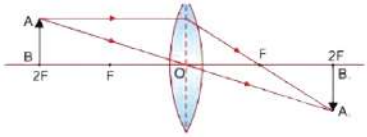
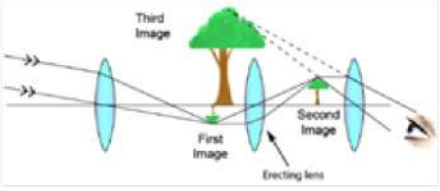
(c) Light rays that pass through the focus of a lens emerge parallel to the principal axis after the refraction in the lens.

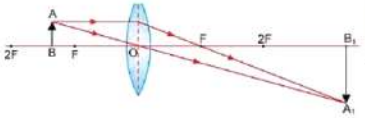
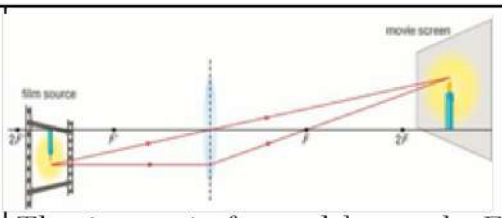
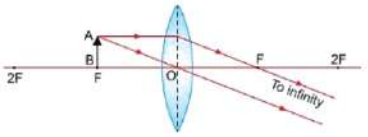
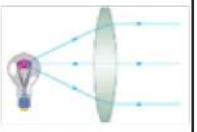
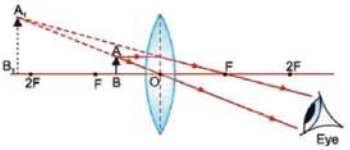
The image formed by a convex lens

Activity 10.13 Observation of the image of a candle formed by a convex lens

Take a convex lens whose focal length was measured in activity 10.11, a small screen prepared by pasting cardboard on a rectangular piece of wood, a candle, a one-meter scale or measuring tape. As shown in figure 10.61, lay the scale or tape on the table. Stand the lens somewhere in the middle of the ruler such that at least a 2f (f = focal length) distance is left on either side of it. Now, place a candle at one side of the lens at various positions. For each position of the candle, put the screen on the opposite side and move it forward and backward until a clear image of the candle is formed on the screen and observe the characteristics of the image. The characteristics of the image formed by a convex lens depend on the position of the object relative to the optical center O. The images formed by placing an object at different positions in front of the convex lens are shown in the diagram and their characteristics are presented in the table.

Figure 10.60 image formed by convex lens

Position of the object	Ray diagram	Position, characteristics and use of image
At infinity	 	 The image is formed at F. It is real, inverted and highly diminished. The objective lens of a telescope forms this type of image.
		In the picture at the side, the parallel rays of sunlight are converged by a hand lens. If the lens is kept stationary for some time, a piece of paper can be burnt as the lens converges the radiation from the sun.
Beyond 2F		The image is formed between F and 2F. The image is real, inverted and diminished. This type of image is formed by a camera. 
At 2F		 The image is formed at 2F which is real, inverted and it is of the same size as the object. This type of image is formed by erecting the lens of a terrestrial telescope.

Between F and 2F		 The image is formed beyond 2F which is real, magnified and inverted. This type of image is formed by a projector.
At F		The image is formed at infinity and it is real, inverted and highly magnified. It is applicable in a flashlight to project the light over a long distance. 
Between F and O		The image is formed on the same side of the object and it is virtual, erect and magnified. It is applicable in hand lenses to enlarge the image.

During the formation of the image, as the object is kept closer to the convex lens, the size of the image gradually increases and vice versa is also true.

Image formed by a concave lens

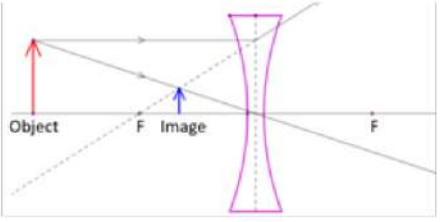


Figure 10.62

Light rays passing through a concave lens move away from the

principal axis after the refraction and never intersect each other physically. As shown in figure 10.62, if the refracted rays are produced in the backward direction, they cut at a point forming a virtual image. Thus, the image of an object at any point in front of a concave lens becomes virtual, erect and diminished. This type of image is formed by the lens used in peephole of a door.

Power of a lens

As in activities 10.14 and 10.11, take a ray box with three slits and three concave and convex lenses having different thicknesses. Then perform the following activities.

a. Allow the light rays from the ray box to fall on the lenses of your friend's or relative's spectacles and then observe their converging and diverging capacities. Then after, ask whether the power of the lens is -4 dioptre (D) or +2 dioptre (D), and so on, to the owner of the respective spectacles. Here, the lenses having positive power are convex lenses whereas those having negative power are concave lenses. The power of a lens is measured in dioptre. Compare the degree of refraction and thickness of two or more lenses. One possible observation is given in the table below.

Order of thickness of the lens	Diverging capacity	Power of the lens used in spectacles
Thickest lens	Having the highest diverging capacity	+4D
.....	.....	.....

Conclusions: : .....

b. Arrange the collected lenses in ascending order of their thicknesses. Measure their focal lengths as in activity 10.11.

c. While measuring the focal length, the distance between the lens and the focus formed by the intersection of real rays is taken as a positive focal length. Similarly, in the case of a concave lens, the refracted rays do not intersect but if they are extended backward

in the side of the incident rays then they appear to intersect at a point which is called apparent focus. The distance between this apparent focus and the lens is the focal length and it is taken as negative. Using these distances, the power of lenses can be calculated by using the formula given in the table below.

For convex lens

Order of thickness of the lens	Focal length	Power $P = \frac{1}{f\ (\text{in metre})}$	Result (relation between focal length and refracting capacity)
Thinnest	$+ 40\text{cm} = + \frac{40}{100}\ \text{m} = + 0.4\text{m}$	$\frac{1}{(+ 0.4\ \text{m})} = + 2.5\ \text{D}$	.....
.....	.....	.....	
Thickest	.....	.....	

When light rays refract through a lens, the degree of refraction is more in a lens with large curvature, i.e., thick lens than the lens with small curvature, i.e., thin lens. The ability of a lens to converge or diverge the light rays is called the power of that lens.

If a convex lens with greater curvature and thickness converges parallel light rays closer to its optical center (O) then its focal length is shorter, but its ability to converge light rays is higher. Similarly, a concave lens of shorter focal length also has a higher ability to diverge the light rays. Therefore, the power of a lens depends on its focal length (f). Mathematically, the power of a lens is defined as the reciprocal of its focal length in meters, i.e., lens power $P = \frac{1}{f\ (\text{in metre})}$

The SI unit of power is diopter. It is indicated by D. The power of a convex lens with a positive focal length is also positive. Likewise, the power of a concave lens with a negative focal length is negative.

The curvature of glass lenses remains constant. It does not change on its own. However, the curvature of the convex lens in our eye can be changed when we observe distant objects or nearby objects, resulting in a change in its power.

Human Eye

The optical instrument that forms the images of objects naturally by refracting the light through a convex lens is the human eye. As shown in figure 10.63, the aqueous humor and vitreous humor inside the eye give it a spherical shape. Important parts of the human eye are described below.

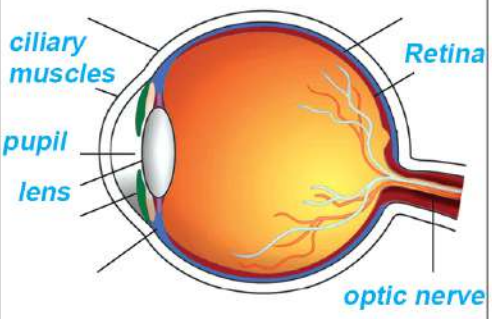


Figure 10.63 Parts of an eye

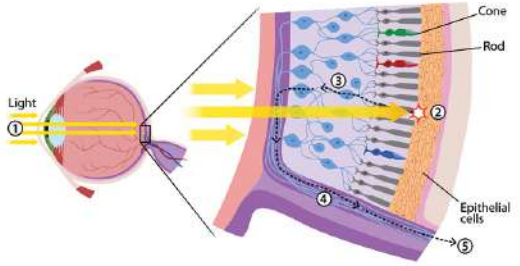


Figure 10.64 Rod and cone cells of the retina

(a) Cornea

Cornea is a transparent layer in front of the eye that allows light to enter. It helps to focus light on the retina. In the process of light rays coming from objects reaching the retina by passing through the air, cornea, aqueous humor, lens and vitreous humor, the cornea bends (refracts) the light more than any other parts of the eye. Thus, the cornea acts like the main lens in the eye.

(b) Pupil

The pupil is the dark hole in the middle of the eye through which light enters. Its size changes according to the brightness of the light. The colour layer of the muscles around the pupil, i.e., the iris, changes the size of the pupil. In bright light, the muscles in the iris relax and the pupil becomes smaller, while in dim light, the muscles in the iris

contract and the pupil becomes wider. Thus, the controlled amount of light enters the eye even at places where the light is very bright or dim.

(c) Eye lens

The convex lens of the human eye is a transparent part made of a natural protein called crystalline. The rays of light refracted from the cornea are refracted further in the lens to converge onto the retina.

(d) Ciliary Muscles

Ciliary muscles are the flexible muscles that change the thickness of the eye lens. The ciliary muscles attached to the lens ensure that light rays converge onto the retina. During the relaxation and contraction of ciliary muscles, the curvature of the lens and its focal length change.

(e) Retina

The retina is a layer of light-sensitive cells located at the back of the eye that can detect the color and brightness of light. When the rays of light are focused onto the retina, an image of the object is formed. Retina has two types of cells - rod cells and cone cells. Cone cells help to detect and identify colours while rod cells convert the light into electrical signals and help determine the brightness of the light.

(f) Optic Nerve

The optic nerve is a bundle of nerve cells in the retina that transmit information about the image to the brain in the form of electrical signals.

Although an inverted image is formed by the convex lens on the retina, our brain inverts it and we see the objects right way.

With the complex structure of the human eye and the functions of its different parts mentioned above, the formation of an image is possible. To form a clear image on the retina, the light rays must always be refracted and focused exactly on the retina whether the

rays come from a nearby object or a distant object.

Accommodation of eye

Considerable question

Compare the change in distance of an object when you move your eyes from the letters on the textbook in your hand to the distant object outside the window, such as clouds in the sky. Also, compare the distance between the lens and the retina (the image distance) in these two cases.

(a) During the process of forming an image by a convex lens, the image distance changes with the change in object distance. Is this process possible for the eye lens too?

(b) In the situation where the image distance of the eye lens remains constant, how should the curvature of the lens change so that it focuses the rays of light from nearby objects as well as from the distant object exactly on the retina?

The object distance becomes shorter on looking the letters in a book that is taken in our hand, while looking at the clouds in the sky, the object distance becomes longer. Since the images of objects at various distances are all formed on the retina, the image distance or the distance between the lens and the retina remains constant. In such a situation, to form a clear image, the curvature of the lens must change, making the rays of light converge more or less. For this, the ciliary muscle of the eye can increase or decrease the thickness of the lens.

As shown in figure10.56, when we look at a distant object, the ciliary muscles relax. In this situation, the lens becomes thin, i.e., its curvature decreases and the focal length increases. As a result, the incoming rays from the distant objects are focused on the retina and we can see the objects clearly. In the same way, while looking at a nearby object, the ciliary muscles contract. In this condition, the curvature of the lens increases, the lens becomes thicker and the focal length decreases. As a result, the incoming rays from the

nearby object are refracted more strongly and focused on the retina. This process of adjusting the focal length of the eye lens according to the distance of the object from the eye by the process of relaxation and contraction of the ciliary muscles is called accommodation of the eye.

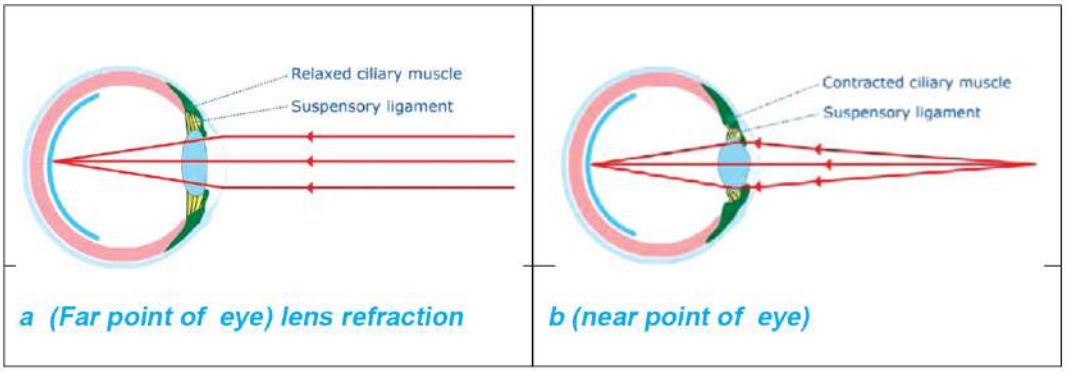


Figure 10.65 Accommodation of the eye

Far point and near point of human eye

The far point is the farthest distance from the eye at which it can see objects clearly. For a normal eye, this point is at infinity. As shown in figure 10.65 a, on looking at a distant object, the lens of the eye becomes the thinnest and it has maximum focal length. Similarly, as shown in figure 10.65b, on shifting the object to a certain distance from the eye, the ciliary muscles attain their maximum possible contraction. If the object is shifted even closer, the ciliary muscles cannot contract any further and hence the image on the retina cannot be clear.

The nearest distance from the eye at which it can see objects clearly is called the near point of the eye. For a normal eye, the near point is at a distance of 25 cm from the eye. This distance is also referred to as the least distance of distinct vision. While looking at an object at the near point, the eye lens has the maximum curvature i.e., it becomes the thickest and has the shortest focal length.

The near point of the eye can vary depending on the person's age and the condition of the eye. For a person with no visual defect, the

range of human vision is from 25 cm to infinity (∞). For individuals with visual defects, the near point and far point of the eye differ from those with normal vision.

Defects of vision

If the letters appear blurry when a book is kept at a normal distance from the eyes, the book has to be brought closer or further away until the letters become clear. As shown in figure 10.66, to see a nearby or distant object clearly, the light rays from the object must be focused on the retina forming a clear image. Otherwise, the object will appear blurry. For humans, the phenomenon where nearby or distant objects appear blurry, i.e., not forming clear images of these objects on the retina, is called a defect of vision.

Types of defects of vision

There are two types of defects of vision in human eyes. They are shortsightedness (myopia) and longsightedness (hypermetropia).

Shortsightedness or myopia

For those suffering from shortsightedness, images of distant objects appear blurry, as shown in figures 10.66a and 10.66b, because the rays of light coming from those objects are focused in front of the retina. However, for closer objects, the retina creates a clear image. The problem, in which one sees nearby objects clearly but not distant objects, is called shortsightedness. This problem occurs primarily for two reasons.

(a) In some people, the eyeball gets elongated, and the distance between the lens and the retina increases. As a result, the parallel rays coming from distant objects are focused in front of the retina.

(b) When looking at distant objects, if the ciliary muscles do not contract enough, then the lens cannot be thin enough. As a result, the focal length of the lens becomes less than required

and the parallel rays of light coming from distant objects are focused in front of the retina. Sometimes, not only the curvature of the lens but also the curvature of the cornea causes myopia. As shown in figure 10.75c, for myopic eyes, the far point is not at infinity but at some finite distance from the eye.

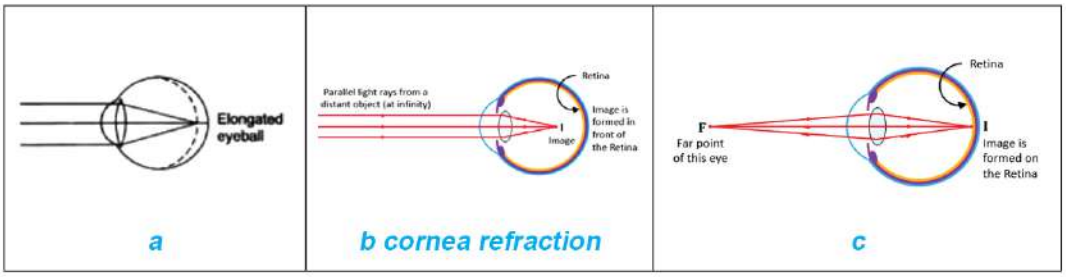


Figure 10.66 Causes of shortsightedness

Correction of shortsightedness

For an eye with the problem of shortsightedness, if the parallel rays coming from distant objects are diverged to some extent before entering the eyes, the problem could be solved. For this, a diverging lens, i.e., concave lens, of suitable focal length is to be kept in front of the eye as shown in figure 10.67. As a result, the incoming parallel rays of light from the distant object get diverged by that lens before entering the eye. After refracting these diverged rays through the cornea and the lens of the eye, they get focused on the retina and the object appears clear.

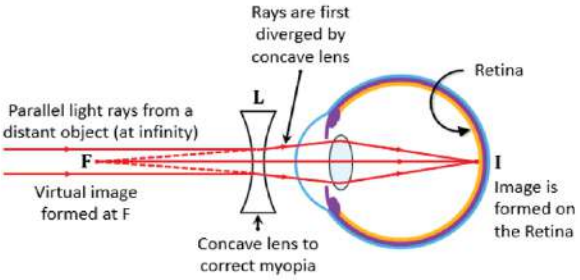


Figure 6.67 Correction of shortsightedness

The focal length of the lens used in the spectacles to correct the defect is selected in such a way that rays diverged by the lens get focused exactly on the retina and the rays from distant objects appear to be coming from the far point F of the defective eye.

Long-sightedness or Hypermetropia

For the eyes with a problem of longsightedness, as shown in figures 10.68a and 10.68b, objects close to them appear blurry because the light rays coming from nearby objects are focused behind the retina. But, for the distant object, a clear image is formed on the retina. The problem, in which one sees distant objects clearly but the nearby objects appear blurry, is called long-sightedness. This problem occurs primarily for two reasons.

(a) In some individuals, the eyeball becomes too circular and hence the distance between the lens and the retina decreases. This causes light rays from nearby objects to be focused behind the retina.

(b) While looking at nearby objects, if the ciliary muscles in the eye cannot contract enough, the lens cannot be made thick enough. This causes an increase in focal length and the light rays from nearby objects get focused behind the retina. As shown in Figure 10.68c, for those with long-sightedness, the near point is not at 25cm from the eye but beyond. Usually, this problem is seen in old age.

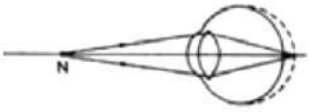


Figure: 68 a

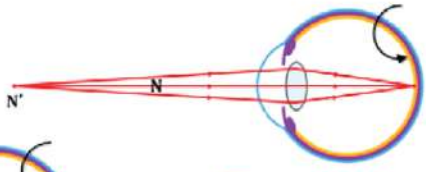


Figure 10.68 c

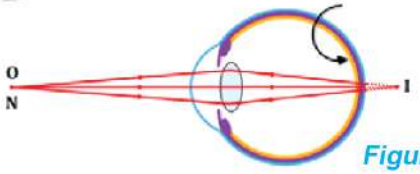


Figure 10.68 b

Figure: 10.68 Cause of long-sightedness

Correction of longsightedness

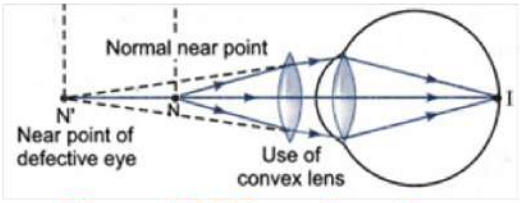


Figure: 10.69 Correction of longsightedness

For eyes with longsightedness, the problem can be solved if the light rays coming from the nearby object are converged to some extent before they enter the eyes. For this purpose, a converging lens, i.e., convex lens, should be placed in front of the eye, as shown in figure 10.69, so that, the rays

from nearby objects get converged to some extent by the lens before entering the eye. When those rays refract through the cornea and the eye lens, they get focused on the retina and the nearby objects start to be seen clearly.

The focal length of the convex lens used in the spectacles for the correction of long-sightedness is selected in such a way that the rays converged by the lens get focused on the retina and they appear to come from the near point N of the eye suffering from longsightedness.

Other ways for correction of defect of vision apart from using spectacles

(a) Contact lens

Figure 10.70
Contact lens

As shown in figure 10.70, a contact lens is a thin artificial lens worn on the surface of the cornea to correct defects of vision. It sits above the thin film of tears on the cornea and covers the iris and pupil of the eye. This refracts the light rays by just the necessary amount before reaching the eye lens. Contact lenses are useful in situations where one does not want to use glasses, for example, while playing sports contact lenses with powerless sunglasses are to be used.

The use of glasses and the use of contact lenses have their distinct advantages and disadvantages. Glasses are very easy to use. The lenses used in it are of high quality and available in different sizes. However, spectacles with high-power lenses are thick and the peripheral vision is distorted while looking right and left through it. But this problem does not occur in the case of contact lenses because they move along with the cornea. Since contact lenses are very closer to the eyes, contact lenses with low power can be used instead of thick glass lenses.

Contact lenses require more careful handling than spectacles. They are to be stored and cleaned in specific ways. Contact lenses are to be cleaned and disinfected before they are reused. To prevent infection, one should always wash his/her hands before wearing contact lenses and before removing them. One should not sleep overnight with contact lenses. The improper use of contact lenses can affect the cornea.

b. Laser eye surgery

Figure: Before the correction of short sightedness

Figure:Laser beam focused on the cornea

Figure: After the correction of short sightedness

Figure 10.71 Laser surgery of the eye to correct shortsightedness

Figure 10.71 shows the cornea of a shortsighted eye being flattened a bit by focusing a laser beam on the central part of the cornea. Hence, the rays of light through the cornea are refracted a little less than before and the myopia problem gets solved. On the contrary, if the laser beam is focused on the edges of the cornea, the middle part of the cornea gets raised a little, and the problem of long-sightedness gets solved. In this way, the process of correcting defects of vision by reshaping the cornea using a special type of ultraviolet laser, i.e., excimer laser, is called laser eye surgery.

Laser eye surgery is performed on the outermost part of the cornea. LASIK (Laser-assisted in situ keratomileusis) is themost popular technique among different laser eye surgery techniques. In this, the laser beam focused on the cornea cuts out a flap. The cutout flap is flipped to reshape the cornea.

Other problems related to the eye, apart from defects of vision

(a) Cataract

As the age of people increases, the crystalline proteins of the lens stick together and the lens becomes cloudy. Thus, the rays coming from the objects do not reach the retina properly and the objects appear blurry. As the opacity of the lens increases, the transparent quality of the lens gets lost and finally complete blindness occurs. A gray-coloured spot appearing in the pupil of the eye due to the cloudiness of the lens is called a cataract. Cataracts are mostly seen in elderly people.

Figure 10.72 Cataract

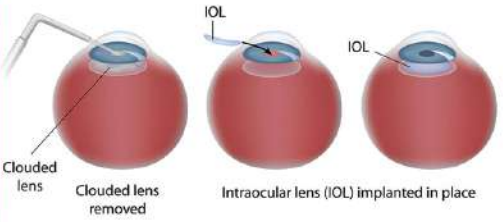


Figure 10.73 Cataract intraocular lenses

In some people, exposure to ultraviolet radiation from the sun, cigarette smoking habits, high diabetes, etc. increase the possibility of cataractbefore reaching old age. Cataracts are treated with surgery.

For cataract surgery, a fine hole is made on the edge of the cornea. The cloudy lens is broken into small pieces by sending an ultrasound through the hole and the pieces are taken out with the help of a vacuum tube. In its place, an intraocular lens made of silicone or acrylic is kept.

Figure 10.74 Dr. Ruit

Nepali Ophthalmologist Dr. Sanduk Ruit developed a very cheap intraocular lens in 1995 and made cataract treatment cheap.

(b) Colour Blindness

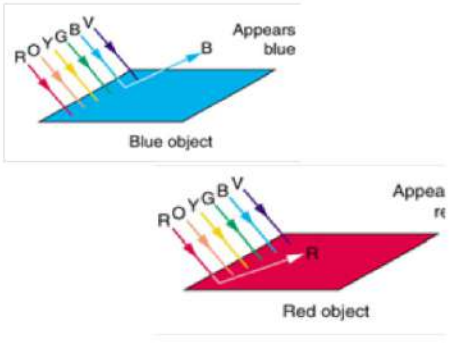


Figure 10.75 Reflection of colour

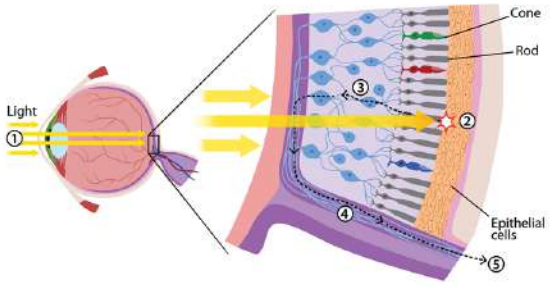


Figure 10.76 Cone cells in the retina

The colour we perceive depends on the light waves of that colour and the cells that identify colors in the retina. As shown in figure 10.75, when looking at a blue-coloured object, the blue-coloured light wave reflected from the surface of the object is absorbed by the blue cone cells of the retina of the eye. The message that the blue color is observed is then sent to the observer's brain. In the retina, there are millions of three types of cone cells, namely blue cone cells, red cone cells, and green cone cells. These cells separate colors. If the cone cells in the retina stop working, we cannot distinguish colors. People with red-green color blindness cannot distinguish red and green colors. Thus, color blindness is the inability of the eyes to distinguish colors due to defects in the cone cells of the retina. The main reason for this is heredity. In addition to this, color blindness occurs when the cone cells are destroyed by mutations and harmful rays. Can you see the number inside the above (10.77) circles?

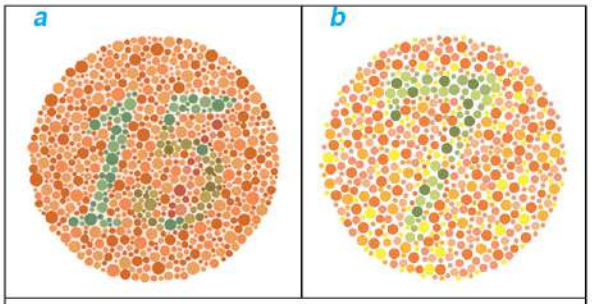


figure 10.77

(c) Night Blindness

The rod cells in the retina enable us to observe objects in dim light. For example, even if the light is very dim in a room, the position of the furniture in that room can be determined. Sometimes, due to disease, injury, lack of proper nutrients, or many other reasons, the rod cells do not function properly and objects in very dim places cannot be seen. Night blindness or nyctalopia is the inability to see well at night or in dim places. This is the problem of the retina. Since the rhodopsin pigment in the rod cells of the retina is made from a type of protein and vitamin A, this pigment is deficientwhen there is a lack of vitamin A in the body. Therefore, the lack of vitamin A in the body is one of the main causes of night blindness. This diseasecan also be caused due toheredity.

Effects of injuries to the cornea in the eyes

Question to consider

What do you do when dust or sandparticles enter the eyes sometime during a storm? What is the effect of continual rubbing of eyes in such situations?

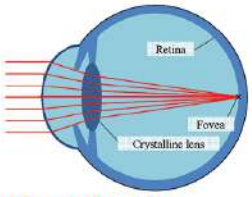


Fig. refraction through the cornea

Fig. Corneal ulcer

Fig . Corneal edema

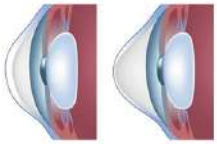


Fig. Keratoconus

Figure10.78 Effectsof corneal injuries on the vision

Cornea plays an important role in refracting light in the eye. The maximum refraction takes place at the cornea. The refractive index of the cornea is 1.376 and its converging power is about +43 D. It represents about two-thirds of the light-refracting capacity of the eye. Thus, the cornea of the eye must be protected from being scratched, hurt or injured. Sometimes, when dust or sand enters the eyes during a storm, the cornea gets scratched if the eyes are constantly rubbed with hands. Similarly, stones, pieces of metal, accidents, etc. may injure the cornea. Continual use of contact lenses and using them without proper cleaning can lead to infection in the cornea. Bacterial, viral, or fungal infections in the cornea can cause corneal diseases and vision problems. The corneal infection causes corneal ulcer i.e., keratitis. If the corneal ulcer is not treated immediately, it will make people go blind. Corneal edema caused by fluid accumulation between the corneal layers also causes blurred vision. Similarly, keratoconus, which occurs when the surface of the cornea changes into a conical shape, causes shortsightednessat first and later the eye loses its vision. Normal corneal problems can be cured by proper treatment. In cases the cornea cannot be cured by treatment, it can be replaced.

Corneal transplantation

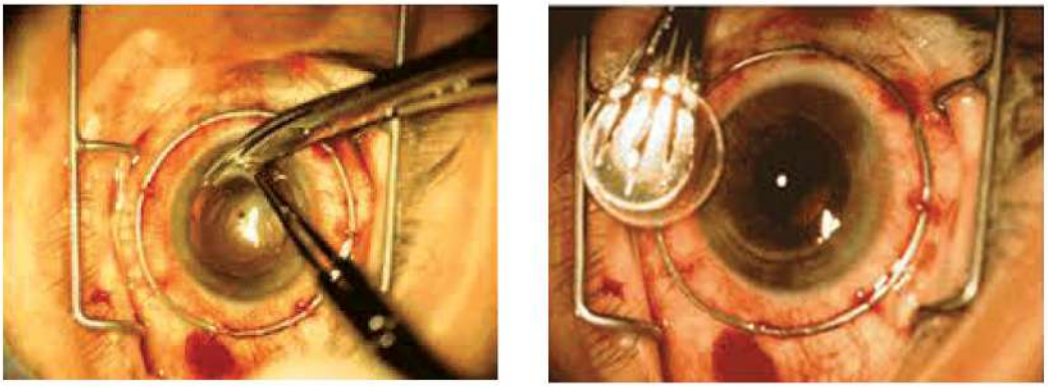


Figure 10.79 Corneal transplantation

The second leading cause of blindness in our country after cataract is corneal degeneration.

Corneal replacement can be done for people who were born with puffy eyes, and people whose corneas were damaged due to the absence of immediate treatments duringvarious infections, injuries, etc. As shown in Figure 10.79, the process of replacing the damaged cornea with a good cornea by eye surgery is cornea transplantation.

Some people donate their eyes to the eye bank so that other people can use the cornea of their eyes after their death. After the death of people who have donated eyes, doctors remove the cornea, not the whole eye, and store it safely. After the death of the donor, the eyelids are closed properly to protect the cornea from direct sunlight, and the cornea is removed from the eye within 8 to 12 hours. The sooner the cornea is removed after death, the better is its quality. In our country, Nepal Eye Bank has been established under Tilganga Eye Institute for the collection, storage, and distribution of corneas.

Project Work:

(a) Contact people of different age groups around your area and collect data about the eye-related problems they have faced, the measures taken to solve those problems, awareness about eye

donation, etc. A table like the one below can be prepared for data collection:

S.N	Name	Age	Eye related problem	Adopted remedies	Awareness about eye donation
....	.....	...	.....	.....	Have/does not have

Analyze the data obtained from the survey and prepare a report including the problems observed, awareness about eye donation, etc.

(b) Get in contact with the people having cornea transplantation or treatment of cataracts and request them to share their experiences. Then, prepare a report.

Exercise

A. Choose the correct option for the following questions.

a. Which of the following rules applies during the refraction of light?

(i) Lightbends onlywhile passing from a rarer medium to a denser medium.

(ii) Light bends towards the normal as it passes from a denser medium to a rarer medium.

(iii) When light passes from a rarer medium to a denser medium, the angle of incidence is smaller than the angle of refraction.

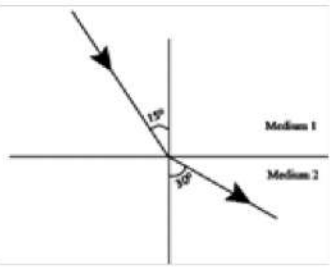
(iv) The angle of refraction becomes greater than the angle of incidence when light travels from a denser medium to a rarer medium.

b. Study the given ray diagram and select the correct statement.

(i) Medium 2 is a denser medium and medium1 is a rarer medium.

(ii) The speed of light in medium 2 is lesser than in medium 1.

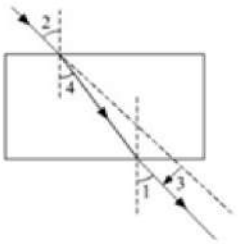
(iii) The speed of light is twice in medium 1 than that in medium 2.



(iv) Medium 1 is a denser medium and medium 2 is a rarer medium.

c. In the refraction of light through a glass slab shown in the figure, identify the correct names that should be placed in the place of the numbers: angle of incidence, angle of refraction, angle of emergence, lateral shift

(i) 1- angle of incidence, 2- angle of refraction, 3- lateral shift, 4- angle of emergence



(ii) 1- the angle of emergence, 2- the angle of incidence, 3- lateral shift, 4- the angle of refraction

(iii) 1- angle of refraction, 2- angle of emergence, 3- lateral shift, 4- angle of incidence

(iv) 1- lateral shift, 2- the angle of refraction, 3- the angle of incidence, 4- the angle of emergence

d. Which of the following is the result obtained from the observation of refraction through a glass slab?

(i) $\angle i = \angle e < \angle r$ (ii) $\angle i > \angle r = \angle e$

(iii) $\angle i < \angle e = \angle r$ (iv) $\angle i = \angle e > \angle r$

e. What is the value of the critical angle of the glass?

(i) 42^{o} (ii) 49^{o}

(iii) 24^{o} (iv) 48^{o}

f. Among endoscopes, spectacles, mirages, dispersion of light, rainbows, optical fibres, and hand lens, in which instruments and processes does the total internal reflection of light, take place?

(i) endoscope, spectacles, and mirage

(ii) dispersion of light, rainbow, and hand lens

(iii) rainbow, optical fibre, and mirage

(iv) endoscope, mirage, andoptical fibre

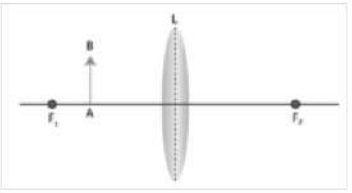
g. The velocities of the green, violet and red light rays seen during the dispersion of the light through a prism are denoted by vg,vv, and vr respectively. Which order is correct

for those velocities?

(i) $v_g > v_v > v_r$ (ii) $v_g > v_v < v_r$

(iii) $v_g < v_r < v_v$ (iv) $v_g > v_r < v_v$

h. Identify the characteristics of the image of the object AB kept in front of the lens as shown in the given figure.



(i) virtual, erect, magnified

(ii) real, inverted, diminished

(iii) real, erect, magnified

(iv) virtual, inverted, inverted

i. Distinguish the correct statement based on the characteristics of the image formed by concave and convex lenses.

(i) Convex lens forms a real, inverted, and diminished image of an object.

(ii) Concave lens forms a virtual, erect, and diminished image of an object.

(iii) Convex lens forms a real, inverted, and magnified image of an object.

(iv) Concave lens forms avirtual, erect, and magnified image of an object.

j. What is the correct understanding of eye problems and related causes?

(i) When the lens of the eye becomes cloudy, color blindnessoccurs.

(ii) When the focal length of the lens of the eye increases, shortsightednessoccurs.

(iii) When the shape of the surface of the cornea changes, defect in vision is seen.

(iv) Night blindness occurs due to the weakness of the cone cells of the retina.

2. Differentiate between

(a) reflection of light and total internal reflection of light

(b) concave lens and convex lens

(c) near point of the eye and far point of the eye

(d) shortsightedness and longsightedness

(e) color blindness and night blindness

3. Give reasons:

(a) Between glass and water, glass is considered a denser medium and water is a rarer medium.

(b) When a coin is placed in glass containing water, it appears to rise a bit.

(c) When the letters written on the paper are observed from the top of a glass slab, the letters appear to be slightly raised.

(d) Stars twinkle.

(e) The sun appears on the horizon about two minutes before the actual sunrise.

(f) A diamond appears to shine but a piece of glass cut to the same shape does not shine.

(g) Sunlight is refracted when it is passed through a prism.

(h) A convex lens converges light rays.

(i) A concave lens diverges the rays of light.

(j) Deficiency of vitamin A in the body is one of the main causes of night blindness.

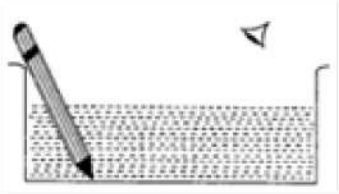
(k) Color blindness occurs when the cone cells of the retina stop functioning.

4. Write short answers to the following questions.

a. What is the refraction of light?

b. Write the laws of refraction of light.

c. What change is noticed in the shape of a pencil that is half immersed in water as shown in the Figure? Explain with a ray diagram. Write the name of the process associated with this observation.



d. When a light ray passes from water to air, the angle of incidence and angle of refraction formed at the water-air separation layer are 40.5o and 60orespectively. Draw a ray diagram showing the refraction and write the reason why an object outside appears to be farther away from its actual position when it is viewed by an observer inside the water.

e. What is a critical angle?

f. What is a total internal reflection of light?

g. Write two conditions necessary for total internal reflection of light.

h. At present, data can be transmitted at a very fast rate through fiber internet. Mention the role of total internal reflection of light in fiber internet.

i. In endoscopy, colonoscopy and keyhole surgery, how is total internal reflection of light applicable to the devices used to send light to the internal organs of the human body without incisions?

j. What is a dispersion of light?

k. Mention the reason for the dispersion of light.

l. Draw a raydiagram showing the following processes:

(i) Refraction of light through a glass slab

(ii) dispersion of light through a prism

m. A person is curious to know why a rainbow always appears semicircular and of the same size. Write down the solution to hiscuriosity. Include in your answer the position of the sun in the rainbow, the position of the water droplets in the air and the process of dispersion of light.

n. Define the following terms related to the lens.

(i) Centre of curvature (ii) Optical centre

(iii) Principal axis (iv) Focus

o. What ismeant by the power of a lens?

p. The powers of two convex lenses are +2D and +4D respectively.

(i) Which of them is thicker? Give reason.

(ii) Calculate the focal length of each lens.

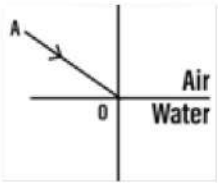
q. In which case is the image formed by a convex lens real and of the same size as the object? Show the ray diagram.

r. Will the spear thrown by the man shown in the figure, from outside the water hit the fish in the water? Explain it based on the real depth of the fish in the water.

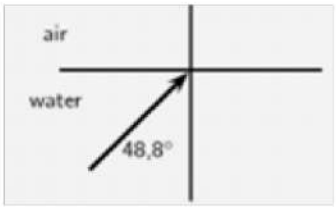
s. What process is shown in the ray diagram? Name any two devices that operate on this process.

t. Complete the ray diagram by copying the given figures to the answer sheet.

(i)



(ii)



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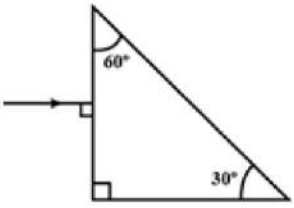
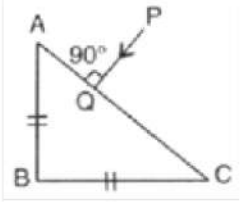
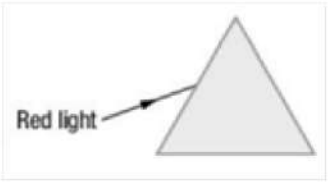


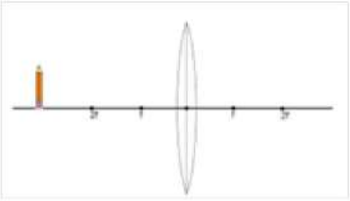
(iv)



(v)

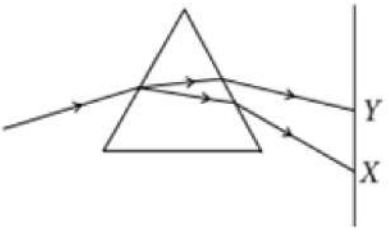


(vi)



u. Mention the facts, along with the ray diagram, applicable to the uses of the lens shown in the figure.

v. The given figure shows the dispersion of a light ray through a triangular prism. Answers the following questions based on the given ray diagram.



(a) Which colours of light waves are indicated by X and Y?

(b) Write down the reason why Y is bent less than X when the light rays come out of the prism.

w. How can the light dispersed by a prism be converted back into white light?

x. The focal lengths of the two lenses are 20cm and -20cm respectively. Mention the types of these two lenses. Out of these two lenses, which one forms a virtual and magnified image when an object is kept 16 cm away from the lens? Explain it by drawing a scaled ray diagram.

y. Write the functions of the following parts of the eye.

(i) Ciliary muscle (ii) Cornea

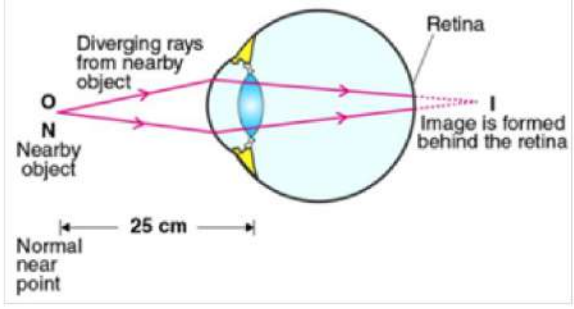
(iii) Lens (iv) Iris

(v) Pupil (vi) Retina

z. Write any two problems that may be seen in corneal injury.

27. Explain the role of the ciliary muscle in the change in the thickness of the eye lens when a studentsitting in a classroom shits his eyes from the letters written on the whiteboard to a distant object seen out the window.

28. Identify the type of defect of vision indicated by the given ray diagram. Write two causes of the defect along with its correction.



29. A student in the class has difficulties in seeing the letters written on the whiteboard when he sits on the last bench but he sees them clearly when he sits on the first bench. Based on this, answer the following questions:

(i) What type of defect of vision does the student have?

(ii) Draw a ray diagram showing this type of defect of vision of the student.

(iii) Write any two reasons for this defect.

(iv) Explain, with a ray diagram, the role of the lens used to correct this defect.

30. Explain, with a ray diagram, the role of the lens used to correct long-sightedness.

31. A student concludes that, 'the effect of defect of vision is more on a person wearing spectacles with thick lenses than one wearing that with thin lenses'. Is this understanding, correct? Justify withappropriate reasons.

32. Compare the use of spectacles and the use of contact lenses to correct visual defects.

33. Explain the laser surgery method used to solve eyesight problems.

34. What is a cataract? Write the role of the intraocular lens developed by Nepal's ophthalmologist Dr. Sanduk Ruitin the treatment of cataracts.

5. Solve the following mathematical problems.

a. If the speeds of light in air and glass are 3×10^8 m/s and 2×10^8 m/s respectively, thencalculate the refractive index of glass with respect to air. [Answer 1.5]

b. T he refractive index of a diamond is 2.42. If the speed of light in glass is 3×10^8 m/s, calculate the speed of light in a diamond. [Answer 1.24×10^8 m/s]

c. When a ray of light falls on the surface of a plastic block, the angle made by the ray with the normal and the angle of refraction are found to be 45^0 and 33^0 respectively. Calculate the refractive index of that plastic. [Answer 1.3]

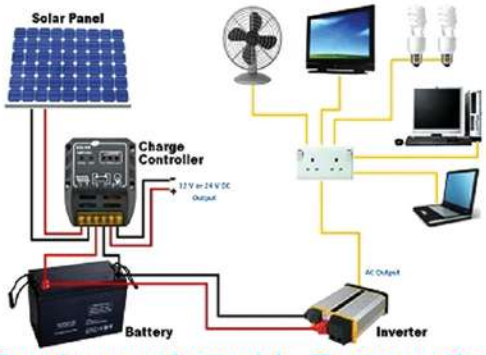
d. Calculate the power of a lens having a focal length of 25 cm. [Answer +4D]

e. The power of the lens used in the spectacles worn by a student is -6D. Calculate the focal length of the lens. Also, mention the type of lens. [Answer 16.67cm]

11 Electricity and Magnetism

The picture showsthe alternative arrangements made by the people during load shedding (electrical power cut).

People use rechargeable emergency lamps. The battery in such devices is charged when there is electricity in the main line.



People use solar panels. By connecting an inverter with this, different electrical devices can be operated.

When there is a main power supply battery can be charged, and many electrical devices can be operated by connecting the battery with an inverter.

Electricity can be generated by using petrol/diesel generators of different capacities whenever there is a need.

Topics related to the various information mentioned above are included in this unit. Types of current, construction of generators, and transformers and their working principles, etc. will also be discussed here.

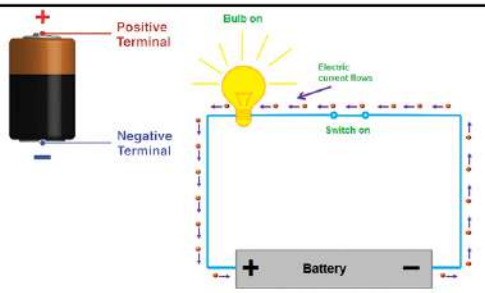


Figure 11.1 Direct current obtained from the cell

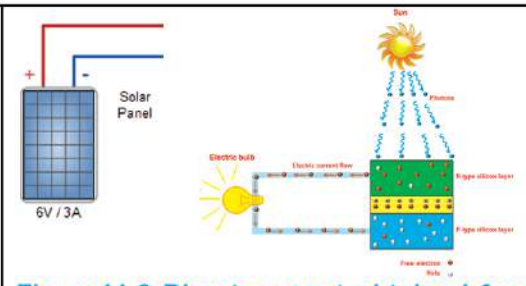


Figure11.2 Direct current obtained from the solar panel

Figure 11.1 shows two poles of a dry cell. It also shows that the electric charges in the conducting wire are flowing in a certain direction (from the negative terminal of the cell to its positive terminal) when the cell is connected to the electric circuit and the light is turned on.

Similarly, Figure 11.2 shows the flow of current through a conducting wire in a particular direction when abulb is lit by the electric current from a solar panel.In this way, the current which flows in a particular direction is called the direct current (d.c.). Dry Cells, photocells (Solar panels), batteries, etc. are the sources of d.c.

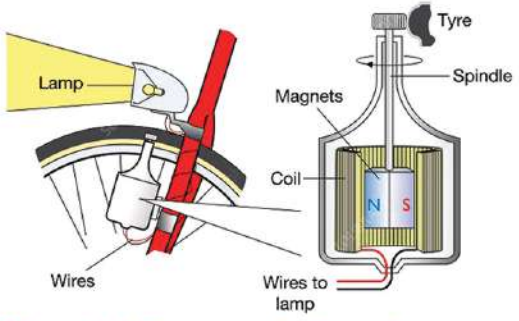


Figure 11.3 Sources of alternating current

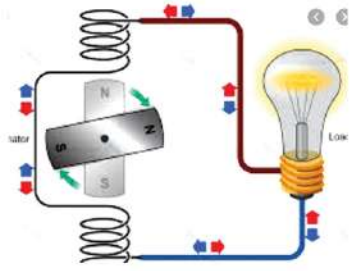


Figure 11.4 Direction of current produced by rotating magnets inside a dynamo

A glowing bulb run by the electricity produced by a dynamo is shown in Figure 11.3. In the above picture, the negative terminal and the positive terminal are not separated as in the dry cell and solar panel. In Figure 11.4, the direction of the current generated when the magnet is rotated between the coils in the dynamo is presented in a simplified manner.

In the same figure, the blue arrow shows that the charge on the conducting wire moves forward, and the red arrow shows that after a

while the same charge flows in the opposite direction. The direction of a current of this type changes at a certain time interval. In the same way, the magnitude of the current also gradually changes from the minimum value to the maximum value. Thus, the current in which magnitude and polarity change continuously at a fixed interval of time is called alternating current (a.c.). Dynamo, a.c. generator, etc. are sources of a.c.

Current time graph

The fact that the magnitude of the current remains constant with respect to time in direct current can be demonstrated in a time current graph as shown in Figure 11.5. Similarly, the variation of magnitude and direction of alternating current with respect to time can be presented as shown in Figure 11.6.

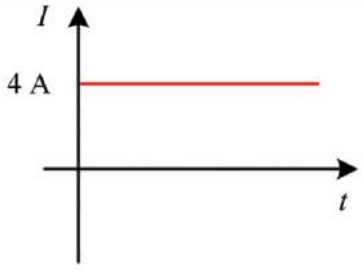


Figure 11.5 Time–current graph of direct current

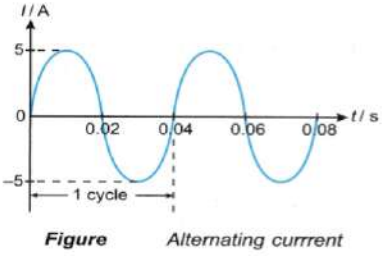


Figure Alternating currrent

Figure 11.6 Time-current graph of alternating current

In the current time graph of direct current, it is shown that the magnitude of the current is constant at 4A even though the time is increasing. Similarly, in the current time graph of the alternating current, it is shown that themagnitudeof the current first increases from zero to 5A and then decreases to zero. After that, the value of the current increases again but in exactly the opposite direction (i.e. goes to -5A) and then again decreases to zero. Thus a cycle is completed. For a.c., the number of cycles completed in one second is called frequency. If one cycle of a.c. is completed in one second, the frequency of that a.c. is 1 hertz (1 Hz). The frequency of a.c. used in our country is 50 HZ and the average voltage ranges from 220 V to 240 V. This means that the direction of a.c. used in our country changes 100 times every second. Since the direction of the current in d.c. does not change with time, the frequency is zero.

Among different electrical appliances used in our daily life, some are run ona.c, some on d.c. and some on both a.c and d.c. Electrical devices such as fans, motors, refrigerators, etc. run on a.c whereas d.c. is used in the internal circuits of electrical appliances such as mobile phones, computers, etc.Electric heaters, filament lamps, etc. can operate in a.c as well as d.c.We can use a rectifier to convert alternating current into direct current.

Figure11.7 Rectifier block line graph

Activity 11.1

Fill in the differences between direct current and alternating currents in the table below.

Direct current (d.c.)	Alternating current (a.c.)

Magnetic effect of electric current

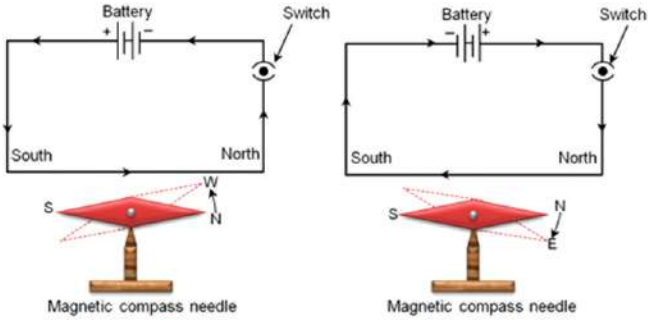


Figure 11.8 Direction of current along with the direction of motion indicated by the compass needle

In the year 1820, Hans Christian Oersted,a Danish physicist and science teacher, discovered the fact that electricity and magnetism are related to each other. He observed the needle of a magnetic compass deflecting near an electric circuit while performing an experiment involving electric current. After further study, it was found that the direction of the deflection of the magnetic needle changes along with the change in the direction of current flow in the circuit. Orested concluded that the deflection of the compass needle is due to the magnetic effect produced by the electric current.

The formation of a magnetic field around a conducting wire when

there is electric current init, is the magnetic effect of current. The direction of the magnetic field thus formed depends on the direction of the electric current in the wire.

Magnetic field around a current carrying straight wire

Activity 11.2

(a) Take a square piece of cardboard. Pierce it with a straight wire and connect it to an electric circuit and connect the wire to the circuit as shown in Figure 11.9. Place plotting compasseson the cardboard and position them around the wire as shown in the figure. Turn on the switch to pass the current in the wire and then observe the needles of the compasses. Observe whether the needles of the magnetic compass around the wire rotate in a certain direction when the switch is turned on. Because there is no proper load in the circuit, the switch should be turned off immediately. Otherwise, the wire heats up if the switch is left on for a long time. Swap the poles of the cell and turn the switch on again and observe if the direction of the needles is opposite to the previous one.

(b) Pierce the cardboard with a straight wire as mentioned above and connect it to an electric circuit. Sprinkle very fine iron powder over the cardboard as shown in Figure 11.10. Turn the circuit switch on and then tap the cardboard gently with your fingers. Observe whether the iron dust settles in a circular geometric pattern or not.

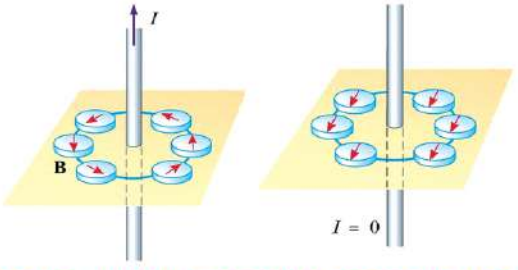


Figure 11.9 The circular magnetic field shown by a magnetic compass around a straight wire when it is carrying current

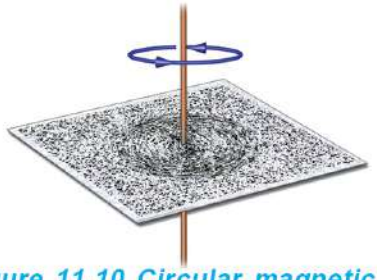


Figure 11.10 Circular magnetic field shown by iron dust when there is current in a straight wire

The magnetic field formed around a straight wire due to the electric

current in it can be observed by drawing lines of magnetic force as shown in Figure 11.10.

When magnetic compasses are placed around the wire in the above activity, the needles of the compass point in a certain direction and indicate a circular pattern as shown in Figure 11.11. This effect is caused by the magnetic field formed in a circular pattern around the wire when there is current in it. The direction of the magnetic field thus formed depends on the direction of the electric current flowing in the wire. As shown in Figure 11.12, if the electric current is going upwards through the wire, the direction of the magnetic field is anticlockwise. On the contrary, if the current flows downwards from the wire, the direction of the magnetic field is clockwise. In the above activity as well, the direction of the magnetic field can also be determined by observing the direction of the pointer of the compass needle.

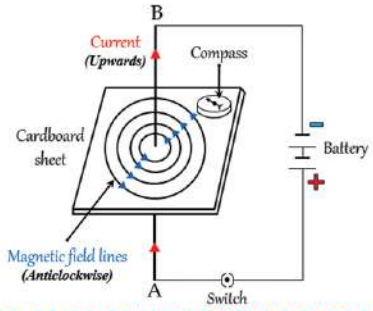


Figure 11.11 Magnetic field formed in a circular pattern around a straight wire when it is carrying current

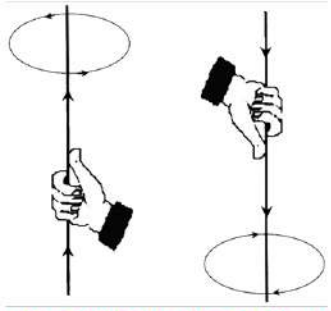


Figure 11.12 Maxwell's right-hand thumb rule to show the direction of the magnetic field produced when current flows through a straight wire

According to Maxwell's right-handthumb rule, if a current-carrying wire is gripped with the right hand such that the thumb indicates the direction of the current flow, as shown in Figure 11.12, then the fingers surrounding the wire indicate the direction of the magnetic field.

The magnetic field around a solenoid

Activity 11.3 Identification of the magnetic poles of a solenoid

Take an insulated copper wire, magnetic compass, 9V battery, and battery connector as shown in Figure 11.13. Wrap the wire around a cylindrical object such as a fine pipe or a marker pen. Make several loops around itand then pull out the cylindrical object to form a

spring-shaped coil. Remove the layer of insulation at both ends of the wire by scratching it with a knife or by heating it in a burning candle. Place a magnetic compass on one side of the coil. Now, connect the two ends to the battery. When electric current flows in the coil, observe which pole of the needle of the magnetic compass is attracted by the coil, and fill in the table shown below. Now swap the poles of the battery connected to the coil. Observe which pole of the needle of the compass is attracted this time, and fill in the table.

figure 11.13

Before changing the poles of the batteries connected to the coils		After changing the poles of the battery connected to the coil	
When the magnetic compass is placed on the right-handside of the coil, the attracted magnetic pole	By placing the magnetic compass on the left-handside of the coil	When the magnetic compass is placed on the right-handside of the coil, the attracted magnetic pole	By placing the magnetic compass on the left-handside of the coil
……..pole	……..pole	……..pole	……..pole
Result: Since the ……. Pole is attracted when the magnetic compass is on the right-hand side, the just opposite pole, i.e., ……. Pole must have been created in the coil.		…….	

A solenoid is a cylindrical coil made of insulated wire as shown in Figure 11.14. Generally, a solenoid is made by wrapping insulated wire around a cylindrical object. When the insulation of the two ends of the wire used to make the solenoid is removed and connected to a battery, current flows through the wire and a magnetic field develops in and around the solenoid. The magnetic field outside the solenoid is

similar to the magnetic field around the bar magnet, i.e., the magnetic field of a solenoid is strong on both sides and weak in themiddle portion. There is a uniform magnetic field inside the solenoid. Generally, when electric current flows in the solenoid, one end of it becomes the North Pole and the other the South Pole.

If the electric current flows in the opposite direction, the poles of the magnetic field formed around it are also reversed.

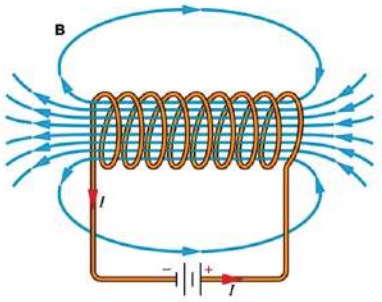


Figure 11.14 Magnetic fields around a solenoid

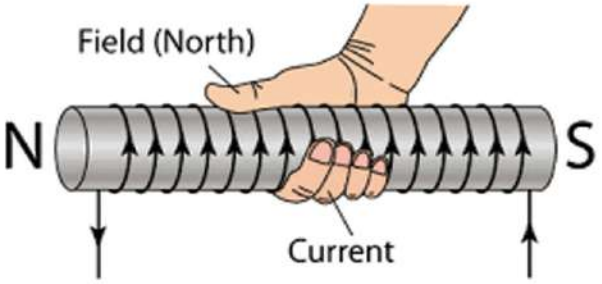


Figure 11.15 Maxwell's right-hand grip rule

The direction of the magnetic field formed around the current flowing solenoid can be found by using Maxwell's right-hand grip rule. According to this rule, if a solenoid is held in the right hand such that the fingers indicate the direction of the current through the solenoid, the thumb points to the north pole of the magnetic field developed in the solenoid. The strength of the magnetic field around a solenoid depends on the following factors.

(a) Magnitude of the current in the solenoid

(b) Number of turns in the coil of the solenoid

(e) A material placed inside the solenoid (core). Material such as a soft iron cylinder increases the strength of the magnetic field.

Since the magnetic field created by the solenoid is temporary, it is used to make an electromagnet.

Magnetic flux

Figure 11.16, shows the magnetic lines of force around a current carrying a straight wire, a wire loop, a solenoid, a bar magnet,and

theEarth. Depending on the source of the magnetic field, the shape of the lines of magnetic force varies. As shown in Figure 11.17, the number of magnetic lines of force on an object placed in a magnetic field depends on location.

To obtain information about the effect of a magnet at different locations within a magnetic field one can simply look at the number of magnetic lines of force on the surface of an object.The total number of magnetic lines of force passing through the surface area within the magnetic field represents the magnetic flux. Magnetic flux is a measure of the magnetic field passing through a surface area within a magnetic field. Magnetic flux is denoted by the Greek letter Φ (Phi). Wb indicates the unit of magnetic flux, weber. The unit is named after the surname of the German physicist Wilhelm Eduard Weber.

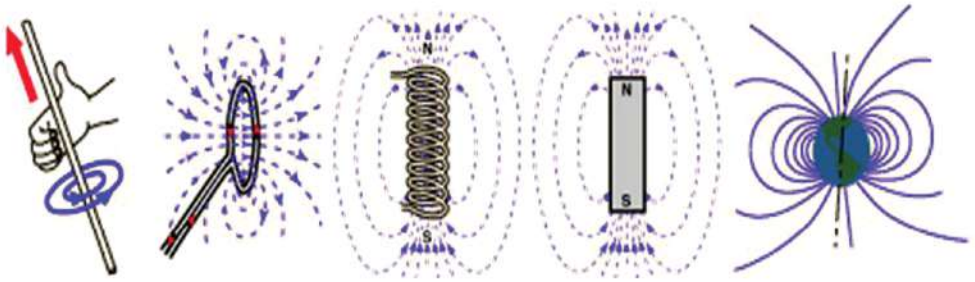


Figure 11.16 Various types of magnetic fields and magnetic lines of force

The density of magnetic lines of force indicates the magnitude of the magnetic flux.The area with denser magnetic lines of force means a strong magnetic flux whereas that of less density means a weak magnetic flux.

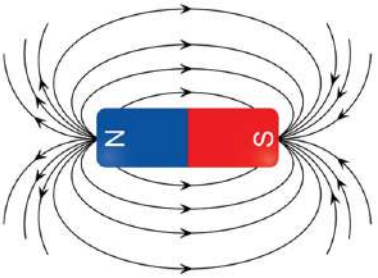


Figure 11.17 Magnetic lines of force of a bar magnet

On observing the density of magnetic lines of force of the bar magnet in figure 11.17, we can tell that the magnetic flux is stronger at the poles than that in the middle portion.

Motor effect

Activity 11.4

Collect a powerful U-shaped magnet, a piece of flexible conducting

wire, 6V d.c. supply or a 9V battery, a thread, etc. As shown in the figure, tie the conducting wire to a thread and hang it so that it can move freely between the two poles of the magnet. Connect the two ends of the wire to the battery and a switch.

Turn the switch on for a moment and observe the wire. Did the wire move in any direction? Present your observations in the table below.

The direction of wire movement before changing the poles of thebattery	**The direction of wire movement after changing the poles of the battery**
Right/Left/Forward/Backward.....	Right/Left/Forward/Backward.....
Result:	

The production of motion in the wire placed in a magnetic field when current is passed through it is called the motor effect. Fans, water pumps, mixer grinders, etc. work because of the motor effect.

In Figure 11.19, the direction of the magnetic field of a bar magnet and the circular magnetic field developed around a wire when electric current flows in it are shown. The force of attraction and repulsion between the two magnetic fields produces motion in the wire.

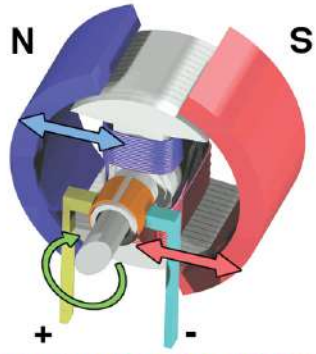


Figure 11.18: DC motor rotor and permanent magnet

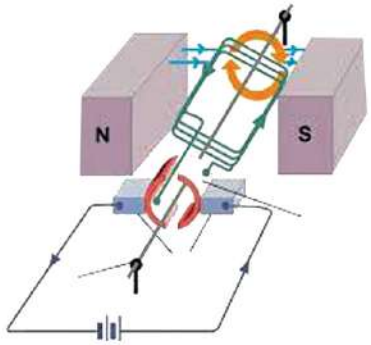


Figure 11.19 Force acting on a DC motor coil

A coil of a motor is formed by winding an insulated wire around a core. The coil is placed between two opposite magnetic poles as shown in Figure 11.17. Then a.c. is passed through the coil. When current is passed through the coil, a magnetic field develops around it. Because of the alternating current, the direction of the magnetic field in the coil

changes continuously. The coil rotates due to the interaction between the magnetic field of the permanent magnet and that developed in the coil. This then rotates the other object attached to it.

Measures such as increasing the number of turns and the surface area of the coil, using a more powerful magnet, and using a soft iron core, can be adopted to increase the speed of rotation of the coil of a motor.

Question to think

Is it possible to generate an electric current from a conducting wire placed in a magnetic field, just the way a magnetic field is developed around the wire when an electric current passes through it?

Electromagnetic induction

Around the beginning of the nineteenth century (1800 AD), the voltaic cell was used as the main source of current. In the year 1831, Michael Faraday discovered that when the magnetic force lines are cut perpendicularly by a conducting wire, a voltage is generated in the conducting wire and an electric current flows when the two ends of the wire are connected in a circuit. This discovery brought a remarkable change in the field of the source of electricity.

Activity 11.5

Connect a galvanometer with the two ends of the solenoid prepared in activity 11.2.

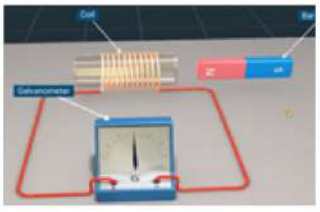


Figure 11.20

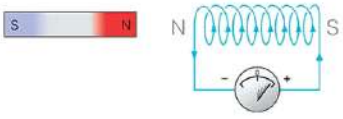


Figure 11.21

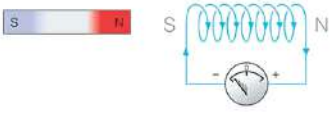


Figure 11.22

Pass a bar magnet in and out ofthe hollow part of the solenoid.Keeping the bar magnet fixed in front of the solenoid as shown in Figures 11.21 and 11.22, observe the position of the needle of the galvanometer when the north pole and the south pole of the bar magnet enter the solenoid. Note down the observation in the table below.

Poles of the bar magnet	The process by which the poles of a bar magnet enter or exit the solenoid	The direction of deflection of the needle of the galvanometer
North pole	In	Left/right
South pole	Out	

What is the difference between the new observation and the previous observation that can be observed when the bar magnet is quickly moved in and out?

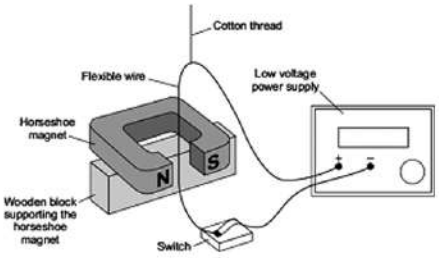


figure 11.23

As shown in activity 11.5, when a bar magnet is moved inside and outside a coil of conducting wire, the number of magnetic lines of force on its surface, i.e., the magnetic flux, changes continuously. As a result, voltage is induced in the coil. Even when a coil of conducting wire is rotated in a magnetic field and the magnetic flux linked with the coil is continuously changed, the voltage gets induced in the coil. In both cases, the work done while changing the speed of the coil or magnet, i.e. mechanical energy, is converted into electrical energy.

In this way, the process of inducing electromotive force (e.m.f.), i.e., voltage, in a conductor when there is a change in magnetic flux linked with that conductor is the electromagneticinduction.

Faraday's law of electromagnetic induction

The voltage produced in a coil depends on the strength of the magnetic field (electromotive force) and the number of turns in the coil. The greater the strength of the magnetic field and the number of turns of the coil, the more the voltage produced. The magnitude of the resulting voltage also depends on how quickly or slowly the magnetic field lines link the coil. On moving the magnet in and out of the coil at a very slow speed, negligible voltage is induced in the coil, but on moving the magnet in and out at a higher speed, more voltage is induced in the coil.

Based on the magnitude of the e.m.f. induced, Faraday's Law can be stated as follows:

When there is a relative motion between a conductor and a magnet, an electromotive force (e.m.f.) is induced in the conductor and the magnitude of such electromotive force is directly proportional to the rate of change of the magnetic flux linked with the conductor.

According to Faraday's law, when a conducting coil is rotated inside the magnetic field, an e.m.f. is induced in the coil due to the change in magnetic flux linked with the coil. This is the working principle of a generator. An induced e.m.f. lasts as long as the change in magnetic flux continues in the circuit or the coil keeps on moving. On increasing the number of turns of the coil, increasing the strength of the magnet, or the speed of rotation of the coil, the rate of change of magnetic flux linked with the coil increases. Thus, the magnitude of induced e.m.f. increases.

Dynamo and a.c. generator

Electric current is produced in bicycles and motorcycles by using a dynamo. Likewise, an a.c. generator is used to produce current that is used in the domestic electric circuits in daily life. A dynamo is used to induce the current on a small scale whereas a generator is used to generate current on a large scale.

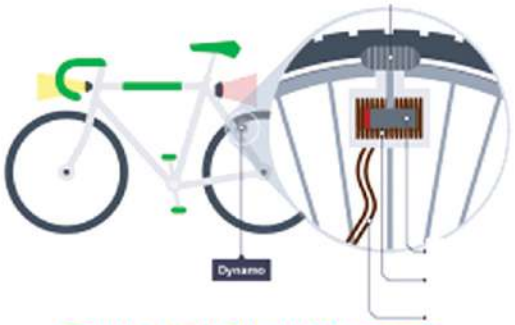


Figure 11.24 Bicycle Dynamo

As shown in Figure 11.24, a magnet is rotated in the bicycle dynamo. A coil is kept closer to the magnet such that it cuts the magnetic lines of force. To change the magnetic flux linked with the coil, the magnet is rotated by producing friction between the cap of the dynamo and the tire of the bicycle.Thus, the magnitude of the induced voltage in the coil depends on the number of turns in the coil, the strength of the magnetic field and the speed of rotation of the magnet, i.e., the rate of change of magnetic flux.

Large-scale sources of electricity

A large quantity of electricity is produced from the generator. For this, a coil placed in a strong magnetic field is rotated at a very high speed. As shown in Figure 11.25, the water stored in the dam of the

hydropower station is allowed to flow at high pressure through the tunnel to the turbines of the generator and rotated with great speed to produce large amounts of electricity from the generators in the hydropower station.Likewise, fossil fuels like coal, diesel,etc. are used in thermal plants to produce electricity. In the thermal plant run with coal, a large amount of coal is burnt to produce heat energy which is used to heat water and produce vapour. The vapour produced in this way generates high pressure androtates the turbine of the generator to produce electricity.In the case of the diesel power plant, the turbine is rotated by a diesel engine. Apart from the sources mentioned above, the turbine of the generator in the windmill is rotated by wind energy and electricity is produced.

The working principle of a thermal plant run by coal is also applied in nuclear power plants. Instead of using coal, the heat energy required to boil water is obtained from the tremendous amount of energy released during the fission of radioactive elements like uranium under the controlled mechanism. This technology for producing electricity is not used in Nepal. According to the data published by the Nepal Electricity Authority in 2022 AD, the hydroelectric potential of Nepal is 2200 MW. In addition, about 487 MW of electricity is produced in Dubahi and Hetauda from the thermal plants. According to the report mentioned above, hydroelectric projects of about 487MW capacity are under construction. Additional 3219 MW of electricity from the Upper Arun Project, Uttar Ganga, and Dudha Kosi (with reservoir) Hydroelectricity Project have been proposed.

Alternating current generator

Figure 11.25: Water stored in Upper Tamakoshi Hydroelectric Dam located in Dolakha District

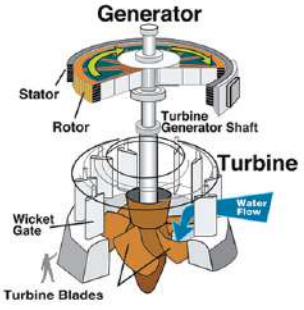


Figure 11.26: A turbine used to spin a generator at high speed in a hydroelectric plant

In Figure 11.26, a rectangular coil of conducting wire is placed in the magnetic field of ana.c. generator. As the coil rotates, it cuts the magnetic field, and the magnetic flux associated with the coil changes. As a result, an electromotive force (e.m.f.) is produced in the coil, and its magnitude is directly proportional to the rate of change of magnetic flux linkage.

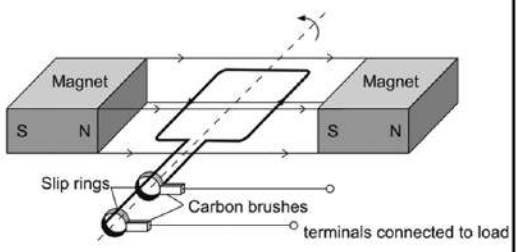


Figure: 11.27: The coil of the a.c.generator

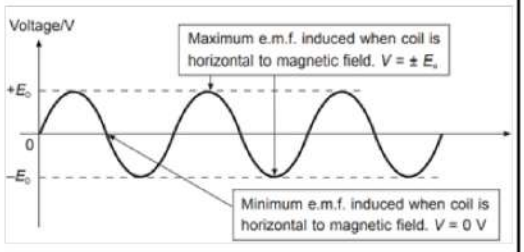


Figure: 11.28: The voltage induced in the coil of the a.c. generator

Transformer

Figure 11.29 shows the specified output voltage rating (5.3V) of a mobile charger. We put the mobile charger in a plug connected to a circuit with an alternating current (AC) of 220V. Here, the device installed inside the charger reduces the 220 a.c. to 5.3V a.c. which is required to charge the mobile.

Figure 11.29 Voltage rating indicated on a mobile charger

Similarly, about 2100V is required to generate microwaves in a microwave oven. For this, the transformer installed inside the oven converts 220V a.c. to 2100V a.c. In this way, the device used to increase and decrease the voltage of alternating current is called a transformer.

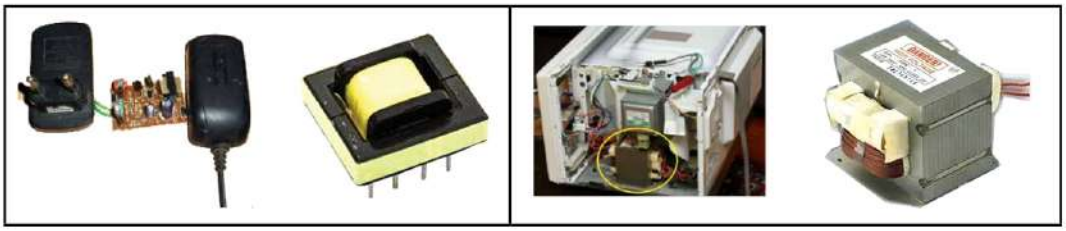


Figure 11.30: Use of transformers in chargers and microwave ovens

Activity 11.6: Compilation of voltage rating of equipment using transformers

Which other devices need a transformer? Collect their voltage rating and fill in the table given below.

Device	Input voltage rating	Output voltage rating
Router adaptor	.....	
Laptop adaptor	.....	

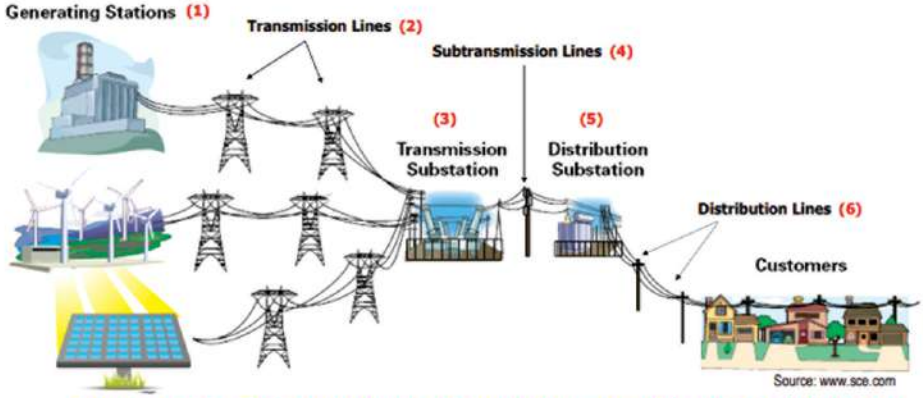


Figure 11.31: Electricity generation, transmission and distribution

The use of a.c. electricity includes three major sections - production, transmission, and distribution. The electricity produced by the generator in the powerhouse is converted into the high voltage (for example 132 kV) a.c. and then transmitted through the transmission line.

Figure 11.32: 400 kV Sub-station located at Dhanusha, Dhalkevar

Before distributing the transmitted electricity for use, its voltage is reduced to a lower value (for example,

220V) at the load transmission center (substation). Transformers are used to change the voltage as required in powerhouses and load transmission centers.

The electricity produced by various power plants in our country can be transmitted within or outside the country through high-voltage transmission lines. For example, the load transmission station at Dhunsha transmits electricity at 400KV.

Construction and working principle of transformer

Although there are some differences in the structure of transformers used in electrical appliances and transformers used for the transmission and distribution of electricity produced by power plants, theirworking principle is the same. They contain two coils that are made by wrapping thin insulated copper wire. As shown in Figure 11.33, a transformer used in electrical equipment consists of two coils. These coils are not connected. When an alternating current is sent through a coil, a magnetic field is created around it that changes periodically. As a result, when the magnetic intensity linked to the nearby coil changes, an emf is induced in the coil. The output current is then drawn from the two ends of this coil. Inducing emf in a coil by changing the current in the adjacent coil is the principle of mutual induction. The transformer is based on the principle of mutual induction. Since there is no mutual induction when direct current flows in the coil instead of alternating current, the voltage of d.c. cannot be changed by using a transformer.

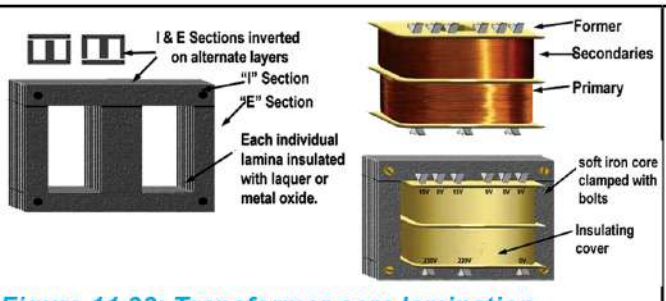


Figure 11.33: Transformer core lamination

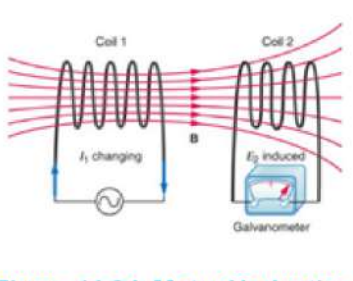


Figure 11.34: Mutual induction

To keep the coils apart in a transformer, the core is constructed by tying several E, U, and shaped iron sheets coated with non-conductive paint into a single block with the help of nutsand bolts.

This process is called core lamination. Laminating the core of the transformer prevents excessive heating of the core caused by the current induced in the core due to the change in the magnetic flux linkage.

Among the two coils of the transformer, the coil into which alternating current is fed (input coil)is called the primary coil and the coil in which alternating current is induced (output coil) is called the secondary coil. The number of turns of wire wound in the primary coil is called primary turns (Np) and the number of turns of wire wound in the secondary coil is called secondary turns (Ns). To change the voltage of alternating current in the transformer, the number of primary windings and secondary windings are kept different. The AC voltage sent to the primary coil of the transformer is called the input voltage or primary voltage (Vp) and the AC voltage received from the secondary coil is called the output voltage or secondary voltage (Vs).

Types of transformer

Transformer increases or decreases the input voltage depending on the number of turns in the coils in the transformer. For the block diagram of the transformer shown in Fig. 11.35, the ratio of the number of primary windings to the number of secondary windings is 2:1. If the input voltage in the said transformer is 220V, then the output voltage is exactly half of the input voltage i.e. 110V. A transformer with fewer turns in the secondary coil than in the primary coil reduces the voltage. A transformer that reduces the voltage of an alternating current is called a step-down transformer.

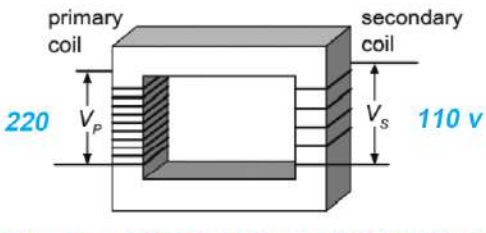


Figure 11.35: Step down transformer block diagram

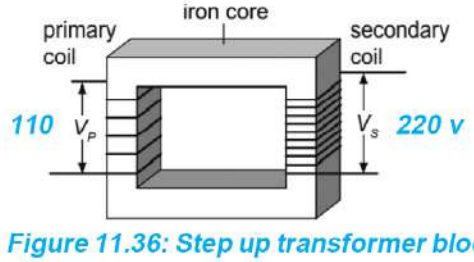


Figure 11.36: Step up transformer block diagram

For the block diagram of the transformer shown in Fig. 11.36, the ratio of the number of primary windings to the number of secondary windings is 1:2. If the input voltage in the said transformer is 110V, then the output voltage is exactly twice the input voltage, i.e., 220V.

A transformer in which the number of windings in the secondary coil is more than the windings in the primary coil increases the voltage. A transformer that increases the voltage of an alternating current is called a step-up transformer.

In transformer, the ratio of the number of turns in the primary coil to the number of turns in the secondary coil is equal to the ratio of the primary voltage to the secondary voltage. This can be presented as the transformer formula:

$$\frac{\text{Primaryturns } (N_p)}{\text{Secondary turns } (N_s)} = \frac{\text{Primary Voltage } (V_p)}{\text{Secondary Voltage } (V_s)}$$

Example 11.1

The accompanying picture shows a router to be connected to a 220V power supply. Observe the voltage rating mentioned on the router adapter. If the number of primary winding in the transformer inside the adapter is 500, calculate the number of secondary winding.

Solution: As given in the question,

Primary Voltage (Vp) = 220V

Secondary Voltage (Vs) = 12V

As per the voltage rating mentioned in the figure

Primary turns (Np) = 500

Secondary turns (Ns) = to be calculated

According to the transformer formula,

$$\frac{\text{Primaryturns } (N_p)}{\text{Secondary turns } (N_s)} = \frac{\text{Primary Voltage } (V_p)}{\text{Secondary Voltage } (V_s)}$$

Substituting the corresponding values into the formula,

$$\frac{500}{N_s} = \frac{220}{12}$$

Or $$\frac{N_s}{50} = \frac{12}{22}$$

Or $$N_s = \frac{6 \times 50}{11} = \frac{300}{11}$$

$$\therefore \quad N_s = 27.27 \cong 28$$

As mentioned in the question, the number of the secondary winding of the transformer is 28.

Example 11.2

The ratio of primary winding to secondary winding in a transformer is 1:10. Calculate the secondary voltage obtained when the transformer is connected to a 220V power supply.

Solution: As given in the question,

Primary Voltage (Vp) = 220V
Secondary Voltage Voltage (Vs) = to be calculated
Primary turns (Np): Secondary turns (Ns) = 1:10
Secondary turns (Ns) = to be calculated

According to the transformer formula,

$$\frac{\text{Primary turns } (N_p)}{\text{Secondary turns" } (N_s)} = \frac{\text{Primary voltage } (V_p)}{\text{Secondary voltage } (V_s)}$$

Substituting the corresponding values into the formula,

$$\frac{N_p}{N_s} = \frac{220}{V_s}$$

or $$\frac{1}{10} = \frac{220}{V_s}$$

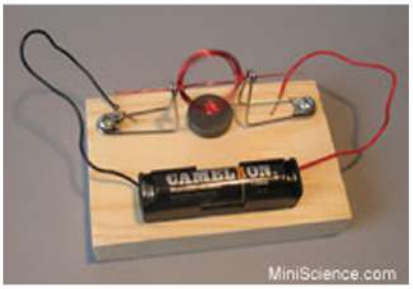
$\therefore$ Vs = 2200 V

The secondary voltage of the given transformer is 2200V.

Project work

(a) Prepare a model using locally available materials, insulated copper wire, etc. to demonstrate the working principle of an a.c. generator/dynamo.

(b) Prepare a model of a motor by connecting coils, magnets, drycells, pins, conducting wires, etc. as shown in the figure.



Exercise

1. Choose the correct option for the following questions:

(a) Which of the following is the source of a.c.?

(i) drycell (ii) solar panel

(iii) dynamo (iv) voltaic cell

(b) Which scientist discovered the magnetic effect of electric current?

(i) Michael Faraday (ii) Hans Christian Oersted

(iii) John Ambrose Fleming (iv) James Clerk Maxwell

(c) Which is the direction of the magnetic field when current is flowing upwards through a conducting straight wire?

(i) anticlockwise direction

(ii) clockwise direction

(iii) perpendicular to the direction of electric current

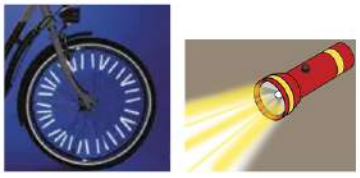
(iv) opposite to the direction of the electric current

(d) Which of the following statements is true for the current source shown in the figure?Figure

(i) The value of electric current produced by A is constant.

(ii) The frequency of electric current produced by B is constant.

(iii) The brightness of the lamp fluctuates if the current produced by A is used.



A B

(iv) The direction of the electric current produced by B changes constantly.

(e) On which of the following principlesis the working of a transformer based?

(i) Electromagnetic induction (ii) Mutual induction

(iii) Motor effect (iv) Lighting effect of current

(f) Which is the transformer's formula?

(अ) $\frac{V_p}{V_s} = \frac{N_s}{N_p}$ (आ) $\frac{V_s}{N_p} = \frac{N_s}{V_p}$

(इ) $\frac{V_s}{V_p} = \frac{N_p}{N_s}$ (ई) $\frac{V_s}{N_s} = \frac{V_p}{N_p}$

2. Differentiate between:

(i) a.c and d.c (ii) dynamo and generator

(iii) motor and generator

(iv) step-up transformer and step-down transformer

3. Give reasons:

(a) When a ceiling fan is connected to the circuit of the solar panel, the fan does not rotate.

(b) When a magnetic compass is placed near a circuit in which an electric current is flowing, its needle deflects.

(c) Electromagnet is used in the electric bell.

(d) The number of primary windings and secondary windings of a transformer are not the same.

(e) The core of a transformer is laminated.

(f) Transformers are used in mobile chargers.

4. Answers the following questions:

(a) The frequency of a.c. in our country is 50 Hz, what does it mean?

(b) Draw the time graph of direct current and alternating current.

(c) Draw the magnetic field lines around the current-carrying straight wire and solenoid.

(d) Explain the following rules.

(i) Maxwell's right-hand thumb ruleto show the direction of the magnetic field produced when an electric current flows through a straight wire.

(ii) Maxwell's right-hand grip rule to find the direction of magnetic field lines of force around a solenoid.

(e) What is the magnetic effect of current?

(f) Define magnetic flux.

(g) How can the magnetic field produced around straight current carrying be demonstrated by using iron dust, cardboard, and conducting straight wire? Explain it.

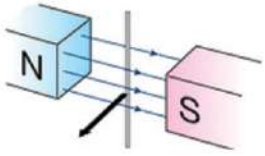
(h) Draw the magnetic field developed around a straight current-carrying wire.

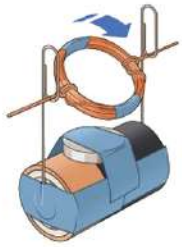
(i) What is Solenoid? Drawa picture showing the magnetic field developed around a solenoid

(j) Write two uses of the solenoid.

(k) Which effects are demonstrated in the given figures?Figures

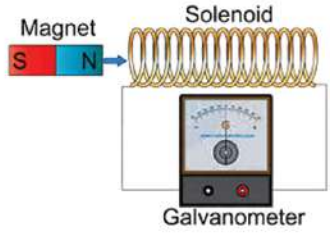
(l) A simple electric motor constructed by usinga coil, paper clips, a dry cell, and a permanent magnet, is shown in the figure. Explain its working process based on motor effect





(m) What is electromagnetic induction?

(n) Study the given picture and write what happens in the following situations.Figure



(i) As the bar magnet is slowly introduced into the solenoid

(ii) While introducing the bar magnet rapidly into the solenoid

(iii) Holding the bar magnet stationary inside the solenoid

(iv) On pulling the bar magnet quickly out of the solenoid

(o) State Faraday's law of electromagnetic production.

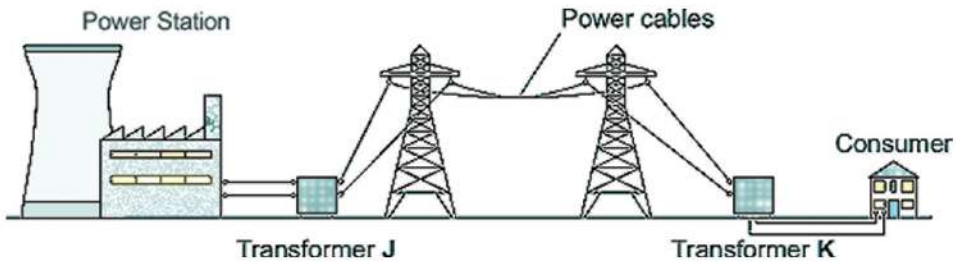
(p) A bulb connected to a dynamo attached to the tire of a bicycleis not found to be glowing with steady brightness. It was found that the bulb was bright, dimmed and also turned off when the cycle came to rest.Mention the reasons for such observations based on the working principle of dynamo.

(q) What can be done to increase the magnitude of current produced by a dynamo? Write any two ways.

(r) Prepare a researchreport on any two sources of electricity in Nepal(Hydro power station, solar power plant) including theircapacity, type of electricity produced, and transmission.

(s) What is a transformer?

(t) Write the type of transformers X and Y shown in the figure.



(u) Draw the block diagrams of the step-up transformer and step-down transformer and write two uses of each.

5. Solve the following mathematical problems:

(a) To charge a laptop of 20V, a charger with 550 primary turns is connected to an a.c. source of 220V. Calculate the number of secondary windings of the charger. [Answer: 50]

(b) The number of secondary windings of the coil of a transformer used in a microwave oven is 10 times the number of windings in the primary coil. If it is connected to a source of 220V, what is the secondary voltage obtained from the transformer?

(c) The ratio of the number of the primary winding to the number of secondary windings of a transformer is 22:1. If an adopter with that transformer is connected to an electric circuit having a potential difference of 220V, calculate the output voltage so obtained.

12

Universe

Look at the picture.Discuss the questions based on your day-to-day experience and observationsand then draw a conclusion.

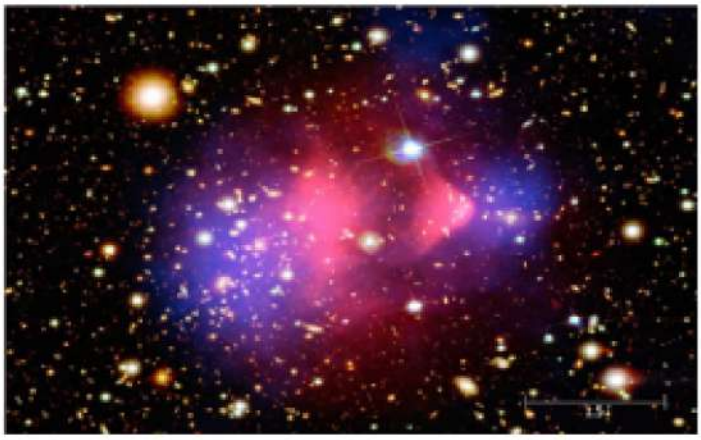


Figure 12.1 Celestial bodies in the universe

(a) What different types of celestial bodies exist in space?

(b) How are all these heavenly bodies stuck in space?

(c) How did the universe with all these celestial bodies originate?

(d) Areall the celestial bodies in the universe,in motion?

We have discussed various celestial bodies in the previous grades as well. The vast area around us is called the universe. There are many celestial bodies in this universe including the planets, stars, comets, satellites, meteors, meteorites, asteroids, etc. A group of many stars form a galaxy. The Solar System is located in the Milky Way galaxy. The universe is a huge region. Even science has not yet been able to obtain concrete information about the size, origin and spread of the universe. There are some very large celestial bodies in the universe. Their mass is also very large. But some celestial bodies are very small too. Their mass is also less.

Some of them are in a gaseous state and some are in a solid state. Celestial bodies have been namedasstars, planets, satellites, baby planets, comets, meteors, meteorites, etc. Due to the gravitational force of attraction, every celestial body including the planets, satellites and starsis held in its position. The collective name of all these celestial bodies is the universe. Astronomers at different times have proposed various theories about the origin of the universe. But, among them, the Big Bang theory is considered to be the most reliable one. According to this theory, all celestial bodies in the universe are moving. Hubble's study of the movement of these celestial bodies is important. Due to the gravitational force that exists between these moving celestial bodies, different hypotheses such as the open universe, closed universe and flat universehave been propoundedabout the future of the universe.

Activity 12.1

Divide the students in your class into four groups. Study the above-mentioned topics on the internet and find out more information on them. Based on this, prepare a collage about the celestial bodies in the universe such as planets, stars, comets, satellites, meteors, meteorites, and baby planets.Exhibit the collages prepared by all four groups in the class and discuss them.

12.1 Importance of gravitational force in the universe

Observe the figure and discuss.

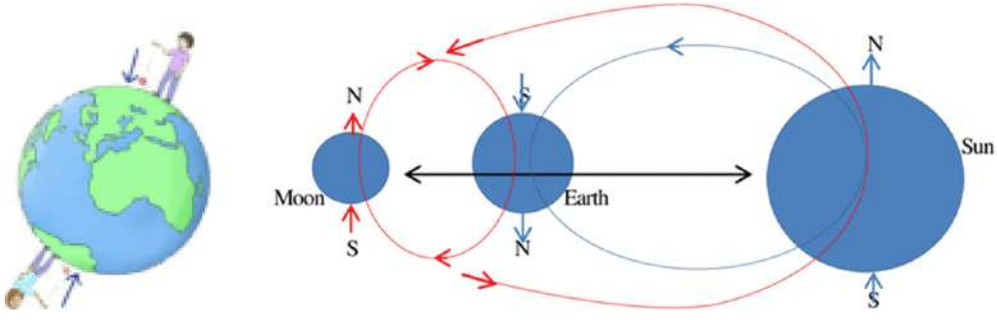


Figure 12.2 Gravitational force

(a) What is the secret of the fact that when a ball is thrown vertically up from either of the poles of the earth, as shown in the above

picture, the balls always fall towards the surface of the earth?

(b) The Sun, the Earth and the Moon are shown in the picture. The Earth revolves around the sun and the moon revolves around the Earth. What is the reason for this?

(c) All these three celestial bodies have their gravity, but how is it possible for them to stay in their place?

(d) Why planets and satellites do not collide with each other while moving in their orbits?

Earth is a planet; it has its mass. That's why it has gravity. Sun, earth and moon have their gravity. As shown in the picture above, there is a mutual force of attraction between them in which the sun is attracting the earth towards its center and the earth is also attracting the sun towards its centre. Similarly, the Earth is attracting the moon towards its center and the moon is also attracting the earth towards its centre. In this way, there is a mutual force of attraction among all celestial bodies in space. This force of attraction is called gravitational force. Due to this gravitational force, the earth rotates on its axis as well as revolvesin its orbit. The moon also revolves around the Earth. Similarly, every celestial body in the solar system revolves around the sun. Gravitational force is responsible for maintaining the alignment of the planets in their orbits and making them revolve around the sun.

12.2 Study of the Universe

Have you ever thought about how the universe originated? What is the shape of the universe?

With similar questions, scientists have carried out various research about it at different times.Universe science is the branch of science that studies various facts about the universe including the history and future of the universe.One of its branches, Astrophysics, studies the origin, structure, and future of the universe.

Big-bang theory

Activity 12.2

Get divided into different groups in the class and search the Big Bang

theory on the internet. After collecting the information about it, have a group-wise presentation via PowerPoint slide in the class.

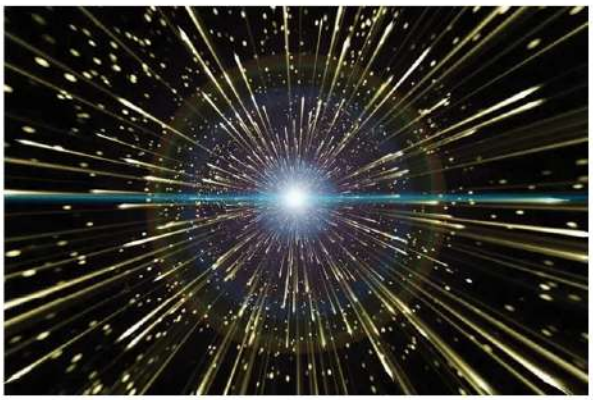


fig 12.3 Huge explosion of atom

Our solar system lies at a distance of about 30,000 light years from the centre of a spiral galaxy named the Milky Way galaxy having a diameter of about 100,000 light years. It is estimated mathematically that there are about 1.5 billion stars in this galaxy alone. Many theories about the origin of the universe have been proposed, the Big Bang theory is considered the most reliable theory. This theory but is believed to have been born from the observation that all the galaxies along with the Milky Way are moving far away from each other with tremendous speed. According to this theory, the universe is believed to have originated from the big explosion of a single atom. The four fundamental forces existing in the universe: gravitational force, electromagnetism, strong nuclear force, and weak nuclear force are considered to have unified as a single force before the explosion. Therefore, in the first stage of existence, the universe is considered to be in a very compressed state. At that time, the universe is believed to be in a very energetic state in the size of a small single atom. According to the Big Bang theory, due to excessive force and pressure, a huge explosion of the atom took place and the universe originated. All celestial bodies in the universe are believed to have originated from this explosion.

Just as the particles scatter and move away from each other in the explosion of an explosive, all the celestial bodies are moving far away from each other after the huge explosion of that dense atom. So, the size of the universe is also increasing day by day. Its expansion is slow but continuous. But, the speed of these bodies is decreasing due to the force of gravity.

Activity 12.3

Take a balloon. Blow a little bit of air into it and close its mouth by pressing with your fingers. Mark a few dots of different colours using sign pens on the surface of the balloon. Now inflate the balloon gradually and observe the distance between the dots. Notice that, as the size of the balloon changes (increases/decreases) so does the distance between any two dots.

Hubble's study

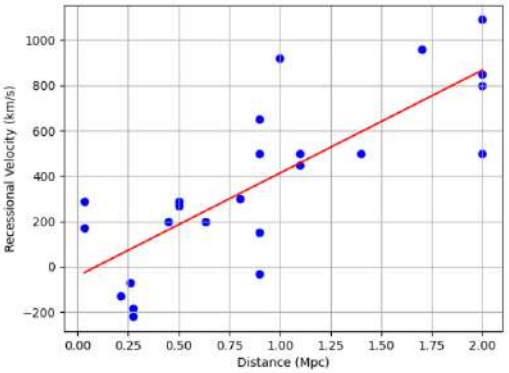


Figure 12.4 Hubble's relation between velocity and distance

It has been discovered that the galaxies in space are moving away from each other. In 1929 BC, the American astronomer Edwin Hubble tried to calculate the velocities of various galaxies using the 100-inch Hooker telescope on Mount Wilson. During his research, he discovered that every galaxy is moving away from other galaxies. His estimation showed that the farther the celestial bodies are from the earth the smaller they appear.And they also have a greater velocity.

He then plotted the velocities of the constellations against their distances on a graph and explained the relationship between the velocities of the constellations and their distances. This relation is represented by the equation v = Hd, and is known as Hubble's law. Here, vrepresents the velocity with which galaxies are moving away from each other, d represents the distance between them and H is Hubble's constant. The value of this constant is 73km/s/Mpc [Kilometer per second per Mega parsec]. This means, if any two galaxies are at a distance of one mega parsec,they are separating away from each other with a velocity of 73 km/s.

If the distance between any two galaxies is expressed in parsec and then multiplied by Hubble's constant, the velocity with which these galaxies are moving away from each other is obtained. Based on the such calculation,we came to know the fact that the galaxies are

moving very far away very quickly. It can also be known from Hubble's equation that the farther the galaxies are,the faster they are separating.

From this conclusion, just as every dot moves away from each other as the size of the air-filled balloon increases, the size of the area occupied by the entire universe is increasing. It is clear that the constellations in the universe are moving away from each other. Therefore, it can be assumed that they were close to each other in the past, which in turn means they were all at the same point a long time ago. Thus, Hubble's study helps to confirm the Big Bang theory.

Question to think:

Why are the stars in the universe moving away day by day?

12.3 Future of the Universe

Activity12.4

After launching a rocket from the earth, the distance of the rocket from the earth increases due to its initial speed, but the speed of the rocket decreases due to the force of gravity. But, the gravitational force also goes on decreasing as distance increases.

(a) If the effect of gravity becomes zero before the speed of the rocket becomes zero, what will be the future of the rocket?

(b) If the speed of the rocket becomes zero before the force of gravity becomes zero, what will be the future of the rocket?

(c) What will happen if the effect of gravity becomes exactly zero when the speed of the rocket becomes zero?

As discussed above, all the galaxies in the universe are moving away from each other at a certain velocity and the size of the universe is increasing, but due to the gravitational pull of the masses in the universe, the velocity of all the galaxies is decreasing. As the distance between the bodies increases, the effect of gravity also decreases. Now the question remains whether the velocity becomes zero before the effect of gravity, the effect of gravity becomes zero before the velocity becomes zero, or both of them become zero at the same time. This determines the future of the universe.

Let us know

According to Newton's universal law of gravitation, every mass exerts a gravitational force on every other mass and they pull each other towards themselves. The magnitude of that force is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centres. Hence, it is obvious that the net gravitational force on any celestial body depends on the total mass in the universe and the volume of the universe. Since the ratio of mass to volume is called density, the net magnitude of the gravitational force depends on the average density of the universe.The average density of the universe required to stop the expanding universe, which could be after billions of years, is called the critical density.

(a) Open universe

If the celestial bodies retain some velocity when the gravity becomes zero, they will then continue to move away from each other forever and the size of the universe will continue to increase. This situation is considered an open universe. If the average density of the universe is less than the critical density, then gravity cannot hold the expanding process and the universe which is continuously expanding now will continue to expand in the future too.

(b) Flat universe

If the gravity and the velocity of the celestial bodies become zero at the same time, the celestial bodies remain in the same position after that and the universe remains stable. Such a state is called a flat universe. If the average density of the universe is equal to the critical density, then the expansion rate of the continuously expanding universe gradually decreases and finally stops. Till then, there will be an infinite distance between each celestial body because of this they will not be affected by mutual gravitational force. Such universe is called flat universe.

(c) Closed universe

If the gravitational effect remains nonzero when the speed of the

celestial bodies becomes zero, the celestial bodies will start to come closer and the universe will come to a single point. The phenomenon in which the vast universe filled with unlimited mass and energy will at one point shrink and collapse is called the Big Crunch. If this happens, the universe created by the explosion of a single point will end up being a point and explode again to form a new universe like the present one. This means, just like the life cycle of a star, the age of the universe is fixed and it also has a life cycle. For the life cycle of the universe to continue, the Big Bang and the Big Crunch must keep appearing in turn. Such universe is called closed universe.

The above facts can be presented in graphs. Open, flat and closed universes are named according to the nature of the graphs. The main factor that determines the future of the universe is gravity. The magnitude of gravity depends on the mass and size, i.e., density of the universe. The density of the universe is estimated based on the masses seen in space.

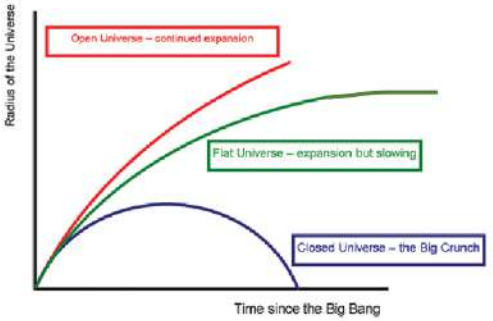


Figure 12.5 Types of Universe

Question to think

Can the actual density of the universe be determined in the days to come? Present your arguments.

Project work

Search the facts about the open, flat and closed universe using the internet or other media. Make models, present in the classroom and discuss.

Exercise

1. Choose the correct option for the following questions:

   (a) Due to the effect of which force,are the celestial bodies in the universe situated at their position?

   (i) nuclear force of attraction

   (ii) gravitational force

   (iii) magnetic force

   (iv) electromagnetic force

   (b) Which theory is considered the most realistic theory about the origin of the universe?

   (i) Geocentric theory

   (ii) Heliocentric theory

   (iii) Big Bang Theory

   (iv) Newton's Law of Gravitation

   (c) According to the Big Bang theory, how did the universe originate?

   (i) from the explosion of an atom

   (ii) from the collision of celestial bodies

   (iii) from the explosion of a star

   (iv) from the adjustment of nebulae

   (d) According to Hubble's theory, which one of the following facts is correct?

   (i) The farther away the galaxies are the more speed they will have.

   (ii) The farther away the galaxies are the lesser the speed they will have.

   (iii) There is no relation between the speed and distance of galaxies.

(iv) The gravitational force of the galaxies does not affect their speeds.

(e) Under what condition can an open universe behypothesized?

(i) When the average density is greater than the critical density.

(ii) When the average density is less than the critical density.

(iii) When average density and critical density are equal.

(iv) When average density and critical density are not comparable.

(f) What is the meaning of H in Hubble's law; $v = Hd$

(i) height

(ii) gravitational constant

(iii) constant of proportionality

(iv) distance

2. Differentiate between:

(a) Closed Universe and Open Universe

(b) Flat Universe and Closed Universe

3. Give reason:

(a) As the distance between celestial bodies increases their separating speedincreases.

(b) Celestial bodies continue to remain in their own place.

4. Answer the following questions:

(a) What is the universe?

(b) State the Big Bang theory.

(c) Write the conclusion of Hubble's study.

(d) According to the Big Bang theory, the universe is continuously

expanding. Is there no limitation to the expansion of the universe? Explain your arguments.

(e) Write the importance of gravitational force in the position of celestial bodies in the universe.

(f) Earth revolves around the Sun; Moon revolves around the Earth. They have their force of gravity as well as the gravitational force between them, but they never collide with each other. Clarify this with reasons.

(g) Explain the concept of a flat universe.

(h) In your opinion, what might be the future of the universe: open, flat or closed? Explain your answer with suitable arguments.

13 Information and Communication Technology

Fig. 13.1 TV with an antenna

Figure 13.2 TV connected with a cable

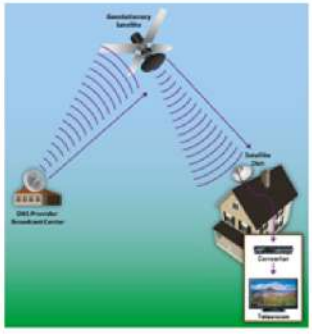


Figure 13.3 Dish TV

Antenna-powered television shown in Figure 13.1 is now replaced with Internet TV and Dish TV shown in Figure 13.2. Before Dish TV came into existence, cable TV like the one shown in Figure 13.2 was very popular. Among all the three types of TV mentioned above, the antenna-connected TV has the poorest audio-visual quality. In this type of transmission, the waves emitted from the transmitter lose energy to the surrounding as they pass through the air before reaching the user's home. Hence, they generate less p.d. on the antenna and the electrical current generated in the wire connected to the antenna also weakens. The same current acts as the modulated signal for television broadcasting.

The signal travelling through the wires similar to the one in Figure 13.4 gets converted to digital signals by the internal circuits of the television, and the audio-visual content is transmitted using these digital signals. In cable TV too, the signals travelling in the wire are the modulated signals. If a computer is to be used as a television by connecting the cable from the computer, it is necessary to have a cable modem. Dish TV, on the other hand, broadcasts digital signals received from the satellite.

In such broadcasts, digital signals must be converted back to analogue signals to regenerate signals that are visible to the eyes and audible to the ears. Thus, for the signal broadcasting, it is necessary to have a device that converts the analogue signals into digital signals and again the digital signals into analogue signals as shown in Figure 13.5.

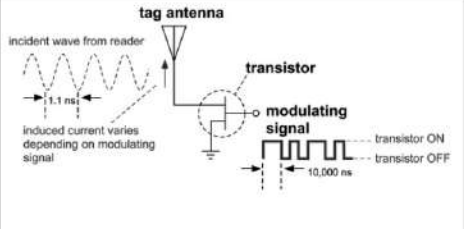


Fig. 13.4 Conversion of signals from the antenna into digital signals

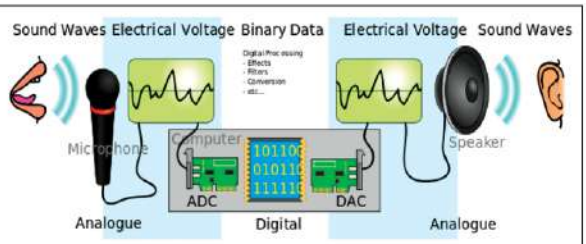


Figure 13.5 Conversion of analogue into digital and again digital into analogue signals

With the ease of transmission of digital signals, its uses have become more extensive in the field of information and communication. With this, a new terminology, 'Digital Native' (Digital Citizen), has been coined due to active participation and the changed behavior of people on social media. Courtesy and other positive behavior while doing online conversation improves people's online reputation. While online facilities can create many positive impacts, their improper use can badly impact our physical, mental, and emotional aspects.

Digital signal

Activity 13.1: Observation of Digital Signal Graph

As shown in Fig. 13.6, construct an electric circuit by connecting a 5 V alternating current source, a bulb, a switch, and conducting wire. If the potential difference between the two ends of the bulb is 5 V, while turning the switch on, then this voltage is considered as a high signal (1). When the switch is turned off, the potential difference between the two ends of the bulb becomes zero. This is considered as a low signal (0). Note the high signals and low signals generated in the circuit as time passes and record them in a table and draw graphs similar to the one shown in Figure 13.6.

समय	1	2	3	4	5
पोटेन्सियल फरक	0	1	1	0	...

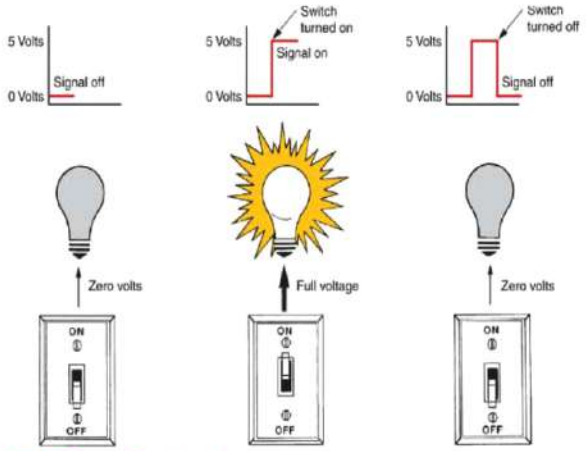


Figure 13.6 On-off signal

The physical quantity that changes with time is a signal. In activity 13.6, digital signals are created by turning the switch on and off. A special device, such as a transistor, is installed in electronic devices to create this type of signal. In the above activity, if the switch was not turned off and a graph of potential difference across two ends of the lightbulb against time were drawn, the voltage would have been seen increasing and decreasing continuously as shown in Figure 13.7. This is an analogue signal.

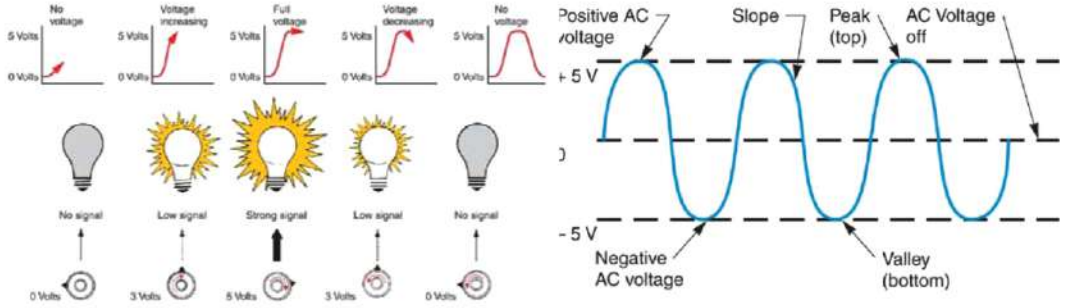


Fig. 13.7 Figure of the bulb showing fluctuation of voltage and related analogue signal

The digital signal is represented by only two digits (0, 1) and is used in the binary system. The combination of these two binary digits represents the digital signals. For example, as shown in Table 1, a binary number is a combination of only two digits, 0 or 1. There are four possible combinations of two binary digits. There are eight possible combinations of the three binary digits.

Table 1		Table 2			
Number of binary digit	**Possible combination**	**Binary number**	**Switches**	**Binary number**	**Switches**
1	0 1	0000		0011	
2	00 01 10 11	0001		0100	
3	000 001 010 011 100 101 110 111	0010		1010	

The digital signals shown in Table 2 indicate different data. This type of data is stored in the computer's memory. In the computer, memory capacity is determined according to the needs of the user. It can store a large amount of data permanently. Users can easily store data in different formats such as text, graphics, audio and video.

The storage capacity of computer memory is measured in the units like Bits, Bytes, Kilobytes (KB), Megabyte (MB), Gigabyte (GB), Terabyte (TB), etc. The relationship between these units is presented in the table below:

1 Bit (Binary Digit)	Binary 0 or 1	1024 kiloBytes	1 MegaBytes (MB)
4 Bits	1 Nibble	1024 MegaBytes	1 GigaBytes (GB)
8 Bits or 2 Nibble	1 Byte	1024 GigaBytes	1 TeraBytes (TB)
1024 Bytes	1 kiloBytes (kB)		

Let us know

Bit : A bit is a smallest form of data on a computer. It is short form of binary digit and it can be either 0 or 1.

Byte : A group of eight bits which works as a single unit of data in computer.

Difference between the digital signal and the analogue signal

Analogue signal	Digital signal
Analogue signal is a signal that indicates the constantly changing physical quantity.	The digital signal is the signal that represents the physical quantity that is changing in segments.
Analogue signal constantly changes with time.	The digital signal changes by any two fixed values continuously along with time.
Analogue signal is represented by a sine wave. For example; the signal that represents -5V to +5V is presented here.	The digital signal is indicated by a square wave. For example; the signal that represents 0V or 5V is presented here.
Analogue to digital converter, ADC changes analogue signal into a digital signal. For example; temperature sensor.	Digital to analogue converter, DAC changes the digital signal into analogue signal. For example; playing music on the computer.

Signal transmission

In our daily life, we communicate with sound as a medium. It is an analog signal. For example, in landline phones, analogue signal of communication is sent through the wire for effective transmission. In this way, the process of signal transformation through a medium or channel is called signal transmission. Similarly, communication can also be done by the transmission of signals created in the form of potential differences, electromagnetic waves, etc. In the traditional method of communication, analogue signals are used for communication.

For example, a radio broadcast using medium waves and the short wave is an analogue signal transmission. In this type of transmission, external effects like the mixing of other waves, atmospheric effects, etc. can make the transmitted signal unclear. Likewise, illegal recording of a telephone conversation that is transmitted in the form of analog signals is also possible. To avoid the problem of signal distortion and for signal protection analog signals are digitalized using various technologies. Digitalized signals make the given signals more clear and more distinct without changing the data. In a digital system, data can be stored, transmitted and recreated using a group of 0 and 1. In this system, data processing work is easier and the possibility of error in processing is very low.

Components of Digital Communication System

The components of digital communication are mentioned below in the block diagrams:

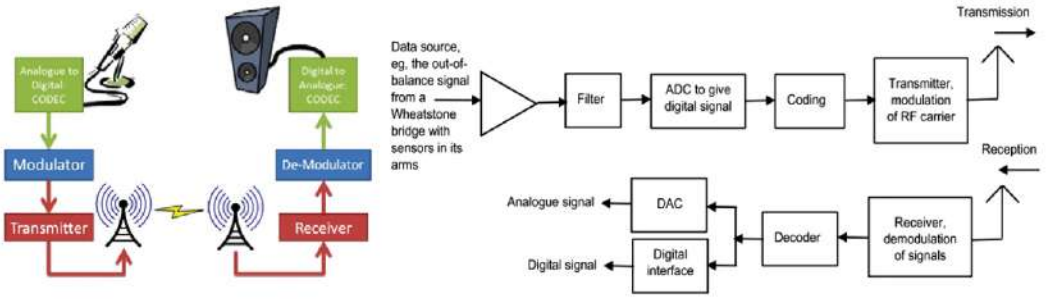


Figure 13.8 Digital Signal Transmission Process and Block Picture

(a) Source

Analogue signals, sound waves, for example, can be taken as a source for signal transmission.

(b) Input Transducer

The input transducer converts the received signals into an electrical signal. For example, a microphone converts sound into electricity.

(c) Encoder

The encoder compresses the data to a minimum number of bits. This process will help in the effective utilization of the available frequency range i.e., Bandwidth.

(d) Modulator

The modulator modulates the data to be transmitted by the carrier. These signals are directed to the medium, i.e., channel for transmission, after converting them into analogue signals. The analogue signals are generated from a digital sequence for transmission through channels or mediums.

(e) Channel

Channel or medium provides the way to the analogue signals up to the receiver after coming out from the transmitter.

(f) Demodulator

This is the first step on the side of the receiver. The signal received in the receiver is demodulated.

(g) Decoder

The received demodulated signals are re-digitized by the decoder. Thus removes the possible errors in the final output signals.

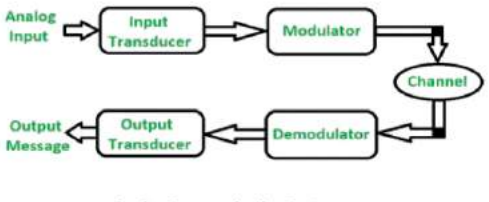
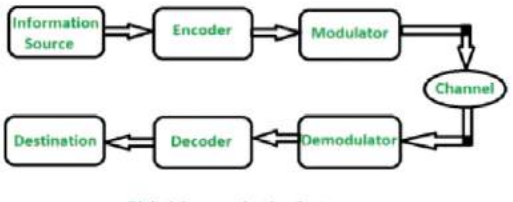
(h) Output transducer

It converts the decoded signals into the original physical signal sent through the source. It changes the electrical signals into physical output. For example, a loudspeaker converts current to sound.

(i) Output Signal

This is the result of the overall signal transmission process. For example, if the sound waves from a source are sent for transmission, the output is obtained as sound waves.

Difference between analogue communication and digital communication

Analogue communication	Digital communication
 Analog Communication System In analogue communication, data are transmitted between transmitter and receiver with the help of analogue signals.	 Digital Communication System The analogue signals are digitalized, transmitted, and then transformed again into analogue signals as output.
Signals through this transmission are highly affected by external influences.	Signals through this transmission are less affected by external influences.
Coding is not possible.	Coding is possible.
It needs small bandwidth.	It needs a large bandwidth.

Baseband transmission and broadband transmission

Baseband transmission means the transmission of digital signals through channels without conversion of digital signals into analogue signals. In this transmission, the process of sending and receiving the signals is done simultaneously in the same channel. It is done for short-distance transmission. For example, sending data from one computer to another one by connecting them with cables is baseband transmission.

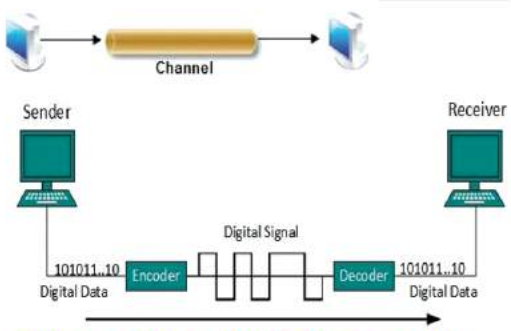


Figure 13.9 Baseband Broadcasting Channel

Activity 13.2

Open the internet browser in the internet-connected device (smartphone or laptop) available to you and search www.speedtest.net. As shown in the figure13.10, click on GO and find the speed of the internet that you are using.

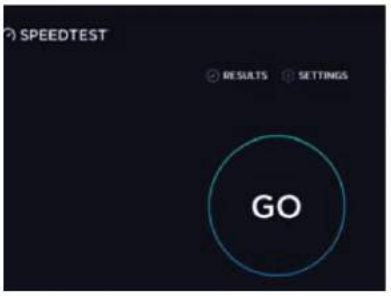
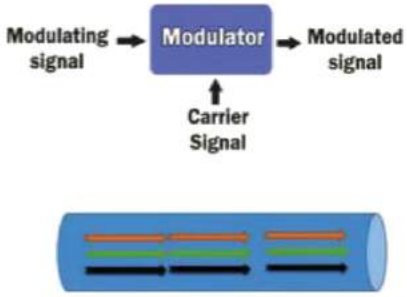


Figure 13.10 Broadband Internet Speed Test

Internet provider	Speed
Nepal Telecom (4G wireless home brand)	.....
.....	.....



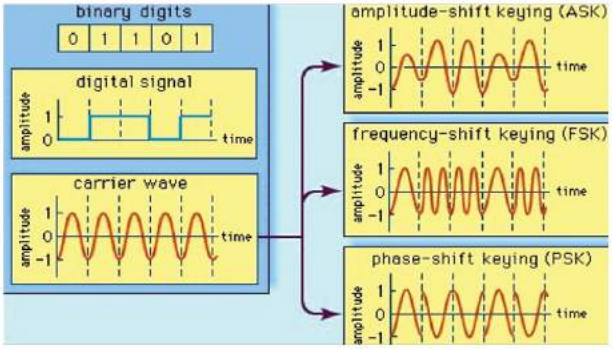


Figure 13.11 Broadband Broadcast Channel *Figure 13.12 Digital Signal Modulations*

Generally, in our language, broadband internet is regarded as high-speed internet. Broadband internet is the broadband transmission of data through various devices. Broadband transmission means the transmission of digital signals to a channel after converting digital signals into analogue signals. This type of transmission requires modulation. By broadband transmission, analogue signals can be transmitted in the form of optical or electromagnetic waves in various transmission frequencies. To send and receive signals, the transmission medium or channel gets divided into two separate channels. As an alternative to this, two separate cables can also be used for broadband transmission. This type of transmission is done for long-distance transmission.

Advantages of digital transmission

The main advantages of digital are as follows:

a. Deterioration and noise effects are very less in digital signals.

b. The circuits used for digital transmission are much more reliable.

c. It is cheap and easy to design digital circuits than the analogue circuit.

d. There is less possibility of signal overlap and cross-talk in digital transmission.

e. The properties of digital signals do not change in normal conditions.

f. The security of information can be maintained in digital transmission by encoding and compression.

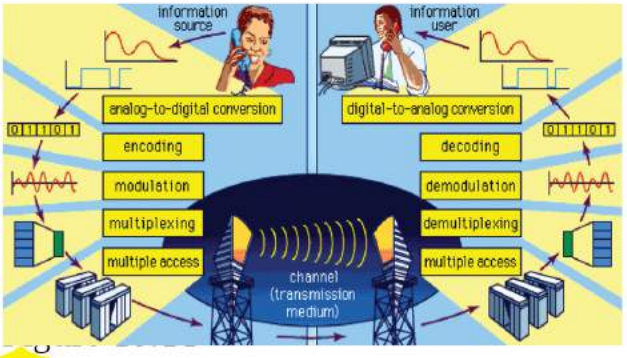
g. Since codes for finding and correcting errors are used, there is less chance of error during transmission.

Influence of digital technology on the development of information and technology

The development of digital technology has increased the quality of information and technology along with its prevalence in use. The modernization of telecommunication, internet facilities, digital media, digital TV, etc. has become possible due to the development of digital technology.

a. Digital telecommunication

Fast communication has become possible due to digital communication. Similarly, through a single channel or bandwidth many telephone calls can be transmitted.



b. Digital media

These days, various mediums are available for information and communication as shown in Figure 13.14. The electronic devices used for communication are digital media. The activities like creating new digital media, watching the news, and online information transmission can be done via electronic devices.

c. Digital TV

As shown in Figure 13.15, digital TVs are of different shapes and unique characteristics. High-definition TVs are made with the latest digital technology.

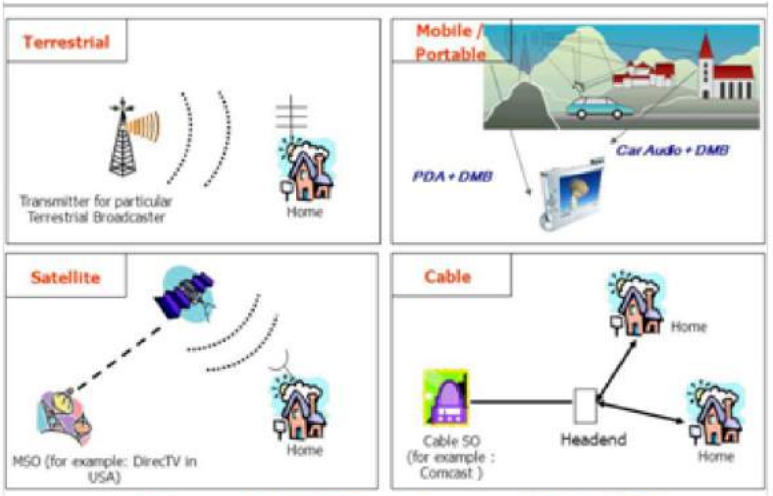


Figure 13.15 different types of digital TV

Dish TV has expanded its television service to different parts of the country.

Digital technologies used in daily life

Infrared and digital thermometer

Calculator

Online Newspaper

Digital wallet

fig 13.16

Digital devices, the product of the development of digital technology, have helped to make human activities very easy. As shown in the figure above, digital technologies are applicable in various fields such as education, health, entertainment, and finance. Although the use of digital technology can make life easier, its misuse and reckless use can also create problems.

Positive and negative effects of digital technology on daily life

With the continuous development of digital technology, the number of users also increases. Some of them can even change the lifestyle of the users. Some of the positive aspects of digital technology are as follows:

(a) Digital Library: Digital versions of textbooks and other reading materials are available in the digital library. It develops book-reading habits in people. For example, various textbooks and different reference materials are kept in the CDC library.

(b) Online newspapers: With the condition of availability of the internet and smartphones, different online newspapers can be read. For example, www.gorkhapatraonline.com is an online portal.

(c) Digital Payment: Digital payment solves the problem of people having to carry a lot of money for shopping. As shown in Figure 13.17, money can be sent to the seller's bank account by scanning the QR code. Digital payments can also be used to pay taxes, book bus and plane tickets, etc.

Figure 13.17 QR code in the market

(d) Online business: It can be used to promote and sell business materials through the Internet.

(e) Social Networks: Social networks have given people the opportunity to express their opinion in public. It connects people digitally even if they are far away physically.

(f) Entertainment: With the development of digital technology, various games and music applications are available for people's entertainment.

Digital media has a direct impact on our lifestyle. Some of the negative effects of digital technology are as follows:

(a) The people who spend an excessive amount of time online experience changes in their social behavior, i.e., the way of interacting with others.

(b) Crimes might be committed through social media and affect people's personal, family and social lives. When a person's reputation is damaged, it creates mental stress.

(c) Excessive use of digital material has reduced the consumption of physical material. This will result in the loss of business opportunities.

(d) Lack of physical exercise in children creates problems like obesity and weakness.

(e) Digital games containing murder and violence adversely affect the mental health and social well-being of an individual as well as spread antisocial activities.

(f) Misuse of digital technology causes harm to other people through activities such as cybercrime.

The use of the Internet plays an important role in creating the positive and negative effects of digital technology mentioned above. Since internet users around the world spend a long time engaging in various common activities, the term 'netizen' is used for such people.

Digital citizenship

In the present age of the internet, all people of the world have the same rights to use the internet and to actively participate in it. So, everyone can be introduced as a citizen of the net. A person who actively uses and engages in the internet is known as a netizen. The word netizen refers to a citizen of the internet. A netizen is therefore a citizen of a globally connected internet. Likewise, digital citizenship is the citizenship of the netizen in the virtual world of the internet. The concept of digital citizenship helps to improve the overall internet world. The development of digital technology has made it possible to connect citizens of different places of the world through different types of communication channels such as telephone, internet phone calls, social network communication, etc. As a result, the concept of global village has been developed.

Questions for discussion

What should be the characteristics of a good digital netizen like the characteristics of a good citizen of a state? List them on a chart paper and discuss them in class.

Characteristics of a good Netizen

The duties of a good netizen and internet etiquette are also connected with digital citizenship. The behavior displayed by netizens online should be socially acceptable. You should use polite and civilized language in online dialogues and communication through email, comments made public on social networks, etc. Online behavior should demonstrate personal respect and respect for others. Everyone should be treated with respect even if they do not see each other personally. Anything posted online is permanent. Intellectual property on the internet is someone else's product. Unauthorized use of such material is not permitted. If the material is to be used, the source must be cited.

Online Reputation

Reputation management is essential for netizens in the world of the internet just as reputation is connected to people's practical life. A

person's real name, photo, and other publicly available details should be used on the online profile.

This shows the authenticity and reliability of the person's profile. Likewise, all social media profiles should have the same user name. The posts, comments, shares, etc. made by the same person in the real and virtual world on social networks show the person's knowledge, expertise, etc. For online reputation management, a person should be careful about internet security. Poor privacy settings on social networks lead to password theft and the possibility of posting content that harms the reputation of an individual.

Online reputation is not only personal but also associated with an organization. Information published on an organization's website and statuses posted on its social media pages are official. The number of followers of that page indicates the credibility of that organization. Similarly, presence on all major sites and social networks is required for institutional digital reputation. Online reputation can be managed by the timely resolution of comments and complaints made on institutionally opened websites and pages.

Digital wellbeing

Figure 13.18 Digital wellbeing

As shown in Figure 13.18, staying online for a long time without maintaining the necessary physical balance can be harmful to health. It can cause problems like obesity, insomnia, vision problems, and mental stress. Likewise, unregulated internet use can cause the problems such as depression, anxiety, dishonesty, low self-esteem, social isolation, loneliness, aggressiveness, etc.

Due to the existence of such problems, the concept of digital health is applied in our online life. The state of being healthy mentally, physically, socially, and emotionally by balancing the time spent on online and offline activities, is called digital well-being. When using online technology, we should take care of digital health and use it in such a way that it does not affect our overall health.

Figure 13.19 Balance for health

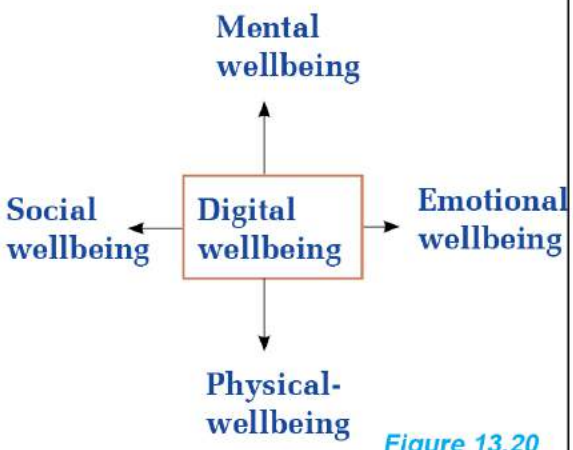


Figure 13.20

Cautions for Digital Wellbeing

Activity 13.3

On average, how much time do members of your household spend on the use of digital devices every day? Discuss the long-term effects of continuous use of digital devices and note down the possible effects.

Addiction to digital technology makes our lifestyle chaotic. Therefore, digital well-being skills are necessary to have awareness of the possible effects of the unnecessary use of digital technology. Digital well-being can be achieved by cultivating the habits such as separating screen time, setting time limits for social media use, and turning off mobile notifications at work. Awareness of digital well-being can be adopted by installing the digital well-being application on the smartphone. For example; the applications such as Beta, Action Dash, Digital Detox, Microsoft Launcher, etc. can be used.

Such applications help reduce the screen time of users.

Activity 13.4 Use of the Digital Wellbeing Application

Download the Digital Wellbeing application from the Play Store with the icon shown in Figure 13.21a. As shown in Figure 13.21 b, when it is opened, the time duration of the use of a particular smart phone by a user per day can be observed. Actions such as turning off notifications and setting a particular time interval for an application can be performed by the use of such applications. Also, mention other features that can be notified from the use of the installed application.

Fig 13.21a

Fig 13.21b

Learning materials can be searched through the use of the Internet. While searching and observing for those materials, caution should be taken for digital well-being. For example, by visiting the website https://www.youtube.com/c/NCEDVirtual, one can get information on audio-visual content related to different subjects. In the same way, additional audio-visual materials can be designed by recording required audio-visual content.

Making audio and audio-visual materials

Audio content can be created by recording sound with the microphone of a computer or smartphone. Audio-visual content can also be created from camera recordings. A smart phone camera or a digital camera can be used for this.

Activity 13.5 Video recording

Take a smart phone, a spring balance and an object with a mass 500g such that it can be hung in the spring balance.

Take the spring with hanging mass and release it from a certain height. At the same moment, tell one of your friends to take a video in slow motion so that the position of the needle of the falling spring can be observed. Does the pointer of the falling spring balance on the video appear to return to zero?

In this activity, the video file extension is also added to the name of the recorded video file, such as class 10 ICT. MP4 file is a video file. Similarly, 3GP, SVI, MOV, etc. are also video file formats. If the audio-visual material recorded here is unnecessarily recorded at any point, the segment can be cut out from the video or more than two video file clips can be combined to form a single video file. This kind of work comes under video editing.

Video editing

A mobile application or software is needed to edit the video recorded by the camera. For example, video can be edited by using computer software like Adobe Premiere Pro and Filmora. Similarly, by using the Windows video editing software in the system software of a computer, a video can also be edited.

Activity 13.6 Video Editing

Copy the video recorded in activity 13.5 to the computer for editing. Remove the unnecessary section in the video. Similarly, combine the fragmented clips to create a complete file. For this, follow the steps given below:

(a) Video cutting

Cut the recorded video and prepare a short clip. Follow the following steps for this purpose.

First of all, launch the Video Editor by clicking on the search bar as shown in Figure 13.22. Click on New video project and type the project name. For example, type Class 10 ICT and click on OK.

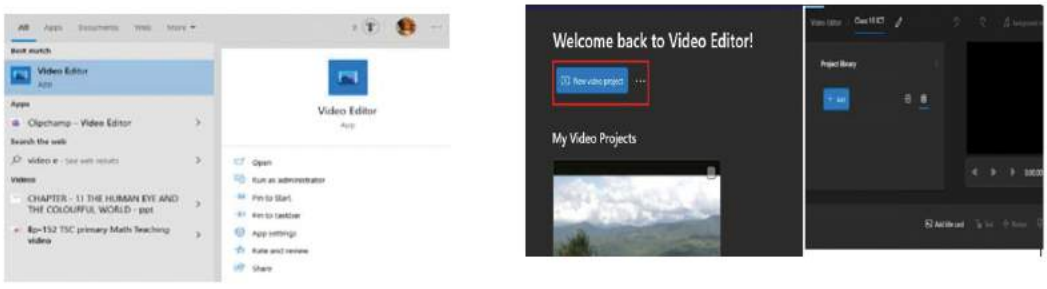


Figure 13.22

Select the video from the computer memory and add it to the project library by dragging it to the editing panel as shown in Figure 13.23. For the video cutting, select the video and click on trim.

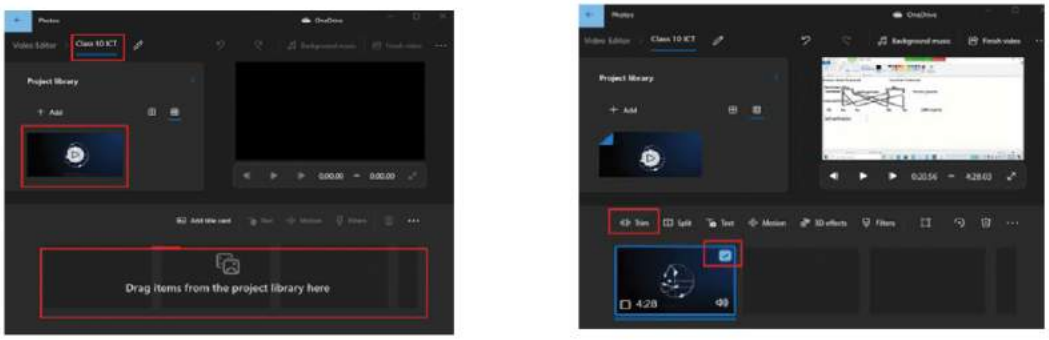


Figure 13.23

To choose the place where the video is to be cut, play the video. Then separate the start time and end time using two blue drag bars as shown in Figure 13.24. Finally, check the required clip length and click on done.

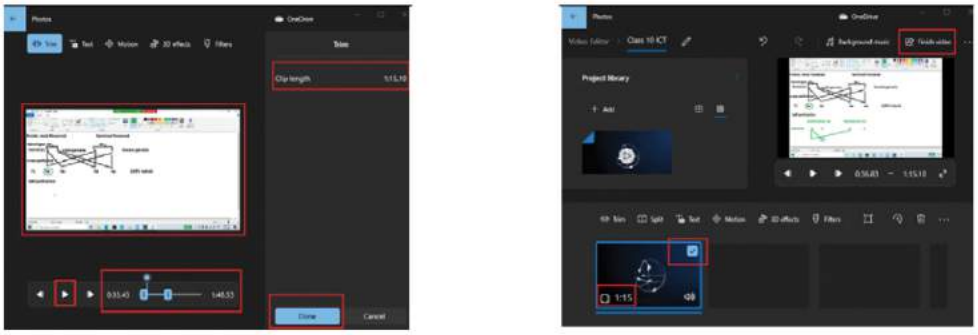


Figure 13.24

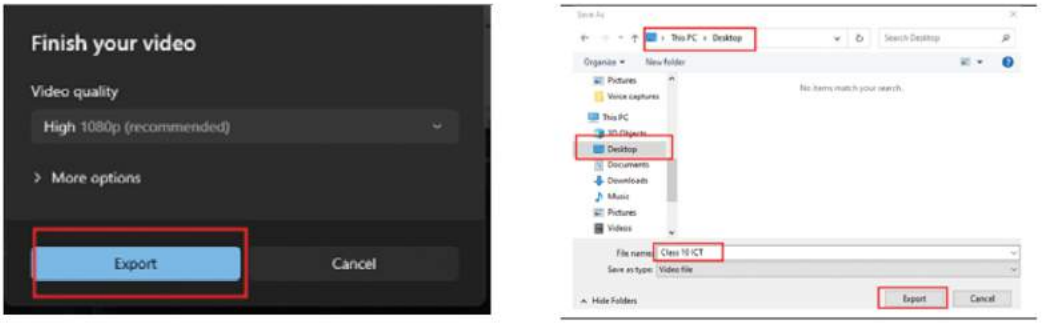


Figure 13.25

Select the cut clip in the editing panel and click finish video at the end. Then click on export in the window that appears. In the end, choose a location on the computer to save the video clip. In Figure 13.25, it is shown that the video file has been saved on the desktop.

(b) Video joining

Copy the clips cut and prepared by all your friends into a single folder. Select all the video clips to be joined and copy them to a single place on the computer. After that, open a video editing software, select the required file from the computer memory and add them to the project library. Select these videos and drag them to the editing panel. As shown in Figure 13.26, select all the files to be joined in the editing panel and click on finish video.

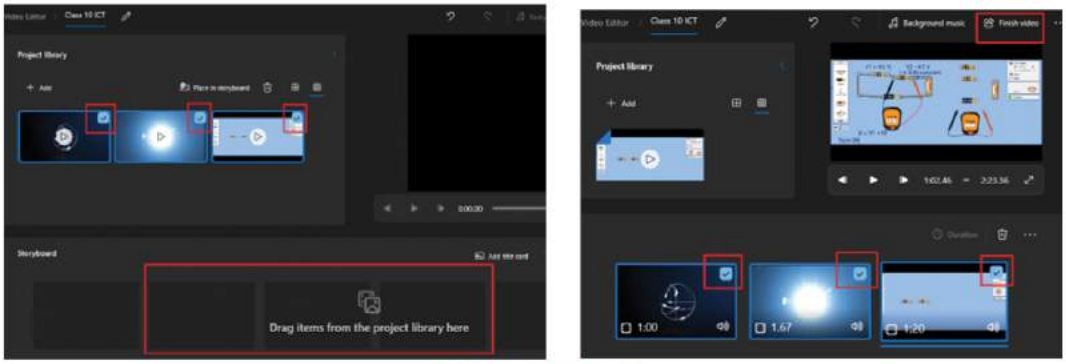


Figure 13.26 a, b

While clicking on the video, a location is to be chosen to save the file on the computer. For this, the video prepared by making clips can also be saved on the desktop, just like saving the file in Video Cutting.

Editing can be done on both computers and smartphones. Smartphones have a separate editing application. To edit the video recorded from the camera, it can be opened from the mobile gallery. While clicking on the video, an edit icon as shown in Figure 13.26 will appear. On clicking on that icon, the cut and crop icon will be seen as shown in Figure 13.26 b. The video can be cut or cropped by clicking on it.

If there is no video editing application on the phone, the required application can be downloaded from Play Store. The application file can be installed on the mobile by clicking on the downloaded location.

Just like editing the video using computer software, an audio file can also be edited. The file extensions of the audio file are MP3, WAV, WMA, etc. If software or application required for audio editing are not installed on the computer or smartphone, they can be downloaded and installed from the windows store, app store, etc. For example, to edit an audio file, audacity can be downloaded from ww.audacityteam.org. Similarly, mp3 cutter software can be downloaded from any official source by using Google search.

Project work

Prepare and conduct a debate programme among classmates on the topic 'use of digital technology has a positive impact on society'.

Exercise

1. Choose the correct option for the following questions.

(a) Which of the following represents an analogue signal?

(i) infrared ray thermometer

(ii) computer

(iii) smartwatch

(iv) medium wave radio

(b) ..... indicates 1byte memory.

(i) 0000 (ii) 00000000

(iii) 100000 (iv) 000001

(c) Which one of the following is the group of variables in the correct order among the steps of digital signal transmission?

(i) source, input transducer, decoder, modulator, channel, demodulator,encoder, output transducer

(ii) source, input transducer, encoder, demodulator, channel, modulator decoder, output transducer

(iii) source, input transducer, encoder, modulator, channel, demodulator decoder, output transducer

(iv) source, encoder, input transducer, modulator, channel, decoder, demodulator, input transducer

(d) Which of the following is an audio file format?

(i) SVI (ii) MP4

(iii) MP3 (iv) 3GP

(e) What does the behavior of posting information about new scientific discoveries from time to time on social networks indicate?

(i) unsystematic use of social networks

(ii) digital well-being skills

(iii) awareness of digital wellbeing

(iv) digital reputation management

2. Differentiate between:

(a) Analogue Signals and Digital Signals

(b) Analogue Signal Transmission and Digital Signal Transmission

(c) Digital Integrity and Digital Reputation

3. Answers the following questions:

(a) Define the bit and byte used in computer memory.

(b) Present the currently used high-speed internet as a Broadband transmission.

(c) Write four advantages of digital transmission.

(d) Explain the impact of digital technology on the development of information and communication technology with any two examples.

(e) Present any four examples of digital technology used in daily life.

(f) Write two positive and negative effects of digital technology in daily life.

(g) Define digital citizenship.

(h) Write four characteristics of a good netizen.

(i) What is online reputation? Write with examples.

(j) What is digital well-being?

(k) Write the advantages of digital well-being.

(l) What four precautions are necessary for digital well-being?

(m) What is digital reputation management?

(n) Give two examples of digital reputation management.

(o) Mention four importance of digital reputation management.

(p) Write two positive effects based on the use and utility of social media.

(q) Write two possible negative effects of using social media.

(r) Write your plan to make a 5-minute audio-visual material covering the topics included in any one unit under the science and technology of class 10. What can be done to make that audio-visual material of 3 minutes? Write, including, the necessary steps.